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Renewable Electricity: Potential Economic Effects of Increased Commitments in Massachusetts

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Table of Contents

Glossary of Terms 11
Abbreviations and Acronyms 15
Executive Summary 17
Chapter 1 Introduction and Background on Electricity Markets 29
- Approach 30
- Organization of the Report 31
- Background on Electricity Markets, Generation Types, and Regulation 32
    - Organization and Regulation of the Sector 33
    - How Prices Are Determined 37
    - Characteristics of Generation Technology 37
    - Types of Generation Technology 41
    - Renewable and Clean Energy Goals and Commitments 45
    - Greenhouse Gas Emissions 46
- Bibliography 48

Chapter 2 Overview of Electricity Markets in New England and Massachusetts 55
- Introduction 55
- Key Findings 55
- Electricity Generation Sources and Rates 56
    - New England: Sources of Electricity 56
    - Trends in Electricity Rates in New England and Massachusetts 64
    - Greenhouse Gas Emissions 67
- Regional and State-level Goals and Commitments in Massachusetts and New England 68
    - Introduction 68
    - Massachusetts 70
    - Other New England State Renewable Portfolio Standard Targets 76
    - Regional Greenhouse Gas Initiative 79
- Potential Available Resources to Meet the Goals and Commitments of New England and Massachusetts 81
    - New England 81
    - Neighboring Markets 87
    - Transmission and Storage Challenges 88
- Bibliography 90

Chapter 3 Quantitative Analysis 99
- Introduction 99
- Key Findings 99
- Model Setup and Background 100

- Massachusetts's Recent Goals and Commitments 100
- Modeling the Cost to Consumers 103
- Modeling Greenhouse Gas Emissions 104

Data Inputs and Model Parameters 105

- Annual Energy Outlook Projections 106
- Model Data and Estimates 107

Modeling Results 108

- Estimated Effects on Costs to Massachusetts Consumers 111
- Estimated Effects on Costs to New England Consumers 114
- Estimated Effects on Massachusetts's Greenhouse Gas Emissions 115
- Estimated Role of Imports in Meeting Massachusetts's Commitments 116
- Summary of Results for Alternative Assumptions 118

Limitations of the Model 119
Bibliography 121

Chapter 4 Case Studies of the Effects of Imports of Hydroelectricity 125

Key Findings 125
General Characteristics of Hydroelectricity 126
The Columbia River Basin 127

- The Columbia River Basin's Electricity Market 129
- Renewable and Clean Energy Commitments 133
- Economic Impacts 136
- Environmental Impacts 139

New York State 141
Minnesota-Manitoba 144
Denmark 146

- Introduction 146
- Denmark's Electricity Market 146
- Renewable and Clean Energy Commitments 150
- Economic Impacts 152
- Environmental Impacts 156

Bibliography 159

Appendix A Request Letter 173
Appendix B *Federal Register* Notices 177
Appendix C Calendar of Hearing Witnesses 183
Appendix D Summary of Views of Interested Parties 189
Appendix E Details of the Economic Model 197
Appendix F Supplementary Figures and Table 225
Appendix G Data Tables for Selected Figures 233

Boxes

Box 2.1 Renewable Portfolio Standards and Carbon Emissions Policies in New England 69
Box 2.2 New England RPS Mandate Variability and Implications for Retail Rates 77
Box 3.1 Challenges to Quantifying the Economic Effects of Renewable and Clean Commitments 104
Box 3.2 AEO Projections of the Effect of U.S. Renewable Portfolio Standards on Prices and Imports 110

Figures

Figure ES.1 New England and Massachusetts electricity generation by source (in terawatt-hours), 2010 and 2018 20
Figure ES.2 Massachusetts clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50 22
Figure ES.3 New England and U.S. average retail price of electricity, for residential and commercial customers (in cents/kWh), 2010–19 24
Figure ES.4 New England and Massachusetts electricity generation industry carbon dioxide (CO_2) emissions rate (in lbs/MWh), 2010–18 25
Figure 1.1 Illustration of electricity generation, transmission, and distribution 34
Figure 1.2 Example of how generation resources set market prices 40
Figure 2.1 New England net electricity generation by source and imports (in terawatt-hours), 2010–19 57
Figure 2.2 New England net renewable electricity generation by energy source (in terawatt-hours), 2010–19 59
Figure 2.3 New England electricity generation and net imports (in terawatt-hours), 2018 60
Figure 2.4 New England electricity generation by state and energy source, 2018 61
Figure 2.5 Massachusetts electricity generation by energy source and net imports (in terawatt-hours), 2010–18 62
Figure 2.6 Massachusetts renewable electricity generation by energy source (in terawatt-hours), 2010–18 63
Figure 2.7 New England (NE) and U.S. average retail price of electricity, residential and commercial customers (in cents/kWh), 2010–19 65
Figure 2.8 New England and Massachusetts electric power industry CO_2 emission rate (in lbs/MWh), 2010–18 67
Figure 2.9 Massachusetts Class I RPS obligation, before and after the 2018 Massachusetts Act to Advance Clean Energy (percentage of electricity consumption) 71
Figure 2.10 Massachusetts renewable portfolio standard obligation (percent of electricity consumption), 2018–50 72
Figure 2.11 Massachusetts clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50 73
Figure 2.12 RGGI allowances for New England states, 2009–20 (by $MmtCO_2$ equivalent) 80
Figure 2.13 Economy-wide emissions targets by New England state, 2010–50 (by $MmtCO_2$ equivalent) 81
Figure 2.14 Estimated installed solar photovoltaic capacity in New England, 2018–25 (commercial, residential, and utility, MW) 82

Figure 2.15 Estimated installed wind capacity in New England, 2018–25 (onshore and offshore, MW) 84
Figure 3.1 Mandated share of load from renewable and clean sources under Massachusetts's recent goals and commitments (percentage of electricity consumption) 102
Figure 4.1 Major dams within the Columbia River Basin 128
Figure 4.2 Power generation in Idaho, Montana, Oregon, and Washington by energy source, in terawatt-hours (TWh) 131
Figure 4.3 Conventional hydroelectricity as a share of total net generation, 1990–2018 (percent) 131
Figure 4.4 Retail power prices for commercial customers in Columbia River Basin states, 2010 and 2019 (in cents per kilowatt-hour) 137
Figure 4.5 Retail power prices for residential customers in Columbia River Basin states and Massachusetts, 2010 and 2019 (in cents per kilowatt-hour) 137
Figure 4.6 CO_2 emissions per MWh of generation, 2012 and 2018 139
Figure 4.7 New York State electricity imports and electric generation by source (in terawatt-hours) 142
Figure 4.8 New York State upstate vs. downstate electricity generation by source, 2015–19 (in terawatt-hours) 143
Figure 4.9 Denmark's electricity transmission system 147
Figure 4.10 Electricity capacity (left, in MW) and generation (right, in terawatt-hours) in Denmark by type, 2010–19 149
Figure 4.11 Denmark's electricity trade, 2010–June 2020 (in GWh) 150
Figure 4.12 Electricity prices in Denmark, 2010–19 (left, in cents/kWh) and components of retail prices in 2019 (right) 153
Figure 4.13 Fossil fuel prices, reservoir levels, wind production, and electricity consumption, 2010–19 154
Figure 4.14 Difference between daily minimum and maximum prices, 2019 (in $/MWh) 155
Figure 4.15 Greenhouse gas emissions (CO_2 equivalent) from electricity, gas, steam and air conditioning supply, 2010–18 (in million tons, left, and grams/euro value added, right) 156
Figure 4.16 Observed CO_2 emissions, non-renewable energy power plants, 2010–18 (in million tons) 157
Figure 4.17 CO_2 emissions per kWh of electricity consumption in Denmark, 2010–18, adjusted (in grams/kWh) 158
Figure E.1 Average revenue minus average cost estimates, 2050 High Renewables Cost case example 207
Figure E.2 Overnight installed capital cost in the United States by technology, Reference and alternative Renewables Cost scenarios (in 2019 dollars per kilowatt). 209
Figure E.3 U.S. electricity generation from selected fuels, Reference, and alternative Oil and Gas Supply scenarios (in terawatt-hours) 210
Figure F.1 Connecticut RPS by class (percent of electricity consumption), 2018–30 227
Figure F.2 Maine RPS by class (percent of electricity consumption), 2020–30. 227
Figure F.3 New Hampshire RPS by class (percent of electricity consumption), 2018–30. 228
Figure F.4 Rhode Island RPS by new and existing sources (percent of electricity consumption), 2018–30 228
Figure F.5 Vermont RPS by tier (percent of electricity consumption), 2017–32 229

Tables

Table ES.1 Summary of case study findings 27
Table 2.1 Average retail price of electricity, residential and commercial customers (in cents/kWh) and percentage change, 2010 and 2019 66
Table 2.3 RPS credits in Massachusetts, 2019 (by tier and location) 76
Table 2.4 Renewable portfolio targets by New England state (percent of electricity consumed with the use of qualifying renewable fuels), 2020, 2030, 2050 77
Table 2.5 Installed solar capacity in New England states by number of installations, MW capacity, and percentage of state electricity from solar, 2019 83
Table 3.1 AEO 2020 Reference case projections for the New England region 107
Table 3.2 Modeling scenarios (“cases”) and alternative assumptions used in the modeling 109
Table 3.3 AEO 2020 projections of percentage change in load, generation, imports, and prices for the New England region: Reference versus RPS Sunset cases 110
Table 3.4 Change in projected generation mix from the addition of RPS commitments in the electric-power sector (as a percentage of RPS Sunset case projections) 111
Table 3.5 Estimated increase in per-unit cost to Massachusetts consumers in different cases (in 2019 cents per kWh) 112
Table 3.6 Estimated increase in total cost to Massachusetts consumers in different cases (in millions of 2019 dollars) 112
Table 3.7 Estimated increase in the cost to Massachusetts residential consumers, monthly cost per customer (in 2019 dollars) 114
Table 3.8 Estimated increase in the cost to Massachusetts commercial consumers, monthly cost per customer (in 2019 dollars) 114
Table 3.9 Estimated savings for New England, excluding Massachusetts, due to Massachusetts’s commitments (in 2019 dollars) 115
Table 3.10 Estimated effect of commitments on carbon dioxide emissions under the Reference case 116
Table 3.11 Change in cost to consumers of removing access to imported hydroelectricity from New York State and Canada (as a percentage increase from the costs when Massachusetts has proportional access to imports) 118
Table 4.1 Top 10 operators of hydroelectric generating plants in Idaho, Montana, Oregon, and Washington in 2018, by MWh of hydroelectricity generation 130
Table 4.2 Columbia River Basin states’ exports of electricity trade with Canada, January–December 2019 133
Table 4.3 Columbia River Basin states’ imports of electricity trade with Canada, January–December 2019 133
Table 4.4 State and utility renewable and clean energy standards in the U.S. Columbia River Basin 134
Table E.1 Renewable and clean energy requirements (as a percentage of total load) 202
Table E.2 Projected share from hydroelectric power, Reference case (as a percentage of total load) 202
Table E.3 Projected renewable generation mix in the electric power sector in the New England region, Reference case (in terawatt-hours) 203

Table E.4 Projected renewable generation mix in the end-use sector in the New England region, Reference case (in terawatt-hours) 204
Table E.5 Average revenue and average cost of the marginal solar generation plant, Reference case (in 2019 dollars per megawatt-hour) 205
Table E.6 Additional renewable generation necessary to meet CES commitment (as a percentage of total Massachusetts load). 208
Table E.7 Carbon dioxide (CO_2) emissions rate of natural gas generation in New England, Reference case (in million metric tons per megawatt-hour) 212
Table E.8 Estimated savings for New England, excluding Massachusetts, due to Massachusetts's commitments (in 2019 dollars) 215
Table E.9 Estimated effect of commitments on carbon dioxide emissions per MWh in Massachusetts, alternative scenarios (in million metric tons, Mmt, per MWh) 216
Table E.10 Estimated effect of commitments on total carbon dioxide emissions in Massachusetts, alternative scenarios (in million metric tons, Mmt) 216
Table E.11 Estimated increase in per-unit cost to Massachusetts consumers with onshore wind as the marginal resource (in 2019 cents per kWh) 217
Table E.12 Estimated increase in total cost to Massachusetts consumers with onshore wind as the marginal resource (in millions of 2019 dollars) 217
Table E.13 Profitability (average revenue minus average cost) of solar (photovoltaic) in New England for all scenarios (in 2019 dollars per megawatt-hour) 218
Table E.14 Profitability (average revenue minus average cost) of onshore wind in New England for all scenarios (in 2019 dollars per megawatt-hour) 218
Table E.15 Estimated increase in per-unit cost to consumers of Massachusetts's increased commitments, varying levels of access to imports, High Renewables Cost Case (in 2019 cents per kWh) 219
Table E.16 Estimated increase in total cost to consumers of Massachusetts's increased commitments, varying levels of access to imports, High Renewables Cost Case (in millions of 2019 dollars) 219
Table E.17 Estimated increase in per-unit cost to consumers of Massachusetts's increased commitments if Massachusetts has no access to imported hydroelectricity (in 2019 cents per kWh) 220
Table E.18 Estimated increase in total cost to consumers of Massachusetts's increased commitments if Massachusetts has no access to imported hydroelectricity (in millions of 2019 dollars) 220
Table E.19 Estimated increase in the cost to residential consumers for high population growth, monthly cost per customer (in 2019 dollars) 220
Table E.20 Estimated increase in the cost to commercial consumers for high population growth, monthly cost per customer (in 2019 dollars) 221
Table F.1 Renewable energy credits in Connecticut (CT), 2019, by tier and location 229
Table F.2 Renewable energy credits in Maine (ME), 2019, by tier and location 230
Table F.3 Renewable energy credits in New Hampshire (NH), 2019, by tier and location 230
Table F.4 Renewable energy credits in Rhode Island (RI), 2019, by tier and location 230
Table F.5 Renewable energy credits in Vermont (VT), 2019, by tier and location 230

Table F.7 Net electricity generation for Columbia River Basin states, 2010 and 2018 (as a percentage of total generation) 231
Table G.1 New England and Massachusetts electricity generation by source (in terawatt-hours), 2010 and 2018........ 235
Table G.2 Massachusetts's clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50........ 235
Table G.3 New England and U.S. average retail price of electricity, for residential and commercial customers in cents per kilowatt-hour (cents/kWh), 2010–19........ 236
Table G.4 New England and Massachusetts electricity generation industry CO_2 emissions rate in pounds per megawatt-hour (lbs/MWh), 2010–18 236
Table G.5 New England net electricity generation by source and imports (in terawatt-hours), 2010–19 236
Table G.6 New England net renewable electricity generation by energy source (in terawatt-hours), 2010–19........ 237
Table G.7 New England electricity generation and net imports (in terawatt-hours), 2018........ 237
Table G.8 New England electricity generation by state and energy source (percentage of total generation), 2018........ 237
Table G.9 Massachusetts electricity generation by energy source and net imports (in terawatt-hours), 2010–18........ 238
Table G.10 Massachusetts renewable electricity generation by energy source (in terawatt-hours), 2010–18........ 238
Table G.11 New England (NE) and U.S. average retail price of electricity, residential and commercial customers in cents per kilowatt-hour (cents/kWh), 2010–19........ 238
Table G.12 New England and Massachusetts electric power industry carbon dioxide (CO_2) emissions rate in pounds per MWh (lbs/MWh), 2010–18 238
Table G.13 Massachusetts Class I RPS obligation, before and after the 2018 Massachusetts Act to Advance Clean Energy (percentage of electricity consumption) 239
Table G.14 Massachusetts renewable portfolio standard obligation (percent of electricity consumption), 2018–50 240
Table G.15 Massachusetts clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50........ 241
Table G.16 RGGI allowances for New England states, 2009–20 (by $MmtCO_2$ equivalent)........ 241
Table G.17 Economy-wide emissions targets by New England state, 2010–50 (by $MmtCO_2$ equivalent) 242
Table G.18 Estimated installed solar photovoltaic capacity in New England, 2018–25 (commercial, residential, and utility, MW) 242
Table G.19 Estimated installed wind capacity in New England, 2018–25 (onshore and offshore, MW) 242
Table G.20 Mandated share of load from renewable and clean sources under Massachusetts's recent goals and commitments (percentage of electricity consumption) 243
Table G.21 Power generation in Idaho, Montana, Oregon, and Washington by energy source, in terawatt hours (TWh) 244
Table G.22 Conventional hydroelectricity as a share of total net generation, 1990–2018 (percent)...... 244

Table G.23 Retail power prices for commercial customers in Columbia River Basin states and Massachusetts, 2010 and 2019 (in cents per kilowatt-hour) 245
Table G.24 Retail power prices for residential customers in Columbia River Basin states and Massachusetts, 2010 and 2019 (in cents per kilowatt-hour) 245
Table G.25 CO_2 emissions per MWh of generation, 2012 and 2018 245
Table G.26 New York State electricity imports and electric generation by source (in terawatt-hours).. 245
Table G.27 New York State upstate vs. downstate electricity generation by source, 2015–19 (in terawatt-hours).. 246
Table G.28 Electricity capacity in Denmark by source, 2010–19 (in MW) 246
Table G.29 Electricity generation in Denmark by source, 2010–19 (in terawatt-hours)......................... 246
Table G.30 Denmark’s imports of electricity, January 2010–June 2020 (in GWh).................................. 247
Table G.31 Denmark’s exports of electricity, January 2010–June 2020 (in GWh) 247
Table G.32 Denmark’s net exports of electricity, January 2010–June 2020 (in GWh)............................ 247
Table G.33 Electricity prices in Denmark, 2010–19 (in cents/kWh).. 248
Table G.34 Components of retail prices in 2019 (as a percentage of the total retail price).................... 248
Table G.35 Fossil fuel prices, reservoir levels, wind production, and electricity consumption, 2010–19 (Index, 2010 = 100) 248
Table G.36 Difference between daily minimum and maximum prices, 2019 (in $/MWh) 248
Table G.37 Greenhouse gas emissions (CO_2 equivalent) from electricity, gas, steam and air conditioning supply, 2010–18 (in million tons).. 249
Table G.38 Greenhouse gas emissions (CO_2 equivalent) from electricity, gas, steam and air conditioning supply, 2010–18 (in grams/euro value added)... 249
Table G.39 Observed CO_2 emissions, nonrenewable energy power plants, 2010–18, in million metric tons (Mmt).. 249
Table G.40 CO2 emissions per kWh of electricity consumption in Denmark, 2010–18, adjusted (in grams/kWh) 250
Table G.41 Average revenue minus average cost estimates, 2050 High Renewables Cost case example 250
Table G.42 Overnight installed capital cost in the United States by technology, Reference case (in 2019 dollars per kilowatt) 251
Table G.43 Overnight installed capital cost in the United States by technology, Low Renewables Cost case (in 2019 dollars per kilowatt).. 252
Table G.44 Overnight installed capital cost in the United States by technology, High Renewables Cost case (in 2019 dollars per kilowatt)... 253
Table G.45 U.S. electricity generation from selected fuels, Reference case (in terawatt-hours)............ 254
Table G.46 U.S. electricity generation from selected fuels, High Oil and Gas Supply case (in terawatt-hours).. 255
Table G.47 U.S. electricity generation from selected fuels, Low Oil and Gas Supply case (in terawatt-hours).. 256
Table G.48 Connecticut RPS by class (percent of electricity consumption), 2018–30 257
Table G.49 Maine RPS by class (percent of electricity consumption), 2020–30 257
Table G.50 New Hampshire RPS by class (percent of electricity consumption), 2018–30...................... 258

Table G.51 Rhode Island RPS by new and existing sources (percent of electricity consumption), 2018–30 258
Table G.52 Vermont RPS by tier (percent of electricity consumption), 2017–32 259

Glossary of Terms

Ancillary services: Services that ensure reliability and support the transmission of electricity from generation sites to customer loads. These services vary among electricity markets; examples may include load regulation, spinning reserve, and voltage support.

Baseload generation: Describes plants that are designed to operate continuously (outside of maintenance outages) and to consistently generate the same level of electricity. These plants are intended to have low enough operating costs (or supply a market with high enough load) to ensure that the plant’s electricity is almost always dispatched.

Behind the meter (BTM): Energy that is generated onsite, rather than energy that is delivered to a facility. For example, a solar panel on a residential customer’s or business’s roof that supplies a portion of that facility’s electricity demand would constitute “behind the meter” energy.

Biomass energy: Energy obtained from any plant-derived organic matter available on a renewable basis. Sources may include dedicated energy crops and trees, agricultural food and feed crops, crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes (garbage), and other waste materials.

Black start: The process of restoring a power station to operation after a total or partial shutdown without relying on the external electric power transmission network.

Class/Tier: In constructing their renewable portfolio standards (RPSs), states will often adopt special tiers or classes within an RPS that specify additional mandates for renewable energy use. Examples could include a mandate requiring that a specific share of electricity used in the state be derived from solar sources or be generated in-state.

Clean energy standards (CESs): Clean energy standards are policies designed to increase generation of electricity from resources that either are carbon free or have very low levels of greenhouse gas emissions. These policies require or encourage electricity producers within a given jurisdiction to supply a certain minimum share of their electricity from designated clean resources. Generally, these resources include renewable energy such as hydroelectricity, wind, solar, geothermal, and biomass, but they often also include nonrenewable energy sources, such as nuclear power; fossil fuel that is paired with carbon capture and storage technology; and programs reducing demand for generation, such as energy efficiency and conservation.

Curtailment: A reduction in the output of a generator from what it could otherwise produce using available resources (e.g., wind or sunlight), typically on an involuntary basis. Common reasons are transmission congestion or lack of transmission access. Solutions for reducing curtailment rates include expanding transmission infrastructure; upgrading interconnections; making operational changes, such as improving forecasting and increasing automation of signaling; and better management of reserves and generation.

Demand-response programs: These are incentive-based programs that encourage electric power customers to temporarily reduce their demand for power at certain times in exchange for a reduction in their electricity bills. Some demand-response programs allow electric power system operators to directly reduce load, while in others, customers retain control.

Dispatch: To bring a generating unit within a power system online (i.e., put it into operation) at a designated output level to meet demand for electricity.

Dispatch order/curve: Within an electric power system, the plants with the lowest variable operating costs are generally dispatched (brought online) first; as electricity demand increases, plants with higher operating costs are brought online in order of cost (those with the highest costs go last or not at all). Dispatch order can vary on a given day or time of day based on the relative prices of the fuel used. The amount of load (demand) and the amount of electricity being generated from wind and solar resources (supply) also affect whether power plants with higher operating costs are dispatched. (Also referred to as **merit order**.)

Distributed energy resources (DERs) (includes distributed generation): Distributed energy resources are small, decentralized generation and storage technologies that are typically located "behind the meter" and near an electricity consumer. Examples of DER technologies include rooftop solar installations, microgrids, combined heat and power systems, backup generation, and small-scale energy storage.

Feed-in tariff: A program typically guaranteeing that customers with eligible generation systems (such as rooftop solar PV) will receive a set price from the utility for all the electricity their system provides to the grid.

Geothermal energy: Hot water or steam extracted from geothermal reservoirs in the earth's crust. Water or steam extracted from geothermal reservoirs can be used for geothermal heat pumps, water heating, or electricity generation.

Greenhouse gases (GHGs): Gases such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride that have a heat-retaining effect. Emissions from these gases are transparent to solar (short-wave) radiation but opaque to infrared (long-wave) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface. A common unit of measure for emissions of GHGs is million metric tons of CO_2 equivalent, or $MmtCO_2e$.

Hydroelectric power: A form of renewable energy that uses the power of moving water to generate electricity. In general, there are three types of hydroelectric power facilities: impoundment (building a dam to create a reservoir), diversion (sometimes known as run-of-the-river), and pumped storage. Hydroelectric facilities range in size, and definitions of "small" and "large" facilities can vary by jurisdiction and policy. The U.S. Department of Energy defines a large hydropower facility as one with a capacity of more than 30 megawatts.

Imports: Throughout this report the term "imports" refers to electricity inflows from both international and interstate sources. For example, Massachusetts receives electricity inflows from an international source (Canada), as well as from interstate sources (other states both within the New England region and outside the region, such as New York).

Independent power producer (IPP): An entity that primarily produces electricity for sale on the wholesale market. It is not a utility, does not own electricity transmission infrastructure, and does not have a designated service area.

Independent system operator (ISO): An independent, federally regulated entity established to coordinate regional transmission and ensure the safety and reliability of the electric system. ISOs were developed in response to orders from the Federal Energy Regulatory Commission on providing nondiscriminatory access to transmission. See also regional transmission organization (RTO).

Investor-owned utility (IOU): An IOU is a for-profit utility.

Levelized avoided cost of electricity (LACE): LACE represents the potential value available to the owner of a future electricity generation project from the project's contribution to satisfying both energy and capacity requirements. LACE takes into account both the variation in daily and seasonal electricity demand and the characteristics of the existing generation fleet to which new capacity will be added.

Levelized cost of electricity (LCOE): LCOE represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. Key inputs for calculating LCOE include capital costs, fuel costs, fixed and variable costs of operations and maintenance, financing costs, and an assumed utilization rate for each plant type.

Load: The amount of electrical power delivered or required at any specific point or points on a system.

Net metering: A billing arrangement between a utility company and customers who generate some or all of their own electricity, crediting customers for the electricity they export to the grid. For example, a utility would bill a household that owns rooftop solar panels based on the difference between the standard monthly charges for the household's consumption and credits for any surplus electricity generation during the daytime.

Peaker plant: Plants which operate only during periods of higher than usual demand. These plants have higher operating costs than baseload plants (see "dispatch order") but tend to be able to more flexibly ramp up and down.

Power purchase agreement (PPA): A long-term agreement to buy electricity. In the wholesale market, this is generally between a utility and an independent power producer. There are also PPAs between renewable energy firms and on-site users.

Publicly owned utility: A nonprofit, state, or local government utility.

Pumped storage: A type of hydropower that works like a battery, in which water is pumped from a lower reservoir to an upper reservoir for storage and is later released from the upper reservoir to generate electricity (using gravity for power).

Regional Greenhouse Gas Initiative (RGGI): An undertaking by a coalition of New England and mid-Atlantic states to cap and reduce carbon dioxide emissions in the power sector.

Renewable energy certificates (RECs): Tradable credits providing proof that electricity was generated from a renewable source. Each certificate represents one megawatt-hour of generation. RECs are also known as renewable energy credits.

Regional transmission organization (RTO): An independent, federally regulated entity established to coordinate regional transmission and ensure the safety and reliability of the electric system. Similar to an independent system operator (ISO), but based on a different order from the Federal Energy Regulatory Commission specifying 12 characteristics and functions the entity must satisfy in order to become certified as an RTO.

Renewable portfolio standards (RPSs): Renewable portfolio standards, also referred to as renewable energy standards (RESs), are policies designed to increase generation of electricity from renewable resources. These policies require or encourage electricity producers within a given jurisdiction to supply a certain minimum share of their electricity from designated renewable resources. Generally, these resources include wind, solar, geothermal, and biomass sources, and generally do not include large hydroelectric dams, but may include other resources such as small hydropower projects, landfill gas, municipal solid waste, and tidal energy.

RPS carveout: A portion of an RPS that is set aside solely to be filled by a specific technology (for example, solar power). Generally, the aim of the carveout is to incentivize the development of capacity for the targeted technology.

Residential: Electricity consumers in single- and multifamily houses, apartments, and mobile homes.

Retail electricity market: The market for the sale of electricity to consumers.

Run-of-the-river: A type of hydropower project that can store only limited amounts of water; it releases water at roughly the same rate as the natural flow of the river.

Solar photovoltaic (PV) power: Energy radiated by the sun as electromagnetic waves (electromagnetic radiation) that is converted into electricity by means of photovoltaic (solar) cells.

Utility (electric): A corporation, person, agency, authority, or other legal entity or instrumentality aligned with distribution facilities to deliver electric energy for use primarily by the public. Included are investor-owned electric utilities, municipal and state utilities, federal electric utilities, and rural electric cooperatives. A few entities that are tariff based (fee based) and corporately aligned with companies that own distribution facilities are also included.

Watt: A unit of electrical power equaling the amount of power produced from one joule of energy in one second. An electricity generator's capacity and the capacity of transmission lines are often measured in watts. Wattage is expressed as follows:
1,000 watts (W) = 1 kilowatt (kW)
1,000 kilowatts (kW) = 1 megawatt (MW)
1,000 megawatts (MW) = 1 gigawatt (GW)
1,000 gigawatts (GW) = 1 terawatt (TW)

Watt-hour: A measure of electricity consumption, generation, and transmission. One watt-hour (Wh) is equal to the steady transferal of one watt of power over one hour. Electricity consumption, generation, and transmission are expressed as follows:
1,000 watt-hours (Wh) = 1 kilowatt-hour (kWh)
1,000 kilowatt-hours (kWh) = 1 megawatt-hour (MWh)
1,000 megawatt-hours (MWh) = 1 gigawatt-hour (GWh)
1,000 gigawatt-hours (GWh) = 1 terawatt-hour (TWh)

Wholesale electricity market: The market for the sale of electricity from companies that generate electricity to utilities/entities that resell the electricity on the retail market.

Abbreviations and Acronyms

Abbreviation or acronym	Term
ACP	alternative compliance payment
AEO	Annual Energy Outlook (EIA)
BPA	Bonneville Power Administration
BTM	behind the meter
CAGR	compound annual growth rate
CAISO	California Independent System Operator
CANWEA	Canadian Wind Energy Association
CEC	clean energy certificate
CES	clean energy standard
CH_4	methane
CHP	combined heat and power
CHPE	Champlain Hudson Power Express
CLCPA	Climate Leadership and Community Protection Act (NY)
CO_2	carbon dioxide
DEEP	Department of Energy and Environmental Protection (CT)
DER	distributed energy resource
DOER	Department of Energy Resources (MA)
EIA	U.S. Energy Information Administration
ERCOT	Electric Reliability Council of Texas
ETS	Emissions Trading System (EU)
EU	European Union
FERC	Federal Energy Regulatory Commission
GHG	greenhouse gas
GWSA	Global Warming Solutions Act (MA)
GW	gigawatts
ISO	independent system operator
ISO-NE	ISO New England
LACE	levelized avoided cost of electricity
LCOE	levelized cost of electricity
LNG	liquefied natural gas
MISO	Midcontinent Independent System Operator
$MmtCO_2e$	million metric tons of carbon dioxide equivalent
MW	megawatt
MWh	megawatt-hour
NE	New England
NEPOOL	New England Power Pool
NREL	National Renewable Energy Laboratory
NERC	North American Electric Reliability Organization
NYISO	New York Independent System Operator
PPA	power purchase agreement
PV	photovoltaic
REC	renewable energy certificate
RES	renewable energy standard
RGGI	Regional Greenhouse Gas Initiative
RPS	renewable portfolio standard
RTO	regional transmission organization
SREC	solar renewable energy certificate
TWh	terawatt-hour

Executive Summary

This report by the U.S. International Trade Commission (Commission or USITC) assesses the potential economic effects of increased renewable energy commitments in New England as a whole and Massachusetts in particular, and the role of renewable electricity imports from both interstate and international sources in meeting these commitments.[1] To do so, it first offers an overview of market trends in New England and Massachusetts, including (1) domestic and imported electricity sources and (2) residential and commercial rates for electricity use. It also reports on the status of the ongoing transition in New England and Massachusetts from nuclear and fossil fuels to renewable sources. This discussion includes a description of these polities' goals and commitments for the use of renewable and clean energy and the resources available to meet these commitments.

In addition, the report presents a quantitative analysis of the potential economic effects on Massachusetts and New England of reaching their increased renewable energy goals and commitments, such as potential price changes for residential and commercial consumers of electricity. It focuses on the economic implications of two commitments in Massachusetts: an increase in Massachusetts's Renewable Energy Portfolio Standard in 2018, and the creation of a Clean Energy Standard in 2017, both of which set electricity sourcing targets that gradually increase through 2050. The report also gives a quantitative analysis of the potential effects on greenhouse gas (GHG) emissions of meeting these goals and commitments.

Finally, the report offers four case studies involving other states, regions, or countries to gain insights into the potential economic and environmental effects of imports of hydroelectricity. Two of the case studies present a broad analysis of the respective electricity markets: the U.S. Columbia River Basin (spanning Idaho, Montana, Oregon, and Washington) and Denmark. These case studies explore the ways access to hydroelectricity can influence the rates paid by commercial and residential electricity consumers, as well as how it can affect the progress of efforts to meet renewable energy targets and to lower GHG emissions. The two other case studies have a narrower focus, highlighting factors affecting the role of hydroelectricity imports in the electricity supply in New York and the central United States.

This report responds to the request of the Committee on Ways and Means of the U.S. House of Representatives for a report on the potential economic effects of increased renewable energy commitments in New England and Massachusetts and on the role of renewable electricity imports—particularly hydroelectricity imported from Canada—in meeting these commitments.

Highlights

As New England—particularly Massachusetts—has shifted away from electricity generation derived from coal, oil, and nuclear energy, it has increased both its reliance on electricity imports and its renewable energy generation. New England as a whole and Massachusetts in particular have increased

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[1] Throughout this report the term "imports" refers to electricity inflows from both international and interstate sources. Data on electricity generation within a particular state or regional wholesale market are available broken down by source, while data on electricity supplied from outside the state or region tend to have fewer details about power sources.

electricity imports from both interstate and international sources to offset internal declines in electricity generation due to retirements of coal, oil, and nuclear plants. New England and Massachusetts continue to rely heavily on natural gas-fired generation within their respective markets: natural gas powers over half of New England's internal electricity generation and over two-thirds of Massachusetts's in-state electricity generation.

Power plants fired by coal and oil have been the main drivers of New England's electricity sector's GHG emissions. Reduced power generation from coal- and oil-fired generation plants was responsible for most of the decrease in electricity sector emissions from 2010 to 2018 in New England and Massachusetts. Many of these plants have been retired, leaving only five coal-fired power plants in New England and none in Massachusetts.

The Commission's economic analysis projects that Massachusetts can meet its increased renewable and clean energy commitments with relatively small increases in the retail electricity rates charged to residential and commercial consumers. This analysis suggests that Massachusetts will meet its Renewable Energy Portfolio Standard commitments through increased generation from wind and solar and will meet its Clean Energy Standard commitments largely through imported hydroelectricity, with wind or solar playing a significant role in the later years of the clean energy commitment. Both these changes will come at a relatively low cost to consumers: a total of between 0 cents and 0.19 cents per kilowatt-hour in 2030 across the scenarios modeled. For comparison, Massachusetts's residential electricity rates in 2019 averaged 22.0 cents per kWh, and commercial electricity rates averaged 16.5 cents per kWh. The upper bound of the cost to consumers is equivalent to an additional $0.76 per month for residential consumers and an additional $5.57 per month for commercial consumers.

These costs stem from the incentives required to prompt the building of additional electricity generation from renewable energy, which are ultimately paid for through additional charges to consumers of electricity. In most of the scenarios modeled, there are no costs to consumers in later years of the commitments, due to declining costs of renewable energy technology that will make renewable generation profitable to build without any incentives. The model also projects that the rest of New England will see small annual savings from Massachusetts's shift to renewables of between $0 and $3 million in each of the years modeled due to the lower cost of electricity produced from renewable energy as compared to natural gas-fired generation.

Massachusetts's renewable and clean energy commitments will help reduce GHG emissions in 2030 and 2035, while additional emissions reductions will happen naturally thereafter as the technology costs for zero-emission solar and wind resources continue to fall. Massachusetts's increased use of renewable and clean sources of electricity generation will reduce its carbon footprint, mostly by displacing natural gas-fired generation (including in neighboring areas that serve the Massachusetts market). The reference case scenario projections for the model show that the Massachusetts's commitments will reduce annual carbon dioxide emissions by 1.94 million metric tons in 2030. This is equivalent to the amount of carbon absorbed by 2.5 million acres of U.S. forests in a year.

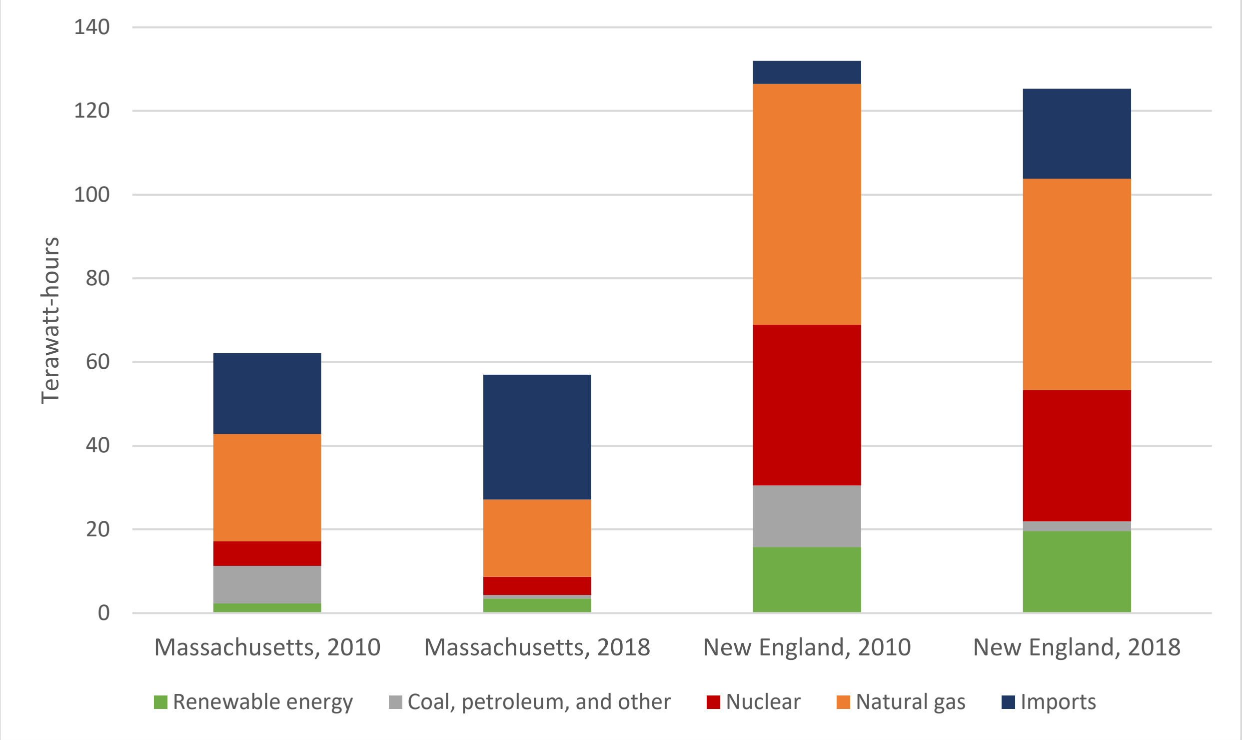
Case studies show the potential for hydroelectricity imports to help stabilize electricity prices, reduce costs to consumers, and make variable renewable energy (such as wind and solar) more profitable. Access to large levels of hydroelectricity is associated with relatively low and stable electricity prices. When hydroelectricity imports are used to balance fluctuations in wind power generation, they reduce price volatility and can increase the revenue available to wind projects. By enabling greater integration of variable renewable energy, hydroelectricity imports have the potential to support meeting both renewable portfolio standard and clean energy standard commitments—even though they typically only qualify directly for clean energy standard targets.

Electricity Generation Trends

New England functions as a single wholesale electricity market, with state-specific variation in policy commitments and in how electricity suppliers are regulated. New England's generation of electricity has declined since 2010, driven primarily by the retirement of nuclear, coal, and petroleum plants, in addition to an overall reduction in demand. Natural gas was the largest fuel source for electricity generation, powering almost half of total generation in the region in 2018, followed by nuclear and renewable sources. Renewable energy was the only generation source within New England that grew between 2010 and 2018. Net electricity imports from both international and interstate sources have nearly quadrupled since 2010. These imports have supplied a larger share of consumption as plants are retired and as natural gas pipeline capacity sometimes falls short during peak demand times. While data on imports are not broken out by generation source, most of these imports came from Quebec and were likely generated from hydroelectric dams.

The commonwealth of Massachusetts is the largest consumer of electricity in the New England region, and more than half of its electricity is imported to meet demand, predominantly from interstate sources. Natural gas fuels a substantial portion of its generation (over two-thirds), followed by renewable resources, which are a small but growing source of generation (figure ES.1). Massachusetts retired its last remaining coal plant in 2017 and its last remaining nuclear facility in 2019.

Figure ES.1 New England and Massachusetts electricity generation by source (in terawatt-hours), 2010 and 2018



Source: U.S. Energy Information Administration (EIA), “Massachusetts Electricity Profile,” table 5 and table 10, (Excel file, accessed March 24, 2020); ISO New England, Net Energy and Peak Load by Source (accessed March 24, 2020)
Notes: Coal-fired generation in Massachusetts in 2018 was zero. Renewable energy in this figure includes all forms of hydroelectric generation and generation from biomass. However, state-level renewable portfolio standards have varying eligibility requirements and may not qualify all of these as renewable generation sources. While data on imports are not broken out by generation source, most of the New England imports came from Quebec and were likely generated from hydroelectric dams. Underlying data for this figure can be found in appendix table G.1.

The majority of Massachusetts’s renewable electricity generation between 2010 and 2018 came from hydroelectric facilities and biomass (organic material from plants and animals, such as municipal solid waste). Over the same period, most of the growth in Massachusetts’s renewable energy generation came from solar and, to a lesser extent, wind. Massachusetts is a regional leader in developing solar, likely due in part to the “carveouts” in its renewable energy commitment, which collectively required that 2.5 million megawatt-hours of generation and 5.4 percent of electricity sales come from solar resources by 2020.

Renewable and Clean Energy Commitments

This report focuses on two recent sets of goals and commitments: Massachusetts’s 2018 update to its Renewable Energy Portfolio Standard (RPS), and its 2017 establishment of a Clean Energy Standard (CES). With respect to Massachusetts’s RPS, consistent with the request letter, the report’s quantitative analysis focuses on the increase in renewable energy commitments between Massachusetts’s pre-2018 RPS and the 2018 update; features of Massachusetts’s RPS that remain unchanged by the 2018 update are not captured in the analysis.

RPSs are widely used by states to establish enforceable commitments to renewable energy. However, they vary from state to state in their coverage, and they are increasingly being supplemented with or replaced by CESs that allow a broader range of qualifying sources. Both clean and renewable energy standards typically apply to the electricity supplied to customers within the state, including sales of electricity imported from neighboring states or countries. There is, however, significant variation among these standards in the specific renewable energy resources that are eligible to meet the commitments and in the design of clean energy commitments.

Massachusetts's RPS includes multiple components. Its Class I obligations set the commonwealth's primary commitment to source 55 percent of its electricity from qualifying renewable energy resources by 2050. Qualifying sources for this commitment include wind, solar, and small-scale hydro, but exclude large-scale hydroelectric facilities. In its original form, Massachusetts's RPS specified that the share of Class I renewably sourced electricity must grow by 1 percentage point per year between 2020 and 2029. The 2018 update to Massachusetts's RPS increased the mandate for this growth to 2 percentage points per year, collectively raising the target for the decade by 10 percentage points. Massachusetts's RPS also includes a separate, narrower category (Class II) for older generators (facilities that generate electricity) and waste-energy generators, as well as carveouts for solar generation, but these targets were not modified in the 2018 update. These components were therefore not included in the Commission's quantitative analysis, given the request letter's focus on the recent changes in Massachusetts's renewable energy commitments and the commitments' increased targets.

Massachusetts's CES mandates that 80 percent of the commonwealth's electricity supply (including electricity imported from neighboring states or electricity markets) come from low-emission sources by 2050. Under Massachusetts's CES, such sources include all RPS Class I sources (such as wind, solar, and small-scale hydro) as well as other sources of clean energy (such as large-scale hydro and nuclear) that started commercial operations in 2011 or later. Clean energy commitments, like Massachusetts's CES, generally set higher targets than renewable energy commitments and generally allow more qualifying resources in terms of meeting the commitments. Massachusetts's 2017 CES was updated in 2020 to allow large-scale hydroelectric facilities and nuclear plants that began operations before 2011 to meet some of the target.

Hydroelectric facilities generally qualify to contribute to clean energy commitments, with limited exceptions in some commitments for newly expanded or developed dams. Clean energy commitments may be used to encourage continued or expanded sourcing from large hydroelectric facilities, nuclear plants, or both. By contrast, most RPS commitments in New England place a capacity limit for hydroelectric facilities, only qualifying relatively small hydroelectric projects that typically use a diverted stream ("run-of-the-river") rather than a dam to generate electricity.[2]

In Massachusetts, the level of renewably sourced electricity that was mandated under the CES commitment started below the level mandated by the RPS (in part because older Class II resources that qualify under Massachusetts's RPS do not qualify under its CES). But Massachusetts's CES commitment for clean energy overall overtakes the level of its RPS commitment for renewable energy after 2030

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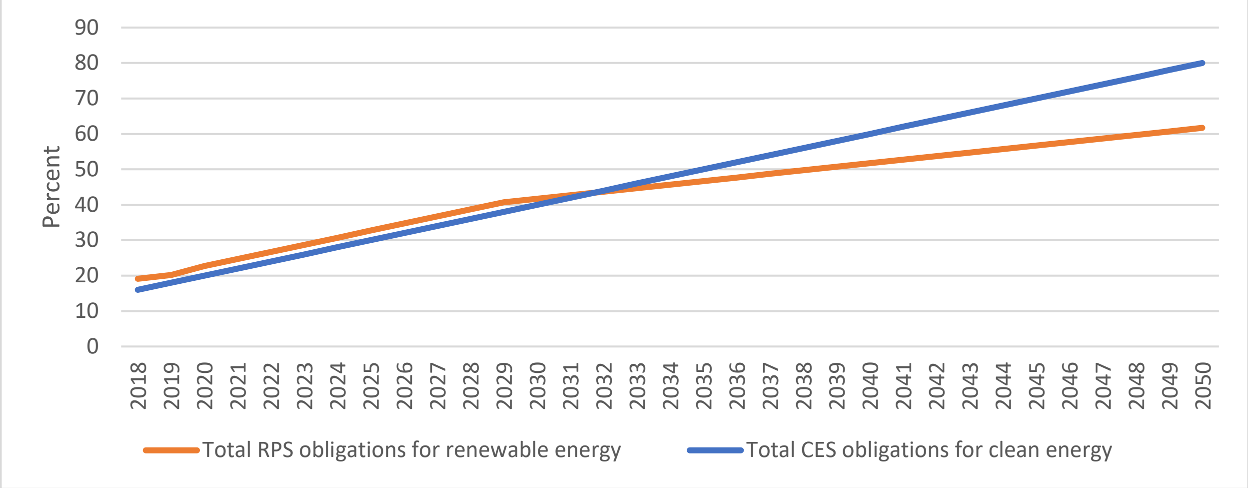
[2] Vermont is the only state in New England where large-scale hydroelectric generation qualifies for the RPS. Vermont also has one of the highest RPS commitments in New England, rivaled only by Maine.

(figure ES.2). By 2050, its CES commitment rises to 80 percent of electricity sales, compared to 61.7 percent of sales for its RPS from Class I and Class II resources combined.

Figure ES.2 Massachusetts clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50



Source: Lawrence Berkeley National Laboratory, "RPS Targets (Percent of Applicable Retail Electricity Sales)," July 2019 (Excel file); State of Massachusetts, Global Warming Solutions Act 10-Year Progress Report, 2017, P. 30, P. 56.
Note: Large-scale hydroelectricity is a qualifying resource for the Clean Energy Standard obligations only. Underlying data for this figure can be found in appendix table G.2.

Potential Sources of Clean and Renewable Energy

Solar and wind are the two fastest-growing sources for renewable electricity generation, within New England and on a global scale. Solar generation capacity in New England is projected to more than double from 2018 levels by 2025 (increasing by over 5 gigawatts, or GW), while wind capacity is projected to triple (increasing by over 4 GW) over the same time frame. Most of the near-term growth in wind is projected to come from offshore wind, with several large projects—including two off the coast of Massachusetts—in varying stages of development. By contrast, electricity generation from biomass and landfill methane in the New England region appears to be slightly decreasing, and the potential for new hydroelectric facilities within the New England region is fairly low.

Renewable energy resources in neighboring markets may also assist New England states in meeting renewable energy targets; New York, New Brunswick, and Quebec each supply electricity directly to the region. New York exports significant amounts of electricity generated from both renewable and nonrenewable sources. Moreover, the state is projected to more than quadruple its solar capacity and to triple its wind capacity between 2018 and 2025. New Brunswick and Quebec are also increasing their renewable capacity, particularly wind. Most of Canada's exports to New England, however, will likely continue to come from large hydroelectric dams. As discussed above, these Canadian resources do not qualify for most of the renewable energy commitments in New England but can help meet Massachusetts's CES and other states' clean energy goals.

While solar and wind show the greatest potential for helping meet renewable energy commitments, challenges remain. The costs of additional investments in transmission capabilities, which are often necessary to connect renewable energy generation projects to urban demand centers, are particularly high for projects located offshore or in other remote areas. Furthermore, New England has one of the lowest levels of large-scale battery storage capacity in the United States. But several states in the region have initiatives to promote energy storage, and costs for large-scale battery capacity are projected to continue to fall.

Hydroelectricity and Variable Renewable Electricity

Hydroelectricity is a relatively flexible generation resource that can balance variable resources like wind and solar, making it easier to incorporate these sources into a state's or region's energy mix. Increasing the share of wind and solar in the electricity supply can create large, rapid fluctuations in the additional supply that is needed from other generation resources. The extent to which other flexible generation resources such as hydroelectricity are available affects how much wind and solar can be integrated into an area's energy system.

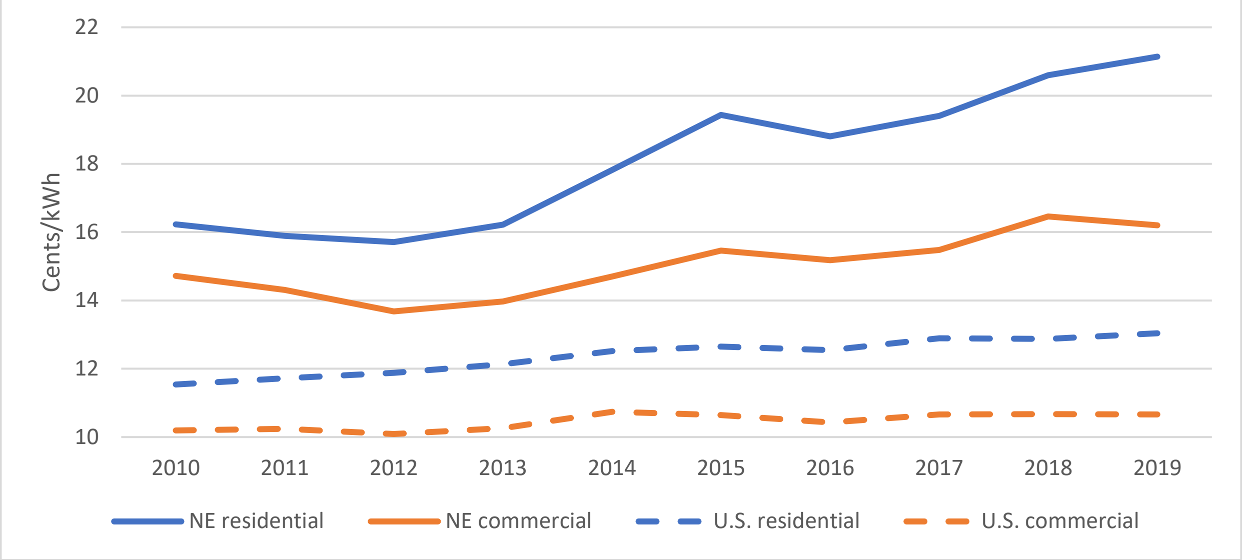
The ability of hydroelectricity imports to balance fluctuations in wind and solar varies depending on factors such as transmission availability, market structure, and contract provisions. In case study markets where hydroelectricity imports have a prominent role supporting variable renewable energy, the imports of hydroelectricity are able to fluctuate in quantity and respond to short-term changes in wholesale prices by quickly rising or falling. These imports are also sizable enough to be able to significantly alter the system's overall electricity supply.

Other flexible generation resources and strategies may also be used to enable higher integration of solar and wind resources. For example, Denmark has relatively high levels of wind generation. And while imported hydroelectricity from Norway helps support integration of this wind power, relatively flexible generation from combined heat and power plants, and transmission connections with other countries (like Germany), further support integration. Moreover, as discussed in the U.S. Columbia River Basin case study, limited reservoir capacity and other factors affecting how hydroelectric facilities are operated can restrict how much hydroelectric generation can be used to balance variability.

Electricity Rates and Greenhouse Gas Emissions

Average retail electricity prices in New England are significantly above the national average (figure ES.3). They reflect relatively high wholesale prices as well as substantial costs specific to retail rates—particularly infrastructure costs (including building transmission lines) and policy costs (including costs associated with RPS and CES compliance). Electricity is freely traded within New England and with neighboring markets in a single wholesale market overseen by an independent authority. New England's high wholesale prices stem from the region's reliance on imported natural gas for most of its electricity generation. Utilities and third-party electricity providers buy electricity at these wholesale prices and sell to customers at higher retail prices, which incorporate the state-specific infrastructure and policy costs mentioned above. Retail prices are further differentiated by type of consumer, with different retail rates charged to residential, commercial, and industrial customers.

Figure ES.3 New England and U.S. average retail price of electricity, for residential and commercial customers in cents per kilowatt-hour (cents/kWh), 2010–19

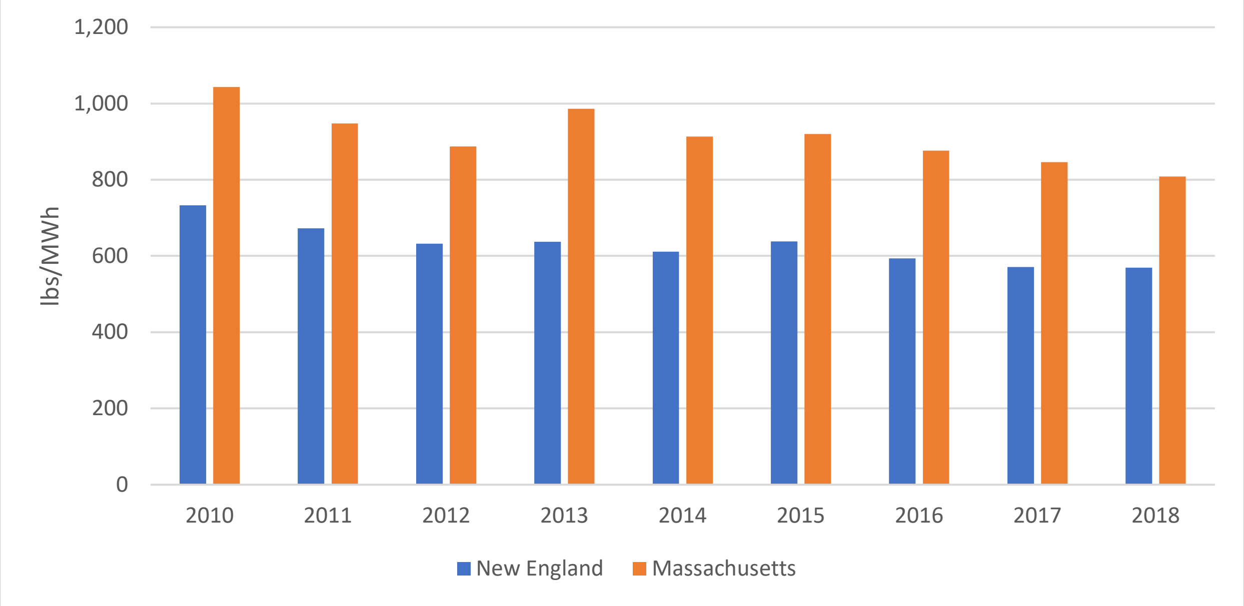


Source: U.S. Energy Information Administration (EIA), "Electric Sales, Revenue, and Average Price," Table 4, (Excel file, accessed March 24, 2020).
Note: This report focuses on trends in electricity prices and potential economic effects on residential and commercial customers, as requested; prices for industrial customers are generally available from the sources cited but not presented in this report. Underlying data for this figure can be found in appendix table G.3.

Massachusetts had the highest retail electricity rates in New England in 2019, which likely reflects both policy and infrastructure costs. Policy costs include the cost of compliance with renewable and clean energy commitments through utilities' purchase of renewable energy credits or certificates, which are passed through to consumers, while infrastructure costs include investments in transmission. In the New England market, transmission costs are allocated to each of the states based on their load; with Massachusetts accounting for slightly less than half of the system's load, it is responsible for paying for a large share of transmission infrastructure. Differences between regional wholesale prices and Massachusetts's retail prices may also be due to costs of energy efficiency programs, which utilities normally pass on to consumers. In addition, long-term contracts can influence retail prices, depending on how the specific terms of the contracts compare to prevailing market prices.

GHG emissions from electricity generation in New England have declined significantly in recent years: carbon dioxide emissions—measured in pounds of carbon dioxide emitted per megawatt-hour (MWh)—fell by over 22 percent between 2010 and 2018 (figure ES.4). This decline is largely driven by reduced generation from coal- and oil-fired plants. The region's total electricity generation also declined over the same period, further reducing total carbon dioxide emissions from electricity generation in the region. Massachusetts experienced similar trends, with both emissions rates and total electricity generation declining from 2010 to 2018.

Figure ES.4 New England and Massachusetts electricity generation industry carbon dioxide (CO_2) emissions rate in pounds per megawatt-hour (lbs/MWh), 2010–18



Source: U.S. Energy Information Administration (EIA), "Massachusetts Electricity Profile," table 7, (Excel file, accessed March 24, 2020); EIA, "Connecticut Electricity Profile," table 7, (Excel file, accessed March 24, 2020); EIA, "Maine Electricity Profile," table 7, (Excel file, accessed March 24, 2020); EIA, "New Hampshire Electricity Profile," table 7, (Excel file, accessed March 24, 2020); EIA, "Rhode Island Electricity Profile," table 7, (Excel file, accessed March 24, 2020); EIA, "Vermont Electricity Profile," table 7, (Excel file, accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.4.

Most of the observed emissions rate reductions resulted from retiring higher-emitting electricity generation sources. Emissions rate reductions in New England appear to have slowed recently, as only limited coal- and oil-fired generation capacity remains in the market. Some of these emitting resources—as well as older gas-fired generation units—are still used to meet seasonal peaks in demand, increasing average emissions rates in years where the additional capacity is needed due to harsher weather. Other than reducing emissions from these "peaker" plants, most future emissions reductions will need to come from displacing gas-fired generation.

Effects of Commitments on Rates and Emissions

This report's quantitative analysis projects that the costs to residential and commercial ratepayers of Massachusetts's increased renewable and clean energy commitments will be relatively small from 2030 to 2050. The quantitative analysis used several different scenarios from the U.S. Energy Information Administration (EIA) Annual Energy Outlook (AEO), including the AEO's Reference case. The Reference case reflects EIA's best estimate of conditions in U.S. and world energy markets over the course of the AEO forecast, which runs through 2050. It assumes reductions in the cost of renewable energy technologies over time, resulting in higher costs in the earlier years of the commitments. Compliance costs are linked to how much of an incentive is needed to make it profitable to generate electricity from renewable and clean resources; as described below, utilities pay eligible generation facilities for certificates associated with their renewable or clean attributes and then pass the cost of these certificates on to consumers. Massachusetts's increased RPS and CES commitments are projected to cost the commonwealth's electricity consumers a total of $19.5 million in 2030 and $11.7 million in 2035 in the reference case. These costs are equally divided across retail electricity sales, such that Massachusetts residential and commercial consumers would each pay an additional 0.04 cents per kilowatt-hour (kWh) in 2030 and 0.02 cents per kWh in 2035. This increase represents a very small share of retail electricity rates; in 2019, Massachusetts's residential electricity rates averaged 22.0 cents per kWh, and commercial electricity rates averaged 16.5 cents per kWh. As described below, costs to consumers of compliance with Massachusetts's renewable and clean energy commitments are projected to fall to zero by 2040 in the reference case.

Renewable and clean energy commitments in New England are enforced by requiring utilities and other entities that sell electricity to retail customers to buy certificates (also called credits) demonstrating that the share of load specified in the commitment is being met by supporting eligible resources. Examples of these certificates include renewable energy certificates (RECs) and clean energy certificates (CECs). The certificates are created each time an eligible facility generates 1 megawatt-hour (MWh) of electricity. Utilities then pass the costs of these certificates through to their retail customers, evenly splitting the cost such that residential and commercial ratepayers face the same charge per unit of electricity consumed.

In later years of most of the scenarios modeled, renewable energy becomes profitable enough to prompt its capacity buildout without receiving any credits, causing the compliance costs (and costs to consumers) to fall to zero by 2040. Installation of solar and wind facilities would increase enough to meet Massachusetts's renewable energy commitments and cover its clean energy commitments up to a point, with imports of hydroelectricity meeting the remainder of Massachusetts's clean energy commitments.

A recent update from Lawrence Berkeley National Laboratory estimated that Massachusetts RPS compliance costs were responsible for over 11 percent of consumer electricity bills in 2018. This is consistent with the reference case's projections that compliance costs will be highest in the early years and decline over time, but it could also signal that factors not covered in the model are contributing to the compliance costs. For example, the solar carveouts within Massachusetts's RPS were not modeled in the quantitative analysis (as these carveouts predated the 2018 version of the state's RPS). Examples elsewhere in New England show that the structure and eligibility requirements for renewable energy commitments can significantly affect the cost and feasibility of meeting the commitments.

The model presented in this report projects that Massachusetts's RPS and CES commitments will also result in modest savings for consumers in the rest of New England in 2030 and 2035. The compliance costs are paid only by Massachusetts consumers, but the increase in renewable energy generation within New England should slightly lower the regional price of electricity. Consumers in the rest of New England are projected to save $0.9 million in 2030 and $3.0 million in 2035 in the reference case.

In the reference case, the model projects that carbon dioxide emissions associated with Massachusetts's electricity supply (including imports) will decrease by 1.94 million metric tons in 2030 and 1.91 million metric tons in 2035 as increased generation from renewable and clean resources displace gas-fired generation. The reductions in 2030 would be approximately equivalent to the carbon absorbed by 2.5 million acres of U.S. forests in one year. These reductions are significant relative to Massachusetts's GHG emissions; Massachusetts's electricity consumption was associated with 13.6 million metric tons of carbon dioxide equivalent in 2017.

Effects of Hydroelectricity Imports on Rates and Emissions

Projected levels of hydroelectricity imports and regional hydroelectricity generation can supply most of the clean energy Massachusetts has committed to above its RPS commitment. This will allow utilities to balance variable renewable energy sources, such as wind and solar, with more flexible hydroelectricity and help maintain a more diverse electricity mix. Additionally, hydroelectricity imports can help offset reductions in fossil fuel-fired generation in both New England and Massachusetts and supplement the gradual growth in local renewable electricity generation.

Hydroelectricity imports can also reduce price volatility and revenue declines for wind and solar generation when wind or solar supply is high, effectively supporting renewable energy development. As described in the quantitative analysis, compliance costs are linked to how much of an incentive is needed to make eligible renewable resources profitable. As is shown by the Denmark case study (table ES.1), hydroelectric facilities can go offline during peak periods of renewable energy generation, thus lessening wholesale price declines for electricity generated by wind and solar facilities. This improves the revenues that variable renewable projects receive and effectively reduces the cost of renewable energy commitments.

Table ES.1 Summary of case study findings

Main case studies	Smaller case studies focused on trade
U.S. Columbia River Basin: Shows the effects of hydroelectricity contributing a large share of the electricity supply. The region’s access to hydroelectricity has yielded consistently low electricity prices, facilitated the integration of wind, encouraged the development of power-intensive industries, and supported relatively low emissions rates.	**New York State:** Shows the importance of intrastate differences in electricity supply and transmission. Supplying more clean energy directly to the downstate market, including hydroelectricity imports, is part of the state’s strategy for meeting its commitments for both renewable energy and emissions reductions.
Denmark: Shows the effects of imported hydroelectricity in a country that has shifted to supplying nearly half of its annual electricity from wind. Hydroelectric facilities in Norway go offline during periods of high wind generation, reducing price volatility and effectively acting as storage at a lower cost than current battery technology. Hydro imports have been one of several important tools for transitioning Denmark towards higher integration of renewables and minimizing wind “curtailment” (a forced reduction in output due to oversupply or insufficient demand).	**Minnesota and Manitoba:** Shows how trade can be structured to capture more synergies between generation from wind and hydroelectricity. Minnesota Power included a “wind storage” provision in a contract to import hydroelectricity, and the Midcontinent Independent System Operator (MISO) adjusted its market bidding to allow Manitoba Hydro to be more responsive to short-term fluctuations in price (which are often linked to variation in wind generation).

Source: Compiled by USITC.

More generally, each of the case studies provides further evidence that greater access to hydroelectricity can reduce electricity rates. The U.S. Columbia River Basin uses hydroelectricity for over 60 percent of its regional generation and had prices of at least 0.5 cents per kWh below the U.S. average in 2010 and 2019. New York’s main transmission connections with Canada provided an estimated $45 million of savings to the state’s wholesale electricity market in 2019, due to imports that mostly consisted of hydroelectricity. Midcontinent Independent System Operator (MISO), the operator of an electricity market including Manitoba and 15 states in the north- and south-central United States, reaped significant cost savings resulting from Manitoba Hydro's participation in real-time energy markets. And in Denmark's regional power market (Nord Pool), wholesale market prices were much lower than prices in other major West European markets, in addition to having relatively low price volatility.

The case studies also underline hydroelectricity's supporting role in reducing emissions. Most of the U.S. Columbia River Basin has carbon dioxide emissions rates from generation facilities well below the national average, likely due to its heavy reliance on hydroelectricity. (The one exception, Montana, uses a lower share of hydroelectric power than the rest of the region.) Denmark's greenhouse gas emissions from its electricity generation, gas, steam, and air conditioning were reduced by more than half between 2010 and 2018. New York is using imported hydroelectricity to help replace the low-emission generation capacity it lost from retiring the last nuclear plant in its downstate market. Similarly, to phase out one of its major coal-fired power plants, Minnesota Power is planning to use a wind farm whose variable generation is supported by hydropower generation in Manitoba.

Chapter 1

Introduction and Background on Electricity Markets

This report assesses the potential economic effects of increased renewable energy commitments in New England as a whole and Massachusetts in particular and the role of renewable electricity imports in meeting these commitments. The commitments require a transition in the sources of electricity used from traditional fossil fuels and nuclear energy, at a time when Massachusetts is experiencing high retail electricity prices and when retirements of nuclear and coal-fired power plants have reduced the regional supply of electricity. As part of its strategy for addressing these challenges, Massachusetts plans to use imports of hydroelectricity from Canada, among other renewable energy resources.

This report responds to a request from the Committee on Ways and Means of the U.S. House of Representatives (Committee) asking that the U.S. International Trade Commission (Commission or USITC) conduct an investigation and provide a report under section 332(g) of the Tariff Act of 1930. The Committee sent a letter on January 23, 2020,[3] asking that the report address the potential economic effects of increased renewable energy commitments in New England and Massachusetts and the role of renewable energy imports in meeting these commitments. The letter requests that the report include, to the extent practical, the following:

1. An overview of the current situation and recent trends in New England and Massachusetts electricity markets with regard to domestic and imported electricity sources and rates for residential and commercial uses, and the status of the transition from nuclear and fossil fuels to renewable sources. This overview will include a description of the commonwealth's most recent renewable energy goals and commitments as compared to previous commitments and initiatives, as well as the renewable energy goals and commitments in other New England states, and the potential available resources to meet those goals.

2. A quantitative analysis of the potential economic effects on the commonwealth, and broader New England region, of Massachusetts reaching its goals and commitments for renewable electricity sourcing. The analysis should include, for example, the potential economic effects on residential and commercial consumers of electricity.

3. A quantitative analysis of the likely effects on greenhouse gas emissions of meeting these goals and commitments.

4. Relevant case studies involving other states, regions, or countries that provide insights into the potential economic effects of imports of hydroelectricity, including on efforts to meet renewable energy targets, the rates paid by commercial and residential customers, and on greenhouse gas emissions.

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[3] The Committee sent a related letter on December 19, 2019, but requested that USITC accept the January 23 letter as a replacement.

The Committee also requested that the analysis not focus on proposed or pending renewable energy transmission projects.

Approach

As requested by the Committee, this report contains qualitative and quantitative analysis to provide a better understanding of the potential economic impact of the commitments in place in New England and Massachusetts to increase the use of renewable energy. This report provides forward-looking analysis and assumes that existing market structures for commitment compliance persist into the future.

There are two recent, related regulatory developments in Massachusetts whose goals and commitments significantly advance the commonwealth's strategy to increase the use of renewable energy. These are the Massachusetts Department of Environmental Protection's publication of the Clean Energy Standard (2017) and the passage of an Act to Advance Clean Energy (2018),[4] which updated Massachusetts's Renewable Energy Portfolio Standard (originally established in 2002). Massachusetts's Renewable Energy Portfolio Standard (RPS) and Clean Energy Standard (CES) both set commitments on the share of retail electricity sales within Massachusetts that must come from eligible sources. The 2018 Act updated Massachusetts's RPS to set higher targets for renewable energy use than those originally established in 2002 and updated in 2009, by raising the annual percentage point increase in the main category of Massachusetts's RPS. This update ultimately raised the total commitment by 10 percentage points, setting a goal of 61.7 percent of electricity sales in the state to be from renewable sources by 2050.[5] The CES sets clean energy targets, in particular aiming for 80 percent of electricity sales in the state be from clean energy sources by 2050. Massachusetts's CES sets a higher minimum requirement for the share of electricity sales that must be from eligible sources but has a broader category of eligible sources than Massachusetts's RPS. For example, electricity generation from large hydroelectric dams (including imports) may qualify under its CES but not under its RPS.[6]

To conduct a quantitative analysis of these goals and commitments, the Commission developed a partial equilibrium model of New England's electricity sector focusing on the direct effects of the commitments. This model uses forecasts of the market costs for clean and renewable sources of generation as well as load, generation, import, emissions, and price projections for the New England region from the U.S. Energy Information Administration's Annual Energy Outlook (AEO) as inputs for estimating the future profitability and expansion of renewable and clean generation resources. The model estimates what the

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[4] The request letter for this investigation refers to the enactment of higher renewable energy targets in the 2018 Act to Advance Clean Energy. USITC also included the 2017 Clean Energy Standard, partly due to interactions between these commitments and partly to ensure that the report's analysis of potential economic effects included goals and commitments that are related to the role of electricity imported from renewable sources, such as large-scale renewable hydropower in Canada. "Clean Energy Standard," 310 CMR 7.75 (2018), 509–23; An Act to Advance Clean Energy, 2018 Mass. Acts 227.

[5] The total commitment for 61.7 percent of electricity sales in 2050 includes targets for Class I and Class II. Class II was not updated by 2018 Act.

[6] Massachusetts's RPS generally limits eligibility of hydroelectric facilities to those with a capacity of 30 MW or less, whereas its CES allows some larger hydroelectric generators to qualify if they meet certain emissions criteria. Renewable Energy Portfolio Standard for Retail Electricity Suppliers, Mass. Gen. Laws ch. 25A, §11 F; Clean Energy Standard, 310 CMR 7.75, 517 (2018); USITC, hearing transcript, July 29, 2020, 58–59 (testimony of Patrick Woodcock, Massachusetts Department of Energy Resources).

commitments will cost residential and commercial consumers in Massachusetts based on how large a financial incentive is needed to make the level of renewable and clean energy resources required in the commitments profitable. To account for uncertainties about the rate of technology improvements, the model includes several different scenarios from the AEO for renewable and clean energy costs and for oil and gas supply. To analyze the potential effects of Massachusetts's commitments on future greenhouse gas emissions, the model used data on emissions rates for different types of generation and projections for how the commitments would change the composition of electricity generation sources.

Policymakers and retail electricity providers may pursue a variety of strategies to help provide greater certainty that Massachusetts will meet these commitments, including efforts to hedge against price risk. For example, state-level regulators could approve utilities entering long-term contracts to secure supply at a fixed price.[7] However, it is not possible to know what contracts (or their terms) Massachusetts electricity providers may be party to between 2021 and 2050 or how these and earlier contracts will perform relative to actual prices. As a result, the quantitative analysis in this report does not include the effects of long-term contracts that may have indirectly resulted from the commitments.[8] It also bases load growth on the AEO forecast, which does not consider the full suite of New England's (or Massachusetts's) emissions reduction targets and therefore may underestimate future growth in electricity demand from electrification of other sectors.[9]

To provide additional context for plans to use imported hydroelectricity to help meet commitments in New England, the report presents four case studies demonstrating the potential effects of hydroelectricity imports. The U.S. Columbia River Basin was identified for a case study due to its substantial levels of hydropower generation. Hydropower trade patterns in New York State and the Minnesota-Manitoba region were selected as smaller case studies focused on trade-specific factors affecting the impact of hydroelectricity. Finally, Denmark was selected as a case study not only because of its significant imports of hydroelectricity, but also because it is a global leader in setting ambitious renewable energy targets and in combining the use of hydroelectricity with variable renewables (particularly wind).[10]

Organization of the Report

This chapter presents background on the report and offers a brief introduction to electricity markets. Chapter 2 examines electricity markets in New England, focusing on conditions within Massachusetts as well as the regional grid's transition toward higher shares of renewable energy. Chapter 3 assesses the

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[7] USITC, hearing transcript, July 29, 2020, 26, 68 (testimony of Patrick Woodcock, Massachusetts Department of Energy Resources); Woodcock, written testimony to USITC, July 27, 2020, 5.

[8] Interested parties provided USITC with a considerable amount of testimony about a long-term contract that Massachusetts entered into with Hydro-Québec in 2018. For more information on views of interested parties and where to find written submissions, see appendix D.

[9] The AEO considers many existing policies, including federal tax credits for electric vehicles and electricity sector emission reductions under the Regional Greenhouse Gas Initiative. However, analysis by the Brattle Group suggests New England will need a substantial increase in electrification of transportation and heating sectors to meet its economy-wide greenhouse gas emissions targets. Such an increase will double the region's electricity demand by 2050. EIA, "Summary of Legislation and Regulations," February 2020, 4, 29; ISO New England, written submission to USITC, August 12, 2020, 1–2.

[10] IEA, "Denmark," updated October 25, 2020.

potential economic effects of Massachusetts reaching its increased renewable and clean energy goals and commitments, on Massachusetts and on the broader New England region. It also analyzes the potential effects of these goals and commitments on greenhouse gas emissions. Chapter 4 describes the effects of imported hydroelectricity in other markets, through case studies on such trade in the U.S. Columbia River Basin, New York State, the Minnesota-Manitoba region, and Denmark.[11]

Background on Electricity Markets, Generation Types, and Regulation

Electricity is the flow of electrical power or charge. It is produced from a primary source of energy, can be transported over large distances, and can be converted to other forms of energy for end use.[12] Primary sources of energy include fossil fuels, nuclear energy, and renewable energy. In the United States, electricity use is responsible for about one-half of total primary energy consumption.[13] Transportation is the second-largest source of primary energy consumption, followed by the industrial sector.[14]

Renewable energy typically refers to energy produced from a naturally replenished source. The main examples are energy produced from wind, solar, geothermal, hydropower, and biomass sources, though, as noted above, some jurisdictions such as Massachusetts exclude large-scale hydropower as an eligible source under specific renewable energy programs.[15] Biomass covers a wide range of organic material from plants and animals, including wood, crops, alcohol fuels, and municipal solid waste (garbage).[16] For some of these sources of energy, multiple technologies have been developed to harness the energy and convert it into electricity, as described in further detail below.

Electricity is subject to physical constraints that distinguish it from other traded goods and services. Electricity is challenging to store directly, so it is mostly produced as needed to exactly match moment-by-moment fluctuations in demand.[17] Moreover, the infrastructure network for producing and

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[11] Appendixes A and B contain copies of the letter from the Committee requesting this report and the *Federal Register* notices issued for this investigation, respectively. Appendix C presents the witness list from USITC's public hearing, held on July 29, 2020. Appendix D lists the positions of interested parties who submitted written statements in conjunction with this investigation. Appendix E explains the methodology used for the quantitative analysis in chapter 3. Appendix F contains supplementary data and tables. Appendix G offers tables listing the data values for each of the figures included in the report.

[12] EIA, "Electricity Is a Secondary Energy Source," updated March 20, 2020.

[13] This includes electrical system energy losses, which are nearly double the amount of electrical energy sold to end users. The losses mostly reflect inefficiencies in generating electricity. EIA, "EIA Updates Its U.S. Energy Consumption," August 28, 2019.

[14] EIA, "EIA Updates Its U.S. Energy Consumption," August 28, 2019.

[15] EIA, "Renewable Energy Explained," updated June 22, 2020.

[16] EIA, "Biomass Explained," updated August 28, 2020. Solid waste can include materials that may not be defined as biomass (and therefore would not be considered renewable). For example, EU legislation classifies only the share of waste that is biodegradable as biomass and therefore only considers some of the electricity generated from incinerating waste to be renewable energy. CEWEP, "What Is Waste-to-Energy?" (accessed May 18, 2020).

[17] Energy storage technologies convert electrical energy into another form of energy (such as kinetic energy in pumped-storage hydro or chemical energy in a battery) and then supply electricity by converting the stored energy back to electricity immediately before use. FERC, Energy Primer, April 2020, 36, 51–52; Bates, "How Does a Battery Work?" May 1, 2012.

delivering electricity—also referred to as the grid—must have a balanced supply and demand of electricity in order to function properly. A temporary imbalance can result in cascading blackouts across the grid or damage to equipment.[18] As a result, it is mandatory to keep the supply of electricity matched to the levels of demand (load), a process that is referred to as load balancing.[19]

Power and energy are two important measures of electricity supply and demand. While closely related, they are not the same. **Power** refers to the rate of electricity flow and is typically measured in watts. For example, "generation capacity" measures the rate of electricity flow from a power plant and thus is a measure of power. The highest level of demand in a specified time period—referred to as peak load—is also measured in terms of power. Peak load provides an important indicator of the total generation needed to avoid an imbalance.[20] By contrast, **energy** measures power over time, and the industry often reports energy units in watt-hours.[21] Units of energy (watt-hours) are used to express how much electricity a power plant generates in a year.

Organization and Regulation of the Sector

Sector Segments

The electricity grid is composed of three segments: generation, transmission, and distribution. Figure 1.1 shows a simplified example of how these segments are organized. Large, centralized power plants traditionally have provided generation.[22] Transmission lines carry the electricity generated across long distances and are therefore designed to conduct electricity at higher voltages to reduce the amount of energy lost during transmission. Distribution lines cover relatively short distances at a lower voltage and are used to deliver electricity from local substations to end users. Transformers adjust voltages (up or down) throughout the grid to allow connections between generation, transmission, and distribution infrastructure.[23]

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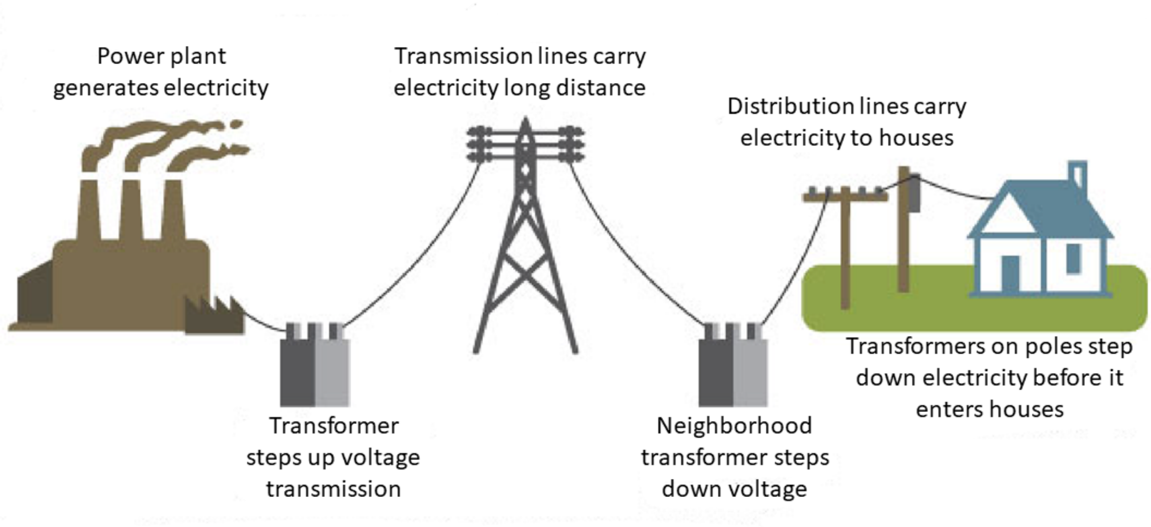
[18] Dunlap, Cleary, and Palmer, "Electricity 101," March 3, 2020.
[19] USDOE, United States Electricity Industry Primer, July 2015, 87.
[20] FERC, Energy Primer, April 2020, 36, 43.
[21] Units of energy have a time dimension only in relation to power. Power is measured as the rate of energy per unit of time: one watt equals one joule per second. Therefore, energy—the product of power and time—can also be simply measured using joules (1 watt-hour equals 3,600 joules). USDOE, United States Electricity Industry Primer, July 2015, 86–88.
[22] IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 30.
[23] EIA, "Electricity Explained," updated October 11, 2019.

Figure 1.1 Illustration of electricity generation, transmission, and distribution



Source: EIA, "Electricity Explained," updated October 11, 2019.

However, as electricity supply diversifies beyond large power plants, the actual structure of these three segments is becoming more complex, and they overlap to a greater degree. One example of this trend is the rise in distributed energy resources (DERs) as an alternative to the traditional centralized, utility-scale resources.[24] DERs encompass generation, energy storage, energy efficiency, and demand response resources located across the distribution system (often near consumers).[25] Many DERs are located on the customers' premises, providing on-site generation or otherwise reducing electricity demanded from the utility at a particular site. Such resources are also known as "behind the meter" (BTM). Small-scale solar projects such as rooftop solar panels are the most common type of distributed BTM generation.[26] These resources typically can still connect to the distribution grid, but they are sent through the customer's on-site electricity meter to the grid (rather than from the grid to the meter).[27] As shown in chapter 2, BTM resources collectively play a significant role in Massachusetts's compliance with its renewable energy commitments.

Key Players and Market Structure

The precise structure of electricity markets varies by jurisdiction, but always in some aspect involves a utility with a monopoly on distribution within its service area (some of these utilities also own generation and transmission assets). Utilities are classified into three types, based on ownership: investor-owned utilities, cooperatives (co-ops), and publicly owned utilities. Investor-owned utilities

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[24] IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 30, 33.

[25] Precise definitions of the scope of DERs have evolved over time and vary by organization. FERC, Distributed Energy Resources, February 2018, 7–10.

[26] FERC, Energy Primer, April 2020, 36, 52–53.

[27] Electric vehicles are also envisioned as a potential DER providing storage (described as vehicle-to-grid or V2G technology). Numerous pilot studies have been conducted to develop V2G, but face challenges such as managing the increased stress on the batteries and determining how vehicle owners are compensated. Deign, "Why Is Vehicle-to-Grid Taking So Long?" March 19, 2018.

have relatively large customer bases, and as of 2017, they provided electricity that served over 70 percent of U.S. customers.[28] Co-ops are member-owned utilities and are most often found in rural areas. Publicly owned utilities may be run at the federal, state, or municipal level of government, or by an independent political subdivision referred to as a public utility district. Municipally run utilities (munis) are a common form of publicly owned utility. Co-ops and publicly owned utilities generally face less regulation from the state government than investor-owned utilities.[29] There are three investor-owned utilities operating in Massachusetts: Eversource, National Grid, and Unitil.[30] Municipally owned utilities serve all or part of 50 municipalities in Massachusetts, supplying about 14.1 percent of Massachusetts's retail electricity sales.[31] Notably, Massachusetts exempts munis from some of its programs, including the renewable and clean energy commitments covered in this report's quantitative analysis.[32]

Most electricity markets in the United States—including New England—have been restructured to allow competition in the generation segment and open access to transmission infrastructure.[33] Utilities, however, have monopoly ownership of the distribution network in their service area. Electricity is freely bought and sold in wholesale markets (see the next section for more detail on how electricity is sold and priced).[34] In the generation segment, utilities may compete with independent power producers. These are non-utility electricity generators that sell electricity into the wholesale market (including to utilities) but do not sell directly to retail customers.[35] In some states, such as Massachusetts, the retail segment is also open to competition, such that an end-use customer may choose who supplies their electricity. The customers may bundle their electricity supply with the utility that provides their electric delivery service, or they may buy electricity from a non-utility electricity service provider that may offer alternative billing and customer service options or support renewable energy suppliers.[36]

Another key player in electricity markets is the grid operator, or simply "operator" (also referred to as the balancing authority), a role that is also sometimes played by the utility. An operator's jurisdiction can vary on a local, state, or regional level. Some operators are independent entities—classified as

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[28] EIA, "Investor-owned Utilities Served 72%," August 15, 2019.

[29] Specifically, co-ops and publicly owned utilities are generally not regulated by state commissions. However, they are still typically subject to state public utility laws and may be required to participate in state programs like renewable portfolio standards. Lazar, Electricity Regulation in the US, 2016, 12, 27–28; NCSL, "State Renewable Portfolio Standards and Goals," April 17, 2020.

[30] Massachusetts DOER, written submission to USITC, July 15, 2020, 5.

[31] Massachusetts DOER, written submission to USITC, July 15, 2020, 6; EIA, "Table 9," March 23, 2020.

[32] Load served by municipally owned utilities is therefore excluded from the quantitative analysis; see appendix E for information on how this adjustment was calculated. "Renewable Energy Portfolio Standard for Retail Electricity Suppliers," Mass. Gen. Laws ch. 25A, § 11 F; "Clean Energy Standard," 310 CMR 7.75 (2018), 508, 511–12.

[33] About one-third of U.S. electricity demand is still met in markets that have not been restructured, with a vertically integrated utility typically acting as the sole provider of generation, transmission, and distribution. FERC, Energy Primer, April 2020, 39; ISO New England, "Markets" (accessed October 16, 2020).

[34] Lazar, Electricity Regulation in the US, 2016, 9, 13; ISO New England, "20+ Years of ISO New England," (accessed October 15, 2020)

[35] Lazar, Electricity Regulation in the US, 2016, 17.

[36] Massachusetts DOER, written submission to USITC, July 15, 2020, 5; EIA, "Participation in Electricity Customer Choice Programs," November 1, 2019.

either an independent system operator (ISO) or regional transmission organization (RTO).[37] ISOs or RTOs manage electricity markets in New England, New York, the mid-Atlantic, parts of the Midwest, Texas, and California.[38] ISO New England manages the electricity market in New England and is responsible for operating the bulk power system, administering wholesale electricity markets (discussed in more detail below), and ensuring that there are adequate generation and transmission resources to meet New England's long-term electricity demand and reliability needs.[39] Notably, electricity is regularly traded between areas managed by different operators; the actual grid is connected into larger regional networks called interconnections.[40]

Federal Regulation

Electricity market operations and planning are shaped extensively by regulators. The Federal Energy Regulatory Commission (FERC) regulates interstate commerce for electricity markets (in terms of both transmission of electricity and transactions in wholesale markets) and oversees most of the ISOs and RTOs.[41] State and municipal governments also regulate some aspects of electricity markets, such as how utilities set retail rates, provide distribution services, and site their projects.[42] A separate set of regulatory bodies are focused on developing standards and monitoring compliance to enhance grid security and reliability. This process is led by the North American Electric Reliability Corporation (NERC), which helps to develop and enforce a shared set of electric reliability standards for the North American bulk power system (spanning both the United States and Canada).[43] NERC delegates its authorities to six regional entities that collectively cover most of the electricity supplied in the United States and Canada, as well as a small area of Mexico near the border with California.[44] Note that imports of electrical energy are not considered to be subject to the tariff laws of the United States.[45]

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[37] The Federal Energy Regulatory Commission sets the criteria for ISOs and RTOs. These two classifications have become very similar; for example, ISO New England started as an ISO and retains its original name, but it was designated as an RTO in 2005. USDOE, Electricity in North America, July 2016, 18; ISO New England, "Industry Standards, Structure, and Relationships," (accessed October 22, 2020).

[38] FERC, Energy Primer, April 2020, 40.

[39] USITC, hearing transcript, July 29, 2020, 43 (testimony of Anne George, ISO NE); George, written testimony to USITC, July 27, 2020, 1–2.

[40] New England is part of the Eastern Interconnection, which covers most of the continental United States east of the Rocky Mountains and parts of central and southeastern Canada. EIA, "U.S. Electric System Is Made Up of Interconnections," July 20, 2016.

[41] FERC does not oversee the Electric Reliability Council of Texas (ERCOT) because ERCOT operates independently from the rest of the U.S. grid. Lazar, Electricity Regulation in the US, 2016, 14, 16, 19–22.

[42] State regulation of utilities applies to all investor-owned utilities but can vary for co-ops and municipally owned utilities. Lazar, Electricity Regulation in the US, 2016, 14–15.

[43] NERC is certified by FERC as the electric reliability organization for the United States and is similarly recognized by Canadian provincial regulatory bodies. Government of Canada, written submission to USITC, July 15, 2020, 2, 22; FERC, Energy Primer, April 2020, 37.

[44] The Northeast Power Coordinating Council oversees New England, New York, and some neighboring provinces in Canada on behalf of NERC. FERC, Energy Primer, April 2020, 47–48.

[45] While "electrical energy" has its own subheading (2716.00.00) in the Harmonized Tariff Schedule of the United States (HTS), with a duty rate of zero, it is considered an intangible (i.e., not an article) and its entry is "in accordance with regulations to be prescribed by the Secretary of the Treasury." USITC, HTS Rev. 28 (2020), Additional U.S. Note 6(b); *ClearCorrect Operating, LLC v. Int'l Trade Comm'n*, 810 F.3d 1283, 1298 (Fed. Cir. 2015).

How Prices Are Determined

In restructured markets such as New England, electricity is traded at wholesale prices and sold to most end users at retail rates. Wholesale prices reflect the short-term market for electric energy, as well as other system costs such as reserving spare generation capacity.[46] Due to the limited responsiveness of customers to short-term fluctuations in prices and the requirement to maintain equal levels of demand and supply, electricity demand generally dictates supply.[47]

End-use consumers of electricity are generally insulated from real-time prices. The precise structure of electricity markets varies by jurisdiction, but most end users are supplied electricity by a utility and charged a rate based on a preset rate structure. State-level regulators approve utility rate design and may also pass through or levy additional fees to finance programs, such as energy efficiency initiatives and renewable energy incentives.[48] Utilities are often directly responsible for complying with these programs (e.g., Massachusetts requires utilities to purchase renewable energy certificates to demonstrate compliance with the RPS), but then pass these compliance costs onto their customers.[49]

Retail rates typically vary by type of end user, with residential, commercial, and industrial customers categorized as different classes of ratepayers. A single large end user with relatively steady demand costs utilities less to supply (per kilowatt-hour) than a smaller end user with fluctuating demand. For this reason, industrial customers are charged relatively low rates, and residential customers are often charged the highest rates.[50]

Characteristics of Generation Technology

Electricity generation can have different traits depending on the energy source and technology used, with important implications for costs, utilization, and eligibility for policy incentives. These tradeoffs

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[46] Electricity is freely traded within New England and with neighboring markets in a single wholesale market overseen by an independent authority. New England's high wholesale prices stem from the region's reliance on imported natural gas for most of its electricity generation. ISO New England uses "forward capacity markets" to ensure that generation capacity remains sufficient to meet projected demand. Generators offer competitively priced bids in a capacity market; if their bids are accepted, they will then receive payments for their availability (regardless of whether they are actually called on to generate). These capacity market payments are financed through wholesale prices and have been increasing in recent years in New England due to significant retirements of generation capacity. ISO New England, "Markets" (accessed September 14, 2020).

[47] There are several strategies that utilities, regulators, and operators use to reduce load, often with a focus on mitigating the high marginal cost of using inefficient generators to meet peak load requirements. These strategies are referred to as demand-side management and include providing incentives to improve energy efficiency, charging time-of-use rates, and introducing other demand-response programs designed to reduce customer demand during brief periods of very high load. FERC, Energy Primer, April 2020, 41, 43–45.

[48] USITC, hearing transcript, July 29, 2020, 22–23 (testimony of Patrick Woodcock, Massachusetts DOER); Woodcock, written testimony to USITC, July 27, 2020, 2–3; Lazar, Electricity Regulation in the US, 2016, 30.

[49] See chapter 3 for more information on utility compliance with Massachusetts's RPS and how this is passed onto retail rates.

[50] Variability in demand is often correlated across residential customers, resulting in a higher peak load that is typically more expensive to serve. In addition, industrial users often have more direct and higher-voltage connections to utilities, which also reduces the utility's cost of electricity delivery to the user. FERC, Energy Primer, April 2020, 42–43.

encourage system planners and policymakers to support a diverse mix of resources. Differences in local resource endowment—such as access to fuels and variations in solar intensity, wind strength, and river geography—also affect the relative competitiveness of a generation resource in different regional electricity markets.

Conventional generation is generally available to supply the grid and can be powered up or down at the request of grid operators. By contrast, electricity is not always available from variable generation technologies such as wind and solar.[51] However, the variability of these generation technologies is often predictable; weather forecasts and technologies such as the Internet of Things and artificial intelligence allow operators to anticipate when wind and solar generation will be on- or offline with increasing accuracy.[52]

Generation technologies also vary in flexibility, which is based on both the technical capabilities to operate at lower levels of capacity utilization and the cost effectiveness of doing so. A question that is often emphasized in gauging a technology's flexibility is whether the generation can be quickly increased—a quality often measured with ramp rates—in order to be more responsive to the minute-by-minute changes in both load and supply from other sources. A more flexible resource faces fewer technical limitations as to when and how it is operated, and can be responsive to short-term price fluctuations.[53] Generation is not the only means of improving a system's flexibility, however; increasing the size or diversity of the electric system or adding demand-side resources or storage can also improve a system's ability to incorporate more variable generation.[54]

"Capacity factor" provides a more specific measure of how often a generation type operates or is expected to operate relative to the facility's maximum capacity.[55] Capacity factors are frequently used to indicate the degree to which variability is expected to affect actual generation from wind and solar projects, but they can also be measured for other generation projects.[56]

The cost structures for developing and operating a new plant vary widely by generation type. Some generation types entail expensive upfront investments and require several years of project development before becoming operational. Fuel costs and fuel storage also vary considerably, resulting in different cost profiles over time and differing levels of price volatility. For certain technologies, maintenance costs are also significant.[57] In order to compare these different cost structures, generation technologies are

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[51] Cleary and Palmer, "Renewables 101," April 15, 2020.

[52] IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 67.

[53] USDOE, "The Importance of Flexible Electricity Supply," May 2011; IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 76.

[54] For example, the elements of a diverse set of variable renewable energy resources can to some degree balance each other, with wind and solar availability tending to peak at different times. IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 21–22; USITC, hearing transcript, July 29, 2020, 150 (testimony of Mark Kresowik, Sierra Club).

[55] NREL, *Electricity Generation Baseline Report*, January 2017, 47.

[56] For example, the average capacity factors for U.S. utility-scale generators in 2019 were 93.4 percent for nuclear, compared to 57.3 percent for natural gas combined-cycle plants, 34.3 percent for wind, and 24.3 percent for solar. Because capacity factors show how much a generation facility actually generates compared to its capacity, they are not just a reflection of variability. Reliability issues and competitiveness in real-time markets can also result in a facility generating below its capacity. EIA, "Table 6.07.A," updated October 26, 2020; EIA, "Table 6.07.B" updated October 26, 2020.

[57] EIA, "Cost and Performance Characteristics," January 2020, 2; FERC, Energy Primer, April 2020, 48–49.

often compared based on their levelized cost of electricity (LCOE). LCOE represents the average revenue per unit of electricity required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. It considers the costs described above as well as financing costs and an assumed utilization rate for the generation type.[58]

Which plants generate electricity at a given point in time is determined by the balancing authority (usually an ISO/RTO or utility) and is primarily based on the plants' variable costs and the level of load on the system. Each plant on the system with anticipated availability to generate submits a bid stating how much energy it can supply and at what price.[59] The operator dispatches these assets, starting from the plant with the lowest bid. Once enough generation is dispatched to meet load, the market clears (leaving the plants with the higher bids offline).[60] Each dispatched plant is compensated based on the highest bid that was accepted to clear the market. Figure 1.2 below provides a stylized example of how this dispatch curve (also referred to as merit order) works. The dashed light green line shows an example where demand is relatively low; a low-cost natural gas generator sets the price and the market clears at price A (shown on the vertical axis). Coal and oil-fired generation typically are not cost-competitive and therefore remain offline. As more megawatts of electricity are demanded, the marginal (added) supply becomes a lot more expensive. At the dotted dark green line, the operator dispatches more fossil-fuel fired generation and the market clears at the much higher price B.

The process for clearing the energy market is typically managed through a two-settlement system. For example, New England procures most of the generation needed to meet forecasted load in a "day ahead" market based on bids submitted the day before the electricity is to be used. It then uses a real-time energy market to settle differences between the day-ahead schedule and actual levels of supply and demand.[61]

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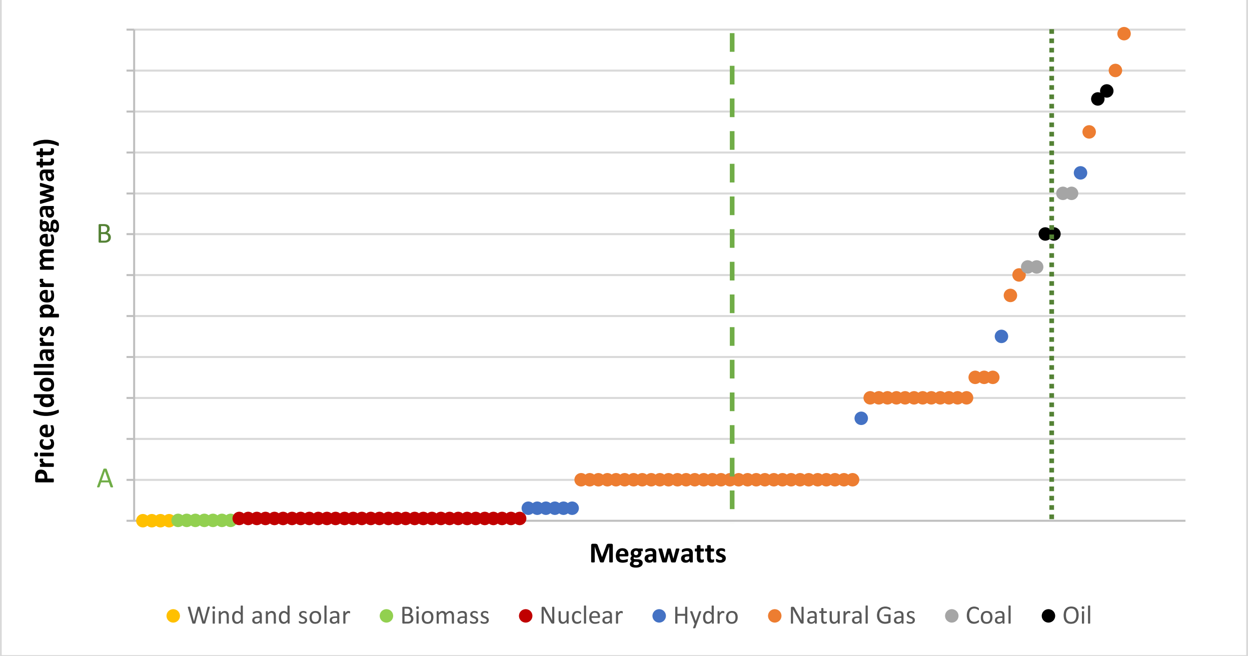
[58] EIA, "Power Plants' Cost and Value to the Grid," May 3, 2017; NREL, Electricity Generation Baseline Report, January 2017, 22–25.
[59] ISO New England, "How Resources Are Selected" (accessed August 31, 2020).
[60] Other factors—such as transmission congestion and reliability requirements—can result in a plant with higher marginal costs being dispatched before a plant with lower marginal costs. While this discussion highlights the role of generation plants, bids can also come from a variety of other sources. For example, demand-response programs can offer bids to reduce or shift system load during price spikes. ISO New England, "How Resources Are Selected" (accessed August 31, 2020); FERC, Energy Primer, April 2020, 43–44.
[61] The day-ahead market helps reduce price volatility in real-time energy markets and provide early price signals for resources with long startup times; the real-time energy market helps account for imbalances caused by factors such as forecast errors and unplanned outages. ISO New England, "How Resources Are Selected" (accessed August 31, 2020); Ela et al., Evolution of Wholesale Electricity Market Design, September 2014, 6–7.

Figure 1.2 Example of how generation resources set market prices



Source: Adapted from ISO New England, "How Resources Are Selected" (accessed November 2, 2020). Illustrative resource bids developed using New England's forecasted dispatch fuel mixes and hourly hub prices for December 19 through December 26, 2019. ISO New England, "Dispatch Fuel Mix," Operations Reports,; ISO New England, "Hourly Day-Ahead LMPs," Pricing Reports.
Note: The example above is a stylized representation of a dispatch curve in New England during winter, simplifying the structure of bids in the real-time and day-ahead markets, the number and diversity of generators, and price variance within the New England region, among other factors.

As the electricity sector transitions to integrating a high share of variable renewable energy, some plants designed for baseload (i.e., to operate continuously outside of maintenance periods and to supply stable amounts of electricity at a relatively low cost) are no longer consistently needed. [62] Variable renewable-energy generation has a low marginal cost (i.e., the additional cost needed to produce one more unit of electrical energy). It can bid at lower prices than plants that need to cover fuel costs, effectively ensuring that these types of renewables can almost always clear the market when available. Consequently, grid operators often report data for "net load," calculating the amount of load on a system after subtracting out the available supply from variable renewable energy sources (mostly wind and solar).[63]

As more variable renewable energy supply is integrated into a system, other sources of generation compete for a shrinking and often more volatile pool of net load. Net load can fall to very low levels during periods of low demand or high renewable electricity generation. At the same time, net load can have steeper increases; these steep ramps are due to both the relatively quick decline in solar generation when the sun sets and short-term variability in wind generation.[64] This increased volatility in

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[62] EIA, "As U.S. Coal-Fired Capacity and Utilization Decline," September 1, 2020; Sierra Club, written testimony to USITC, August 7, 2020, 4.
[63] Ela et al., Evolution of Wholesale Electricity Market Design, September 2014, 1.
[64] The California Independent System Operator (CAISO) coined the term "duck curve" to describe the steep ramp in net load as the sun sets in systems with high shares of solar generation. NREL, "Ten Years of Analyzing the Duck Chart," February 26, 2018.

net load creates incentives for other generation resources to be flexible.[65] The transition to more renewables is one reason a significant number of older baseload plants (such as coal-fired power plants) have either retired or invested in retrofits to allow more flexibility.[66]

Another strategy for addressing the variability of most wind and solar power generation technologies is to "firm" the variable supply source (i.e., make it more consistently available), such as by pairing a wind or solar project with an investment in battery storage.[67] While specific generation technologies tend to be characterized in binary terms (such as baseload versus peaker plants), there are many engineering and operational strategies that have been developed to address these challenges and enhance the services different generators can offer to balancing authorities.[68]

Generation technologies also have different technical capabilities that support the reliability of the grid, referred to as ancillary services. One example is the ability to start up and generate electricity with no external power support. This capability is known as black start service and is used to restart the grid in the event of a blackout.[69] ISO New England oversees a separate market that directly compensates providers for ancillary services.[70]

Types of Generation Technology

Electricity generation comes from one of three types of sources—fossil fuels (coal, natural gas, and petroleum products); nuclear energy; and renewable sources. Each of these sources can be captured using multiple generation technologies, with important implications for the generation's flexibility, dispatchability, costs, and environmental impact. The most common generation technology in the United States is steam turbines, which are designed to supply baseload at a relatively low cost but traditionally have limited flexibility. Steam turbines are used in nuclear power plants and coal-fired power plants, as well as in some natural gas, petroleum, geothermal, solar thermal, and biomass power plants.[71]

Fossil Fuel Generation

Fossil fuels are the largest source of U.S. electricity generation, led by natural gas and coal. Some power plants are designed with the capability to use multiple fossil fuels, such as switching to using fuel oil or other petroleum products when natural gas supply is limited. The use of coal-fired power in the United

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[65] IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 29.

[66] Other factors behind baseload plant retirements include rising maintenance costs, regulatory compliance costs, low wholesale electricity prices, and challenges competing with relatively inexpensive and flexible natural gas-fired plants. EIA, "U.S. Coal Plant Retirements," December 3, 2019; EIA, "Coal Plants Installed Mercury Controls," September 18, 2017; CRS, Financial Challenges of Operating Nuclear Power Plants, December 14, 2016, 7 –10.

[67] IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 42.

[68] For example, some "baseload" power plants can be retrofitted to increase flexibility. The flexibility of natural gas power plants can vary based on their design and age. IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 75; FERC, Energy Primer, April 2020, 49.

[69] Ancillary services generally relate to the minute-by-minute balancing of supply and demand, maintenance of a stable system frequency, and availability of reserves to compensate for unexpected generation losses. FERC, Energy Primer, April 2020, 56–57.

[70] ISO New England, "Markets" (accessed October 22, 2020).

[71] EIA, "Electricity Explained," updated March 20, 2020.

States has decreased substantially since the late 2000s, as part of the trend of older baseload plant retirements mentioned above.[72] The decline in emissions from coal-fired power generation has been the leading driver of the overall reduction in carbon dioxide emissions from the U.S. electricity sector.[73] Natural gas plants have historically used different designs based on the intended use of the generation. Combined-cycle gas turbines are optimized to provide baseload at a lower cost per megawatt-hour (MWh), while simple-cycle gas turbines have greater flexibility to adjust their generation in response to rapid shifts in supply and demand.[74] Both coal- and gas-fired power plants may be modified to increase their flexibility, with component modifications and process changes that reduce the plant's minimum load requirement, shorten startup time, increase the average ramp rate, and reduce minimum uptimes and downtimes.[75]

Nuclear Generation

Nuclear energy continues to be an important source of electricity, supplying 20 percent of U.S. utility-scale generation in 2019.[76] Notably, the process of generating electricity from nuclear energy does not directly produce any carbon dioxide emissions.[77] Nuclear power plants are designed to supply baseload generation, only coming offline for maintenance, fueling, or an outage. Consequently, nuclear facilities have by far the highest capacity factors of U.S. utility-scale generation (e.g., 92.6 percent in 2018).[78] Since 2013, operators of a number of U.S. nuclear power plants have retired plants or announced planned retirement dates. Many of these early retirement decisions were in response to increased competition with natural gas and renewable energy sources and slowing growth in electricity demand, but environmental and safety concerns and expensive maintenance requirements have also prompted some of the closures.[79]

Renewable Generation

Renewable energy is typically defined as energy produced from sources that are naturally replenishing. However, many of these resources have limits on how much energy is sustainably available from an individual generation site within a short period of time. The major types of renewable energy sources are solar, wind, hydropower, geothermal, and biomass.[80] The term "renewables" is sometimes used to refer to subsets of these sources, such as sources meeting specific technology, capacity, and/or environmental criteria (e.g., sources qualifying for Massachusetts's RPS) or renewables with variable

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[72] Gas-fired power plants' fuel costs have generally fallen below those of coal-fired power plants, due to declines in U.S. natural gas prices combined with the fact that natural gas-fired plants are generally more efficient. EIA, "Natural Gas Expected to Surpass Coal," March 16, 2016; EIA, "U.S. Coal-Fired Electricity Generation in 2019 Falls," May 11, 2020.

[73] EIA, "Table 11.6: Carbon Dioxide Emissions from Energy Consumption: Power Sector," September 24, 2020 (Excel file).

[74] One MWh equals 1,000 kilowatt-hours. FERC, Energy Primer, April 2020, 49.

[75] IRENA, Innovation Landscape Brief: Flexibility in Conventional Power Plants, 2019; Trabish, "A User's Guide to Natural Gas Power Plants," May 6, 2014.

[76] EIA, "What Is U.S. Electricity Generation by Energy Source?" updated February 27, 2020.

[77] EIA, "Nuclear Explained," updated January 15, 2020.

[78] EIA, "Despite Closures, U.S. Nuclear Electricity Generation," March 21, 2019.

[79] EIA, "Three Mile Island Is the Latest," June 13, 2017; CRS, Financial Challenges of Operating Nuclear Power Plants, December 14, 2016, 7 –10.

[80] EIA, "Renewable Energy Explained," June 27, 2019.

output (solar, wind, and some hydroelectric power).[81] Hydropower has historically been the largest source of renewable electricity generation, but solar and wind power generation led renewable growth in 2019.[82]

Solar

Solar is leading global growth in renewable capacity and is forecast to continue leading growth through at least 2025.[83] There are multiple types of solar technologies, but solar photovoltaic (PV) is by far the most common technology used. Solar PV is a modular technology that uses cells made of thin layers of material such as crystalline silicon to convert sunlight into an electrical current.[84]

The ability to easily scale up or down the size of a solar PV project has enabled solar PV to grow in a variety of applications. While small solar projects are more expensive on a per-MWh basis than larger utility-scale projects, policy incentives have helped support their development.[85] Solar PV designs have continued to evolve and benefit from substantial decreases in cost. From 2015 to 2019, the unsubsidized cost per MWh of utility-scale solar generation decreased by a compound annual growth rate of 13 percent, falling from $58–$70 per MWh to $36–$44 per MWh.[86]

Wind

Wind is typically categorized as onshore or offshore, as the differences in location can affect installation, maintenance, wind speed, the size of the turbine, and how the projects are regulated.[87] Onshore wind projects have lower capital costs on average than offshore projects and are less expensive to maintain. Like solar PV, onshore wind has undergone substantial global growth and design improvements. In particular, onshore wind projects have started using taller towers with larger turbines and longer blades. This design change enables onshore wind projects to be profitable in a greater range of wind speeds (unlocking more locations for new projects).[88]

Offshore wind is a less mature technology (with most existing capacity located in Europe), but its siting generally offers stronger and more consistent wind speeds.[89] This significantly reduces the variability of

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[81] For example, "renewables integration" generally refers to the electric power system changes required in order to support increased sourcing from variable wind and solar power. "Renewable" is also sometimes used interchangeably with "clean," even though clean is generally considered a much broader category of energy sources. CRS, "Variable Renewable Energy," June 25, 2019; Beck and Gordon, "The Devil's in the Details," March 14, 2019.

[82] IRENA, "Renewable Capacity Highlights," March 31, 2020, 1.

[83] IRENA, "Renewable Capacity Highlights," March 31, 2020; IEA, Renewables 2020, November 2020, 32.

[84] NREL, "Solar Photovoltaic Technology Basics" (accessed October 23, 2020).

[85] State policy incentives generally determine how small-scale projects are compensated for electricity generated on their property (e.g., net metering). CRS, Solar Energy, January 27, 2020, 2, 4–5.

[86] Based on levelized cost of energy (LCOE) analysis, which converts lifetime costs of different generation technologies into an average net present cost measure to allow comparisons between technologies with different capital and fuel costs. Lazard, "Lazard's Levelized Cost of Energy Analysis," November 2019, 8.

[87] One illustration of these location-specific differences is that the offshore wind industry shares significant supply chain elements and technological needs with the offshore oil and gas industry. IEA, Offshore Wind Outlook 2019, October 2019, 19–21, 40, 62–63.

[88] IEA, "Wind," updated September 16, 2020.

[89] IEA, Offshore Wind Outlook 2019, November 2019, 11, 17, 22, 39.

the generation and makes offshore wind's generation profile more similar to that of a baseload power source.[90] The strong potential for offshore wind to supply large amounts of electricity around the world, its relatively high capacity factor, declining technology costs, and extensive policy support have resulted in projections that global offshore wind will rapidly increase by 2040.[91]

Hydroelectric

Hydroelectric power is most commonly generated using one of three types of facilities (described below): impoundment, run-of-the-river, or pumped storage.[92] The technology type affects the characteristics of the generation, including environmental impacts. While hydroelectricity is commonly associated with constructing large dams, most of the planned hydropower development in the United States consists of smaller projects using conduits (e.g., canals and pipelines) or upgrades to existing infrastructure.[93] The distinction between impoundment dams and run-of-the-river facilities is not always clear cut, as some run-of-river facilities may have storage capabilities, and the ability to control the generation of electricity in either type of facility varies considerably.[94] More information on the general characteristics of hydroelectric dams appears in chapter 4.

Impoundment dams (also referred to as reservoir hydro) are the most common type of hydroelectric power plant and most large-scale hydroelectric facilities take this form. A river is dammed (impounded), flooding an area of land to create a reservoir of stored water. The operator releases water from the reservoir and gravity pulls the water through a turbine. The rotation of the turbine activates a generator, producing electricity.[95] Hydropower produced from an impoundment facility is typically very flexible and provides a variety of ancillary services.[96] However, some environmental and social justice groups emphasize that creating new dams can have significant environmental effects on emissions and the local ecosystem, as well as on the local communities that rely on the ecosystem's resources.[97]

Run-of-the-river facilities channel part of the river rather than capturing the entire flow. A series of canals or tunnels divert part of the river through a set of turbines. After flowing through the turbines, the diverted water is released back into the river at a downstream location. Unlike impoundment dams, diversion facilities are often small-scale and typically have little to no storage capability.[98]

Pumped-storage hydro plants connect an upper reservoir of water with a body of water at a lower elevation. These facilities use electricity to pump water into the upper reservoir during periods of low electricity demand and prices. During periods of higher prices, water is released from the upper

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[90] Hook, "Wind Power Has Capacity," October 25, 2019.
[91] IEA, Offshore Wind Outlook 2019, November 2019, 19–21, 40, 62–63.
[92] IRENA, "Hydropower," June 2012, 8.
[93] Johnson and Hadjerioua, Small Hydropower in the United States, September 2015, 5, 8.
[94] U.S. industry representative, interview by USITC staff, May 27, 2020; International Hydropower Association, "Types of Hydropower" (accessed October 25, 2020).
[95] IRENA, "Hydropower," June 2012, 5–7.
[96] IRENA, "Hydropower," June 2012, i.
[97] See chapter 4 for more information on emissions associated with hydroelectric dams. Sierra Club, written submission to USITC, July 15, 2020, 3; NAMRA, written submission to USITC, July 15, 2020, 3–5.
[98] IRENA, "Hydropower," June 2012, 8–9.

reservoir to generate electricity. Pumped-storage facilities have net negative generation, but they can be used to meet peak demand and to even out fluctuations in variable generation.[99]

Biomass

Two of the most common forms of biomass used in electricity generation are wood-derived products and municipal solid waste (garbage). Waste-to-energy plants burn waste to generate electricity. In addition, landfills naturally produce a methane-containing gas that may be processed into renewable natural gas or used on-site for heat or power generation.[100]

Renewable and Clean Energy Goals and Commitments

Renewable portfolio standards (RPSs) have been established in over 30 states, including each of the six New England states. These standards mandate that a certain percentage of electricity sold within the state must come from eligible renewable energy resources. The standards often also include tiers or classes that require a certain percentage of the RPS be met from a more limited list of technologies (e.g., new solar projects). The specifics of each standard vary by state, but generally restrict eligibility by capacity, technology, and operational date. See box 2.1 in chapter 2 for an overview of the different RPS commitments in New England.

Clean energy standards (CESs) have recently emerged as an alternative or complement to RPS commitments, particularly in areas with significant large-scale hydropower or nuclear resources. Like an RPS, a CES requires that a certain percentage of retail electricity sales come from qualifying sources of generation. However, CESs typically allow a broader range of zero- or low-carbon resources to qualify toward meeting CES commitments.[101] CES programs are not as widespread as RPS policies and vary significantly state-to-state.[102]

Both RPS and CES commitments typically use tradable certificates—also referred to as credits—to track the amount of electricity sourced from eligible generation facilities. Facilities that are eligible for the standard receive a certificate for each MWh of electricity generated. RPS commitments use renewable energy certificates (RECs), while CES standards use clean energy certificates (CECs). These certificates or credits may be bundled with the sale of qualifying electricity or traded separately.[103] As discussed further in chapter 2 ("Massachusetts RPS and CES Compliance"), utilities and other entities selling electricity to retail customers are required to demonstrate compliance with these standards through some combination of purchased certificates and alternative compliance payments (ACPs).[104]

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[99] IRENA, "Hydropower," June 2012, 9–10.

[100] Waste-to-energy involves incinerating some materials that may not be defined as biomass (and therefore are not always counted as a 100 percent renewable source). Biomass also includes wood and wood products, agricultural crops, alcohol fuels (e.g., ethanol), and methane captured from animal manure holding ponds. CEWEP, "What Is Waste-to-Energy?" (accessed May 18, 2020); EIA, "Biomass Explained," updated August 28, 2020.

[101] Cleary, Palmer, and Rennert, "Clean Energy Standards," January 2019, 2.

[102] Cleary, Palmer, and Rennert, "Clean Energy Standards," January 2019, 1, 3.

[103] C2ES and RAP, Clean Energy Standards, November 2019, 6.

[104] C2ES and RAP, Clean Energy Standards, November 2019, 40.

Greenhouse Gas Emissions

Greenhouse gases (GHGs) are gases that trap heat in the atmosphere, resulting in direct effects on climate change. Seven gases are commonly tracked as GHGs: carbon dioxide (CO_2), methane, nitrous oxide, and four types of fluorinated gases (hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride).[105] Carbon dioxide is by far the most common, comprising about 81.3 percent of U.S. GHG emissions resulting from human activities.[106] Other air pollutants such as sulfur oxides and nitrogen oxides are also often monitored, but have indirect effects on climate change and therefore are not covered in this report.

GHGs can be measured in different ways. Their impacts vary based on the concentration of the particular gas in the atmosphere, how long the gas remains in the atmosphere, and how strongly they absorb energy. One common measure is million metric tons of carbon dioxide equivalent ($MmtCO_2e$), which converts other GHGs to their carbon dioxide equivalent based on their global warming potential over a specified time horizon.[107] For example, methane emissions are measured as 28–36 times more potent than carbon dioxide over a 100-year period; methane has a much shorter atmospheric lifetime than carbon dioxide, but still has a much greater warming potential due to how strongly it absorbs energy.[108] However, such carbon dioxide equivalent measures are mostly used to track economy-wide emissions, and they are not consistently available on a subnational, sector-specific level.

As of 2018, the electricity sector contributed about 27 percent of U.S. GHG emissions. The transportation sector and industrial sector were also large contributors (28 percent and 22 percent, respectively).[109] In Massachusetts, GHG emissions associated with electricity consumption have declined significantly in recent years, falling from 22.9 $MmtCO_2e$ (27.5 percent of the commonwealth's gross emissions) in 2010 to 13.6 $MmtCO_2e$ (18.6 percent of gross emissions) in 2017.[110]

GHG emissions from the electricity sector vary by generation technology and fuel used. The main source of electricity sector emissions are generation facilities that use coal, natural gas, or petroleum products.[111] Carbon dioxide contributes most of the GHG emissions for this sector. Smaller amounts of

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[105] This list reflects gases that the United Nations Framework Convention on Climate Change requires parties to include in their national GHG inventories. Some halogenated substances containing fluorine, chlorine, or bromine are also considered GHGs, but are separately regulated under the Montreal Protocol on Substances That Deplete the Ozone Layer. Water vapor and ozone are also considered naturally occurring greenhouse gases. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, April 13, 2020, I-4.

[106] EPA, "Carbon Dioxide Emissions" (accessed September 18, 2020).

[107] The United Nations Framework Convention on Climate Change directs countries to report GHGs using this measure. EPA, "Understanding Global Warming Potentials" (accessed September 14, 2020).

[108] The calculations used for carbon dioxide equivalency have important implications for how each emission is weighted. For example, global warming potential can be measured for shorter or longer periods. When using a 20-year time horizon, methane's warming potential is 84–87 times greater than that of carbon dioxide. EPA, "Understanding Global Warming Potentials" (accessed September 14, 2020).

[109] The industrial sector is also a major consumer of electricity; when including GHG emissions from electricity generated for industrial end users, industry contributed 28.9 percent of U.S. GHG emissions in 2018. Other sources include agricultural activities and the residential and commercial sector (e.g., heating and cooking in homes and businesses). EPA, "Sources of Greenhouse Gas Emissions" (accessed September 15, 2020).

[110] MassDEP, "Appendix C" ("1990–2017 Sector" and "Summary" tabs), October 2020, (Excel file).

[111] EIA, "What Are U.S. Energy-related Carbon Dioxide Emissions?" updated October 19, 2020.

methane and nitrous oxide are also emitted but are not consistently reported in publicly available data. Recently impounded hydroelectric dams also release emissions from flooded, decaying plant material.[112] This report focuses on carbon dioxide emissions per MWh, to facilitate comparisons between different states, regions, and countries (regardless of their size) and to leverage available data on carbon emissions by generation type. Estimates from Massachusetts's Department of Environmental Protection (DEP) suggest that about 99 percent of the GHG emissions released by electricity generators come from carbon dioxide.[113]

Specific types of generation or projects can also be compared using a measure that more broadly considers their environmental impacts. This is a life cycle analysis, which evaluates emissions associated with every stage of the project divided across the total generation the project is anticipated to provide before retiring. Life cycle analysis considers emissions associated with building a generation facility (extracting the raw materials, manufacturing construction materials, and constructing the project); extracting, processing, and delivering fuels used for generation; operating the generation facility (including fuel combustion); and taking apart the facility and disposing of its materials when it is retired.[114] The results for life cycle analyses of a given type of generation can range widely, due to differences in the precise technology evaluated, the methods used, and the assumptions made (e.g., about system design).[115]

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[112] These emissions can vary significantly based on the dam's size and location and are not generally tracked as part of electricity sector emissions. For more information on emissions from dams, see chapter 4.

[113] Based on the pounds of carbon dioxide equivalent emitted in carbon dioxide, methane, and nitrous oxide. MassDEP derives its estimates of methane and nitrous oxide emissions using the heat energy consumed by emitting generators. These data for electricity generator emissions do not capture emissions elsewhere in the supply chain (such as from resource extraction or methane leakage). MassDEP, "Calculation of 2018 GHG Emission Factors" ("Generation CO2e" and "GWPs and Fuel EFs" tabs), (Excel file; accessed December 2, 2020).

[114] NREL, "Life Cycle Greenhouse Gas Emissions from Electricity Generation," January 2013.

[115] Despite this variability, some of the comparisons between technologies are similar. For example, life cycle emissions from renewable technologies are much lower than life cycle emissions from fossil fuel-fired generation. NREL, "Life Cycle Greenhouse Gas Emissions from Electricity Generation," January 2013.

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Chapter 2
Overview of Electricity Markets in New England and Massachusetts

Introduction

This chapter provides an overview of the electricity markets in New England, with an in-depth focus on Massachusetts, for 2010–19.[116] It identifies the types of electricity generation in place; the status of the transition to renewable energy sources; and trends in three key areas, including (1) electricity imports from both interstate and international sources, (2) retail electricity rates for residential and commercial customers, and (3) greenhouse gas emissions rates. In addition, this chapter assesses progress towards meeting the renewable energy goals and commitments found within New England, including Massachusetts, and points to the potential available resources to meet these goals.

Key Findings

- New England's generation of electricity has declined since 2010, driven primarily by the retirement of nuclear, coal, and petroleum plants, and by a reduction in demand. In 2019, natural gas was the largest generation source, fueling almost half of total generation in the region, followed by nuclear and renewable sources.
- In Massachusetts, natural gas-generated electricity made up a substantial portion (over two-thirds) of its generation, followed by renewable resources. Massachusetts eliminated coal-fired generation in 2017 and retired its last remaining nuclear facility in 2019.
- Both New England's and Massachusetts's reliance on electricity generated outside of the regional market has increased since 2010. These imports increasingly comprise a larger share of supply as plants in New England are retired and while current supply lines limit the interstate trade of natural gas.[117] As the largest consumer of electricity in New England, Massachusetts supplies more than half its demand with interstate imports.
- Retail electricity rates across New England are among the highest in the United States. This is due to both high prices for wholesale electricity, which are tied to natural gas prices, and state-specific costs such as those for transmission infrastructure and compliance with renewable or clean energy standards. Because a significant portion of the retail rates that residential and commercial customers pay is tied to state-specific infrastructure and policy costs, there is considerable variation in rates among the states.

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[116] Due to limited availability of state-level data for 2019, some of the discussion only covers 2010–18.

[117] Throughout this report the term "imports" refers to electricity inflows from both international and interstate sources. For example, Massachusetts receives electricity inflows from an international source (Canada), as well as from interstate sources (other states within the New England region and outside the region, such as New York).

- Massachusetts has the highest residential rates in New England, increasing over 50 percent from 2010 to 2019. Various factors such as new transmission projects, distribution system maintenance and replacement, and the cost of complying with state policies such as the RPS and CES may have contributed to these high rates.
- New England states have varying forms of RPSs, with differing targets and qualifying energy sources that are met by electricity generation in New England, New York, and Canada. These states appear to be on track to meet their standards, and only rarely has a state suspended a scheduled increase in its RPS. Some states—including Massachusetts—also have clean energy standards (CESs), which allow a broader range of low- and zero-emission sources to qualify toward meeting the standard's targets.
- All New England states have adopted special classes or tiers within their RPSs that specify that a share of electricity sales in the state be derived from particular renewable sources or certain types of facilities (e.g., new facilities or in-state facilities). These tiers can create compliance challenges and increase compliance costs.
- Planned investments in renewable electricity generation are principally focused on expanding wind and solar generation. These resources are likely to grow substantially, in both New England and other regions that feed into the New England grid, and will contribute to meeting the states' RPS requirements. Increased imports of hydroelectric energy from Canada will likely support Massachusetts's carbon emissions reduction goals and help it meet its CES requirements.

Electricity Generation Sources and Rates

New England: Sources of Electricity

The New England region generated 97.8 terawatt-hours (TWh) of electricity in 2019, a decrease of 22.6 percent since 2010. The primary drivers of this decline were (1) reduced generation from coal and petroleum, nuclear, and natural gas sources, and (2) a drop in overall demand. Figure 2.1 shows New England's electricity generation by source (as well as imports) from 2010 to 2019.

Since 2010, generation using coal and petroleum has declined substantially, from roughly 15 TWh in 2010 to 0.7 TWh in 2019. This reduction is mostly due to the retirements of many of the region's coal- and oil-fired plants, as well as the fact that the remaining coal plants are running less frequently.[118] The

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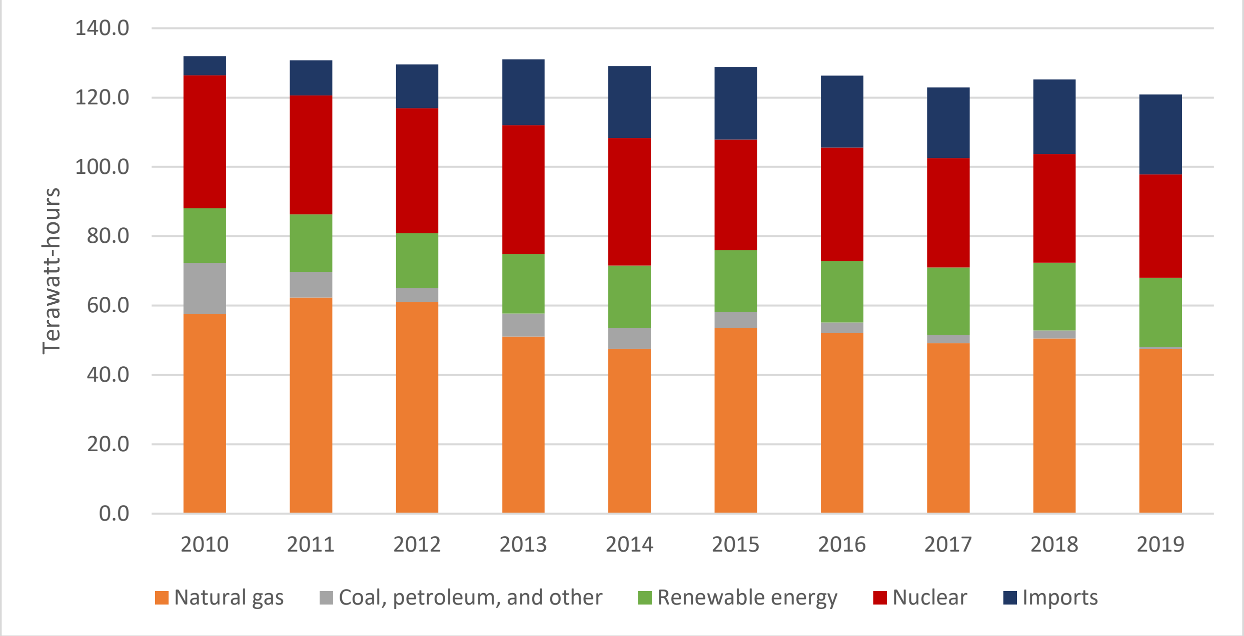
[118] Recent coal or oil-fired retirements include the 1,535-megawatt Brayton Point Coal Power Station (Massachusetts) in 2017 and the 342-megawatt oil-fired Norwalk Harbor Station plant (Connecticut) in 2013. Older oil and coal plants are generally slated for retirement due to relatively high fuel costs and limited flexibility (e.g., long ramp-up times as well as occasional mechanical problems due to their age and lack of use). ISO New England, "Power Plant Retirements" (accessed April 14, 2020).

region currently has five coal plants; after Connecticut's last remaining coal-fired plant is retired in 2021, only four will remain in operation.[119]

Figure 2.1 New England net electricity generation by source and imports (in terawatt-hours), 2010–19



Source: ISO-NE, Net Energy and Peak Load by Source (accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.5.

Nuclear generation has also declined in the region over this decade, from 38.4 TWh in 2010 to 29.8 TWh in 2019—a 22.3 percent reduction. New England currently has two nuclear energy facilities that serve the region's electricity market: the Millstone facility in Connecticut, and the Seabrook facility in New Hampshire.[120] Two other large nuclear facilities in New England—the Vermont Yankee power plant and the Pilgrim power plant in Massachusetts—were shut down in 2014 and 2019, respectively, and several smaller facilities were also shut down over the last 20 years.[121] Several issues have contributed to the decline of nuclear electricity generation in New England, including the economics of operating smaller facilities (less than 1,000 MW) as well as local opposition in certain instances.[122] Despite these

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[119] Connecticut's 383-megawatt Bridgeport Harbor coal power plant, retiring in 2021, will be replaced with a natural gas-fired plant. EIA, "Connecticut Profile Analysis" (accessed May 4, 2020). The region's remaining four coal-fired power plants are in New Hampshire and Maine. EIA, "Coal-fired Electricity Generation in New England and New York" (accessed May 4, 2020).

[120] The combined capacity of the Millstone and Seabrook nuclear power plants constitute approximately 26 percent of the daily load of the New England region. EIA, "Entergy Corporation Closes the Pilgrim Nuclear Power Station," June 13, 2019.

[121] State of Vermont, DPS, "A Brief History of Vermont Nuclear Power" (accessed April 15, 2020); EIA, "Entergy Corporation Closes the Pilgrim Nuclear Power Station," June 13, 2019.

[122] State of Connecticut, DEEP, Comprehensive Energy Strategy, February 8, 2018, 29.

developments, nuclear generation remains an important generation source for the region, supplying 30.5 percent of generation in 2019.[123]

The largest source of generation in New England is natural gas-fired plants, which contribute roughly half of the region's electricity generation. While generation from natural gas is down 17.6 percent from 2010, output has varied throughout the past decade due to generation capacity fluctuations from plant retirements and new builds as well as seasonal pipeline capacity challenges.[124] New England does not have its own natural gas production, and instead relies on imports of natural gas.[125] Some of these imports originate from the Marcellus and Utica shale formations, passing through a network of pipelines that extend from Pennsylvania through New York State as well as from Canada.[126] However, these important pipeline connections are insufficient to meet heating and electricity sector demand for natural gas during winter months.[127] As a result, the region relies on significantly higher priced international liquified natural gas (LNG) imports, predominantly from Trinidad and Tobago, to meet demand.[128]

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[123] The 2019 data include generation from Massachusetts Pilgrim Nuclear Power Station through May 31, 2019, when it was officially shut down. Pilgrim's closure will affect future nuclear generation in the region and the share of nuclear generation in New England's overall resource mix.

[124] Future retirements include the 2,001-megawatt Mystic Generating Station in Massachusetts. However, there are a number of new natural gas-fired plants coming online in the region and ISO New England projects that by 2027, there will be an additional 1,700 MW of gas generating capacity, compared to 2018. ISO New England, "Power Plant Retirements" (accessed April 14, 2020). Additionally, there are several planned natural gas projects to mitigate pipeline capacity issues. EIA, "EIA Expects Pipelines Will Increase Natural Gas Deliverability in New England" (accessed April 14, 2020).

[125] EIA, "Liquified Natural Gas Imports Limited Price Spikes" (accessed April 14, 2020).

[126] EIA, "Massachusetts: State Profile and Energy Estimates" (accessed April 14, 2020).

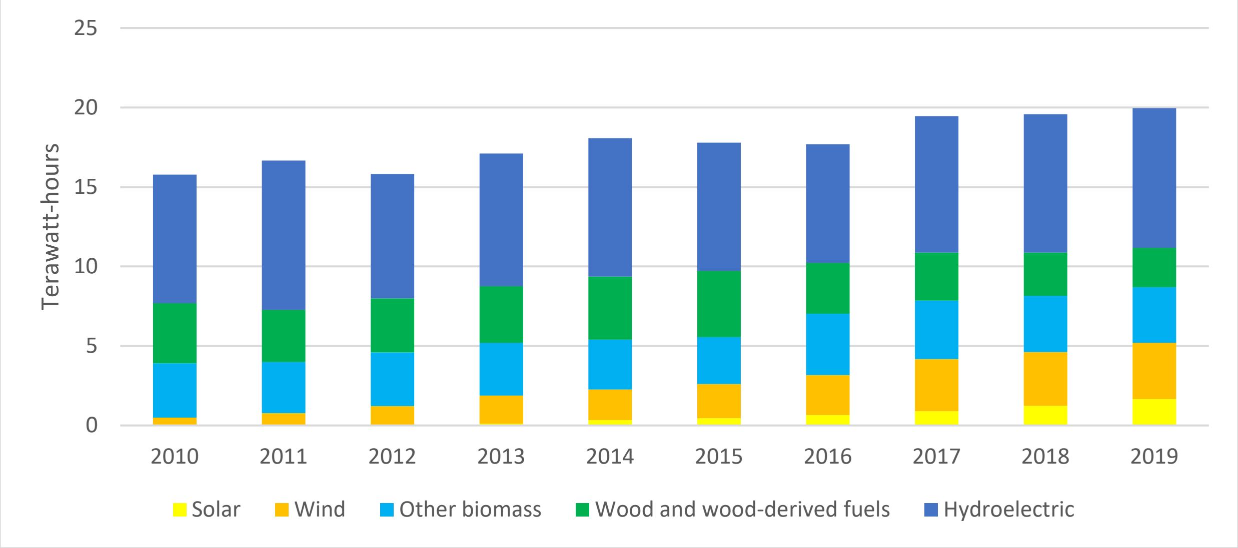
[127] According to the Massachusetts Department of Energy Resources (DOER), Massachusetts households primarily heat their homes with natural gas (51.1 percent), followed by fuel oil (27.4 percent) and electricity (15.3 percent). State of Massachusetts, DOER, written submission to USITC, August 7, 2020, 3.

[128] LNG imports to the region come through a single terminal in Everett, Massachusetts, which is the primary import-focused terminal left in the mainland United States. In 2019, LNG imports to the Everett terminal from Trinidad and Tobago totaled over 35,000 million cubic feet and represented 67 percent of all LNG imports to the United States. Prices for LNG imported to the United States averaged $7.43 per thousand cubic feet, while pipeline gas imports to the United States averaged $2.44 per thousand cubic feet. EIA, "Natural Gas: U.S. Natural Gas Imports by Point of Entry" (accessed May 28, 2020).

Since natural gas is the primary resource used for the region's electricity generation, natural gas-fired plants tend to set the price for wholesale electricity.[129] Increases in natural gas prices due to peak demand, limited pipeline capacity, and LNG imports impact wholesale electricity prices in the region.[130]

Renewable sources were the only New England generation source to increase electricity generation (26.6 percent) over this period. The region's leading source of renewable generation is hydroelectric power, comprising 44.0 percent of the total. Generation from hydroelectric power remained consistent over the past decade (figure 2.2) and in 2019 totaled 8.8 TWh. The next two leading sources of renewable generation were biomass and wind. While solar represented a small share of total renewable generation in 2019 (8.3 percent), it has risen substantially since 2010 (when only 0.002 TWh were generated).

Figure 2.2 New England net renewable electricity generation by energy source (in terawatt-hours), 2010–19



Source: ISO-NE, Net Energy and Peak Load by Source (accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.6.
Note: Hydroelectric generation in this chart includes both run-of-the-river hydroelectric and large-scale hydro. In this discussion, all forms of hydroelectric generation and generation from biomass are considered renewable. However, state-level renewable portfolio standards have varying eligibility requirements and may not qualify all of these as renewable generation sources; for example, Massachusetts does not qualify large-scale hydroelectricity under its RPS.

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[129] The price of U.S. natural gas for electricity generation in New England is higher than most of the United States and, in the case of Massachusetts, well above the U.S. average. In 2019, the average price of U.S. natural gas for electricity generation was $2.98 per thousand cubic feet. In Connecticut the price was $3.46 per thousand cubic feet, and it was $4.65 per cubic feet in Massachusetts. There was no natural gas delivery into Vermont, and the data for Maine, New Hampshire, and Rhode Island were suppressed in order to avoid disclosing proprietary data. EIA, Natural Gas: Natural Gas Prices, (accessed May 28, 2020).
Limited pipeline capacity and lack of available storage facilities can increase the price paid for U.S. natural gas in certain locations, such as New England. EIA, "Natural Gas Explained: Natural Gas Prices" (accessed May 28, 2020).

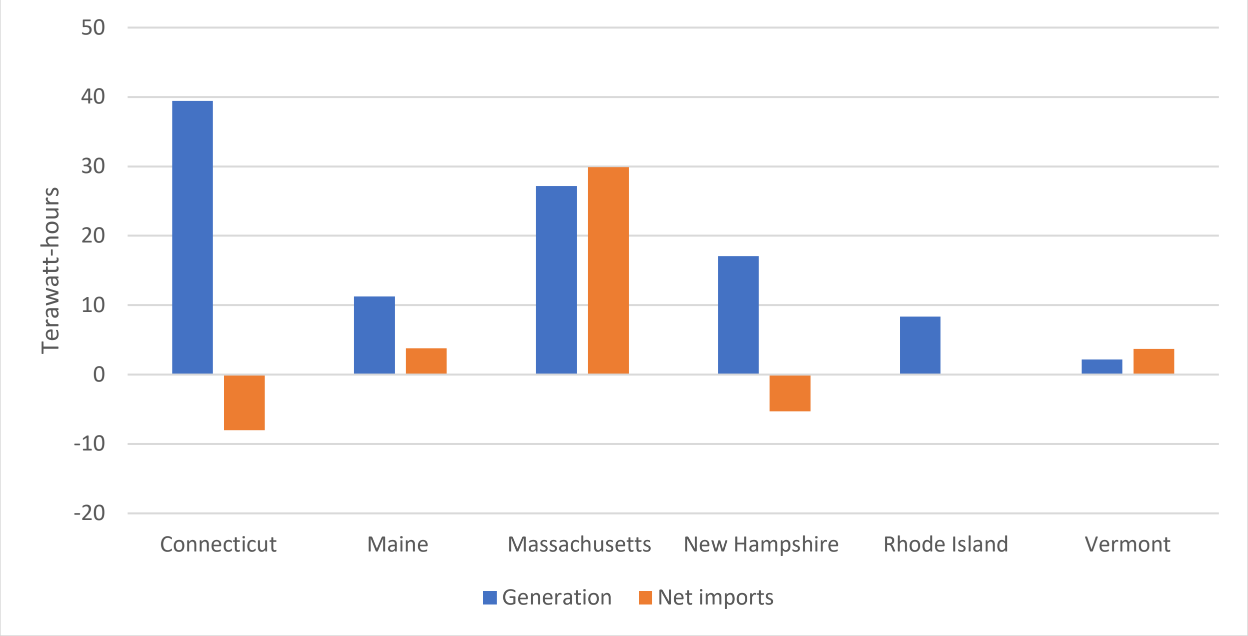
[130] EIA, "New England's Competitive Electricity Market" (accessed May 12, 2020);
ISO New England, "Monthly Wholesale Electricity Prices and Demand" (accessed May 15, 2020); USITC, hearing transcript, July 29, 2020, 50 (Patrick C. Woodcock, Commissioner, Massachusetts Department of Energy Resources).

Electricity imports have been essential to meet demand and to offset declining regional generation. Net imports of electricity have increased from 5.5 TWh in 2010 to 23.0 TWh in 2019 (figure 2.1). New England electricity imports include interstate sources (primarily New York) and international sources (Canada). In 2019, three-quarters of the region's electricity net imports originated from Canada, with the majority coming from large hydroelectric dams in Quebec.[131]

Variation by New England State

New England states vary significantly in both the amount of electricity they generate and their resource mix. Massachusetts and Connecticut are the largest generators of electricity in the New England region (figure 2.3). While most of Massachusetts's generation directly supplies the state, over 20 percent of Connecticut's generation and over 30 percent of New Hampshire's is exported out of state (including via trade with other New England states). Massachusetts, Vermont, and Maine each import a significant amount of electricity, from both interstate and international sources (figure 2.3). Indeed, Vermont's net imports are almost double its total generation.[132]

Figure 2.3 New England electricity generation and net imports (in terawatt-hours), 2018



Source: EIA, "Massachusetts Electricity Profile," table 5 and 10 (Excel file, accessed March 24, 2020); EIA, "Connecticut Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020); EIA, "Maine Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "New Hampshire Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020); EIA, "Rhode Island Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020); EIA, "Vermont Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.7.

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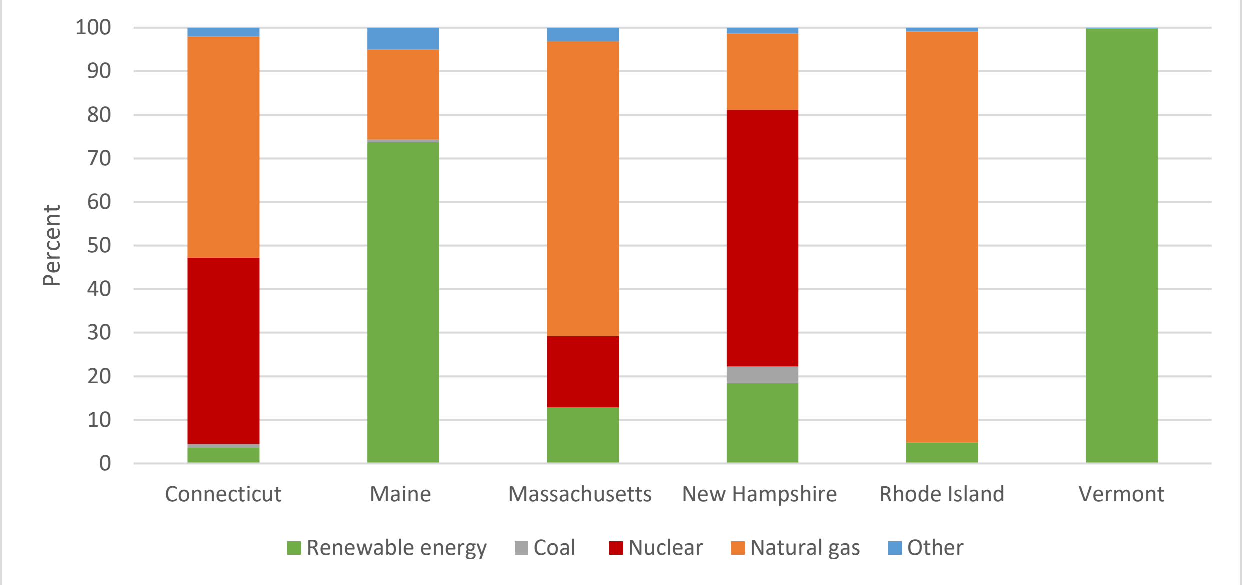
[131] Imports from New Brunswick made up 14.0 percent of all New England net imports, while imports from Quebec made up 61.0 percent. The main hydroelectric generation sources in Quebec that supply the New England market are Hydro-Québec Highgate and Hydro-Québec Phase II. ISO-NE, "Net Energy and Peak Load by Source" (accessed March 24, 2020).

[132] Vermont is unique in that it is a significant importer and exporter of electricity. In 2018, Vermont imported 9.7 TWh of electricity from Canada and exported 6.0 TWh to interstate markets.

Similarly, the generation resource mix varies significantly by state. Figure 2.4 shows the generation resource mix as a percentage of total generation. As noted above, nuclear power remains a notable contributor to the electricity mix of New England—from Connecticut and New Hampshire in particular.[133] However, the largest share of generation in the region comes from natural gas-fired plants, driven by the resource mix in Connecticut and Massachusetts. While over 94 percent of Rhode Island's generation is from natural gas (7.9 TWh), the bulk of generation from natural gas in the region—over 38 TWh—originates in Massachusetts (discussed below) and Connecticut. Since 2018, the latter two states have brought several new natural gas projects online.[134]

Figure 2.4 New England electricity generation by state and energy source (percentage of total generation), 2018



Source: EIA, "Massachusetts Electricity Profile," table 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Connecticut Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Maine Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "New Hampshire Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020).
EIA, "Rhode Island Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Vermont Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.8.

While renewable sources constitute roughly 20 percent of electricity generation in the New England region, they make up a majority share of generation in Maine and Vermont. Maine leads the region in renewable electricity supply, generating 8.3 TWh (43.8 percent of the region's renewable generation) and comprising over 70 percent of the state's generation. The largest renewable sources in Maine in 2018 were hydroelectricity (3.3 TWh), wood (2.5 TWh), and wind (2.4 TWh). Wood experienced a significant decline from 2010 to 2018 (26.0 percent), while wind experienced an almost fivefold

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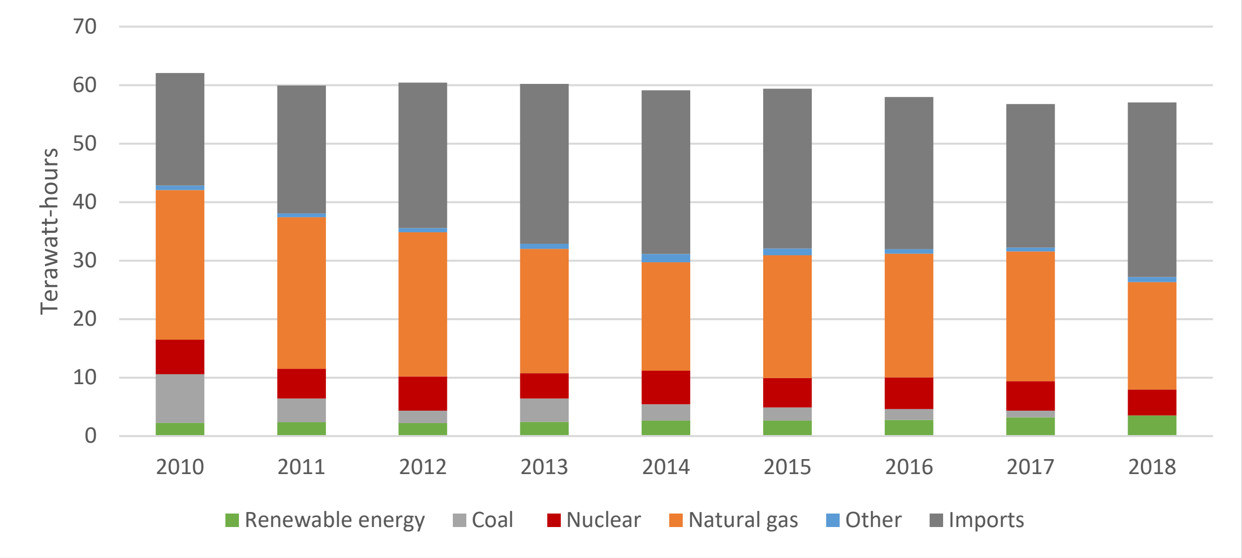
[133] Connecticut has highlighted the importance of nuclear energy in its energy mix: "Ensuring a diversity of sufficient zero-carbon resources, including nuclear generation, is an important strategy that could meet all of our key objectives to provide cleaner, cheaper and more reliable power to Connecticut residents and businesses . . . Moreover, the Millstone units are critical to both Connecticut and the New England region, in terms of fuel security and meeting greenhouse gas reduction goals." Massachusetts, on the other hand, retired its lone remaining nuclear facility in 2019. State of Connecticut, DEEP, Comprehensive Energy Strategy, February 8, 2018, 29.
[134] ISO New England, "Power Plant Retirements" (accessed April 14, 2020).

increase. Although Vermont relies primarily on imports for its electricity supply (net imports totaling 3.7 TWh), almost 100 percent of the 2.1 TWh it generates is renewable (mostly hydroelectric power).

Massachusetts Generation

Massachusetts has experienced an overall reduction in generation—36.5 percent between 2010 and 2018—primarily due to the elimination of coal-fired plants within the state (figure 2.5). During the same period, Massachusetts maintained a consistent reliance on natural gas and an increasing reliance on imports of electricity, primarily from other states. While nuclear generation was significant throughout this period, Massachusetts's last remaining nuclear plant went offline in 2019.

Figure 2.5 Massachusetts electricity generation by energy source and net imports (in terawatt-hours), 2010–18



Source: EIA, "Massachusetts Electricity Profile," table 5 and table 10, (Excel file, accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.9.

The primary source of generation in Massachusetts is natural gas, supplying just over two-thirds of the state's electricity generation in 2018 (figure 2.5). However, gas-fired generation has declined significantly—from 25.6 TWh in 2010 to 18.4 TWh in 2018, a 28.1 percent decrease. As mentioned in the regional discussion above, generation levels from natural gas-fired plants can vary by year and season due to pipeline capacity constraints, competing demand for natural gas for heating during winter, and plant retirements.

Generation from renewable sources comprises a small yet growing share of the state's electricity resource mix. The majority of Massachusetts's renewable generation comes from hydroelectric projects and biomass (in the form of municipal solid waste).[135] In 2018, Massachusetts had 30 hydroelectric plants (primarily dams) and one pumped-storage facility.[136] Solar generation has experienced the largest increase over the time period, from close to zero generation in 2010 to 1.0 TWh in 2018, contributing

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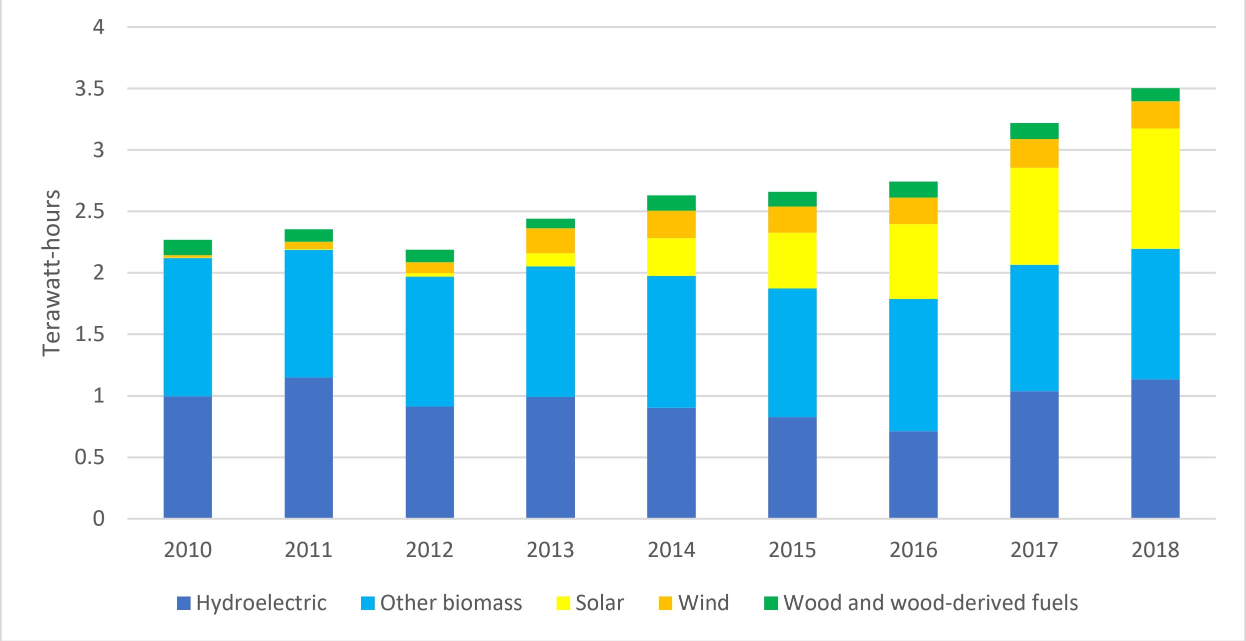
[135] EIA, "Massachusetts: State Profile and Energy Estimates" (accessed April 14, 2020).
[136] EIA, "Massachusetts: State Profile and Energy Estimates" (accessed April 14, 2020).

3.6 percent of Massachusetts's total electricity generation (figure 2.6).[137] As a share of total electricity generation this is second only to Vermont's (4.6 percent of total generation) and is well above the New England average of 1.7 percent. The other large increase in renewable generation came from wind power.[138] Wind supplied only 0.2 TWh in 2018, but like solar power it rose quickly from very low levels in 2010.

Figure 2.6 Massachusetts renewable electricity generation by energy source (in terawatt-hours), 2010–18



Source: EIA, "Massachusetts Electricity Profile," table 5 (Excel file, accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.10.

Massachusetts's reliance on expensive natural gas imports for generation makes electricity imports competitive. Increasing electricity imports, the majority of which are from interstate sources,[139] have offset a substantial share of the decline in generation and comprised over 50 percent of Massachusetts's supply in 2018 (figure 2.5). Imports rose from 19.3 TWh in 2010 to 29.9 TWh in 2018, an increase of 55.1 percent.

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[137] Massachusetts has the largest number of solar installations and produces the most megawatts from solar in the region. The majority of Massachusetts's solar generation comes from small-scale installations generating 5 MW or less, such as rooftop solar panels. ISO New England, "Solar Power in New England: Concentration and Impact" (accessed May 15, 2020).

[138] Massachusetts has over 44 onshore wind projects that together total 100 MW of capacity. State of Massachusetts, DOER, "Onshore Wind" (accessed May 28, 2020). Offshore wind projects are in the planning phase, including an 800-MW project in Martha's Vineyard. State of Massachusetts, DOER, "Offshore Wind" (accessed May 28, 2020).

[139] While interstate imports have been the primary source of imports into Massachusetts, Canada has also supplied electricity to the commonwealth. However, the amount of imports from Canadian sources has varied over time. In 2011, imports from Canada were 20.3 percent of total Massachusetts imports, but in 2018 they fell to 3.3 percent.

Trends in Electricity Rates in New England and Massachusetts

The New England region has among the highest electricity rates in the United States, over 50 percent higher than the U.S. average for residential customers (figure 2.7). Regional wholesale electricity prices often move with natural gas prices, frequently spiking during cold weather events in winter. Increased demand for natural gas for heating, gas pipeline congestion, and the use of higher-priced imported LNG increase the costs of gas-fired generation.[140] This can contribute to higher regional electricity rates compared to other regions of the country.[141] However, the wholesale price of electricity is only one component of the retail rate residential and commercial customers pay.[142] Other costs reflected in consumers' retail rates include infrastructure costs such as distribution charges, costs to build new transmission lines, and costs to maintain existing transmission and distribution networks, as well as policy costs such as the cost of compliance with state RPSs and energy efficiency programs.[143]

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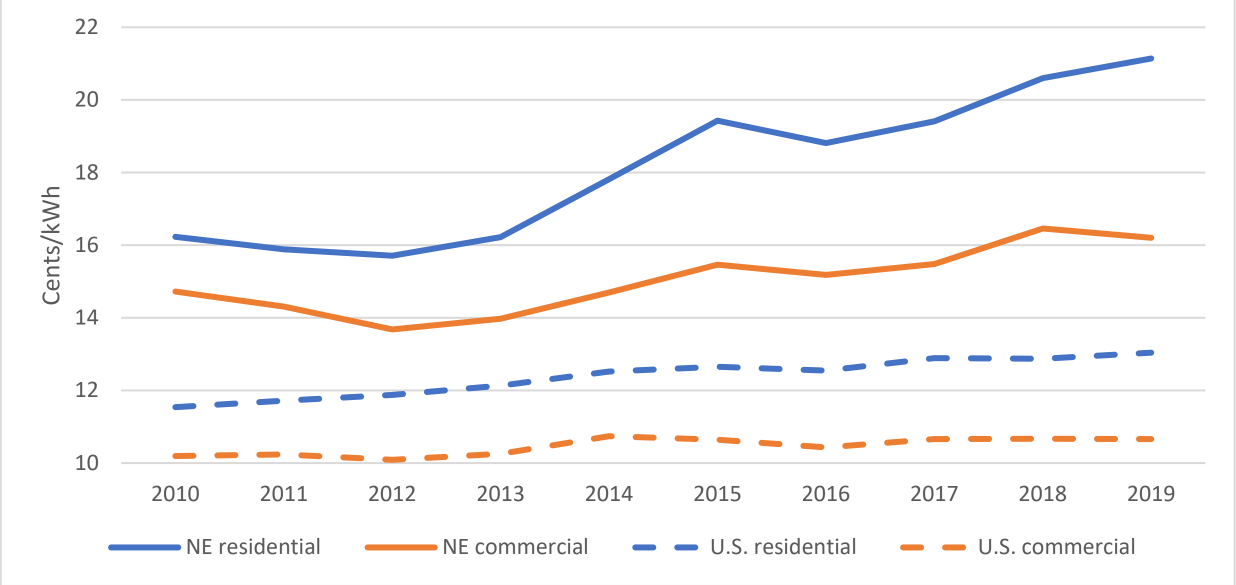
[140] According to the EIA, "energy delivery infrastructure constraints and outages can have a pronounced influence on New England's wholesale energy prices, energy flows, and operations." EIA, "EIA's New Interactive New England Dashboard" (accessed April 14, 2020). For example, peak wholesale prices have normally reflected demand for natural gas in winter (especially in 2013, 2014, and 2018). Nonetheless, wholesale energy prices were far lower in 2019 ($30.67/MWh) than they were a decade earlier ($80.56/MWh in 2008). However, there have been some significant increases in wholesale prices in recent years (for instance, they rose 38 to 40 percent from 2017 to 2018), due in large part to substantially increasing wholesale capacity costs driven by a number of plant retirements. ISO New England, 2018 Report of the Consumer Liaison Group, March 12, 2019, 31.

[141] USITC, hearing transcript, July 29, 2020, 50 (Patrick C. Woodcock, Commissioner, Massachusetts Department of Energy Resources); EIA, "New England's Competitive Electricity Market" (accessed May 12, 2020).

[142] USITC, hearing transcript, July 29, 2020, 44 (Anne George, ISO New England). According to the hearing testimony of Anne George, ISO New England, wholesale rates comprise less than half of the retail rate paid by consumers. Retail rates are generally made up of two components: the supply portion, part of which is composed of the wholesale cost of electricity, and the distribution portion, which covers the cost of delivery to households and businesses.

[143] USITC, hearing transcript, July 29, 2020, 23 (Anne George, ISO New England). According to ISO New England, the cost to comply with state renewable portfolio standards is housed in the supply portion of consumers' energy bill, while the costs associated with energy efficiency are housed in the delivery portion of the bill.

Figure 2.7 New England (NE) and U.S. average retail price of electricity, residential and commercial customers in cents per kilowatt-hour (cents/kWh), 2010–19



Source: EIA, “Electric Sales, Revenue, and Average Price,” table 4 (Excel file, accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.11.

New England’s residential and commercial retail rates have diverged significantly, a trend also seen in the national averages for these rates. Figure 2.7 shows the average retail price of electricity for both residential and commercial customers in New England and the United States. While both residential and commercial rates in New England have gone up since 2010, residential customers have experienced an increase in rates three times those of commercial customers, rising 30.3 percent from 16.2 cents/kWh in 2010 to 21.1 cents/kWh in 2019. According to industry experts, because commercial customers have more buying power, they “tend to take efforts to manage their bills using competitive electricity supply opportunities and sometimes operate in demand-response programs to mitigate pricing effects.”[144]

As noted above, the retail rate consumers pay is driven by a number of factors in addition to the wholesale cost of electricity. As a result, rates can vary substantially between states, depending on infrastructure costs and the policy costs in an individual state.[145] Table 2.1 shows the average retail price of electricity for residential and commercial customers in each New England state. All New England states experienced a substantial increase in residential electricity rates from 2010 to 2019; in every state except Vermont, residential ratepayers bore larger rate increases than commercial ratepayers.

Massachusetts experienced the largest increase in residential prices—rising from 14.6 cents/kWh in 2010, the lowest in New England, to 22.0 cents/kWh in 2019, the highest in New England—up

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[144] USITC, hearing transcript, July 29, 2020, 57 (Patrick C. Woodcock, Commissioner, Massachusetts Department of Energy Resources).

[145] Wholesale prices can also vary among states. However, in recent years there has been little variation between states. According to ISO New England, in 2018 wholesale market costs in individual New England states ranged from 7.48 cents/kWh to 7.81 cents/kWh, while retail supply costs ranged from 8.92 cents/kWh to 13.51 cents/kWh (for prices effective Jan 1, 2019). ISO New England, 2018 Report of the Consumer Liaison Group, March 12, 2019, 31.

50.9 percent (table 2.1). The next-largest increase was experienced in Rhode Island (36.6 percent), followed by New Hampshire (23.0 percent).

There are several possible reasons for the increase in Massachusetts rates beyond wholesale market prices, including new transmission projects, distribution system maintenance and replacement, and the cost of complying with state policies.[146] In addition, long-term contracts can influence retail prices depending on how specific terms of the contracts compare to prevailing market prices. For example, there has been significant regional investment in new (or upgraded) transmission projects. Since transmission costs for the region are allocated to the states based on load—and Massachusetts comprises half of the load in New England—the state bears a large share of these costs.[147] Additionally, recent research has shown that Massachusetts has some of the highest RPS compliance costs in the nation, accounting for over 11 percent of consumers' electricity bills in 2018.[148]

Table 2.1 Average retail price of electricity, residential and commercial customers (in cents/kWh) and percentage change, 2010 and 2019

	2010	2019	% change
Residential customers			
Connecticut	19.3	21.9	13.7
Maine	15.7	17.9	13.7
Massachusetts	14.6	22.0	50.9
New Hampshire	16.3	20.1	23.0
Rhode Island	15.9	21.8	36.6
Vermont	15.6	17.7	13.6
Commercial customers			
Connecticut	16.5	16.8	2.3
Maine	12.5	12.8	2.2
Massachusetts	14.5	16.5	13.6
New Hampshire	14.3	15.9	11.9
Rhode Island	13.1	16.4	25.1
Vermont	13.4	16.0	19.2

Source: EIA, "Electric Sales, Revenue, and Average Price," table 4 (Excel file, accessed March 24, 2020).
Note: kWh = kilowatt-hour.

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[146] Given the limited transparency and standardization of rate design, there is little conclusive information on how much each of these associated costs has contributed to the overall increase in average retail rates. Another recent study similarly concluded that it was difficult to identify specific underlying reasons for rate variation in New England. Littell and Sliger, "New England's Rate Design Disconnect," April 2019.

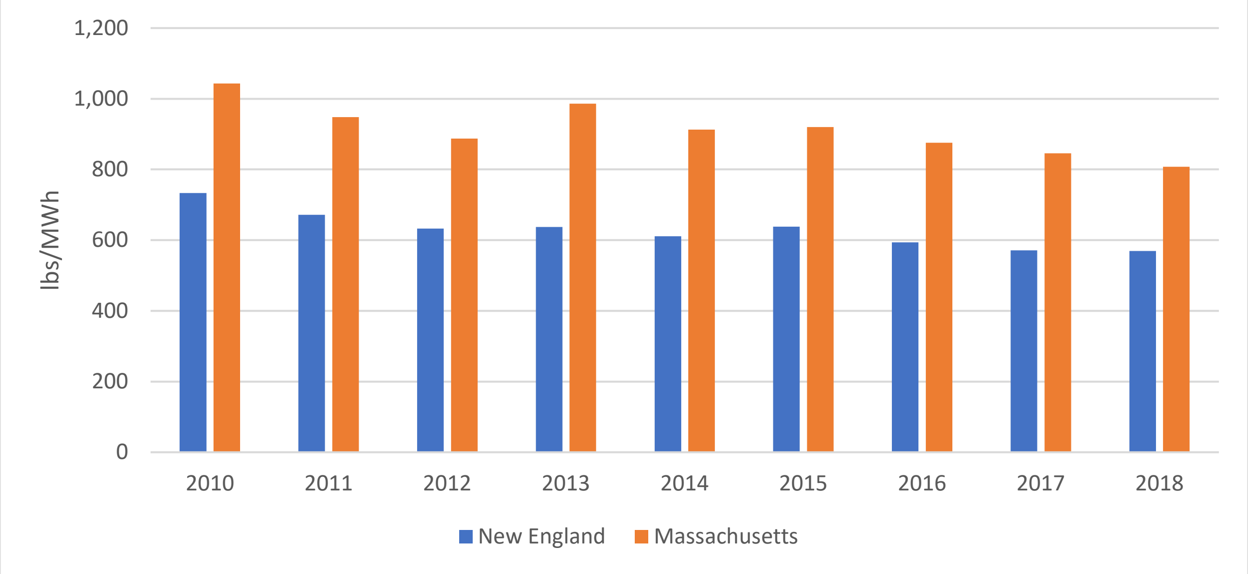
[147] Industry representative, interview by USITC staff, September 1, 2020. ISO New England, "Transmission Cost Allocation" (accessed November 9, 2020).

[148] Barbose, *U.S.* Renewables Portfolio Standards, July 2019, 42. In this report, RPS compliance cost is based on total renewable energy credit (REC) and alternative compliance payment (ACP) expenditures in 2018. For Massachusetts, this was primarily driven by the high cost of solar renewable energy certificates (SRECs) that were required starting in 2010. For more information on Massachusetts RPS commitments and compliance, see the section "Regional and State-level Goals and Commitments in New England and Massachusetts," below. As noted in chapter 3, this report's quantitative analysis is based on a different timeframe and focused on the updated Class I commitments, whereas the Lawrence Berkeley estimates include the costs of all classes. Thus, the results of the Lawrence Berkeley report are not directly comparable to the quantitative results presented in chapter 3.

Greenhouse Gas (GHG) Emissions

The GHG emissions rate from regional electricity generation has declined significantly, from 733 lbs/MWh in 2010 to 570 lbs/MWh in 2018, a decrease of over 22 percent (figure 2.8). A key driver of this decline was a reduction in generation from higher-emitting sources, particularly coal and oil-fired plants. However, the decline in emissions rate has been uneven in recent years, primarily due to variation in seasonal weather and the levels of peak load.[149] The higher-cost plants used to meet seasonal peaks in demand include coal-fired plants, less efficient gas-fired plants, and oil-fired plants, all of which tend to have higher emissions rates than the rest of generation mix. An example of the effect of seasonal weather variation occurred in 2017, when winter was milder than average and summer was cooler than average, resulting in a 3.8 percent decline in the emissions rate.[150] Similarly, emissions from Massachusetts's electricity sector have also been declining, supported by the reductions in electricity generation and consumption discussed above. In 2018, electricity generation within Massachusetts emitted 10.0 million metric tons of carbon dioxide (compared to 27.3 million metric tons of carbon dioxide for all of New England), or 808 pounds of carbon dioxide per MWh.[151]

Figure 2.8 New England and Massachusetts electric power industry carbon dioxide (CO_2) emissions rate in pounds per MWh (lbs/MWh), 2010–18



Source: EIA, "Massachusetts Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Connecticut Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Maine Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "New Hampshire Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Rhode Island Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Vermont Electricity Profile," table 7 (Excel file, accessed March 24, 2020).
Note: Underlying data for this figure can be found in appendix table G.12.

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[149] ISO New England, "Air Emissions" (accessed April 30, 2020).
[150] ISO New England, "Air Emissions" (accessed April 30, 2020).
[151] EIA, "Massachusetts Electricity Profile 2018," December 31, 2019.

Goals and Commitments in Massachusetts and New England

Introduction

In an effort to encourage the development of renewable energy and reduce carbon emissions, the six New England states have all adopted policies at the state level and through regional coalitions. These goals are largely captured by state-level renewable portfolio standards (RPSs), which set annual targets for the share of electricity sold by utilities in the state that must come from the state-defined renewable energy sources. States have also set economy-wide carbon emissions targets, which can have further impacts on state-level electricity sectors. Beyond state-level initiatives, regional endeavors such as the Regional Greenhouse Gas Initiative (RGGI) have also contributed to emissions reductions goals.

This section begins with a discussion of Massachusetts renewable energy and emissions commitments, continuing with a discussion of the RPS policies of each of the New England states. These discussions cover different sources of renewable energy, including how they qualify as complying with RPS standards (box 2.1) and renewable energy mandates in each state’s electricity market. It concludes with an exploration of regional greenhouse emissions goals through RGGI, looking at individual goals for the New England states.

Box 2.1 Renewable Portfolio Standards and Carbon Emissions Policies in New England

Renewable portfolio standards (RPSs) are standards that have been created by a state setting an annual target for electricity sales that must come from an energy source (or sources) characterized by that standard as renewable. More than 30 U.S. states have adopted some form of RPS, though they vary by the annual share of electricity that must be achieved to meet that standard, as well as the type of energy sources that qualify as renewable.

Although they vary by state, each New England state has an RPS. As shown in the table below (table 2.2), several sources—small-scale hydroelectric power, geothermal, wind, and solar power—qualify under each state's RPS standard. However, other sources, including municipal solid waste and biodiesel, may or may not qualify depending on the state's individual standard. Only Vermont's RPS qualifies large-scale hydroelectric power as meeting its renewable portfolio standards. In certain instances, large-scale hydroelectric power and other sources not eligible for an RPS can qualify under other state-level standards and mandates (particularly emissions standards). In Massachusetts, large-scale hydroelectric power does qualify under the state's Clean Energy Standard (described in greater detail in the Massachusetts section below).

Table 2.2 Selected qualifying sources of renewable energy to meet state-level renewable portfolio standards (RPS), by New England state, 2019

Generation source	Connecticut	Maine	Massachusetts	New Hampshire	Rhode Island	Vermont
Large-scale hydro	No	No	No	No	No	Yes
Small scale hydro	Yes	Yes	Yes	Yes	Yes	Yes
Geothermal	Yes	Yes	Yes	Yes	Yes	Yes
Wind	Yes	Yes	Yes	Yes	Yes	Yes
Solar	Yes	Yes	Yes	Yes	Yes	Yes
Wood and wood waste	Yes	Yes	Yes	Yes	Yes	Yes
Municipal solid waste	Yes	Yes	Yes	No	No	No
Landfill gas and biomass	Yes	Yes	Yes	Yes	Yes	Yes

Source: Compiled by USITC.
Note: Because the share they contribute to electricity generation is quite small, two resources—wood and other biomass, and municipal waste—are not included in this table.

In addition to having differing targets and qualifying sources of electricity to meet RPS requirements, states will often adopt special tiers (also referred to as classes) within their RPS that may specify further mandates for that share of renewable energy consumption. For example, a state might require that a certain portion of its RPS requirement come from solar power, or it might mandate that a certain portion come from new sources of generation. A state may also set ceilings on the level of generation from a facility to qualify for the state's RPS, and it may set a tier where only local production can qualify.

Each tier of the RPS is met through the purchase of a certain number of renewable energy certificates (also sometimes referred to as renewable energy credits, or RECs). RECs represent the positive environmental attributes of renewable electricity generation, and one REC is created for every 1 MWh of qualified electricity generated. Electricity suppliers, such as utilities, purchase a required number of RECs to comply with state-specific renewable or clean energy policies. Further discussion of how renewable and clean energy credits work is in the section "Massachusetts RPS and CES Compliance" (later in this chapter).

Massachusetts

Massachusetts has adopted several policies to support the reduction of carbon emissions and increase electricity from clean and renewable energy sources. These obligations are codified in the Clean Energy Standard (CES) and Renewable Energy Portfolio Standard (RPS). Both standards share a common overarching goal of reduced carbon emissions from the power sector. However, Massachusetts's CES focuses on increasing the use of generation technologies with relatively low emissions, while its RPS focuses on supporting the development and growth of specific renewable generation technologies. Because the primary objectives of these standards differ, the eligibility requirements differ. In Massachusetts, all RPS Class I qualifying energy sources qualify for the CES as does large-scale hydroelectric generation.

Renewable Energy Portfolio Standard (RPS)

Massachusetts enacted its first renewable portfolio standard obligation with the Electricity Restructuring Act of 1997, with implementing regulations in 2002.[152] In 2009, the Massachusetts RPS was updated under the Green Communities Act of 2008. The update increased the annual obligation for utilities in Massachusetts to obtain electricity from renewable sources by 1 percentage point annually for facilities established after 1997 (Class I) and created a second class (Class II) for existing renewable energy plants (generation facilities with an operation date prior to 1998) and waste-energy generation facilities.[153] Qualifying renewable energy sources for purposes of RPS compliance include wind, solar, ocean and tidal energy, and biomass (table 2.2).[154]

In 2018, the Massachusetts Act to Advance Clean Energy increased the renewable portfolio standard obligation in Massachusetts.[155] Class I renewable sources represent the vast majority of the total RPS obligation in Massachusetts; the annual percentage increase of electricity that must be derived from these sources was increased between 2020 and 2029 from 1 percentage point annually to 2 percent, returning to a 1 percentage point growth rate from 2030 until 2050. Under the prior 2009 obligation, the Class I RPS mandated that 16 percent of electricity must be derived from Class I sources in 2021 and 45 percent in 2050 (figure 2.9).[156] Under the 2018 act, the Class I obligation will rise to 18 percent of the electricity provided by Massachusetts utilities in 2021, and 55 percent of the electricity provided by

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[152] The 1997 act required the establishment of a renewable energy portfolio standard for all retail electricity suppliers selling electricity to Massachusetts's end-use customers. The 2002 regulations began with a mandate that 1 percent of electricity sales in 2003 be met with renewable sources, increasing by 0.5 percentage points each year. From 2009 to 2020, the required annual increase in renewables was raised to 1 percentage point annually. State of Massachusetts DOER, Massachusetts Renewable and Alternative Energy Portfolio Standards: Massachusetts RPS and APS Annual Compliance Report for 2015, October 10, 2017, 3.

[153] State of Massachusetts, "Solar Carve-out (SREC) and Solar Carve-out II (SREC II) Current Status" (accessed July 31, 2020); State of Massachusetts, "Program Summaries: Summaries of all the Renewable and Alternative Energy Portfolio Standard programs" (accessed May 12, 2020).

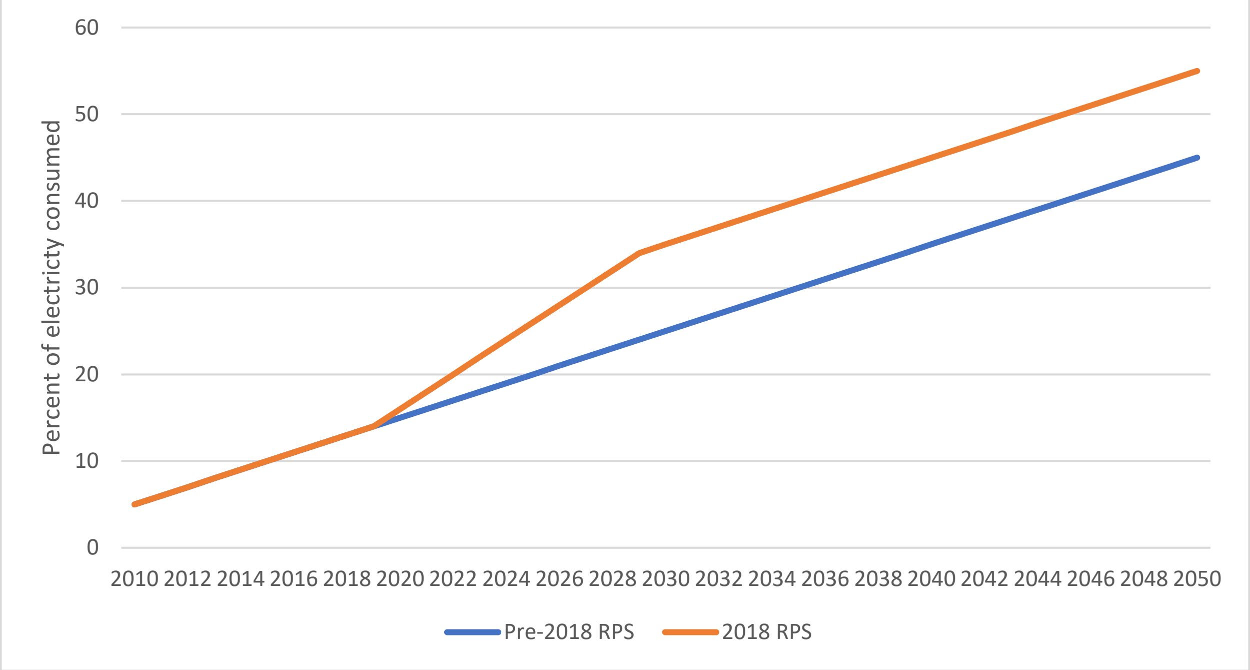
[154] Under Massachusetts's RPS, eligible fuels include solar, wind, ocean waves, fuel cells, landfill gas, some new hydro, biomass, geothermal, biogas, and agricultural crop and vegetative material waste.

[155] An Act to Advance Clean Energy, 2018 Mass. Acts 227; Renewable Energy Portfolio Standard for Retail Electricity Suppliers, Mass. Gen. Laws ch. 25A, § 11 F.

[156] An Act to Advance Clean Energy, 2018 Mass. Acts 227; Renewable Energy Portfolio Standard for Retail Electricity Suppliers, Mass. Gen. Laws ch. 25A, § 11 F.

Massachusetts by 2050.[157] The 2018 update did not alter the Class II mandates or the carveouts for solar (discussed below) contained in the previous RPS.

Figure 2.9 Massachusetts Class I RPS obligation, before and after the 2018 Massachusetts Act to Advance Clean Energy (percentage of electricity consumption)



Source: An Act to Advance Clean Energy, 2018 Mass. Acts 227; Renewable Energy Portfolio Standard for Retail Electricity Suppliers, Mass. Gen. Laws ch. 25A, § 11 F.
Note: Underlying data for this figure can be found in appendix table G.13.

By 2030, Massachusetts's RPS (as revised in 2018) requires that 35 percent of electricity must come from Class I sources (increasing a further 1 percent each year afterwards), and that 6.7 percent of electricity must derive from Class II sources (Class II mandates vary by year) (figure 2.10).[158] Finally, Massachusetts's RPS contains two more mandates (referred to as the solar "carveouts") requiring that a portion of the renewable energy used to meet the RPS Class I mandate be met by solar sources: the first was introduced in 2010 and the second in 2014. By 2020, the two solar carveouts combined required that 2.5 million MWh and 5.4 percent of electricity sales come from solar sources. In an effort to establish a long-term program to promote solar capacity in Massachusetts, these carveouts are being phased out (solar photovoltaic systems operational after November 26, 2018, cannot participate in the program) and replaced with the Solar Massachusetts Renewable Target (SMART) program.[159]

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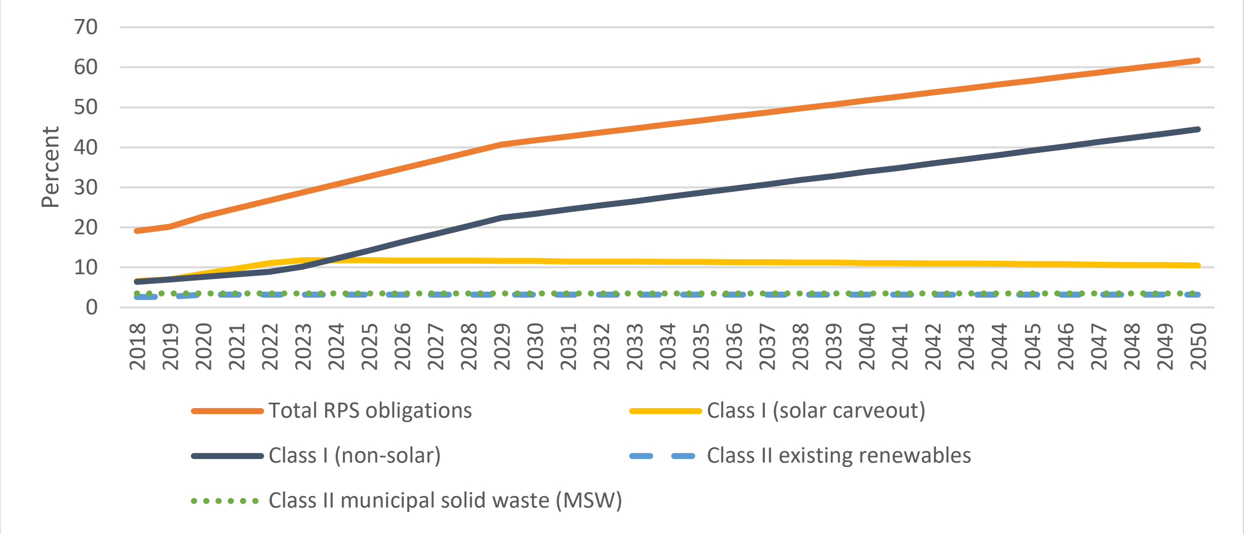
[157] An Act to Advance Clean Energy, 2018 Mass. Acts 227; Renewable Energy Portfolio Standard for Retail Electricity Suppliers, Mass. Gen. Laws ch. 25A, § 11 F.

[158] State of Massachusetts, "Program Summaries: Summaries of all the Renewable and Alternative Energy Portfolio Standard programs" (accessed May 12, 2020); Massachusetts, DOER, "RPS Solar Carve-Out Program Overview," November 2016.

[159] Further information on the SMART program can be found at https://www.mass.gov/info-details/solar-massachusetts-renewable-target-smart-program. State of Massachusetts, "Solar Carve-out and Solar Carve-out II Program Information" (accessed December 3, 2020).

Figure 2.10 Massachusetts renewable portfolio standard obligation (percent of electricity consumption), 2018–50



Source: Lawrence Berkeley National Laboratory, "RPS Targets (Percent of Applicable Retail Electricity Sales," July 2019.
Note: Underlying data for this figure can be found in appendix table G.14.

Emissions Targets and the Clean Energy Standard (CES)

In recent years Massachusetts has enacted several statutes and regulations to reduce the generation of GHG emissions in the state. These stem from the 2008 Global Warming Solutions Act (GWSA), which set economy-wide targets to commit to a 25 percent reduction of GHGs from 1990 levels by 2020 and an 80 percent reduction by 2050. In the electricity sector, this act was followed by the 2016 Massachusetts Act to Promote Energy Diversity, which mandated the establishment of a clean energy standard for electricity sales to Massachusetts consumers, and the subsequent 2017 Clean Energy Standard, which updated Massachusetts emissions targets.[160]

In August 2017, the Massachusetts Department of Environmental Protection (MassDEP) finalized the commonwealth's Clean Energy Standard (CES). The CES mandates that a certain portion of electricity procured for the Massachusetts market be from clean energy sources from facilities that started commercial operations after 2010. This mandate is slightly below Massachusetts's RPS initially, but has a faster rate of growth and surpasses RPS commitments in 2032. Massachusetts's CES rises to 80 percent of Massachusetts electricity consumption by 2050 (figure 2.11).[161] While the MassDEP notes that the CES is designed to be "compatible with and complementary to [Massachusetts's] RPS," its standard for qualifying sources differs.[162] While all Massachusetts RPS Class I sources qualify as CES sources, and RPS

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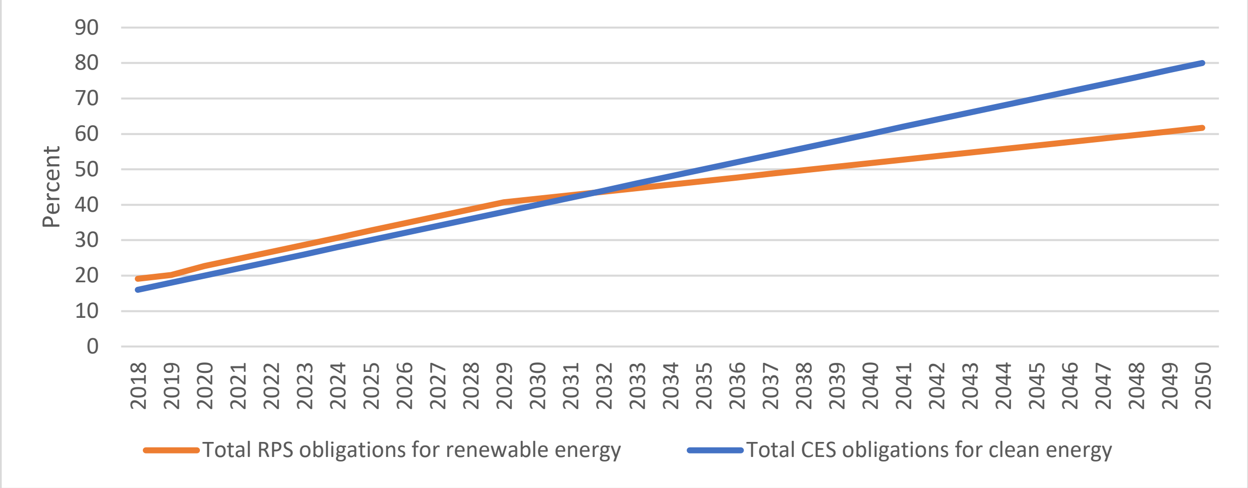
[160] The Massachusetts Act to Promote Energy Diversity was designed to help Massachusetts meet its obligations under the GWSA and stabilize electric rates. The central component of this law required the procurement of approximately 1,200 MW of clean energy, whether in baseload hydropower, onshore and offshore wind, or other renewable sources. State of Massachusetts, Office of Governor Charlie Baker, "Governor Baker Signs Comprehensive Energy Diversity Legislation," August 8, 2016. State of Massachusetts, Global Warming Solutions Act 10-Year Progress Report, 2017, 5-7.
[161] State of Massachusetts, DEP, "310 CMR 7.75 Clean Energy Standard Frequently Asked Questions," July 2020.
[162] State of Massachusetts DEP, "310 CMR 7.75 Clean Energy Standard Frequently Asked Questions," July 2020.

compliance through RECs qualify as meeting CES standards, other electricity sources—including large-scale hydroelectric production and nuclear power—can also qualify for Massachusetts's CES.[163]

Figure 2.11 Massachusetts clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50



Source: Lawrence Berkeley National Laboratory, "RPS Targets (Percent of Applicable Retail Electricity Sales)," July 2019 (Excel File). State of Massachusetts, Global Warming Solutions Act 10-Year Progress Report, 2017, 30, 56.
Note: Underlying data for this figure can be found in appendix table G.15.

In 2020, the Massachusetts DER expanded its definition of power sources that qualify for Massachusetts's CES to include output purchased from existing nuclear or large-scale hydroelectric generators operational before 2011. This expansion is expected to count older large-scale hydroelectric power and nuclear generators toward CES compliance.[164] Before the expansion, these resources were not eligible for either Massachusetts's RPS or CES. The new CES provisions for these existing generation sources, or "CES-E," is designed to ensure that non-emitting generators that began operations before 2010 can still qualify to meet reduced emissions goals. In addition to having begun operations before 2010 (and having not qualified for the other CES and RPS provisions), CES-E qualifying sources must be exported from locations (like New Hampshire or Quebec) that historically have exported significant non-emitting energy to Massachusetts.

Massachusetts RPS and CES Compliance

For Massachusetts electricity providers, compliance with the commonwealth's RPS and CES commitments is facilitated by using a credit system, where renewable energy certificates (RECs) and clean energy certificates (CECs) are used to track the generation, imports, and sales of renewable and clean energy. RECs are tradable assets signifying that one megawatt-hour (MWh) of electricity was generated from a qualifying renewable source; they are used to track compliance with RPS commitments. Likewise, clean energy certificates (CECs) are tradable assets signifying that a MWh of electricity was generated from a qualifying clean energy source; they are used to track compliance with CES obligations. RECs and CECs are used to verify that retail electricity providers are meeting RPS and

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[163] State of Massachusetts, DEP, "310 CMR 7.75 Clean Energy Standard Frequently Asked Questions," July 2020.
[164] State of Massachusetts, "Expanding the CES," October 2019.

CES commitments, because electricity cannot be directly traced back from its point of retail sale to its source of generation. RECs and CECs facilitate a region's transition to larger shares of renewable or clean generation by providing an additional revenue stream to generators of renewable and clean energy without requiring government payments to any of the involved parties.

For Massachusetts and the rest of New England, the issuance, tracking, and retirement of certificates is handled by an independent verifier: certificates are tracked by the New England General Information System (NE-GIS), which is maintained by the New England Power Pool (NEPOOL).[165] Each quarter, NEPOOL issues certificates to generators for each MWh of electricity generated in New England, or imported into New England from neighboring markets. Each certificate records the electricity's attributes.[166] NEPOOL then tracks the sale (and potential resale) of certificates for renewable or clean energy as they move through the market. While certificates are issued for all types of generation, not all are traded, as those that do not contribute to meeting RPS or CES commitments have no financial value. At the end of each year, RECs and CECs are transferred from the retail electricity provider to NEPOOL to demonstrate compliance, and NEPOOL then retires the certificates. The intermediate steps—between the creation of the certificates and their retirement—and the role of electricity generators and retail electricity providers are described below.

Certificates are designed to incentivize the construction of new renewable energy generation.[167] Because generators of renewable or clean energy sell the certificates they are issued, the certificates provide an additional source of revenue for these generators, supplementing revenue from electricity sales to make renewable or clean generation competitive with other types of generation that may be less expensive to build, like natural gas-fired generation.[168] Generators producing renewable or clean energy generally have three options to sell the certificates they are issued. First, the generator may sell the certificates to retail electricity providers looking to meet their annual requirements.[169] Second, the generator may have a pre-existing contract to sell its electricity output and certificates (bundled) to a retail electricity provider at a predetermined price.[170] Finally, the generator may sell the certificates to

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[165] Massachusetts Clean Energy Center, "Generation Information System (NE-GIS)" (accessed December 3, 2020).

[166] SRECTrade, "Massachusetts Class I RECs (New England)" (accessed December 3, 2020). RECs and CECs are based on the attributes of the electricity generated—in particular, whether the electricity was generated from sources that qualify under a particular RPS or CES, respectively. NE-GIS assigns certificates to all types of electricity generated in the New England region (and fed into the New England region via imports) regardless of fuel used. If a generator does not report the attributes of its generation to NE-GIS, then NE-GIS assigns a default certificate based on data from the highest-emitting coal-fired generation. Massachusetts Clean Energy Center, "Generation Information System (NE-GIS)" (accessed December 3, 2020); State of Massachusetts, "Program Summaries" (accessed December 3, 2020).

[167] EIA, "Renewable Energy Explained," November 20, 2020; EPA, "Offsets and RECs," February 2018.

[168] EIA, "Cost and Performance Characteristics," January 2020, 2.

[169] Massachusetts Clean Energy Center, "Generation Information System (NE-GIS)" (accessed December 3, 2020). This process is done through bidding, where generators or third parties in possession of credits make bids to sell them to electricity generators. Eversource, "Renewable Energy Credits (Massachusetts)" (accessed December 3, 2020).

[170] C2ES and RAP, Clean Energy Standards, November 2019, 12.

secondary sellers of certificates (who would then trade the certificates with other NEPOOL REC and CEC market participants).[171]

The final use of certificates—after whatever trading occurs among market participants—is as a certificate proving that a retail electricity provider has “purchased” (or supported the generation of) the correct amount of renewable or clean electricity, as required by RPS or CES commitments. The electricity that a retail provider supplies cannot be directly traced back to the source of generation to verify that the provider has met its commitments; once electricity is generated, it enters a large pool from which retail electricity providers pull to distribute to customers and in which the source of the generation is impossible to determine.[172] It is the ownership of a certificate that allows a retail electricity provider to show that it has supported the generation of a MWh of electricity by a renewable or clean energy source.[173] At the end of the year, retail electricity providers must transfer the correct number of certificates to NEPOOL to demonstrate the provider’s compliance with the commitments.

A retail electricity provider typically demonstrates compliance through a combination of three different options. The first option is through RECs or CECs purchased within the compliance year, as discussed above. The second is through “banked compliance,” in which a supplier can count toward the current year’s renewable and clean energy commitments RECs or CECs purchased in the two years prior (for up to 30 percent of the supplier’s REC or CEC requirement for that year).[174] The third is through alternative compliance payments (ACPs), which are available if the generator cannot purchase enough RECs or CECs in the market. ACPs can be purchased to satisfy any shortfall in the retail electricity provider’s holdings of RECs or CECs at the end of the year (one ACP is equivalent to one REC or one CEC in meeting the compliance requirements). ACPs can be purchased from the Massachusetts’s Department of Energy Resources (DOER) at a predetermined price set when the commonwealth’s RPS and CES commitments were initially adopted.[175] Because the ACPs are always available as an alternative to RECs or CECs, they effectively set a ceiling on the price of credits.[176]

In 2019, Massachusetts utilities met their RPS and CES obligations from a variety of sources. In meeting the 2019 RPS Class I and II requirements, the plurality of obligations (49.2 percent) were met by centralized sources within New England (through ISO-NE settlement certificates, table 2.3).[177] Following that, the remainder were nearly evenly split between New England-generated behind-the-meter

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[171] Like any market in which assets are traded, there are several resources tracking information on trading prices, like S&P Global Market Intelligence, which provides information on current prices for RECs from several states by year in which they were created. Luhavalja, “Solar, Non-solar REC Prices Slide,” June 6, 2019.

[172] MCAN, “Renewable Energy Certificates (RECs) Factsheet” (accessed December 3, 2020).

[173] This system of compliance does not trace whether individual retail electricity providers sourced the specified share of their electricity sales directly from compliant generators. Instead, it prevents double-counting of renewable generation by ensuring the generation earning credits for a particular RPS or CES state commitment is not also counted towards other state commitments. MCAN, “Renewable Energy Certificates (RECs) Factsheet” (accessed December 3, 2020).

[174] “Renewable Energy Portfolio Standard—Class I,” 225 CMR 14.08 (2016), 36; “Clean Energy Standard,” 310 CMR 7.75 (2017), 512.

[175] “Renewable Energy Portfolio Standard—Class I,” 225 CMR 14.08 (2016), 36; “Clean Energy Standard,” 310 CMR 7.75 (2017), 513.

[176] Solsystems, “Alternative Compliance Payment (ACP)” (accessed December 8, 2020).

[177] Information about the renewable energy credits purchased to meet the other New England state RPS requirements is in appendix F.

certificates (23.8 percent of certificates) and imports from New York (21.2 percent).[178] Imports from Canada's Maritime provinces and Quebec constituted the remainder, jointly totaling approximately 5.8 percent of Massachusetts RPS RECs. The vast majority of both solar carveouts were met by behind-the-meter certificates (98.8 percent combined). CES compliance can be achieved in Massachusetts with compliance with RPS Class I requirements. As Massachusetts's 2019 CES mandate did not exceed its 2019 RPS Class I mandate, the RPS certificates were used by utilities to also meet their CES obligations for 2019.

Table 2.3 RPS credits in Massachusetts, 2019 (by tier and location)

Eligibility	Total certificates by eligibility	Imports from New York	Imports from the Maritime provinces	Imports from Quebec	ISO-New England settlement certificates	Behind-the-meter certificates
MA APS Alternative Generation Unit	2,420,318	0	0	0	0	2,420,318
MA RPS Class I Renewable Generation Unit[a]	10,705,565	2,504,736	330,994	467,034	4,235,536	3,167,265
MA RPS Class II Renewable Generation Unit	1,387,789	415,159	0	0	864,107	108,523
MA RPS Class II Waste Energy Generation Unit	1,676,898	0	0	0	1,676,898	0
MA Solar Carve-Out I Unit	746,460	0	0	0	15,970	730,490
MA Solar Carve-Out II Unit	1,603,394	0	0	0	11,757	1,591,637

[a] Compliance with the MA CES in 2019 was entirely met with MA RPS Class I credits.

Source: New England Power Pool Generation Information System (NEPOOL GIS), Certificates by Eligibility and Location (accessed November 4, 2020).

Notes: Massachusetts CES obligations can be met by Massachusetts RPS Class I sources. The Maritime provinces include portions of Maine not in the ISO-NE control Area. For purposes of these data, New York is defined as the New York ISO control area.

Other New England State Renewable Portfolio Standard Targets

All other New England states have renewable portfolio standards, and nearly all have binding emissions reductions targets (New Hampshire has a suggested emissions target which is not binding). These renewable standards vary across state, particularly in the share of electricity consumption that must be derived from renewable sources (table 2.4).

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[178] "Behind-the-meter" refers to energy that is generated onsite, rather than energy that is delivered to a facility. For example, a solar panel on a resident or business's roof that supplies a portion of that facility's electricity demand would constitute a "behind-the-meter" energy source.

Table 2.4 Renewable portfolio targets by New England state (percent of electricity consumed with the use of qualifying renewable fuels), 2020, 2030, 2050

State	2020 target (percent)	2030 target (percent)	2050 target (percent)
Connecticut	29	48	[a]
Maine	42.5	80	100
Massachusetts	22.7	41.7	61.7
New Hampshire	20.7	25.2	[a]
Rhode Island	16	31	[a]
Vermont	59	71	[a]

Sources: compiled by USITC.

[a] Commitment does not extend to 2050.

Additionally, the renewable energy targets of the New England states can vary in what qualifies as renewable (highlighted in table 2.2 above), as well as the classes (or tiers) within each state's RPS standard. These additional targets can be divided by type of fuel used, the age of the generating facility, the capacity of the generating facility, and the location of the facility (Box 2.2).

Box 2.2 New England RPS Mandate Variability and Implications for Retail Rates

RPS mandates in New England are often subcategorized to include specific carveouts for certain types of renewable energy production, or to reflect other state-level priorities. Specific carveouts can be for a variety of functions. Examples include:

- The Massachusetts RPS mandate that a certain percentage of renewables come from sources installed after December 31, 1997 (Class I).[a]
- The New Hampshire RPS mandate that a certain portion of electricity from renewables derive from thermal sources (Class I).[b]
- The Vermont RPS mandate that a certain share of renewable electricity be generated from within Vermont (Tier 2).[c]
- The Maine RPS mandate that some qualifying renewable sources of generation must only come from facilities with 100MW or less of generation.[d]

As a result, there are sometimes instances where a state's overall RPS target is met for a given year, but a more specific mandate may prove more challenging to meet.

For example, the local source requirement in the Vermont RPS (Tier 2) will likely be costly to implement relative to Vermont's overall RPS requirement. The Vermont Department of Public Services estimates that implementing the state's RPS Tier 2 standards (which mandate that 10 percent of renewable energy must be generated within Vermont by 2032) will cost between 16 and 24 times as much as Vermont's Tier 1 requirement (which says 75 percent of electricity overall must be generated from renewable sources by 2032).[e] Implementing the Tier 2 requirements will likely constitute between 71 and 85 percent of the total cost of meeting Vermont's aggressive RPS standards, despite representing a relatively small portion of the state's overall requirements. This compliance will also likely push up costs. According to the Vermont Department of Public Services, compliance with Vermont's RPS will cause retail rates to rise "between 0.60% and 1.15% higher over the next ten years because of the RES, but possibly as much as 2.0% higher if compliance costs turn out significantly greater than the range [the Vermont Department of Public Services] currently considers probable."[f]

[a] DSIRE, "Renewable Portfolio Standard: Massachusetts," July 9, 2018.
[b] University of New Hampshire Sustainability Institute, *New Hampshire RPS Retrospective 2007–2015 Report*, August 19, 2016, 11–12.
[c] State of Vermont, DPS, *2018 Annual Report on the Renewable Energy Standard*, January 2018, 4–5, 10. .
[d] State of Maine, An Act to Reform Maine's Renewable Portfolio Standard, Sec. 1. 35-A MRSA § 3210 (2)(B), June 2019.
[e] State of Vermont, DPS, *2018 Annual Report on the Renewable Energy Standard*, January 2018, 10.
[f] State of Vermont, DPS, *2018 Annual Report on the Renewable Energy Standard*. January 2018, 10.

Connecticut

Under Connecticut's 2018 Comprehensive Energy Strategy, Connecticut maintains a collective mandate that increases renewable energy's share of electricity consumption by increments, from 29 percent in 2020 to 48 percent by 2030 (appendix figure F.1).[179] Connecticut's RPS is split into three classes, and encompasses solar, wind, fuel cells, geothermal, certain waste-to-energy, and some combined heat and power sources.

Maine

Under the 2019 Act to Reform Maine's Renewable Portfolio Standard, the mandate for electricity consumption from renewable energy as a share of overall electricity consumption in Maine was increased significantly from prior mandates. By 2030, 80 percent of retail sales of electricity in Maine must be derived from renewable sources, rising to 100 percent of retail sales by 2050 (appendix figure F.2).[180] Maine's RPS is split into Class I, IA, and 2, and includes solar, wind, certain biomass, and some other sources.

New Hampshire

Under current New Hampshire regulation, 25.2 percent of electricity must be derived from renewable sources from 2025 onward (appendix figure F.3).[181] This mandate is split into four classes and includes solar, wind, small-scale hydroelectric facilities, and biomass and methane.

Rhode Island

The mandates for electricity consumption from renewable sources in Rhode Island are derived from the June 2004 Renewable Energy Standard; a subsequent 2016 law extended this regulation from 2019 to 2035.[182] From 2018 to 2030, the share of renewable energy to be used in electricity is expected to rise from 13 percent to 31 percent (appendix figure F.4).[183] Rhode Island RPS compliance is split between

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[179] Under the Comprehensive Energy Strategy, Class I sources must constitute 17 percent of electricity in Connecticut in 2018, increasing to 40 percent of electricity by 2030. Class II and Class III each have a 4 percent flat yearly mandate (Class II energy consumption can also be met by additional energy consumption from Class I sources). Connecticut DEEP, Comprehensive Energy Strategy, February 8, 2018, 29; DSIRE, "Renewable Portfolio Standard: Connecticut," July 12, 2018; DSIRE, "Renewable Energy Standard: Connecticut," July 12, 2018.
[180] An Act to Reform Maine's Renewable Portfolio Standard, Sec. 1. 35-A MRSA § 3210 (2)(B), June 2019.
[181] State of New Hampshire. Public Utilities Commission. "Electric Renewable Portfolio Standard (RPS)" (accessed May 12, 2020).
[182] Rhode Island's H.B. 7413, from June 2016, extended this regulation from 2019 to 2035. DSIRE, "Renewable Energy Standard: Rhode Island," June 26, 2018.
[183] DSIRE, "Renewable Energy Standard: Rhode Island," June 26, 2018.

two classes, distinguishing between new sources (Class I) and existing sources (Class II).[184] A variety of renewable energy sources qualify, including wind, solar, and hydroelectric facilities (up to 30 MW in capacity).[185]

Vermont

Promulgated in 2015, Vermont's renewable energy standard (RES) specifies that 55 percent of electricity consumption in Vermont be derived from renewable sources in 2017, increasing incrementally to 75 percent of sales by 2032 (appendix figure F.5). Additionally, the 2016 Vermont Comprehensive Energy Plan envisions that 90 percent of Vermont energy will be supplied by renewable sources by 2050.[186] The Vermont RPS is split into three tiers, divided into overall renewable electricity from any qualifying source, Vermont-generated renewable electricity, and energy transformation projects.[187] Qualifying renewable sources include solar, wind, certain biomass, and certain hydropower.[188] In contrast to all other New England states, large-scale hydroelectric power qualifies as renewable for purposes of meeting Vermont's renewable portfolio standard (the other New England states qualify only small-scale hydroelectric power as renewable for purposes of the state RPS).[189]

Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) is a broad agreement by a coalition of the New England states, joined by the mid-Atlantic states of Delaware, Maryland, New Jersey, and New York, to cap and reduce carbon dioxide emissions in the power sector.[190] This coalition was recently expanded to include Virginia, which will become a participant in RGGI in January 2021.[191] Starting in 2009, under RGGI, fossil fuel-fired generators that produce more than 25 MW of electric power have been required to procure allowances for their CO_2 emissions. From 2013 to present, the number of these allowances, reflected as

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[184] State of Rhode Island, Public Utilities Commission, Annual RES Compliance Report for Compliance Year 2015, June 2017, 15.

[185] The generation sources that qualify under Rhode Island's renewable portfolio standard are classified under the 2004 renewable energy standard, in §39-26-5. Eligible sources include solar, wind power, ocean and tidal power, thermal power, hydroelectric facilities with up to 30MW in capacity, biomass facilities in compliance with air permits, and fuel cells. State of Rhode Island, Title 39: Public Utilities and Carriers: Chapter 39-26 Renewable Energy Standard, 2004.

[186] This plan also calls for a reduction of total energy consumption by 15 percent by 2025 and more than one-third by 2050. State of Vermont, DPS, *Vermont Comprehensive Energy Plan (CEP)*, 2016.

[187] DSIRE, "Renewable Energy Standard: Vermont," June 26, 2018. State of Vermont, DPS, *Vermont Comprehensive Energy Plan (CEP)*, 2016, 234.

[188] The generation sources that qualify under Vermont's renewable energy standard (RES) are "energy produced using a technology that relies on a resource that is being consumed at a harvest rate at or below its natural regeneration rate." This includes methane gas and other flammable gases produced by the decay of sewage, landfill wastes, and anaerobic digestions of agricultural products and food waste. Other qualifying sources include hydro, solar, wind, and biomass. State of Vermont, General Assembly, Act No. 56, An Act relating to Establishing a Renewable Energy Standard (H.40), 2015, 2–3.

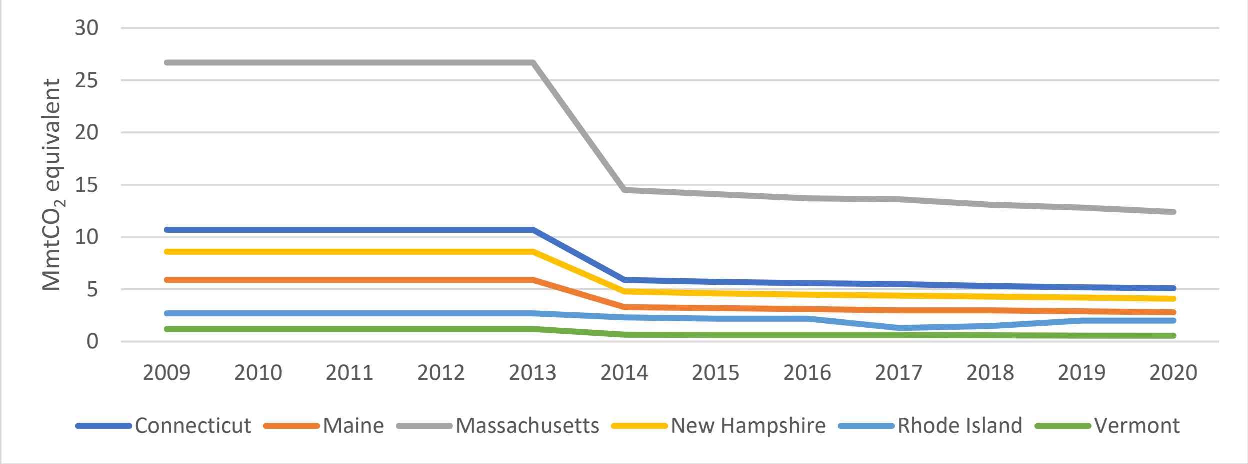
[189] DSIRE, "Renewable Energy Standard: Vermont," June 26, 2018.

[190] RGGI, "Elements of RGGI: Program Overview and Design," 2020.

[191] State of Virginia, DEQ, "Carbon Trading: What's New," August 2020.

the allowed amount of $MmtCO_2$ equivalent in each state, will decrease annually for each state participating in the program (figure 2.12).[192]

Figure 2.12 RGGI allowances for New England states, 2009–20 (by $MmtCO_2$ equivalent)



Source: RGGI, "Allowance Distribution," September 2020.
Note: Underlying data for this figure can be found in appendix table G.16.

As shown in figure 2.12, RGGI allowances for CO_2 emissions in New England have declined from 2013 to 2020. These allowances, which are set by the individual RGGI states and allocated among the coalition members, were previously stable, with 55.8 million metric tons (Mmt) of CO_2 equivalent allocated to the whole of New England between 2009 and 2014 (figure 2.12).[193] However, following a two-year program review, each New England state received a steeply reduced number of allowances starting in 2014, and the number of allowances has steadily decreased since then. Most state allocations fell by nearly one-half in 2014: Massachusetts's declined 45.7 percent, Connecticut's 44.9 percent, New Hampshire's 44.2 percent, Maine's 44.1 percent, Rhode Island's 14.8 percent, and Vermont's 45 percent.[194] In 2020, the total allocation of CO_2 allowances across New England fell to 26.9 $MmtCO_2$ equivalent, a decline of 51.8 percent since 2013.[195] These declines coincide with economy-wide emissions target reductions for each of the New England states to 2050 (figure 2.13).

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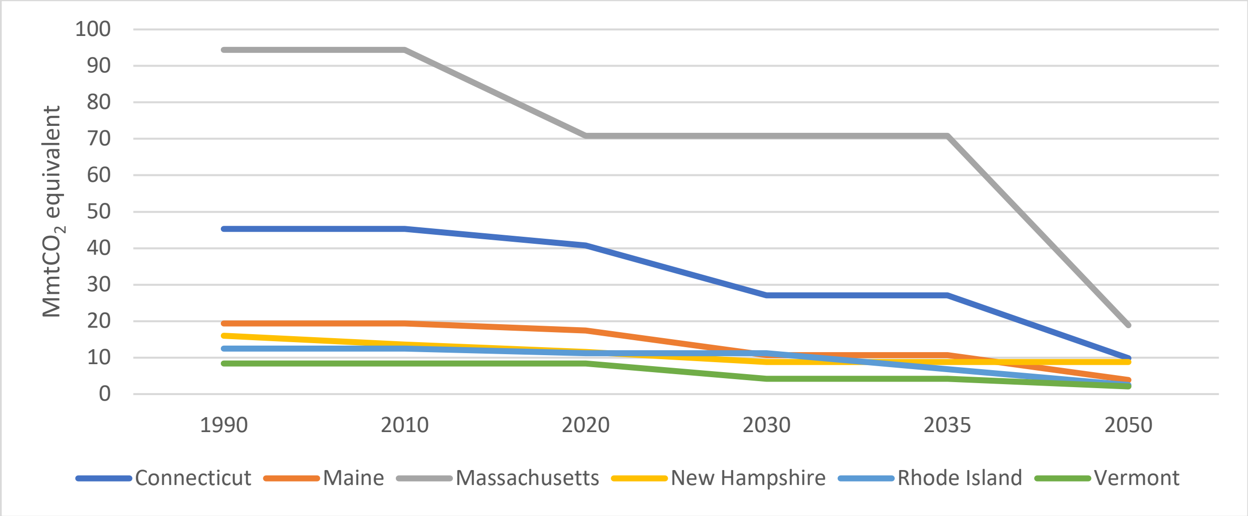
[192] RGGI, "Elements of RGGI: Program Overview and Design," 2020.

[193] Further information on RGGI, which has been amended several times and is currently governed by the 2017 Model Rule, can be found here on RGGI's website.

[194] RGGI, "Allowance Distribution," September 2020.

[195] RGGI, "Allowance Distribution," September 2020.

Figure 2.13 Economy-wide emissions targets by New England state, 2010–50 (by MmtCO₂ equivalent)



Source: Compiled by USITC.
Note: There is no statutory requirement in New Hampshire that economy-wide greenhouse gas emissions be either reported or reduced. However, the state has an unofficial target of reducing emissions to 45 percent below 1990 levels by 2030. National Council of State Legislatures, "State Renewable Portfolio Standards and Goals: New Hampshire," April 17, 2020. Underlying data for this figure can be found in appendix table G.17.

Sources to Meet the Goals and Commitments of New England and Massachusetts

Several sources are likely to come online in the next five years to contribute to meeting Massachusetts's renewable energy goals and commitments.[196] These include generation facilities across New England, as well as external suppliers (particularly in New York and Canada) that serve the New England electricity market. However, industry stakeholders have noted several challenges that may affect the capacity of the New England states to meet their renewable energy goals and commitments. Integrating renewable energy into existing state (or regional) grids often requires multiple strategies to mitigate variability (discussed in further detail in chapter 1), and investments in transmission and storage are often needed to ensure that renewable energy can be provided consistently to a market.

New England

Energy projects from a wide variety of renewable sectors (though principally solar and wind) have been completed or are currently under construction across New England states. These projects are typically smaller scale, though some larger projects are also currently under construction.

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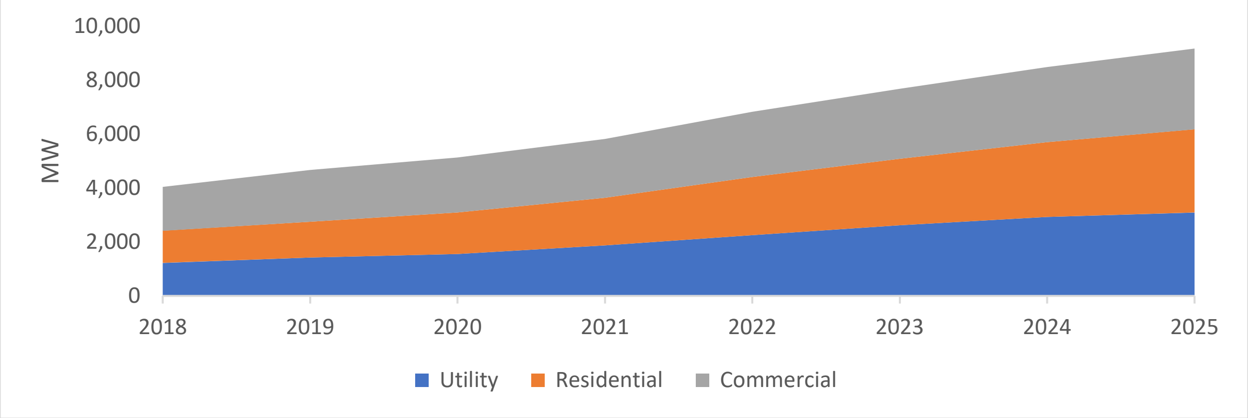
[196] This section focuses on RPS requirements rather than CES requirements because CES requirements in the New England states can also be met by RPS-qualifying sources of energy (as well as other types of energy in some instances).

Solar

Solar PV facilities (both large and small-scale) will likely experience the largest absolute increase in installed renewable energy capacity in New England between 2020 and 2025 (figure 2.14). This is likely to occur despite New England's lower solar intensity relative to other regions in the United States (particularly the Southwest), owing to certain state-level policies encouraging solar energy development (for example, Massachusetts's solar carveouts in its RPS standards).[197] Additionally, the accessibility of small-scale solar energy (e.g., rooftop solar) to residential consumers may enable the expansion of solar relative to other RPS-qualifying renewable sources of electricity (such as wind).[198] One energy firm estimates that total installed solar capacity in New England will rise 127.2 percent during 2018–25, from 4,038 MW to 9,175 MW.[199] Another study offered similar projections, noting that between 2020 and 2025, installed solar capacity in New England is predicted to rise by 3,451 MW, concentrated principally in Massachusetts (1,418 MW), Maine (1,128 MW), and Connecticut (750 MW).[200] While nonresidential solar PV installations currently represent the highest share of installed solar capacity (40.3 percent), followed by utility installations (30.4 percent) and residential installations (29.3 percent), this study estimates that solar PV installations will be about evenly distributed among the three sectors by 2025.[201]

Figure 2.14 Estimated installed solar photovoltaic capacity in New England, 2018–25 (commercial, residential, and utility, MW)



Source: BloombergNEF (accessed June 9, 2020).
Note: Underlying data for this figure can be found in appendix table G.18.

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[197] Several industry representatives have noted a variety of programs in New England states (as well as specific solar carveouts in some RPS standards) as likely to incentivize production of solar energy in the region. In Maine, for example, the governor in 2019 signed An Act to Promote Solar Energy Projects and Distributed Generation Resources to incentivize the creation and local installation of 375MW of solar power in Maine, which would represent a substantial increase over the current solar production capacity in the state. Industry representatives, interview by USITC staff, April 29, 2020; industry representative, interview by USITC staff, May 4, 2020; State of Maine, Office of the Governor, "Governor Mills Signs Major Renewable and Climate Change Bills into Law," June 26, 2019; WRI, "United States Solar Radiation Map," 2009.

[198] SEIA, "Residential Consumer Guide to Solar Power," June 2018.

[199] BloombergNEF (accessed June 9, 2020).

[200] SEIA, "Solar State by State" (accessed October 18, 2020).

[201] BloombergNEF (accessed June 9, 2020).

Solar generation in New England is characterized by small-scale projects, both residential and nonresidential. Often these installations do not individually account for a significant portion of New England's total electricity generation.[202] However, the Solar Energy Industries Association estimates that there are over 170,000 total installations in New England. The share of electricity derived from solar energy varies substantially by New England state, from close to zero in Maine and New Hampshire to nearly 5 percent in Vermont (table 2.5).[203]

Table 2.5 Installed solar capacity in New England states by number of installations, MW capacity, and percentage of state electricity from solar, 2019

State	Existing installations	MW capacity	Percentage of state electricity generated by solar (percent)	Planned additional capacity (2020–2025) (MW)
Connecticut	45,263	759.1	0.3	590
Maine	2,224	91.8	0.0[a]	761
Massachusetts	104,528	2,852.3	3.6	1,324
New Hampshire	8,521	119.8	0.0[a]	247
Rhode Island	6,228	284.6	0.3	276
Vermont	8,908	356.2	4.9	253
Total for New England	175,672	4,463.8	1.2	3,451
Total for United States	2,439,272	81,102.3	1.5	569,000

[a] Less than 0.05 percent increase.

Source: Solar Energy Industries Association, "Solar State by State" (accessed June 18, 2020); BloombergNEF (accessed June 9, 2020); USITC calculations.

Wind

New England is likely to experience a significant increase in installed wind capacity over the next decade (figure 2.15).[204] One study estimates that there will be a roughly threefold increase in installed wind capacity in New England between 2018 and 2025, from 1,430 MW to 5,657 MW (figure 2.15).[205] The majority of this increase is estimated to come from an increase in offshore wind capacity, which in 2018 constituted about 2 percent of installed wind capacity.[206]

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[202] An example of a small-scale residential project could be a solar panel installation on the roof of a home. An example of a nonresidential installation would be a similar solar panel installation on the roof of a commercial facility.

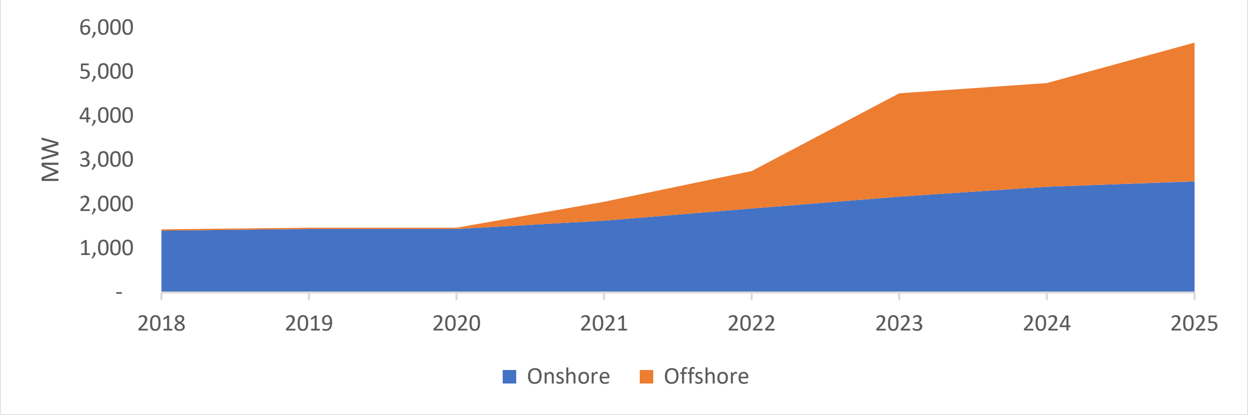
[203] SEIA, "Solar State by State" (accessed June 18, 2020); Eskom, "What Is a Megawatt?" March 2015.

[204] BloombergNEF (accessed June 9, 2020).

[205] BloombergNEF (accessed June 9, 2020).

[206] BloombergNEF (accessed June 9, 2020).

Figure 2.15 Estimated installed wind capacity in New England, 2018–25 (onshore and offshore, MW)



Source: BloombergNEF (accessed June 9, 2020).
Note: Underlying data for this figure can be found in appendix table G.19.

Offshore wind production is expected to increase in New England over the next 10 years. New England currently has the only offshore wind farm in the United States—the 5-turbine 30 MW farm around Block Island off the Rhode Island coast.[207] However, projects are currently underway to significantly expand the capacity of offshore wind in New England, with the majority in Massachusetts:

- The Revolution Wind project off the Rhode Island and New York coasts, under joint construction between Eversource and Ørsted, is estimated to add an additional 700 MW in combined wind power to the region's electricity supply.[208] The electricity generated will be split between Rhode Island (400 MW) and Connecticut (300 MW).[209] Generation is expected to commence in 2023.[210]

- The Mayflower wind farm off the coast of Massachusetts near Martha's Vineyard, under joint construction by Shell New Energies and EDP Renewables, is estimated to add 1,600 MW to New England's regional electricity supply.[211] The project is split into two parts, and will largely serve the Massachusetts market.[212] The Mayflower 1 wind farm is expected to be operational by 2025 and add 804 MW of capacity.

- The Vineyard wind farm is another planned offshore wind project sited near Martha's Vineyard, with an expected 800 MW of capacity. It will be operated by a joint venture between Copenhagen Infrastructure Partners and Avangrid Renewables.[213] Although construction was expected to begin in late 2019 with commercial operations in 2021, the work has been delayed. This project, which will largely serve Massachusetts's market,[214] is expected to come online no earlier than 2023.[215]

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[207] Woods, "US Has Only One Offshore Wind Energy Farm," December 13, 2019.
[208] NS Energy, "Revolution Wind Project" (accessed June 18, 2020).
[209] NS Energy, "Revolution Wind Project" (accessed June 18, 2020).
[210] NS Energy, "Revolution Wind Project" (accessed June 18, 2020).
[211] NS Energy, "Mayflower Wind Farm, Massachusetts" (accessed June 18, 2020).
[212] NS Energy, "Mayflower Wind Farm, Massachusetts" (accessed June 18, 2020).
[213] NS Energy, "Vineyard Wind Farm, Massachusetts" (accessed June 18, 2020).
[214] NS Energy, "Vineyard Wind Farm, Massachusetts" (accessed June 18, 2020).
[215] Young, "Vineyard Wind Announces New Delay," February 11, 2020.

Industry representatives have also noted potential for other wind resources, including promising developments in floating offshore wind (particularly in Maine) and onshore wind farms.[216] Current production varies significantly by New England state, with Massachusetts and some other New England states deriving less than 1 percent of their electricity generation from wind power in 2018, while Maine derived more than 20 percent, suggesting significant room for growth.[217] However, some challenges remain in the adoption of both larger- and smaller-scale wind capacity, particularly with respect to transmission costs and the difficult terrain in some parts of New England.[218] As many of the offshore wind farms are planned in federal waters, limited experience with the federal permitting process may slow down the trajectory for offshore wind in New England.

Hydroelectric Power

The potential for capacity additions for both large-scale and small-scale hydroelectric power in New England is fairly low. According to one publication from the Connecticut Department of Energy and Environmental Protection (DEEP), bringing large-scale hydroelectric power from within New England would be difficult; it "will require new transmission lines and therefore likely a significant financial commitment by ratepayers."[219] Industry representatives have also noted that public opposition can make the creation of new hydroelectric generating facilities more difficult.[220]

Smaller run-of-the-river hydropower stations have less of an environmental footprint than hydroelectric dams and would qualify for New England's RPS standards, but do not appear to have much potential in new renewable energy generation in New England.[221] One ISO New England representative characterized a station of this kind as "a relatively small installation and so [one] would need likely many, many run of river installations around the region . . . you would need several run of river hydro stations."[222] Additionally, one government official noted that many smaller-scale facilities in New England had been recently removed, particularly as the economics of licensing costs have become more unfavorable and as the perceived environmental benefits of restoring rivers assumed greater importance.[223] Finally, a report from the Massachusetts Department of Energy Resources (DOER) noted that while there may be up to 291 MW of additional new small-scale hydroelectric capacity within New England, less than 10 MW of that capacity is in Massachusetts.[224] By contrast, the smallest of the three already-mentioned offshore wind projects under construction in New England is expected to supply 700

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[216] Industry representatives, interview by USITC staff, May 7, 2020; industry representative, interview by USITC staff, May 4, 2020.

[217] BloombergNEF (accessed June 9, 2020).

[218] One industry representative noted that the transmission costs may be too high for a single company to bring a larger wind project online. As a result, the potential generator may have to work with other generators or regulatory intermediaries to bring projects online. Industry representatives, interview by USITC staff, April 29, 2020.

[219] State of Connecticut, DEEP, Comprehensive Energy Strategy, February 8, 2018, 30.

[220] USITC, hearing transcript, July 29, 2020, 210–11 (Mark Kresowik, Sierra Club).

[221] Run-of-the-river hydropower is defined in chapter 1 of this report.

[222] USITC, hearing transcript, July 29, 2020, 89 (Anne George, ISO New England).

[223] USITC, hearing transcript, July 29, 2020, 89–90 (Patrick C. Woodcock, Commissioner, Massachusetts Department of Energy Resources).

[224] State of Massachusetts, DOER, *Report on Permitting Small and Low Impact Hydropower Products in Massachusetts*, August 30, 2016, 3.

MW of power to the New England states. Multiple industry reports have also noted that the FERC licensing process can be complex and contribute to delays for hydroelectric facilities, with one noting that the process adds “significant time, cost, and bureaucratic complexity” to small-scale hydroelectric facility production.[225]

Biomass and Landfill Methane

Biomass and landfill methane represent a mixed picture for possible future contributions to renewable energy generation in New England. Although there have been some increases in generation from these sources in certain areas of New England, the general trend appears to be a slight reduction. This outlook is likely due to a variety of factors, including high cost and the varying energy and emissions intensities of the fuels processed.[226]

Connecticut’s DEEP, for example, has projected that the use of biomass and landfill gas to meet Connecticut’s RPS requirements is likely to decrease over time. As DEEP noted in 2018, “It appears there will be a surplus of regional renewable generation through 2020, . . . DEEP therefore believes it is a good time to begin phasing down the value of biomass and landfill gas.”[227] In addition to reducing the value of biomass and landfill RECs, the Connecticut DEEP envisions a capacity reduction in the biomass- and landfill methane-powered generation eligible to qualify for Connecticut’s Class I RECs, with a 50 percent reduction between 2018 and 2035 (from 800 MW to slightly more than 400 MW).[228]

In contrast, New Hampshire increased its alternative compliance payment (ACP)[229] price for Class III resources (which include biomass) from $45 to $55 per MWh in 2017 as part of an effort to ensure the mandate would be met. (New Hampshire’s generation of biomass increased approximately 36 percent between 2013 and 2017.)[230] According to a New Hampshire report, the difficulty meeting the state’s biomass RPS mandates (despite increased local generation) was likely due to demand from other states. For example, New Hampshire biomass generation was likely used to meet biomass requirements in Connecticut, where biomass RECs were generally more expensive. This issue likely also contributed to New Hampshire’s decision to reduce its RPS for Class III sources between 2012 and 2016 and readjust it in 2017. (Issues regarding RPS mandates and pricing complications are discussed further below.)[231]

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[225] This report noted that the National Environmental Policy Act and the Endangered Species Act of 1973 in particular “compounded hydropower’s regulatory complexity.” Another industry source noted that those delays (in both FERC’s and California’s regulatory approval processes) are “deterring investment in new hydropower projects and even making some companies decide against renewing their [existing hydroelectric power] licenses at all.” Lowenstein, “Troubled Water,” 2018, 255–58; Kern, “Permit Delays Dam Up Hydro Projects,” October 30, 2018.

[226] Forest 2 Market, “More Challenges for New England Biomass,” March 21, 2018.

[227] State of Connecticut, DEEP, Comprehensive Energy Strategy, February 8, 2018, 30–32.

[228] State of Connecticut, DEEP, Comprehensive Energy Strategy, February 8, 2018, 34.

[229] As noted in chapter 1, ACPs are a mechanism to ensure that certificate prices do not spike above a certain level.

[230] Patel, “Interactive Chart: Change in U.S. Biomass Generation,” 2018.

[231] University of New Hampshire Sustainability Institute, *New Hampshire RPS Retrospective 2007–2015 Report*, August 19, 2016, 11–12.

Finally, Maine, which is the largest biomass generator in New England, has experienced recent declines.[232] Between 2013 and 2017, Maine experienced a 24 percent decline in biomass electricity generation.[233] This decline was likely due to rising biomass production costs.[234] This large reduction in biomass generation effectively negated increases in biomass generation in the other New England states. Overall, the region experienced a slight decline in biomass generation in the 2013–17 period: New England's generation fell 73 MW or approximately 1 percent, in contrast to the 5.2 percent increase in biomass generation nationally.[235]

Neighboring Markets

Production of renewable energy from neighboring markets that feed into the New England electricity grid may also assist New England in meeting its renewable energy targets. These markets include New York as well as the Canadian provinces that feed into the New England energy grid (New Brunswick and Quebec). As noted above, many New England states have used generation from these markets to meet their REC obligations.

New York exports significant renewable and nonrenewable electricity to the New England region and will likely see increases in installed solar and wind capacity.[236] Installed solar capacity (principally from larger, utility-scale projects) is estimated to more than quadruple, from 1,800 MW in 2018 to 7,271 MW in 2025.[237] Likewise, wind capacity in New York is projected to nearly triple, from 2,008 MW of installed wind to 5,922 MW by 2025.[238]

In Canada, there appears to be limited potential for generation to qualify for New England's RPS standards. Large-scale hydroelectric power, which can meet emissions standards such as the Massachusetts CES and Connecticut CES, does not meet the RPS definition of a renewable source in most New England states (Vermont is the exception). For example, in June 2019 Massachusetts signed an agreement to bring an additional 9.45 TWh of hydroelectric power from Canada to the Massachusetts market over the next 20 years. This added electricity can be used to meet the Massachusetts's CES requirement, but not its RPS requirement.[239]

Canadian wind and solar energy production are likely to increase between 2019 and 2025, though industry representatives in New England did not identify Canadian solar and wind production as likely to be significant contributors to meeting RPS requirements in the region.[240] In 2019, installed capacity of

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[232] Patel, "Interactive Chart: Change in U.S. Biomass Generation," 2018.

[233] The decline was the third-highest relative decline among U.S. states, with only Idaho (29 percent) and West Virginia (100 percent) experiencing larger relative declines in biomass production in the 2013–17 period. In absolute terms, Maine experienced the largest decline in biomass generation in this period. Patel, "Interactive Chart: Change in U.S. Biomass Generation," 2018.

[234] Patel, "U.S. Biomass Power," 2018.

[235] Patel, "Interactive Chart: Change in U.S. Biomass Generation," 2018.

[236] BloombergNEF (accessed June 9, 2020).

[237] BloombergNEF (accessed June 9, 2020).

[238] BloombergNEF (accessed June 9, 2020).

[239] These imports may qualify for either the Massachusetts CES or CES-E (depending on their operational date). Hydro-Québec, "Energy Supply Contracts Get Green Light from Massachusetts," June 26, 2019.

[240] Industry representatives, interview by USITC staff, May 7, 2020; industry representative, interview by USITC staff, May 4, 2020; industry representative, interview by USITC staff, April 29, 2020.

wind power in Quebec was 3,882 MW, while New Brunswick had 314 MW of installed capacity (combined, the two provinces represented 31 percent of Canadian wind capacity).[241] Additionally, the Canadian Wind Energy Association (CANWEA) has specifically described the carbon emission caps of the New England states and the ability to export to the region as an incentive for expanding the production of wind energy in Canada, particularly in Quebec.[242] One wind power project in Quebec, the Apuiat phases 1 and 2, is currently undergoing the review process, and it is expected to supply 200 MW of generating capacity annually beginning in 2022–23.[243]

Transmission and Storage Challenges

Despite the potential of new resources both within New England and in neighboring markets, several industry representatives from multiple New England states have noted that distributing increased volumes of renewable energy generation represents a challenge.[244] Transmission of generated energy to distribution lines in New England can prove challenging. Generating facilities are often located in remote areas away from dense urban centers—areas that may also be difficult and expensive to link to via a transmission system (notably offshore wind farms, which require undersea cables). The cost to construct new transmission capabilities or update older ones can be substantial.[245] The need for effective and reliable transmission for renewable energy-generating facilities can be particularly acute due to the variable output associated with some renewable sources of electricity (particularly wind and solar).[246]

Multiple industry representatives have noted that one of the largest challenges in bringing renewable energy online is the ability to transmit that generated energy to distribution systems, which can require multibillion-dollar projects.[247] Another report from the Connecticut DEEP highlighted the uncertainty of compliance costs for the state's RPS, due in part to the expense of bringing renewable sources online: "transmission lines would likely need to be built in order to bring this significant amount of renewables online by 2030."[248] While some transmission lines are under construction, others are still going through the regulatory approval process for construction in multiple New England states.[249] Industry representatives and environmental groups have also noted the that the construction of transmission lines can entail some environmental risk, with potential impacts on local communities.[250]

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[241] CANWEA, "Wind Energy Installed Capacity," December 2019.

[242] CANWEA, "Quebec," December 2019.

[243] A smaller 6.4 MW project, the Dune-du-Nord, began producing wind power in Quebec in October 2019. Government of Quebec, Department of Energy and Natural Resources, "Wind Energy Projects in Quebec," 2020.

[244] Industry representatives, interview by USITC staff, May 7, 2020; industry representative, interview by USITC staff, May 4, 2020; industry representative, interview by USITC staff, April 29, 2020.

[245] State of Massachusetts, DOER, written submission to USITC, August 7, 2020, 4.

[246] Cleary and Palmer, "Renewables 101: Integrating Renewable Energy Resources," April 15, 2020.

[247] Industry representatives, interview by USITC staff, May 7, 2020; USITC, hearing transcript, July 29, 2020, 187–88 (testimony of Margaret Sheehan, North American Megadam Resistance Alliance).

[248] This report also suggested lowering alternative compliance payments for most sources or renewable energy to limit ratepayer exposure. State of Connecticut, DEEP, Comprehensive Energy Strategy, February 8, 2018, 29.

[249] Key, "Renewables behind Proposed Transmission Projects," June 3, 2020; Sharp, "Maine Agency OKs $1B Hydropower Transmission Line," January 8, 2020.

[250] USITC, hearing transcript, July 29, 2020, 36 (testimony of Sophie Brochu, Hydro-Québec); USITC, hearing transcript, July 29, 2020, 133, 137 (testimony of Margaret Sheehan, North American Megadam Resistance Alliance).

Like the challenge of transmitting electricity from renewable energy sources, the issue of storing electricity is important to the development of renewable energy in New England. While there was only 19 MW of installed battery capacity in New England in 2017, proposed projects in the region through 2022 would raise that capacity to 846 MW.[251] This increase would allow the integration of more renewables into the electricity grid, supporting the expansion of solar and wind energy generation in the region.

Recognizing the importance of battery storage in the potential future generation of renewable energy in the region, several New England states have taken measures to promote energy storage through batteries and other means. The Massachusetts Energy Storage Initiative is a Massachusetts-funded initiative to support the development of battery technology and to craft appropriate policies to encourage battery development. Connecticut has permitted energy storage projects in the state to compete with generation facilities for clean energy and grid-modernization proposals, and Vermont's Clean Energy Development Fund is permitted to support energy storage projects, in addition to the development of clean energy generation plants.[252]

The high cost of storing electricity through the use of battery technology represents the largest challenge to the increased adoption of battery technology for renewables. In 2018, only 3 percent of installed small-scale storage power capacity in the United States was directly connected to a distribution grid, and the ISO New England region has one of the lowest levels of large-scale battery storage capacity.[253] One 2020 study from the U.S. Energy Information Administration differentiated among capital cost estimates for large-scale batteries based on storage capacity. Short-duration (less than 30 minutes) batteries had a capacity-weighted per-unit cost of $2,425 per kWh. For batteries with storage duration of 30 minutes to two hours, the cost was $1,710 per kWh, and for batteries with storage beyond two hours the cost was $772 per kWh.[254] These costs and duration have improved over the last five years and are projected to continue improving in the next few years: according to one study, the cost of four-hour batteries is projected to fall between 11 to 67 percent by 2030, and between 32 and 80 percent by 2050.[255]

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[251] ISO New England, "Battery Storage Is 'Charging Ahead' in New England," August 21, 2018.

[252] ISO New England, "Battery Storage Is 'Charging Ahead' in New England," August 21, 2018; State of Massachusetts, "Energy Storage Initiative," (accessed August 31, 2020).

[253] EIA, "Battery Storage in the United States: An Update," July 2020, 12, 21.

[254] EIA, "Battery Storage in the United States: An Update," July 2020, 17.

[255] Cole and Frazier, "Cost Projections for Utility-Scale Battery Storage," June 2019, 5.

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Chapter 3
Quantitative Analysis

Introduction

This chapter provides a quantitative analysis of the effects of Massachusetts's increased renewable energy and clean energy goals and commitments on the rates paid by residential and commercial electricity consumers and on greenhouse gas (GHG) emissions. To conduct this quantitative analysis, the Commission developed a partial equilibrium model of New England's electricity sector. The model uses forecasts from the 2020 edition of the Annual Energy Outlook (AEO) produced by the U.S. Energy Information Administration (EIA) as inputs for estimating the future profitability and expansion of renewable generation resources to meet Massachusetts goals and commitments. The model projects the effect of the increased goals and commitments on residential and commercial electricity consumers and on carbon dioxide emissions. To take into account uncertainty about future renewable technology costs and the future supply of oil and gas, the model includes several different scenarios from the AEO in addition to using the AEO's Reference case (the EIA's best estimate of conditions through 2050, including projected technological improvements in the energy sector and current laws and regulations).

The first section of this chapter discusses the general setup of the model, including a deeper look at the commitments modeled. The second section outlines the data inputs to the model, describing the role that data from the AEO play in model calculations. The third section provides model estimates of the effects of the commitments on (1) the costs to Massachusetts residential and commercial electricity consumers, (2) the cost to the rest of New England, and (3) the GHG emissions associated with Massachusetts's electricity supply. These effects are estimated in five-year increments from 2030 to 2050. The third section then concludes with a description of the role of hydroelectricity imports in meeting Massachusetts's commitments. The final section discusses the challenges of quantifying the effect of Massachusetts's goals and commitments several decades into the future.

Key Findings

- The model projects that Massachusetts's updated Renewable Energy Portfolio Standard (RPS) commitment and the addition of the Clean Energy Standard (CES) commitment will cost consumers between 0 and 0.12 cents per kilowatt-hour in 2030, with the upper bound of the cost to consumers being equivalent to an additional $0.76 per month per residential consumer or $5.57 per month per commercial consumer.[256]
- EIA projects that technical progress will reduce the cost of new renewable generation, mitigating future cost increases to consumers. For the Reference case, the Commission's model projects that new renewable resources could be profitable without any incentives by 2040 and

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[256] The model assumes that the cost burden of the commitments per kWh is the same for both customer types; however, the total monthly cost to each actually differs, given that individual commercial customers consume more electricity in a month.

that Massachusetts's RPS and CES commitments could be met without additional costs to consumers by 2040.

- The Massachusetts RPS and CES commitments are projected to slightly reduce the wholesale cost of generation for the rest of New England. New generation resources developed to meet these commitments will increase electricity supply in the region and replace natural gas-fired generation (which has a higher marginal cost of operation). These cost reductions are projected to result in savings for the rest of New England of between $0 and $3 million dollars in each year in which the Massachusetts's commitments incentivize additional generation.
- The commitments are projected to reduce annual carbon dioxide emissions by 1.94 million metric tons in 2030 by incentivizing the construction of new renewable resources. This is equivalent to the amount of carbon absorbed by 2.5 million acres of U.S. forests in a year.
- Based on model assumptions about Massachusetts's access to imports, the incremental commitment of Massachusetts's CES beyond its RPS is projected to be satisfied fully by imported hydroelectric power in 2030 and 2035 for all cases. In later years of the model, however, renewable generation is also needed to meet these commitments.

Model Setup and Background

Massachusetts's Recent Goals and Commitments

The quantitative analysis outlined in this chapter focuses on potential economic effects of two commitments in Massachusetts: an increase in Massachusetts's RPS in 2018, and the creation of a CES in 2017. The analysis compares projections for electricity rates and carbon dioxide emissions with and without these increased commitments in place in 2030, 2035, 2040, 2045, and 2050. The modeling focuses on aspects of the commitments that require Massachusetts utilities to source an increasing share of electricity from qualifying clean and renewable electricity sources.[257]

Before adopting these two commitments, Massachusetts had a mandate to derive 15 percent of electricity sales from Class I renewable sources by 2020, with a 1 percentage point increase each year thereafter, reaching 45 percent in 2050. [258]

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[257] In 2016, Massachusetts adopted An Act to Promote Energy Diversity, which required the acquisition of long-term (15- to 20-year) contracts for renewable and clean resources. Such supply-side commitments are not modeled here. The first provision of the 2016 act required acquisition of up to 1,600 MW of energy through offshore wind. This commitment was satisfied by "Vineyard Wind Bid 2," with 800 MW coming online as soon as 2023, and "Mayflower Wind," with 804 MW coming online before 2025. The second provision is the commitment to acquire, through a 20-year contract, a minimum of 9.45 terawatt-hours per year of clean energy generation by December 31, 2022. This commitment resulted in a 9.55 terawatt-hour contract with Hydro-Quebec for imported hydroelectric power. An Act to Promote Energy Diversity, 2016 Mass. Acts 188, §§ 83C, 83D (2016).

[258] This is the commitment for Class I renewable resources. The original RPS before Massachusetts's new commitments included Class II requirements and carveouts for solar as well. State of Massachusetts, "Program Summaries" (accessed September 16, 2020). Further discussion of other classes of renewables in Massachusetts can be found in chapter 2 of this report.

In 2017, Massachusetts added a commitment to clean energy. Massachusetts's CES requires sourcing 16 percent of electricity sales from clean energy sources by 2018 and increases by 2 percentage points per year until reaching 80 percent in 2050.[259] Notably, this commitment recognizes large-scale hydroelectric power (built after 2010) and nuclear power (built after 2010) as qualifying energy sources, in addition to any resources that qualify as "renewable" under Massachusetts's RPS.[260]

In 2018, Massachusetts added the second commitment addressed in the quantitative analysis in this chapter, the Act to Advance Clean Energy (the Act). The Act increased the requirement for sales coming from Class I renewable sources to 16 percent of electricity sales in 2020, with a further increase of 2 percentage points per year until reaching 34 percent in 2029, then growing 1 percentage point per year from 2030 until reaching 55 percent in 2050.[261] It is worth noting there are differences between classes of renewables in the legislation, and the numbers presented here reflect the focus of the Commission's quantitative analysis on Class I renewables only. For discussion of Massachusetts's commitments and how mandate variability (such as the classes and carveouts that are not addressed in the quantitative analysis) can affect compliance costs, see box 2.2 in chapter 2 of this report.

The relevant aspects of the 2017 and 2018 renewable and clean electricity portfolio mandates, as well as the previous renewable portfolio standard, are summarized in figure 3.1.[262] Massachusetts's initial RPS commitments are depicted by the gray line. The blue line shows how the adoption of the 2018 commitment increased Massachusetts's RPS requirement. The orange line represents the 2017 CES, which allows a broader set of electricity sources to satisfy its requirements. Given the significant role of

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[259] "Clean Energy Standard," 310 CMR 7.75 (2017), 509, 513–14.

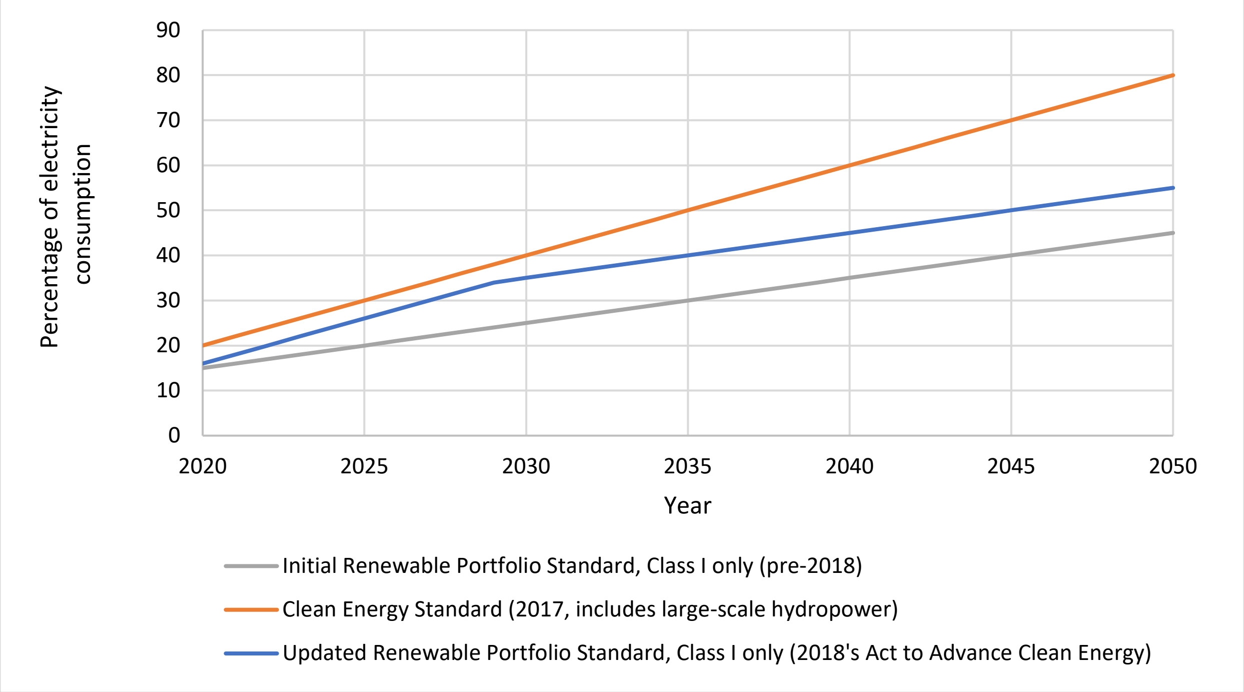
[260] For additional discussion of New England's or Massachusetts's markets and commitments, see chapter 2. Chapter 2 further discusses the qualifying sources of renewable and clean energy in the section on Massachusetts's regional and state-level goals and commitments, including table 2.2, which outlines the full set of qualifying sources of renewable energy under Massachusetts's commitments. Massachusetts's CES originally limited eligibility for nuclear and hydroelectric resources to facilities that entered into operations after 2010, but amendments implemented in 2020 allow older facilities to meet some of the target. Massachusetts Department of Environmental Protection, "Clean Energy Standard Amendments," 310 CMR 7.75, July 10, 2020, 3, 6–7, 12.

[261] An Act to Advance Clean Energy, 2018 Mass. Acts 227 (2018); Renewable Energy Portfolio Standard for Retail Electricity Suppliers, Mass. Gen. Laws ch. 25A, § 11 F. More information on classes of renewables under Massachusetts's commitments is available in chapter 2 of this report. The Act also commits Massachusetts to investigate the benefits and costs of acquiring 1,600 MW of offshore wind contracts in addition to the commitments from An Act to Promote Energy Diversity (discussed in footnote 257) by the end of 2035. There were two other additions to Massachusetts's goals and commitments that are not included in the modeling for this report: the CES-E Standard and the Clean Peak Standard, which took effect in July and August of 2020, respectively. The CES-E standard (310 CMR 7.75(4)(b)) allows existing clean-energy producers to qualify for 20 percent of energy sales as a part of the CES commitment. ("Existing" is defined as generation facilities built before 2011.) The Clean Peak Standard (225 CMR 21.00) sets a minimum level of peak demand that must be met with qualifying clean resources, starting with 1.5 percent of retail electricity sales in 2020 and increasing at least 1.5 percentage point each year to reach at least 16.5 percent by 2030. This policy results in a new form of energy certificates—Clean Peak Energy Certificates, or CPECs. "Clean Peak Energy Portfolio Standard (CPS) (225 CMR 21.00)," August 7, 2020, 1, 10.

[262] Note that these standards are applied only to investor-owned utilities, not municipally owned utilities. The latter account for about 14.1 percent of Massachusetts's total electricity demand (see "Data Sources" section in appendix E). For discussion of the applicability of standards to municipally owned utilities, see chapter 1.

hydroelectricity in Massachusetts's electricity sourcing, it is likely that the majority of the difference between the orange and the blue lines will be satisfied by large-scale hydroelectric power.[263]

Figure 3.1 Mandated share of load from renewable and clean sources under Massachusetts's recent goals and commitments (percentage of electricity consumption)



Source: State of Massachusetts, "Program Summaries: Summaries of All" (accessed September 16, 2020); "Clean Energy Standard," 310 CMR 7.75 (2017); An Act to Advance Clean Energy, 2018 Mass. Acts 227 (2018).
Notes: This figure is focused on the aspects of Massachusetts's commitments relevant to the modeling in this report (namely, the Class I portion of the commitment). Figure 2.11 depicts the full commitment, inclusive of other classes of resources. Underlying data for this figure can be found in appendix table G.20.

The Massachusetts commitments function as a backstop ensuring that the targeted increases in the relative use of renewable and clean energy resources are met. It is possible that future costs of renewable and clean electricity generation will be low enough that renewable electricity generation is profitable without the need for any incentives. If this is true, then the commitments do not directly cause the shift to renewable and clean resources, and total renewable generation may even exceed the targets.

Note that for this chapter, "renewable" refers to resources that qualify for Massachusetts's RPS and "clean" refers to resources that qualify for Massachusetts's CES, unless otherwise specified.

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[263] This is demonstrated using projections by the U.S. Energy Information Administration (EIA) later in the chapter. See table E.2.

Modeling the Cost to Consumers

Massachusetts's commitments affect consumer costs in two ways: they impose a direct cost that utilities pass through to retail rates, and they indirectly affect wholesale electricity prices in New England by altering the electricity supply.

First, the direct effect of the regulations arises from credits used to ensure compliance with the commitments. Retail electricity suppliers are required to acquire renewable energy credits (RECs) and clean energy credits (CECs) for a mandated share of the Massachusetts electricity load that they serve.[264] Energy providers then pass the cost of purchasing the credits to consumers in the form of additional rates charged per kilowatt-hour (kWh) of electricity. These compliance charges for the purchase of renewable energy credits and clean energy credits are the most direct effect of the commitments on consumers. The costs of the credits are passed on to all Massachusetts consumers, and there is evidence the costs are applied somewhat evenly across customer classes, though large commercial customers may pay a slightly lower rate on a per-kWh basis.[265] For the purposes of the modeling, the Commission assumes the costs of the credits are applied equally to all customer classes. The renewable and clean energy standards are Massachusetts-specific, so the cost of the credits mandated by the standards are specific to utilities' service areas within Massachusetts.

The indirect effect of the commitments on consumers is the effect on New England's wholesale electricity prices. Generally, the increased cost to consumers from the compliance credits is likely to be partly offset by a reduction in wholesale electricity costs in New England, because the commitments encourage a higher share of renewables (with relatively low marginal costs) in the region. This price effect arises from an increase in total generation supplied to the region and is likely to be small compared to the cost of compliance credits. The effects on the wholesale electricity market and wholesale prices are not Massachusetts-specific, however; the wholesale market comprises the entire New England region, with interconnections to New York and to Canada. Therefore, any reductions in wholesale prices due to Massachusetts's commitments will also benefit the rest of New England.

Other studies confirm the role of both the direct cost of RECs and the indirect cost of reduced wholesale electricity costs as relevant to calculating the cost of renewable commitments.[266] Of particular importance is a 2014 survey of state-level studies examining the effect of renewable portfolio standards on electricity rates produced by the National Renewable Energy Laboratory (NREL) (hereafter "NREL

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[264] For example, consider Massachusetts's RPS and CES in 2035: Massachusetts is committed to 40 percent of sales coming from renewable sources and 50 percent of sales coming from clean sources that year. In order to comply with the commitment, a retail electricity supplier selling 100 MWh of electricity would need to purchase at least 40 RECs, since one REC covers one MWh of electricity sales, and an additional 10 CECs or RECs so that the total number of clean and renewable credits adds up to 50 percent of sales.

[265] There is limited public information on how REC, CEC, and ACP costs affect retail rates. The cost of RECs and CECs enter into retail rates through the Basic Service Cost. A 2009 filing by National Grid to the Massachusetts Department of Public Utilities shows that from November 2005 to February 2009 these costs were applied equally to residential and small commercial customers, while large commercial paid more in some months and less in others. Finding precise information on how REC, CEC, or ACP payments are passed through to customers is difficult, as utilities try to keep this information confidential to assist in future negotiations on pricing for the compliance credits. National Grid, "Massachusetts Electric Company," April 1, 2009, 3, 20–22; National Grid, "Motion for Protective Treatment," March 17, 2020, 3.

[266] Additional review of related literature is available in appendix E of this report.

survey”). This survey notes that in states with restructured electricity markets (such as Massachusetts), the main cost of renewable commitments arises from the cost of buying RECs or making any alternative compliance payments.[267] The NREL survey finds that for states with restructured electricity markets, the estimated incremental compliance costs were between 0.1 percent and 3.8 percent of retail rates, or between 0.2 and 4.8 cents per kilowatt-hour.[268] The survey also notes that six state-level studies found that the RPS commitments reduced wholesale prices of electricity due to the shift to increased supply of low-marginal-cost resources, though these price reductions were small.[269]

Modeling Greenhouse Gas Emissions

The renewable and clean energy standards are likely to reduce GHG emissions from the electric power generation associated with Massachusetts’s electricity loads. Most of the renewable energy resources that meet the standards generate few or no GHG emissions, replacing resources like natural-gas-fired generation that do emit greenhouse gases. The standards do not, however, specifically require the construction of new renewable or clean generation in Massachusetts or New England. The standards require only that Massachusetts utilities purchase compliance credits, including by contracting for power from renewable or clean sources outside of New England. These sourcing decisions will determine the size of the effect of the standards on GHG emissions.[270]

Box 3.1 Challenges to Quantifying the Economic Effects of Renewable and Clean Commitments

There are several challenges to estimating the size of the economic effects of the Massachusetts commitments. First, markets for electric power and compliance credits are complex economic systems. Prices depend on many factors, including the load on the regional electrical system, the costs of different generation technologies and fuels, and transmission and regulatory constraints.[a] The analysis in this chapter does not build a new model of the electricity system in New England, but instead starts from detailed projections from the National Energy Modeling System model developed by EIA, as reported in its 2020 AEO, adjusting these projections to address the specific Massachusetts commitments analyzed in this report.

Second, Massachusetts’s commitments and their economic effects extend decades into the future, and there is significant uncertainty about technologies, electricity loads, and other market conditions over long time horizons. Nevertheless, it is standard practice in the electric power industry and its regulatory community to project market outcomes decades into the future. Though imperfect, these long-term

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[267] Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, 3. Because REC and CEC prices represent the largest and most direct cost to consumers of renewable and clean commitments, the modeling analysis focuses on these costs and not on other secondary costs. For further discussion of this point, see the “Limitations of the Model” section of this chapter. For discussion of restructured electricity markets and for additional information on alternative compliance payments, see chapter 1 of this report. Chapter 1 provides general information on market structure and policies.

[268] Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, v.

[269] Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, vii.

[270] Though the model does not distinguish the source of greenhouse gas emissions, emissions calculations include emissions from generating electricity, regardless of where it is generated. This is in keeping with Massachusetts’s Greenhouse Gas Emissions Inventory, which is “consumption-based, meaning the Inventory accounts for emissions attributable to Massachusetts’s electricity consumption, whether generated in-state or out-of-state.” Massachusetts DOER, written submission to USITC, August 7, 2020, 5.

projections are used to analyze and justify long-lasting investments in generation and transmission. Long-term projections, including the AEO, are a critical part of business planning in the sector: they are relied on in regulatory review of siting requests and long-term contracts and are a key component in government oversight of the sector. In its 2014 survey of state-level RPS analysis, NREL notes that examining the costs and benefits of RPS commitments typically require a forward-looking study, as some of the benefits accrue well into the future.[b]

Third, the compliance credits are traded financial assets, and the future value of asset prices such as these is difficult to predict accurately.[c] Still, it is sensible to assume that the prices of the credits will revert over time to the value implied by their economic fundamentals. Credit prices will reflect the many factors that affect the profitability of newly added renewable electric power generation, such as capital and operating costs for the new projects and any new revenue opportunities.

It is appropriate, and standard industry practice, to reflect all of this uncertainty by creating *projections* of the future under scenarios representing alternative assumptions about the future. While *forecasts* usually assign weights to a single outcome or a small number of probable outcomes, projections under different *cases* (or scenarios) depict a range of possible outcomes, and they identify the specific assumptions leading to each of the possibilities. The modeling in this chapter focuses on the Reference case discussed in the 2020 AEO, while also presenting results for four additional scenarios. These four scenarios include the High Renewables Cost case and the Low Renewables Cost case, which assume different levels of "learning by doing" in building new renewable resources, and the High Oil and Gas Supply and Low Oil and Gas Supply cases, which assume different levels of technological progress in oil and gas extraction, among other things.

[a] EIA, "Assumptions to Annual Energy Outlook 2020," January 29, 2020, 19–21.
[b] Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, vii.
[c] NREL notes that "there is substantial variability in [renewable energy credit (REC)] prices from year to year depending on how states are meeting their RPS targets. In oversupply situations, REC prices can fall dramatically while in shortages they can rise to the level of the ACP." The ACP (alternative compliance payment) essentially serves as a price ceiling for the RECs. Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, 11.

Data Inputs and Model Parameters

The modeling in this report focuses on how Massachusetts's recent commitments relate to four separate metrics: electricity rates in Massachusetts, electricity rates in New England apart from Massachusetts, emissions in Massachusetts, and the role that imports into New England from Canada and New York can play in Massachusetts's ability to meet its commitments. These projections are built using a combination of data from the AEO 2020 forecasts and data from ISO New England to supplement where AEO forecasts are unavailable.[271]

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[271] For more information on ISO New England see chapter 1 of this report. Because the model uses the AEO's 2020 projections, the model does not account for changes in the Massachusetts and New England electricity markets that occurred in 2020—including those stemming from the COVID-19 pandemic. A post-hearing submission from ISO New England stated that "Beginning in mid-March, ISO New England began observing a decline of about 3 to 5 percent in consumer demand for electricity related to societal responses to the COVID-19 pandemic." The submission noted, however, that by the beginning of August demand had returned close to normal levels. Thus, it seems possible that the long-term effects of the pandemic on electricity markets will be minimal. ISO New England, written submission to USITC, August 12, 2020, 2.

Estimating these four items requires projections of future energy load, imports, electricity generation by source, and profitability of new generation. The following sections will first discuss AEO projections on relevant data series; they will then go into more depth about the model's key parameters and the focus of the estimates.

Annual Energy Outlook Projections

The 2020 AEO reports detailed projections for the electricity market in the New England region for each year through 2050, the year in which Massachusetts's commitments will have been fully phased in. The AEO uses a comprehensive general equilibrium model of the U.S. economy with extensive detail on the energy sector. It represents EIA's "best assessment of how the U.S. and world energy markets will operate through 2050, based on key assumptions intended to provide a base for exploring long-term trends." Projections in the AEO assume technological progress in energy production, delivery, and consumption.[272]

The 2020 AEO includes in its calculations the commitments Massachusetts made in a 2018 revision to the commonwealth's RPS. The AEO generally includes the laws and regulations that affect the energy sector. More broadly, the AEO includes the RPS commitments for Massachusetts and for all regions that have such commitments in place (29 states and the District of Columbia). However, the AEO does not include Massachusetts's Clean Energy Standard in its model.[273]

Table 3.1 reports load, generation, import, and price projections for the New England region in the AEO 2020 Reference case. The AEO projects that the net energy for load will increase over the forecast window by about 21 terawatt-hours (TWh), reflecting growth in demand net of the projected increase in solar and wind production.[274] The model projects an increase in total generation from within the region of about 15 TWh. The growth in load projected by the AEO takes into account existing federal policy incentives for electric vehicles, but does not incorporate all state-level commitments and incentives.[275] As stated in a footnote in chapter 1, analysis by the Brattle Group suggests that vehicle electrification and electric heating will be key to New England reaching its economy-wide greenhouse gas emissions targets, potentially doubling the region's electricity demand by 2050.[276] Thus, the AEO's projections may underestimate the total load growth likely in the region.

Returning to table 3.1, the projected level of international imports (satisfied by Canada) is anticipated to remain relatively constant, while the level of interregional imports (largely satisfied by New York State) is projected to fall in the immediate future and then return to the 2019 level by 2045. The AEO

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[272] EIA, Annual Energy Outlook 2020, January 29, 2020, 4.

[273] EIA, "Summary of Legislation and Regulations," February 2020, 3, 6, 8, 30–38. The AEO projections also include Massachusetts's solicitations for offshore wind and energy storage mentioned in an earlier footnote in this chapter, energy efficiency requirements, and the regional power sector emissions caps in RGGI (discussed in chapter 2). EIA, "Summary of Legislation and Regulations," February 2020, 11, 13.

[274] EIA defines net energy for load as "net generation of main generating units that are system-owned or system-operated, plus energy receipts minus energy deliveries." Net energy for load reflects the total generation used to meet demand in a region, which exceeds total sales in a region by the amount of transmission and distribution losses. EIA, "Glossary" (accessed September 21, 2020).

[275] EIA, "Summary of Legislation and Regulations," February 2020, 4, 29.

[276] ISO New England, written submission to USITC, August 12, 2020, 1–2.

Reference case also projects that retail rates (not including renewable energy credit (REC) and clean energy credit (CEC) costs) will remain relatively stable over the forecast window.[277]

Table 3.1 AEO 2020 Reference case projections for the New England region

Projected outcome	Units	2019	2030	2035	2040	2045	2050
Net energy for load	TWh	119.1	120.9	124.4	128.4	133.4	139.8
Total generation	TWh	95.2	99.0	102.0	103.5	105.4	109.3
International imports	TWh	14.9	14.0	13.9	14.4	14.5	15.0
Interregional imports	TWh	9.3	6.9	6.5	7.8	9.8	10.5
Retail electricity price, all sector average	2019 cents per kWh	17.7	18.2	18.0	18.3	18.3	18.1
Retail electricity price, residential sector	2019 cents per kWh	19.5	20.4	20.3	20.6	20.6	20.4
Retail electricity price, commercial sector	2019 cents per kWh	16.6	17.1	16.9	17.1	17.0	16.7

Source: EIA, Annual Energy Outlook 2020, table 54.7 (Excel file, accessed August 26, 2020).
Note: Retail electricity prices do not include renewable or clean energy credit costs.

The AEO projects a significant expansion of wind and solar generation in New England over the next 30 years, due at least in part to Massachusetts's increased RPS commitment.[278] This projected expansion coincides with the substantial retirements of coal and nuclear generation, and displacement of a significant amount of natural gas-fired generation.[279] Because the AEO does not also account for Massachusetts's CES, it likely underestimates the expansion of wind and solar that will occur in some years.

Model Data and Estimates

The Commission's model is a practical framework for incorporating available information while building on projections from the 2020 AEO. In its analysis in this chapter, which quantifies future effects on costs to consumers and emissions, the model adopts two principles. First, the model presents a number of cases that demonstrate the range of outcomes possible under different assumptions about future market conditions, rather than focusing on a single estimate. Second, the model focuses on the electric power sector and the effects specifically identified in the USTR's request letter and does not attempt to translate these into economy-wide effects.

The modeling relies on inputs from several different sources. The most important source is the AEO 2020 projections for the New England region, including five main AEO scenarios ("cases"): Reference, High Renewables Cost, Low Renewables Cost, High Oil and Gas Supply, and Low Oil and Gas Supply.[280] Specifically, the modeling relies on AEO estimates of the average revenue per megawatt-hour (MWh) available to new generation over the life cycle of the investment and the average cost of building and

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[277] According to the AEO, "the price of electricity to the consumer consists of the price of generation, transmission, and distribution, including applicable taxes." Each of these cost items are described in further detail in the AEO's documentation on the Electricity Market Module. EIA, "Assumptions to Annual Energy Outlook 2020," 19–21, January 29, 2020.

[278] Tables E.3 and E.4 outline electricity generation forecasts for the AEO Reference case for all renewable electricity sources that broadly qualify for Massachusetts's RPS.

[279] EIA, Annual Energy Outlook 2020, 2020, 56, 86.

[280] Expanded details of data used in the modeling are available in appendix E of this report.

operating the generation over this life cycle.[281] The AEO's calculations of the life cycle construction, operation, and maintenance costs vary with the type of plant, the region of the country, fuel costs (if any), operation and maintenance costs, and technology available in the years of operation.[282] Life cycle revenues depend on market conditions, including competing generation in the market, capacity factors, and dispatchability in peak hours, among other factors.[283] The values are calculated by EIA for New England for each year to 2050 based on the general equilibrium framework that underlies the 2020 AEO. The model uses the AEO's projections to assess the profitability of new generation from different renewable plant types in 2030, 2035, 2040, 2045, and 2050.

The model also uses the time profiles for Massachusetts's RPS and CES, as set out in Massachusetts state law. Projections of future Massachusetts loads are based on AEO projections for Massachusetts, ISO New England data on Massachusetts's share of the total New England load, and data on the share of Massachusetts load served by municipal utilities.[284] Data on carbon dioxide emissions rates for displaced natural gas generation in New England are also from the AEO.

The model uses the share of international and interregional imports that are from clean resources to determine whether or not Massachusetts's clean energy commitments are satisfied by projected clean energy generation and compliance with Massachusetts's updated RPS. If, in a given time period, projected clean energy imports in Massachusetts are not enough to satisfy the incremental requirements of Massachusetts's CES, then the model uses AEO profitability estimates to figure out the least-cost clean or renewable resource that can be built to satisfy the remaining unmet share of the CES commitment.[285]

Appendix E provides additional details about the model's data sources.

Modeling Results

This section outlines the effects of Massachusetts's increased renewable energy and clean energy goals and commitments on the four key items: electricity rates in Massachusetts; emissions in Massachusetts; electricity rates in New England apart from Massachusetts; and imports into New England from Canada and New York. These results are examined for various assumptions underlying the model, given the uncertainty inherent in modeling projections 30 years into the future.

Table 3.2 outlines the modeling scenarios and assumptions presented throughout the modeling in this report. The table first includes the list of scenarios presented in this chapter: these are five "pictures" of the future, selected from the AEO's projections. The alternative assumptions outlined in the table are then used to modify the model for each of the five scenarios to see how the results change. These alternative assumptions provide a more complete picture of the potential effects of Massachusetts's

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[281] The measure of average costs is called the levelized cost of electricity, or LCOE. The average revenue measure is called the levelized avoided cost of electricity, or LACE.

[282] EIA, "Levelized Cost and Levelized Avoided Cost," February 2020, 1.

[283] EIA, "Levelized Cost and Levelized Avoided Cost," February 2020, 2–4.

[284] For additional information on data sources, see appendix E of this report.

[285] A data limitation of the model is that it does not have a direct estimate of the future costs of imported hydroelectricity; rather, it relies on AEO projections that imports will be an economical part of the energy supply portfolio even without additional incentives.

goals and commitments, given uncertainty over future developments. Examples of these uncertain future variables include the mix of resources that will fill demand for new renewables, the share of New England's total imports to which Massachusetts will have access, and the rate at which Massachusetts's population will grow. The results for these alternative assumptions are reported in appendix E, the modeling appendix to this report. Finally, the RPS Sunset case, where the model assumes RPS commitments in the United States are all eliminated, is used as context for the model's estimates and to estimate the effect of Massachusetts's commitments on wholesale electricity prices in New England (see box 3.2).

Table 3.2 Modeling scenarios ("cases") and alternative assumptions used in the modeling

Scenario/assumption	Location of results	Details
Main scenarios:		Five main scenarios are reported throughout the analysis.
Reference case	Chapter 3	Reference case provides EIA's best estimate of conditions over the course of the AEO forecast.
High Renewable Cost case	Chapter 3	Overnight capital cost[a] for renewables remains at 2019 levels.
Low Renewables Cost case	Chapter 3	Overnight capital cost,[a] operating and maintenance costs, and fuel costs (where applicable) for renewables fall 40 percent lower than the Reference case equivalents by 2050.
High Oil and Gas Supply case	Chapter 3	Assumed 50 percent higher well output and 50 percent higher technological improvement of extraction technologies and practices than the Reference case.
Low Oil and Gas Supply case	Chapter 3	Assumed 50 percent lower well output and 50 percent lower technological improvement of extraction technologies and practices than the Reference case.
Alternative assumptions:		Alternative assumptions are used to calculate results for the five main scenarios. These results are included in the modeling appendix to this report, appendix E.
Marginal resource	Solar in chapter 3; wind in appendix E	Impacts all projections. Model assumes solar photovoltaic will meet clean commitments not filled by hydroelectricity based on AEO's projected growth in solar. Alternative projections look at commitments when wind is the marginal resource.
Access to imports	Access to imports proportional to demand in chapter 3; alternatives in appendix E	Impacts all projections. Model assumes Massachusetts receives 45.6 percent of New England's imports (largely hydroelectricity) proportional to Massachusetts's share in New England's load. Alternative compares where Massachusetts has the baseline (45.6 percent), moderate (30 percent), low (20 percent), and no access to New England imports of clean electricity.
Residential and commercial customer growth	Constant customers in chapter 3; linear growth in appendix E	Impacts only the cost to retail and commercial consumers projections. Model assumes population remains constant at 2018 levels. Alternative assumes population and commercial growth from 2020 to 2050 follows a linear trend based on 1990 to 2018 trend.
Additional analysis:		
RPS Sunset case	Box 3.2	RPS commitments in the U.S. are all eliminated. Provides an upper bound for the impact of Massachusetts's increased RPS and CES commitments.

Source: Compiled by USITC. EIA, "Annual Energy Outlook 2020: Case Descriptions," January 2020, 8–9; EIA, Annual Energy Outlook 2020: Full Report, January 29, 2020, 16.

[a] Overnight capital cost is a hypothetical measure equal to the cost of building a new power plant, assuming no interest accrues during the process. EIA, "Capital Cost Estimates for Utility Scale Electricity," November 1, 2016, 1.

Box 3.2 AEO Projections of the Effect of U.S. Renewable Portfolio Standards on Prices and Imports

The AEO quantifies the effects of renewable portfolio standards in the United States, though it does not isolate the incremental effect of Massachusetts's increased RPS commitments. This can be seen in a comparison of the Reference case (which includes the enforceable commitments of 29 states and the District of Columbia in its modeling) to the AEO's "RPS Sunset" case (which assumes the complete elimination of RPS commitments nationwide beginning in 2020). Table 3.3 reports the percentage change in load, generation, imports, and prices projected by the addition of RPS commitments through a comparison of the Reference case to the RPS Sunset case.

The AEO's model projects that RPS commitments have a small effect on net energy load—less than 1 percent in all forecast years. The addition of RPS commitments does increase total generation in New England, however, which results in a corresponding decrease in New England's international and interregional imports. The model also projects that the addition of RPS commitments leads to a reduction in retail electricity prices (excluding the cost of REC and CEC credits), across an average of all consumer classes and for residential and commercial customers specifically. This reduction in prices reflects the fact that the marginal cost of generation for renewable resources like solar, wind, and hydro is lower than it is for emitting resources like natural gas.

Table 3.3 AEO 2020 projections of percentage change in load, generation, imports, and prices for the New England region: Reference versus RPS Sunset cases

Projected outcome	2019	2030	2035	2040	2045	2050
Net energy for load	0.0[b]	0.1	0.3	0.2	0.3	0.1
Total generation	0.1	4.4	7.8	5.7	6.2	1.9
International imports	0	-1.9	-2.9	-0.2	-2.1	-1.1
Interregional imports	0.0[b]	-36.0	-50.4	-40.2	-33.7	-12.8
Retail electricity price, all sector average[a]	0.0[b]	-0.6	-2.1	-1.1	-1.6	-1.0
Retail electricity price, residential[a]	-0.1	-0.3	-1.8	-0.9	-1.4	-0.7
Retail electricity price, commercial[a]	0.0[b]	-0.6	-2.3	-1.2	-1.8	-1.1

Source: Compiled from EIA. USITC calculations. All estimates are of the percentage change from the RPS Sunset case to the Reference case, thus approximating the combined effects of all state-level RPS commitments. EIA, Annual Energy Outlook 2020, table 54.7: Reference Case, (Excel file, accessed August 26, 2020); EIA, Annual Energy Outlook 2020, Table 54: Renewable Portfolio Standard Sunset (accessed August 26, 2020).

[a] These retail electricity price projections do not include renewable or clean energy credit costs.

[b] Less than 0.05 percent increase.

In the Commission's modeling, the effect on retail electricity prices is used to approximate what the likely effect on electricity prices will be for the rest of New England. For further discussion of the calculation of that price effect, see appendix E.

Table 3.4 reports how the addition of RPS commitments to the AEO model impacts the forecast generation mix in New England (by comparing the percentage change going from the RPS Sunset case to the Reference case). Unsurprisingly, the addition of the 30 RPS programs results in a significant increase in generation of clean and renewable energy. The largest effects on generation are in the near term, as technological progress gradually lowers the marginal costs of renewable generation below alternative sources. This technological progress encourages the transition even in the absence of RPS commitments. The largest growth from the RPS commitments in the relevant renewable sources is seen in solar and wind.

Table 3.4 Change in projected generation mix from the addition of RPS commitments in the electric-power sector (as a percentage of RPS Sunset case projections)

Type of generation	2019	2030	2035	2040	2045	2050
All renewable and clean	0.0[a]	39.4	36.6	35.0	33.7	26.6
Solar (photovoltaic)	0.0[a]	24.5	24.9	24.8	25.6	12.0
Offshore wind	0	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Onshore wind	0	90.0	86.0	79.6	74.9	66.3
Hydroelectric power	0.0[a]	0.0[a]	0.0[a]	0.0[a]	-0.1	0.0[a]

Source: Compiled from EIA. USITC calculations. All estimates are of the percentage change from the RPS Sunset case to the Reference case, thus approximating the combined effects of all state-level RPS commitments. EIA, Annual Energy Outlook 2020, table 57.7: Reference Case (Excel file, accessed August 26, 2020); EIA, Annual Energy Outlook 2020, table 57: Renewable Portfolio Standard Sunset (accessed August 26, 2020).

Note: Because the share they contribute to electricity generation is quite small, two resources—wood and other biomass, and municipal waste—are not included in this table.

[a] Less than 0.05 percent increase.

Estimated Effects on Costs to Massachusetts Consumers

Calculations of the cost of the commitments to Massachusetts retail and commercial consumers are based on a partial equilibrium model of the market for renewable and clean energy credits. In the model, the profitability of new generation investments can be assessed by comparing the average cost per kWh over the life cycle of the plant to the available revenue opportunities for generation built in New England.[286]

The direct cost to Massachusetts consumers of the commitments is equal to the value of credits per MWh that would be needed to supplement a generator's revenue to the point that it will be profitable to invest in new renewable generation in the New England region using AEO projections of average costs and average revenues from new renewable generation.[287] The model estimates the increase in the costs of compliance to consumers per kWh by multiplying the credit value by the amount of load needed to meet Massachusetts's CES and increased RPS.

The indirect effect of the commitments on wholesale electricity prices is then calculated to complete the analysis of the cost to Massachusetts consumers. The expansion in generation in response to credit incentives should reduce the price of generation in New England's electricity market overall, but not by much. For example, compare the Reference and RPS Sunset projections in AEO 2020 (table 3.3): moving from no RPS at all to the status quo in the 2020 Reference case is projected to reduce the prices of electricity in New England by only 0.6 percent in 2030 and 1 percent in 2050.

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[286] Assessing the profitability of new generation is a complex calculation requiring a very large amount of information about the entire electricity sector in New England and interconnected regions. A more detailed description of the model used here is in appendix E.

[287] The average revenue and cost data indicate that onshore wind and solar photovoltaic are the most profitable types of new renewable generation in 2030–50. EIA, Annual Energy Outlook 2020: LACE (available from EIA on request; accessed October 2, 2020); EIA, Annual Energy Outlook 2020: LCOE (available from EIA on request; accessed October 2, 2020). See tables E.13 and E.14 for details of the average cost and average revenue estimates.

The cost to Massachusetts consumers detailed in tables 3.5 and 3.6 combines the increase in compliance costs (equal to the value of the credits) and the small decline in electricity prices due to the expansion in renewable generation. In cases where there are no positive credits, the commitments have no effect on the market (they are unneeded), and so there is no effect of the commitments on the price of generation or on any other costs to consumers.

Table 3.5 Estimated increase in per-unit cost to Massachusetts consumers in different cases (in 2019 cents per kWh)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	0.041	0.119	0.027	0.044	0
2035	0.024	0.112	0	0.019	0
2040	0	0.249	0	0.001	0
2045	0	0.298	0	0	0
2050	0	0.299	0	0	0

Source: USITC calculations.

Table 3.6 Estimated increase in total cost to Massachusetts consumers in different cases (in millions of 2019 dollars)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	19.5	56.5	12.7	21.0	0
2035	11.7	55.0	0	9.3	0
2040	0	126.6	0	0.7	0
2045	0	157.7	0	0	0
2050	0	165.9	0	0	0

Source: USITC calculations.

The Reference case of the AEO assumes that there is technological progress in the building of renewable resources.[288] This leads to reductions in the cost of renewables over time and means there is a reduction in the annual cost to consumers of Massachusetts's RPS and CES commitments between 2019 and 2050, with renewables being profitable without the aid of credits by 2050.

The Low Renewables Cost case in the AEO assumes approximately a 40 percent greater reduction in the cost of renewables by 2050 than under the Reference case.[289] As a result, in the Low Renewables Cost case, the Massachusetts commitments only cost consumers in the near term, with renewables becoming profitable without credits by 2040. Some third parties have highlighted the tendency of previous AEO projections to underestimate renewable energy growth. This makes the Low Renewables Cost case a useful tool in addressing uncertainty about cost reduction potential in renewables and future policies.[290]

The High Renewables Cost case assumes that the cost of new renewable resources is the same in 2050 as it was in 2019.[291] As a result, this projection anticipates a rise in the annual cost of Massachusetts's RPS and CES commitments over time compared to the Reference case, in which the cost of new

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[288] EIA, Annual Energy Outlook 2020, January 29, 2020, 4.

[289] EIA, "Annual Energy Outlook 2020: Case Descriptions," January 2020, 6.

[290] EIA, Wind and Solar Data and Projections, March 2016, 1, 16.

[291] EIA, "Annual Energy Outlook 2020: Case Descriptions," January 2020, 6.

renewable resources falls over time. The projected consumer costs for the High Renewables Cost case significantly increase in 2040 because the projected hydroelectricity imports and generation are not large enough to meet Massachusetts's entire CES commitment that year. Specifically, 0.4, 5.1, and 10.9 percent of load must be sourced from renewable generation in 2040, 2045, and 2050, respectively, and all of the new renewable generation must be incentivized. This means the model is switching from valuing the clean energy credit at zero to all CES-eligible resources receiving a credit (amplifying the cost of even a relatively small credit). In this scenario, imported hydroelectricity's ability to fulfill the part of Massachusetts's CES commitment that is not met by the RPS commitment can substantially reduce the costs to consumers.[292]

For the High Oil and Gas Supply case, the commitments are more costly than in the Reference case, because the next-best alternative, natural gas generation, is less expensive, and so the renewable energy credits need to be higher in order to incentivize production. In the Low Oil and Gas Supply case, the next-best alternative is more expensive than the new renewable generation, so it is always profitable, even without credits.

It is helpful here to refer back to the Lawrence Berkeley estimates mentioned in chapter 2, which found RPS costs in Massachusetts contributed to over 11 percent of retail rates in 2018. the Lawrence Berkeley estimates of costs break down into three categories: Class I (approximately 0.4 percent of retail rates), Class II (approximately 0.5 percent of retail rates), and solar carveouts (approximately 10.8 percent of retail rates). Because Class II and solar carveout commitments were not changed by Massachusetts's 2017 and 2018 commitments, only the Class I component is relevant to the modeling. This 0.4 percent of retail rates in 2018 translates to a cost of 0.07 cents per kWh for commercial consumers and 0.09 cents per kWh for residential consumers, both of which fit within the bounds of the model's estimates.[293]

As a final caveat, the Commission's model of the costs of the commitments focuses on the costs of the commitments laid out in the policies; it does not adjust for announced or potential future contracts. In addition to the standards discussed above, Massachusetts has also made commitments to enter into long-term contracts for baseload electricity supply. These contracts securing sources of renewable and clean electricity reduce uncertainty by locking in future prices inclusive of compliance credit costs. These contracts are financial transactions that might benefit Massachusetts ratepayers, depending on how the specific terms of the contracts compare to prevailing market prices. The model does not try to quantify the gains or losses from these financial transactions. Instead, tables 3.5 and 3.6 calculate the effects on the costs to consumers independent of whether these costs are offset or magnified by the terms in long-term contracts.

Using EIA's state energy profile of Massachusetts and the AEO's projections for total residential electricity consumption and commercial electricity consumption, tables 3.7 and 3.8 provide context for the cost to consumers presented in table 3.5 and 3.6 by providing total monthly costs per customer.

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[292] See "Varying Access to Imports" in appendix E for more discussion of this point.

[293] EIA, "Average Retail Price of Electricity, Massachusetts, Annual" (accessed December 10, 2020); Barbose, U.S. Renewables Portfolio Standards, July 2018, 42.

Table 3.7 Estimated increase in the cost to Massachusetts residential consumers, monthly cost per customer (in 2019 dollars)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	0.26	0.76	0.17	0.29	0
2035	0.16	0.74	0	0.13	0
2040	0	1.71	0	0.01	0
2045	0	2.13	0	0	0
2050	0	2.23	0	0	0

Source: USITC calculations.

Table 3.8 Estimated increase in the cost to Massachusetts commercial consumers, monthly cost per customer (in 2019 dollars)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	1.89	5.57	1.23	2.04	0
2035	1.12	5.35	0	0.90	0
2040	0	12.23	0	0.06	0
2045	0	15.26	0	0	0
2050	0	16.16	0	0	0

Source: USITC calculations.

The added cost to both residential customers and commercial customers is relatively low on a monthly basis in all cases except for the High Renewables Cost case, which jumps in 2040 when imported hydroelectricity is no longer adequate to satisfy Massachusetts's CES commitment and high-cost renewables must be used to make up the difference. Again, the model assumes that the cost burden of the commitments per kWh is the same for both customer types. But the total monthly cost to each actually differs, given that individual commercial customers consume more electricity in a month.

The Commission compared these modeling projections to those from similar studies of Massachusetts renewable energy commitments. These other studies are discussed in more detail in appendix E. The modeling results in table 3.8 are comparable to those from the 2017 Massachusetts Energy study on Massachusetts's policy commitments, which found an additional monthly cost to consumers between \$0.15 and \$2.17 by 2030.[294] The Commission's results and the results from the 2017 Massachusetts Energy study stand in contrast with the 2018 Massachusetts Senate Study, which projected that the adoption of the version of Massachusetts's RPS update they modeled would result in a slight decline in costs to consumers' electricity bills by 2030.[295]

Estimated Effects on Costs to New England Consumers

The Massachusetts RPS and CES commitments imply benefits or costs to the rest of New England only to the extent that they impact the price of generation in the region, since the compliance credit costs are paid only by Massachusetts consumers.

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[294] Knight et al., An Analysis of the Massachusetts Renewable Portfolio Standard, May 2017, v.

[295] Stanton et al., An Analysis of the Massachusetts 2018 'Act,' June 21, 2018, 9.

Model results shown in table 3.9 illustrate that the shift of Massachusetts to more renewable energy generation results in an estimated cost savings for consumers in the five other New England states of between $0.9 million and $3 million in a given year when the commitments are incentivizing. Massachusetts's commitments to more renewable and clean resources are projected to increase total supply of generation and cause a shift toward low-cost renewables, driving down the overall price of electricity in the region in future years when the incentives are operative (as shown in the projections for 2030 and 2035).

Table 3.9 Estimated savings for New England, excluding Massachusetts, due to Massachusetts's commitments (in 2019 dollars)

Year	Price effect (cents per kWh)	Total annual savings, Reference case (million $)
2030	-0.0013	0.87
2035	-0.0044	2.98
2040	0	0
2045	0	0
2050	0	0

Source: USITC calculations.
Note: Results for alternative cases are available in table E.8 in appendix E of this report.

The previously mentioned survey report from NREL, as well as another survey report issued in 2019 by the Berkeley Lab—hereafter the "Berkeley Lab report"—also point to the way that cost savings from low-marginal-cost resources lead to a reduction in the market-clearing price of wholesale electricity. These cost savings also tend to be small, around 0.1 cents per kWh of total electricity sales (between 0.2 cents and 5 cents per kWh when expressed as a fraction of renewable energy generation).[296] The Berkeley Lab report cites studies which find a median of about 3 cents per kWh of renewable energy generation.[297]

Estimated Effects on Massachusetts's Greenhouse Gas Emissions

Quantification of the effects of the two Massachusetts commitments on emissions of greenhouse gases from electricity generation is based on two factors: (1) the additional share of Massachusetts's load required to be renewable or clean electricity in each year under the updated RPS and CES commitments, and (2) the emissions rate of the generation that will likely be displaced by the new renewable and clean sources. AEO analysis indicates that the displaced generation will be predominantly natural gas, and so the model uses emissions rates for natural-gas-fired generation in New England to estimate the effects on GHG emissions.[298]

Note that, similar to the projected cost to consumers, the model attributes GHG emissions reductions to the commitment only if the commitment directly incentivized the addition of new renewable

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[296] Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, 24.
[297] Barbose, U.S. Renewables Portfolio Standards, 2019, 39. Additional information about other costs that are likely associated with the increase in renewables associated with RPS commitments are available in the Berkeley Lab report.
[298] Note that this is reflected in figure 2.5 in chapter 2, which shows that natural gas generates the largest share of power in Massachusetts.

resources.[299] In years where the new renewables are profitable without any incentive, the projected reduction in GHG emissions will be zero to reflect this fact. In years where new renewables are not profitable without incentives, however, the projected reduction in GHG emissions reflects the renewable generation that must be added in response to the commitments.[300]

The analysis of the impact on GHG emissions is focused on the impact Massachusetts's commitments have on emissions of carbon dioxide from electricity generated for consumption in Massachusetts.[301] Table 3.10 reports the estimated reduction in the carbon dioxide emissions rates, in million metric tons per MWh, and the total annual reduction every five years between 2030 and 2050, using data from the AEO 2020 Reference case.

Table 3.10 Estimated effect of commitments on carbon dioxide emissions under the Reference case

Year	Change in emissions per MWh (million mt per MWh)	Change in total emissions (million mt)
2030	-0.041	-1.94
2035	-0.039	-1.91
2040	0	0
2045	0	0
2050	0	0

Source: USITC calculations.
Note: Results for alternative cases are available in tables E.9 and E.10 in appendix E of this report.

Although the numbers in table 3.10 may appear small, the EPA Greenhouse Gas Equivalencies Calculator can provide some context. For example, 1.94 million metric tons of carbon dioxide emissions are generated by driving a car around the equator approximately 193,000 times (about 4.8 billion miles). In terms of carbon removal, removing 1.94 million metric tons of carbon is equivalent to the carbon absorbed by 2.5 million acres of U.S. forests in one year.[302] The estimated reductions for 2030 are also significantly higher than the projected reductions in GHG emissions that the 2018 Massachusetts Senate study anticipated would result from the version of Massachusetts's RPS update their model analyzes, which came to 0.6 million metric tons of GHG emissions.[303]

Estimated Role of Imports in Meeting Massachusetts's Commitments

Imports of hydroelectricity are projected to play an important role in satisfying electricity demand in New England and in ensuring Massachusetts meets its clean energy commitments throughout the model's time frame. The role of hydroelectric power as an important resource in New England is a result of the large supply of low-cost hydroelectric power coming from Canada and, to a lesser extent, from

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[299] Any long-term changes in the trajectory of emissions resulting from the collective impact of Massachusetts's RPS and other similar policies on the profitability of renewable generation are outside the scope of the study.
[300] The emissions reductions projections net out reductions from renewable generation that would have been built without the incentivizing policy in place. This functions slightly differently than the cost calculations. For the projected cost to consumers, the incentive is paid to all eligible resources, regardless of whether or not those resources would have been built without the policy in place.
[301] See chapter 1 for additional context on data availability for GHG emissions and on this report's focus on carbon dioxide emissions rates.
[302] EPA, "Greenhouse Gas Equivalencies Calculator," March 2020.
[303] Stanton et al., An Analysis of the Massachusetts 2018 'Act,' June 21, 2018, i.

New York State.[304] The potential to expand imports of hydroelectricity from Canada or from New York State, however, is limited by international and regional transmission constraints.[305]

The amount of hydroelectricity imports already projected by the AEO for Massachusetts is adequate to fulfill the entire difference between Massachusetts's CES and RPS commitments through the early years of the 2020 to 2050 window. The additional commitment of CES (beyond the RPS) requires Massachusetts retail electricity providers to purchase between 5 percent (in 2020) and 25 percent (in 2050) of their electricity from clean resources in addition to their renewable targets.[306] Because imports from large-scale hydroelectric facilities qualify to meet Massachusetts's CES but not its RPS commitments, they can be used to meet this share of Massachusetts's commitments.

The model assumes that the difference between Massachusetts's CES and RPS commitments is first supplied by the projected hydroelectric imports mentioned above and then by other renewables. For 2050 across all cases, about 10 percent of the 25 percent of Massachusetts's load contained in the CES commitment above the RPS is not met by existing CES-eligible resources or imports.[307] In all cases other than the High Renewables Cost case, the additional 10 percent is available from renewable generation that would be built whether or not the commitments were in place (resulting in no cost to consumers in 2050). For the High Renewables Cost case, however, assuming the additional 10 percent is met with RPS-qualifying renewables could overestimate the cost effects, if it will instead be met by expanding import capacity to allow for more hydroelectric power imports to avoid the cost of satisfying Massachusetts's CES with high-cost renewables. This potential for the Commission's model to overestimate the cost of Massachusetts's CES is present for any year in which some share of the CES is met with renewables.

The role of hydroelectricity imports in limiting the costs of Massachusetts's commitments is further demonstrated by restricting the modeling to assume there are no imports of hydroelectricity. Consider if Massachusetts does not receive any of New England's imported hydroelectricity from New York State or from Canada. When this is the case, the share of the total CES commitment that must be satisfied by renewable resource buildout on top of the renewables necessary to meet the RPS commitment starts out at 5 percent in 2030, increasing by 5 percent in 2035, 2040, 2045, and 2050, reaching 25 percent in 2050.

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[304] To qualify for Massachusetts's CES, large-scale hydroelectricity must have started operations after 2010. Hearing testimony from Hydro-Québec confirmed recent build out of dams on the Romaine river (some of which are complete, some of which are still under construction) were built at least in part due to anticipated growth in demand for clean energy in New England. USITC, hearing transcript, July 29, 2020, 117, 122 (testimony of Gary Sutherland, Hydro-Québec, and Martin Imbleau, Hydro-Québec).

[305] The significant role of hydroelectric power in satisfying Massachusetts's electricity demand and the limited potential for expansion of this resource is reflected in the flatness of AEO projections of international and interregional imports at their 2019 levels (table 3.1).

[306] Table E.1 in the appendix on the details of the economic model provides the full schedule of Massachusetts's commitments.

[307] More specifically, this 10 percent of load refers to 10 percent of Massachusetts non-municipal load. For more discussion of municipal electricity providers, see chapter 1 of this report.

Removing access to imports increases costs in the years in which renewables must be incentivized, in many cases more than doubling the costs (table 3.11). In most of the years and scenarios, however, renewable energy costs are low enough that no incentive is needed.

Table 3.11 Change in cost to consumers of removing access to imported hydroelectricity from New York State and Canada (as a percentage increase from the costs when Massachusetts has proportional access to imports)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	54.3	51.5	56.6	54.0	n/a
2035	127.5	105.9	n/a	134.8	n/a
2040	n/a	8.5	n/a	1,613.0	n/a
2045	n/a	12.5	n/a	n/a	n/a
2050	n/a	24.7	n/a	n/a	n/a

Source: USITC calculations.

Note: Cells containing “n/a” indicate that the policy is costless to consumers whether or not Massachusetts has access to imports. This table compares the figures in table E.17 to table 3.5.

Summary of Results for Alternative Assumptions

As outlined in table 3.2, the appendix on the details of the economic model (appendix E) demonstrates how relaxing or altering some of the modeling assumptions affects the results of the model. These projected outcomes are in addition to the five main scenarios presented above.

The first alternative assumption involves the marginal resource used to fill demand. The baseline version of the model assumes that solar photovoltaic is the marginal resource that fills demand for building new renewable generation. The assumption that solar would be the marginal resource is based on the profitability of solar forecasted in the AEO’s modeling.[308] The greatest impact of changing the marginal resource to wind is demonstrated by the High Oil and Gas Supply estimates in 2045: this is the only projection year in which, by switching the marginal resource, the commitment goes from not needing incentives in the baseline to requiring incentives. In other projection scenarios and years, the effect of changing the marginal resource to wind varies by impacting consumer costs. In the High and Low Renewables Cost cases, wind as the marginal resource lowers the cost to consumers of Massachusetts’s commitments. In the other scenarios, making wind the marginal resource raises the costs. For a complete examination of these results, see appendix E.

The second assumption examined in appendix E is the one about Massachusetts’s access to imports of electricity. The baseline estimates of the model assume that Massachusetts has access to imports in proportion to Massachusetts’s share of New England’s total load, which is about 45.6 percent. This assumption is important to relax, given that geographically, Massachusetts is farther from Canada, New England’s largest source of clean imports, than most other New England states are. Appendix E examines how a reduction in access to imports to 30 percent (“moderate access”) and 20 percent (“low access”) of total load affects the costs to consumers. The appendix then examines how removing all access to imports impacts consumers. Because New England’s imports are largely clean resources (such as hydroelectricity from Canada and New York State), eliminating access to imports would potentially

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[308] See tables E.13 and E.14 for the AEO’s estimates of the profitability of solar and wind in the five modeling scenarios.

lead to Massachusetts sourcing its clean energy commitments from additional renewables.[309] Some of the results of this alternative assumption are presented in the previous section, including table 3.11. The results for moderate and low access are presented in tables E.15 and E.16 of appendix E.

The final alternative assumption, involving growth in residential and commercial consumers, is the most straightforward change to make, as it impacts only the model's estimated monthly costs to retail customers (baseline results presented in tables 3.7 and 3.8). The baseline assumption is that the number of residential and commercial customers remains constant at their 2018 levels. This makes the cost estimates in table 3.7 and 3.8 a conservative estimate of the monthly cost to consumers. In appendix E, tables E.19 and E.20 provide estimates of the monthly costs for the Reference case when the number of residential and commercial customers grow according to a linear trend based on growth rates between 1990 and 2018. As would be expected, this results in a decrease in the monthly costs to retail customers, because it increases the number of residences or businesses paying without changing the total cost.

Limitations of the Model

The model has several limitations. First, as noted above, there is considerable uncertainty about the values of the model inputs, which are projections decades into the future. For example, although AEO modeling does include both current federal tax incentives and their scheduled phaseout, if there were significant new or extended federal tax incentives for investing in renewable electricity technologies, then the model would overestimate the increase in the costs to consumers.[310] Reporting estimates for five scenarios with different assumptions about future costs of renewable resources and future supply of oil and gas addresses some of this uncertainty.

Second, the model does not try to estimate the effects of the commitments on total load in Massachusetts. Instead, it takes total load as given by the Reference case in the 2020 AEO projections for New England, adjusted by the current share of Massachusetts's load in the New England total (approximately 45.6 percent).[311] Analysis in the 2020 AEO indicates that increases in the renewable portfolio and clean energy standards are likely to have at most a very small effect on total load, so it is reasonable to treat total load as constant at the level projected in the 2020 AEO.[312]

Third, the model does not address long-term contracts for renewable or clean electricity, like the imported hydroelectricity contract, the offshore wind contracts, and others not yet transacted. There are several contracts already undergoing the approval and permitting process in response to the

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[309] See discussion of table E.2 for more information on the share of hydroelectricity in imports.

[310] There are two major federal incentives of renewable energy: the production tax credit and the investment tax credit. The production tax credit was set to expire at the end of 2020 and the investment tax credit started a step-down schedule in 2020. However, the U.S. Congress extended these tax credits as part of a broader federal spending package passed on December 21, 2020. EIA, Annual Energy Outlook 2020, January 29, 2020, 78, 122; St. John, "Congress Passes Spending Bill," December 22, 2020.

[311] Using data from ISO New England and EIA, calculations show that Massachusetts's share of New England load averaged 46.1 percent between 2008 and 2018. Massachusetts's share was equal to 45.8 percent in 2008, fluctuating in the intervening decade from a high of 47.1 percent to a low of 45.6 percent in 2018. ISO New England, "Net Energy and Peak Load by Source" (accessed March 24, 2020); EIA, "State Electricity Profiles" (accessed March 24, 2020).

[312] Recall from table 3.3 how small the load difference is between the Reference case and the RPS Sunset case in 2050, the year in which most of the state-level RPS commitments will have reached their maximum levels.

resource specific carveouts in Massachusetts's Act to Promote Energy Diversity from 2016, which required the acquisition of long-term (15- to 20-year) contracts for renewable and clean resources.[313]

Another limitation is that the model does not attempt to quantify secondary costs associated with RPS and CES commitments. For example, the model does not consider any potential distribution, integration, battery storage, or other costs associated with adding new renewable and clean resources to the grid. The 2014 NREL report on estimating RPS costs notes that relying on REC pricing also does not take into account the costs of integrating new variable RPS-eligible resources into the grid, nor does it take into account the cost of expanding transmission capacity.[314] However, the NREL survey also notes that wind integration cost studies tend to find integration costs are generally below $5 per MWh even for high penetration levels of wind power.[315] The Berkeley Lab report cites studies which found the cost of transmission and distribution associated with new renewable projects was between $2 and $10 per MWh of renewable energy.[316]

Finally, the model does not take into account secondary costs associated with the commitments. Secondary costs from renewable energy programs are visible in consumer rate sheets, but these are often from commitments established before Massachusetts's updated RPS and CES commitments and are therefore not a direct result of the commitments examined in this chapter. Examples of secondary costs appearing in some fashion on Massachusetts ratepayers' bills include the Long-Term Renewable Energy Contract Adjustment Factor, the Net Metering Recovery Surcharge, the Solar Cost Adjustment, and the Renewable Resource Charge.[317]

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[313] The details of the required contracts are outlined in a footnote at the beginning of this chapter. "Act to Promote Energy Diversity (H4568)," 2016, §§ 83C, 83D, 18–32.
[314] Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, 13.
[315] Heeter et al., A Survey of State-Level Cost and Benefit Estimates, May 2014, 24.
[316] Barbose, U.S. Renewables Portfolio Standards, 2019, 39. On the other hand, the Berkeley Lab report also cites studies that found RPS commitments lead to transmission and distribution benefits ranging between 0.4 cents and 5 cents per kWh due to avoided or deferred investments.
[317] National Grid, "Revenue Decoupling Mechanism Filing," January 15, 2020, 43–58; Unitil, "Residential Delivery Service: Schedule RD-1," May 20, 2020, 2–3.

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National Grid. *See* Massachusetts Electric Company and Nantucket Electric Company d/b/a National Grid (National Grid).

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U.S. Energy Information Administration (EIA). Annual Energy Outlook 2020, Table 54: Electric Power Projections by Electricity Market Module Region | Case: Renewable Portfolio Standard Sunset | Region: Northeast Power Coordinating Council / New England, n.d. https://www.eia.gov/outlooks/aeo/data/browser/#/?id=62-AEO2020&region=5-7&cases=norps&start=2018&end=2050&f=A&linechart=&sourcekey=0 (accessed August 26, 2020).

U.S. Energy Information Administration (EIA). Annual Energy Outlook 2020, Table 54.7: Electric Power Projections by Electricity Market Module Region | Case: Reference case | Region: Northeast Power Coordinating Council / New England, n.d. https://www.eia.gov/outlooks/aeo/supplement/excel/suptab_54.7.xlsx (Excel file, accessed August 26, 2020).

U.S. Energy Information Administration (EIA). Annual Energy Outlook 2020, Table 57: Renewable Energy Capacity, Generation, and Consumption by Fuel and Electricity Region | Case: Renewable Portfolio Standard Sunset | Region: Northeast Power Coordinating Council / New England, n.d. https://www.eia.gov/outlooks/aeo/data/browser/#/?id=67-AEO2020&region=5-7&cases=norps&start=2018&end=2050&f=A&sourcekey=0 (accessed August 26, 2020).

U.S. Energy Information Administration (EIA). Annual Energy Outlook 2020, Table 57.7: Renewable Energy Capacity, Generation, and Consumption by Fuel and Electricity Region | Case: Reference | Region: Northeast Power Coordinating Council / New England, n.d. https://www.eia.gov/outlooks/aeo/supplement/excel/suptab_57.7.xlsx (Excel file, accessed August 26, 2020).

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Unitil. *See* Fitchburg Gas and Electric Light Company d/b/a Unitil (Unitil).

Chapter 4
Case Studies of the Effects of Imports of Hydroelectricity

This chapter presents case studies on the potential economic effects of imports of hydroelectricity. First, the U.S. Columbia River Basin case study analyzes a market where hydropower is the primary source of electricity supply. Smaller case studies on New York State and the Minnesota-Manitoba trade region supplement this analysis with a focus on how the transmission infrastructure and specific trade arrangements can affect the potential role of hydroelectricity imports in helping integrate higher shares of variable renewable energy and transition to a low-carbon electricity sector. Lastly, a case study on Denmark demonstrates the effects of hydroelectricity imports in a market that has already transitioned to sourcing a large share of its electricity from variable sources of renewable energy (particularly wind). The case studies on the U.S. Columbia River Basin and Denmark highlight the effects of hydroelectricity on efforts to meet renewable and clean energy commitments, the electricity rates paid by commercial and residential customers, and greenhouse gas (GHG) emissions.

Key Findings

In the case of the U.S. Columbia River Basin—which for the purposes of this report includes Idaho, Montana, Oregon, and Washington— substantial hydroelectric capacity has yielded consistently low electricity prices, facilitated the integration of wind, encouraged the development of power-intensive industries, and supported relatively low emissions rates. Residential and commercial electricity rates in each of the region’s states were at least 0.5 cents per kilowatt-hour (kWh) below the U.S. average in 2010 and 2019, and each of the region’s states, except Montana (which has the lowest share of hydroelectricity), posted substantially lower emissions rates from electricity generation than the average U.S. rate in 2012 and 2018.

Concentrated demand and transmission constraints have resulted in New York State effectively operating as two separate markets. The downstate market relies heavily on local fossil-fuel fired generation and nuclear (which is scheduled to fully retire in 2021), while the upstate market is largely reliant on domestic hydropower and nuclear facilities and imported clean energy from Canada. Recent increases in New York State’s renewable and clean energy commitments and the planned retirement of downstate nuclear generation require the downstate market to shift to low-emission resources. To meet these commitments, New York is targeting its efforts towards directly connecting the downstate market with more renewable energy (including Canadian hydroelectricity).

Minnesota and Manitoba have developed a relationship within the Midcontinent Independent System Operator (MISO) market that allows two-way electricity trade to be highly responsive to real-time changes in wind power in Minnesota. This is done through the wind storage provision in a contract between Minnesota Power and Manitoba Hydro and enhanced throughout the MISO market by a change in how MISO accepts bids from Manitoba Hydro. These two examples demonstrate how transactions can be structured to leverage the flexibility of imported hydroelectricity in U.S. electricity markets that have significant variable renewable energy.

Denmark's wind power generation accounted for nearly half of its annual electricity generation in 2019. Imported hydroelectricity has been one of several important tools the country used to transition towards higher renewable integration and minimize curtailment (forced reductions in variable renewable energy output owing to transmission congestion or other problems). Denmark shares a power market with several other European countries. Norwegian and Swedish hydroelectric facilities help keep wholesale market prices lower and less volatile than prices in other European markets. Emissions in Denmark have declined substantially, as Denmark's fossil fuel-fired generation is gradually displaced by both increased domestic generation from renewables and increased imports of hydroelectricity.

General Characteristics of Hydroelectricity

The effects of imported hydroelectricity described in this chapter's case studies are directly related to the general properties of large-scale hydroelectric generation. Hydroelectric dams are typically very flexible generation resources, a trait that has become increasingly important as integration of variable renewable energy into markets' power systems grows.[318] By contrast, an inflexible supply can result in power outages or forced curtailment of variable renewable energy.[319] Generation from hydroelectric dams can be ramped up or down relatively quickly, similar to the flexibility provided by many natural gas-fired generators. However, gas-fired plants are more exposed to fuel costs, and they experience wear and tear from heat fluctuations that may shorten their operational life and increase maintenance costs.[320] At the same time, hydroelectric dams' ability to balance variable renewables is finite, with factors such as reservoir levels and uses of the dam for activities other than electricity generation affecting how and when a dam generates.[321] For more context on other sources of flexibility, the importance of flexibility, and the effect of dispatch decisions—decisions on which plants will generate power at a given point in time—see chapter 1. Several interested parties also submitted information noting the related reliability benefits of hydroelectric generation, highlighting how U.S. imports of Canadian hydroelectricity have helped restore power after major blackouts and storm-related outages.[322]

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[318] IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 21, 71.

[319] IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 21–22.

[320] Exposure to fuel costs can be particularly high in markets, like Massachusetts, that rely on imported liquefied natural gas. Having a larger fleet of gas-fired generators and shorter time intervals in the energy market allows the grid operator to reduce strain on individual generators. IRENA, Innovation Landscape for a Renewable-Powered Future, 2019, 71; industry representative, telephone interview by USITC staff, June 9, 2020; USDOE, EERE, "The Importance of Flexible Electricity Supply," May 2011, 2–3.

[321] Industry representative, telephone interview by USITC staff, August 12, 2020; Manitoba Hydro, written submission to USITC, August 14, 2020, 11.

[322] See appendix D for positions of interested parties. Specific examples included blackouts affecting the eastern United States and Canada in 1965 and 2003, and windstorms in the Dakotas and Minnesota that temporarily forced transmission lines connecting to Eastern states out of service. WIRES, written submission to USITC, July 15, 2020, 3; Hydro-Québec, written submission to USITC, July 15, 2020, 9–10; Manitoba Hydro, written submission to USITC, August 14, 2020, 19.

Hydroelectric dams are also generally considered a low-carbon source of electricity. They do not directly produce GHG emissions from incremental electricity generation and can reduce electricity sector emissions rates by displacing fossil fuel-fired generation.[323] However, dams also have some adverse environmental effects. As discussed briefly below, these negative effects are primarily related to the creation of new reservoirs, are highly dependent on the precise design and location of the dam, and do not directly affect importers of hydroelectricity. For these reasons, the case studies in this chapter focus on the effect of hydroelectric generation on emissions rates.

Like the development of other types of power generation plants, creating a hydroelectric dam does entail some GHG emissions from construction and construction materials. In addition, hydroelectric dams result in some additional emissions of the major GHGs carbon dioxide and methane, which can be released from biomass decomposing in the dam's reservoir. Such emissions are larger in tropical regions with a large amount of vegetation and are reportedly highest within four years after the dam is initially filled via flooding.[324] Reservoirs in a cooler climate have much lower initial emissions than newly created dams in warmer climates. Overall, research suggests that dams in Canada typically have GHG emissions well below those of the average gas-fired plant.[325]

Assessments of life cycle emissions have traditionally classified the life cycle emissions for dams as comparable to those associated with wind or solar generation. However, additional research in the past decade has shown relatively high emissions from some individual dams.[326] At the same time, these studies highlight the scientific complexity of estimating emissions attributable to hydropower and the lack of a standardized methodology for doing so.[327] In addition to environmental concerns due to the emissions from reservoirs, the construction of new hydroelectric dams can also be controversial due to the impacts on biodiversity, the local ecosystem, and indigenous communities.[328]

The Columbia River Basin

As mentioned, for the purposes of this case study, the U.S. Columbia River Basin includes the states of Idaho, Montana, Oregon, and Washington. This region depends heavily on hydroelectric generation for the power it uses, and as a result, it provides an indication of the potential effects of reliance on hydroelectricity. Hydroelectric facilities in the Columbia River Basin (figure 4.1) are responsible for a substantial share (over 40 percent) of all hydroelectric generation in the United States.[329] The region's

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[323] Manitoba Hydro, written submission to USITC, August 14, 2020, 8; Hydro-Québec, written submission to USITC, July 15, 2020, 9–10.

[324] EIA, "Hydropower Explained: Hydropower and the Environment," April 9, 2020; Scherer and Pfister, "Hydropower's Biogenic Carbon Footprint," September 14, 2016; Canadian Electricity Association, written submission to USITC, August 7, 2020; Government of Canada, written submission to USITC, August 7, 2020; Hydro-Québec, written submission to USITC, August 7, 2020.

[325] Ocko and Hamburg, "Climate Impacts of Hydropower," October 23, 2019, 2, 8, 10–11.

[326] Steinhurst, Knight, and Schultz, "Hydropower Greenhouse Gas Emissions," February 14, 2012, 9–11; Ocko and Hamburg, "Climate Impacts of Hydropower," October 23, 2019, 1.

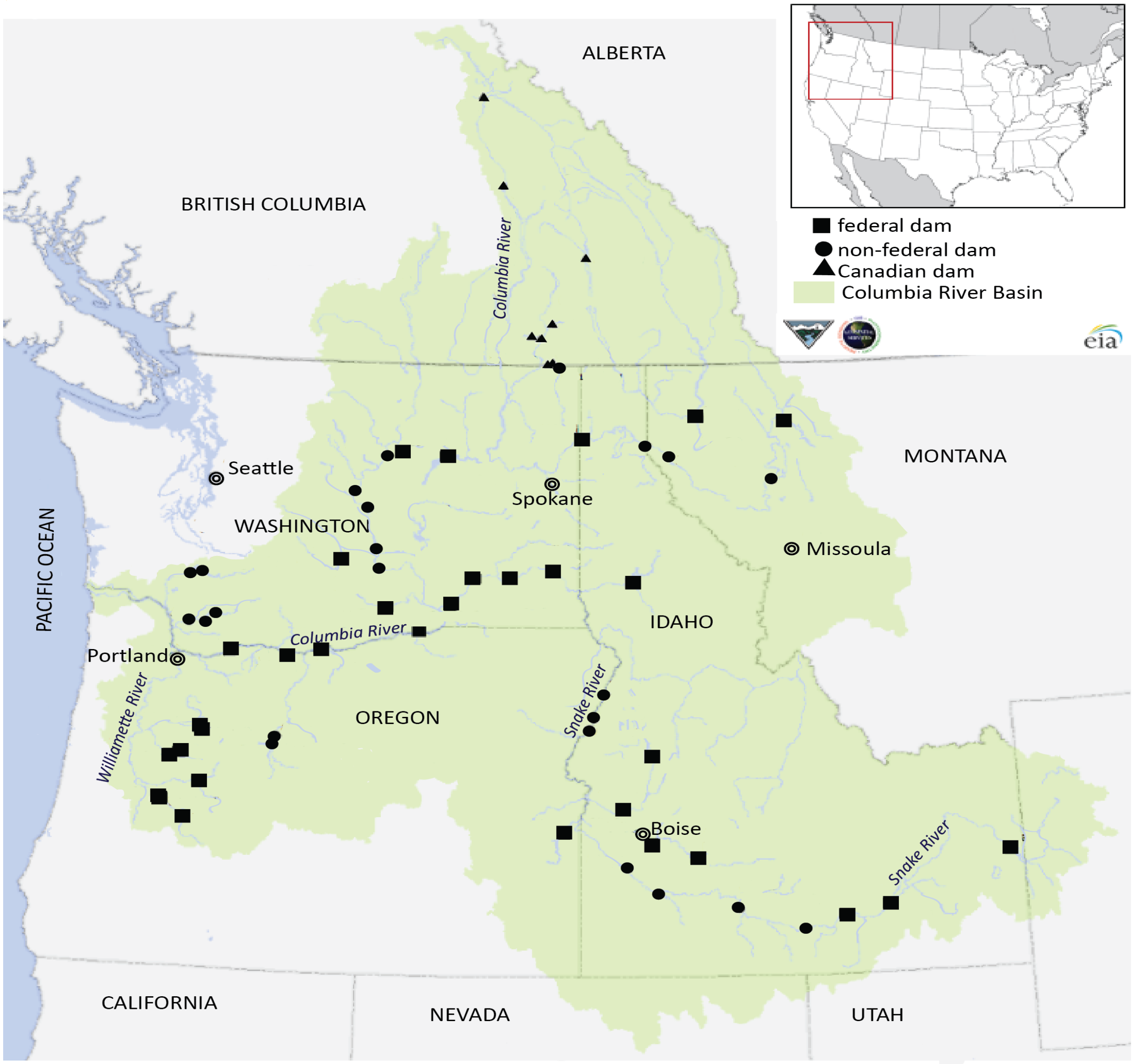
[327] Steinhurst, Knight, and Schultz, "Hydropower Greenhouse Gas Emissions," February 14, 2012, 15–16, 18–1; Ocko and Hamburg, "Climate Impacts of Hydropower," October 23, 2019, 1–2.

[328] NAMRA, written submission to USITC, July 15, 2020, 3–5.

[329] EIA, "The Columbia River Basin," June 27, 2014.

reliance on hydroelectricity (61.1 percent of the region's electricity generation in 2018)[330] is a product of the region's geography and topography and predates policies encouraging the development of renewable electricity. While there has been no development of new, large hydroelectric facilities in recent years, the continued use of existing hydroelectric infrastructure offers the region a plentiful supply of relatively inexpensive energy. Most of the region's hydroelectricity is locally generated, but modest two-way trade with other states and with British Columbia may have a small impact on supply and costs.

Figure 4.1 Major dams within the Columbia River Basin



Source: EIA (from Bonneville Power Administration), "The Columbia River Basin," June 27, 2014.

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[330] USITC calculation based on EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (accessed May 18, 2020).

The Columbia River Basin's Electricity Market

The geography of the Columbia River Basin makes the region a particularly favorable location for hydroelectric generation.[331] The Columbia River travels through mountainous terrain featuring steep gradients, a somewhat consistent drop rate, and substantial snowmelt which supplies a large volume of water to the entire river system.[332] Major construction of hydroelectric facilities in the Columbia River Basin started in the 1930s, as public works projects—such as the Bonneville and Grand Coulee Dams—were launched to address the effects of the Great Depression.[333] The construction of large hydroelectric dams in the region continued until 1975, when the Lower Granite Dam and the Libby Dam were completed. The entire Columbia River Basin[334] currently includes 274 hydroelectric dams (255 in the United States) with 34,318 megawatts (MW) in combined generating capacity.[335] Facilities in the system include very large dams as well as a number of plants with capacities of less than 100 MW.[336]

The U.S. government is the top generator of hydroelectric energy in the focus states, with the U.S. Army Corps of Engineers accounting for over 53 million megawatt-hours (MWh) and the U.S. Bureau of Reclamation for 24 million MWh of these states' combined net hydroelectricity generation in 2018 (table 4.1). Together, these entities account for over half of the focus states' net hydroelectricity generation.[337] The U.S. Bureau of Reclamation operates the largest dam in the region and the United States' largest hydroelectric facility—the Grand Coulee dam, which generated over 21 million MWh of hydroelectricity in 2018. Other top hydro operators in the region include the Chelan County Public Utility District, Idaho Power, and the City of Seattle.[338]

The Bonneville Power Administration (BPA), a federal marketing body that is part of the U.S. Department of Energy, also plays a key role in the region's electricity industry by marketing the power generated by the 31 federally operated dams in the Columbia River Basin, as well as power generated by several nonfederal facilities.[339] BPA's customers include various publicly owned and investor-owned utilities, federal and tribal government entities, direct service industries,[340] and marketers, among others.[341] Overall, BPA-supplied power meets about one-quarter of the U.S. Northwest's power

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[331] Industry representative, telephone interview by USITC staff, May 27, 2020.
[332] Ingram, "Hydro in the Pacific Northwest," August 15, 2018; EIA, "The Columbia River Basin," June 27, 2014.
[333] Industry representative, telephone interview by USITC staff, May 27, 2020; Northwest Power and Conservation Council, "Dams: History and Purpose," (accessed June 3, 2020).
[334] In addition to the focus states, the Columbia River Basin encompasses small areas of Utah, Wyoming, and Nevada as well as British Columbia. EIA, "The Columbia River Basin," June 27, 2014.
[335] Northwest Power and Conservation Council, "Dams" (accessed June 3, 2020).
[336] EIA, "The Columbia River Basin," June 27, 2014.
[337] USITC staff calculations based on EIA, "EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2018 Final Revision."
[338] USITC calculations based on EIA, "EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2018 Final Revision" (accessed June 26, 2020); EIA, "The Columbia River Basin," June 27, 2014.
[339] BPA is also a key provider of high-voltage transmission in the four focus states as well as in sections of Utah, Wyoming, Nevada, and California. BPA, "BPA Facts," April 2019.
[340] Through its history, BPA's direct services industry customers have included aluminum, chemical, and pulp and paper facilities. Harrison, "Direct-Service Industries," October 31, 2008.
[341] Ball, "Bonneville Power Administration Overview," January 22, 2019,; Ikakoula, "BPA Overview," December 18, 2009; BPA, "BPA Facts," April 2019.

needs.[342] BPA also supplies power to utilities in other Western states (including California) and Canada.[343] BPA's sales to utilities located in California and the U.S. Southwest reportedly allow them to charge lower power rates for customers in the U.S. Northwest.[344]

Table 4.1 Top 10 operators of hydroelectric generating plants in Idaho, Montana, Oregon, and Washington[a] in 2018, by MWh of hydroelectricity generation

Operator	State	Net generation (TWh)
U.S. Army Corps of Engineers Northwestern Division[b]	ID, MT, OR, WA	53.6
U.S. Bureau of Reclamation	ID, MT, OR, WA	24.8
Public Utility District No. 1 of Chelan County	WA	9.3
Idaho Power Co.	ID, OR	8.7
City of Seattle, WA	WA	6.4
Public Utility District No. 1 of Douglas County	WA	4.4
Avista Corp.	ID, MT, WA	4.0
PacifiCorp	ID, MT, OR, WA	2.9
NorthWestern Energy	MT	2.7
City of Tacoma, WA	WA	2.4

Source: USITC calculations based on EIA, "EIA-923 Monthly Generation and Fuel Consumption Time Series File, 2018 Final Revision" (accessed June 26, 2020).
Note: TWh = terawatt-hours.
[a] This table includes all hydroelectricity generation in the focus states, regardless of whether the generating facilities are located in the Columbia River Basin.
[b] In addition, the U.S. Army Corps of Engineers' Omaha District operates the Fort Peck Dam in Montana. This dam is located in the Missouri River Basin.

The Northwest Power Act of 1980[345] also has a significant impact on the operation of hydroelectric facilities in the Columbia River Basin. Among other things, the act authorized the creation of an interstate organization currently called the Northwest Power and Conservation Council. With members from Idaho, Montana, Oregon, and Washington, this group is tasked with drafting plans for a reliable, cost-effective, and efficient supply of electricity in the region, as well as formulating wildlife protection plans and providing energy-related information to the public.[346] The council's plans inform decisions about acquiring new generation resources and water flows at hydroelectric facilities.[347]

Columbia River Basin states depend heavily on hydroelectricity as a source of electricity (figure 4.2). Data on electricity generation for Idaho, Montana, Oregon, and Washington indicate that hydroelectricity has accounted for a relatively high share of total net generation in each of these states since at least 1990 (figure 4.3). Conventional hydroelectricity accounted for 61.1 percent of total electricity generation in these four states in 2018.[348] Overall, the Columbia River Basin—which spans this

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[342] BPA, "BPA Facts," April 2019.

[343] Ball, "Bonneville Power Administration Overview," January 22, 2019.

[344] Ikakoula, "BPA Overview," December 18, 2009.

[345] Pacific Northwest Electric Power Planning and Conservation Act, Pub. L. No. 96-501, 94 Stat. 2697 (Dec. 5, 1980) (codified as amended at 16 U.S.C. § 839).

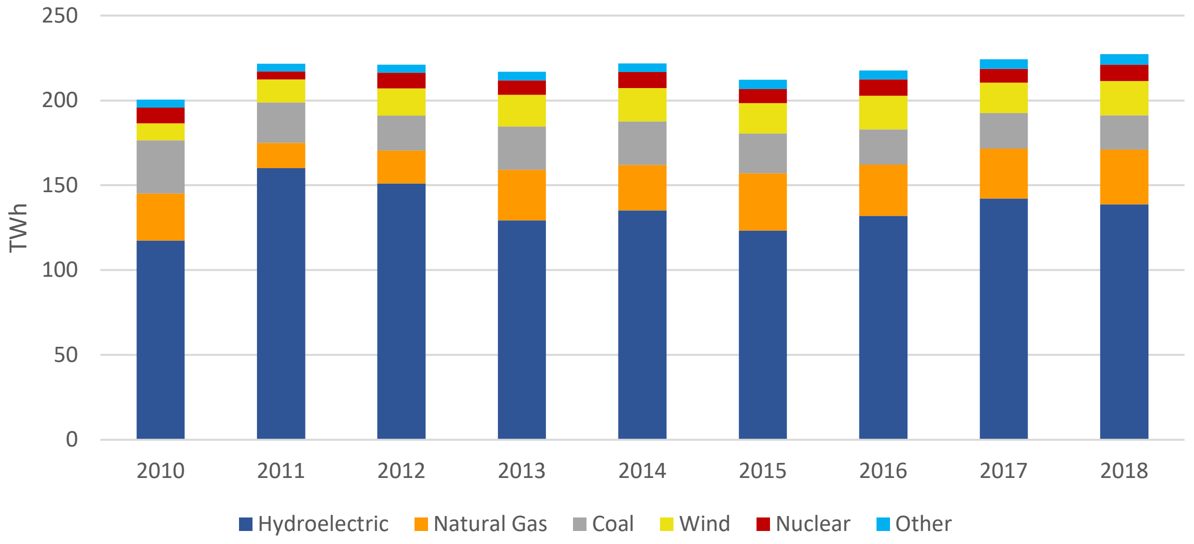
[346] Oregon Encyclopedia, "Northwest Power Act (1980)," March 17, 2018.

[347] Northwest Power and Conservation Council, "Northwest Power and Conservation Council" (accessed June 9. 2020).

[348] EIA defines conventional hydroelectric plants as plants in which all of the power is produced from natural streamflow as regulated by available storage; this definition includes run-of-the-river systems and reservoir dams but excludes pumped-storage hydropower facilities. USITC calculations based on EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (accessed May 18, 2020).

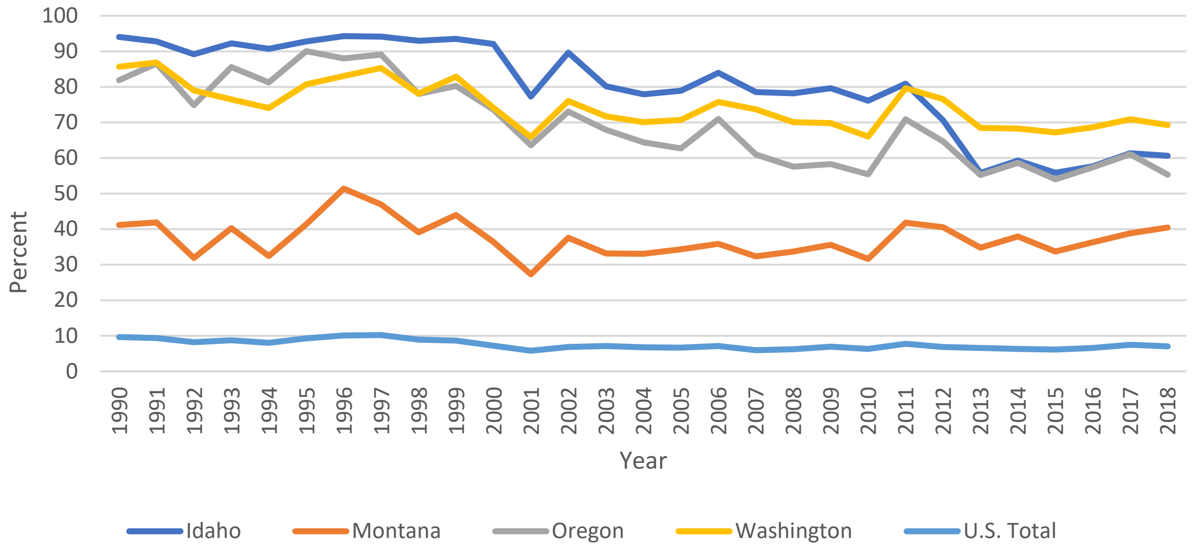
case study's four focus states as well as small sections of Nevada, Utah, and Wyoming—accounts for 44 percent of all U.S. hydroelectricity generation.[349]

Figure 4.2 Power generation in Idaho, Montana, Oregon, and Washington by energy source, in terawatt-hours (TWh)



Source: EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (accessed May 18, 2020).
Note: Underlying data for this figure can be found in appendix table G.21.

Figure 4.3 Conventional hydroelectricity as a share of total net generation, 1990–2018 (percent)



Source: EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (accessed May 18, 2020).
Note: Underlying data for this figure can be found in appendix table G.22.

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[349] EIA, "The Columbia River Basin," June 27, 2014.

Since 2010, hydroelectricity has remained a key source of power in each of the focus states, although increases in wind-powered generation and decreases in coal-fired generation have altered the resource mix in the region.[350] For example, hydroelectricity's relative contribution to Idaho's net generation fell by over 15 percentage points during 2010–18, largely due to a substantial increase in wind-powered generation. Wind power capacity has surged in Idaho (nearly tripling from 352.2 MW in 2010 to 970.4 MW in 2018),[351] and a proposed 1,000 MW wind project in southern Idaho may further boost the share of wind power in that state's electricity generation mix.[352] Montana, Oregon, and Washington have also experienced increases in wind power generation, but substantial declines in coal-fired generation have led to either an increased or a stable reliance on hydroelectricity in each of these three states. Weather conditions (such as drought and high winds) may also impact the availability of hydroelectricity, wind power, and solar power generation in a particular year.[353]

The Columbia River Treaty,[354] signed in 1961, has a substantial impact on hydroelectricity generation and management in the region. This treaty aimed to improve hydroelectricity generation and flood control in the Columbia River Basin through coordinated river management and development. Under the provisions of the treaty, Canada built and operates three storage dams on the Canadian portion of the Columbia River, providing flood control while offering water flow to support power generation at downstream U.S. dams.[355] In return for this benefit, the United States shares with Canada the additional power that it derives through the operation of Canada's upstream dams.[356] An industry source indicates that this electricity is often sold back to the United States (for example, to California).[357]

Separately, Columbia River Basin states trade electricity with other U.S. states, such as California, and when water levels are high, the region produces surplus power that it exports to Canada.[358] In 2019, Idaho, Oregon, Montana, and Washington jointly posted a surplus in electricity trade with Canada, in

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[350] EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (accessed May 18, 2020).

[351] All four of the focus states experienced rapid growth in wind power capacity during 2010–18, with such capacity increasing by 175.5 percent (from 352.2 MW to 970.4 MW) in Idaho, 106.6 percent (from 379.2 MW to 783.5 MW) in Montana, 60.2 percent (from 2,004.0 MW to 3,210.2 MW) in Oregon, and 33.8 percent (from 2,296.3 MW to 3,073.1 MW) in Washington. EIA, "State Electricity Profiles," March 23, 2020.

[352] Magic Valley Energy plans to begin construction on a 1,000 MW wind farm on Bureau of Land Management (BLM) land in 2022. If completed, the facility would double the state's wind generation capacity and would rank as one of the world's biggest wind farms. Tiernan, "This Massive Proposed Idaho Wind Farm," March 22, 2020; EIA, "Idaho State Energy Profile" (accessed June 4, 2020).

[353] Industry representatives, telephone interviews by USITC staff, June 9, 2020.

[354] Treaty Relating to Cooperative Development of the Water Resources of the Columbia River Basin between the Governments of the United States of America and Canada, January 17, 1961, 587 U.N.T.S. 19 (hereinafter Columbia River Treaty).

[355] Through the operation of these dams, Canada is required to provide the United States a certain volume of "assured annual flood control" for a period of 60 years, as well as "on call flood control" under certain conditions throughout the lifetime of these dams. Under the treaty, the United States agreed to pay Canada almost $65 million in total for the assured flood-control benefit, and to cover the operational costs of called-on flood control. Columbia River Treaty, Article II, January 7, 1961; Columbia River Trust, "An Overview," July 13, 2018.

[356] Columbia River Treaty, January 7, 1961; Columbia River Trust, "An Overview," July 13, 2018.

[357] Industry representative, telephone interview by USITC staff, June 9, 2020; Government of Canada, written submission to USITC, August 7, 2020.

[358] EIA, "U.S.-Canada Electricity Trade Increases," July 9, 2015; Canadian Electricity Association, written submission to USITC, August 7, 2020; EIA, "The Columbia River Basin," June 27, 2014.

terms of both quantity (MWh) and value. In that year, the four focus states together exported about 11.3 million MWh of electricity (valued at $389.7 million) to Canada and imported 2.7 million MWh (valued at $145.2 million), yielding a regional trade surplus of $230.6 million (tables 4.2 and 4.3).[359] While trade has some impact on the region's electricity supply, this impact is likely small. For example, these four states' exports of electricity to Canada accounted for about 5 percent of net generation in the region in 2019, while these states' imports from Canada accounted for less than 2 percent of retail electricity sales in the region.[360]

Table 4.2 Columbia River Basin states' exports of electricity trade with Canada, January–December 2019

State	Quantity (MWh)	Value ($US)	$US per MWh
Idaho	20,450	386,119	$18.88
Montana	883,106	40,728,232	$46.12
Oregon	669,353	15,755,352	$23.54
Washington	9,691,182	332,804,533	$34.34
Regional total	11,264,091	389,674,237	$34.59

Source: Canada Energy Regulator. Values were converted to US$ using the exchange rate for December 31, 2019.

Table 4.3 Columbia River Basin states' imports of electricity trade with Canada, January–December 2019

State	Quantity (MWh)	Value ($US)	$US per MWh
Idaho	7,849	361,147	$46.01
Montana	67,584	3,649,855	$54.00
Oregon	679,291	38,963,983	$57.36
Washington	1,958,796	102,194,799	$52.17
Regional total	2,713,521	145,169,784	$53.50

Source: Canada Energy Regulator. Values were converted to US$ using the exchange rate for December 31, 2019.

Renewable and Clean Energy Commitments

Overview of Existing Targets

Renewable and clean energy goals have been established at the state level in Washington, Oregon, and Montana, and at the utility level in Idaho (table 4.4). These require electricity suppliers to source certain shares of power from specific types of clean and renewable sources. In general, the targets in these initiatives have increased over time, with some recent initiatives mandating 100 percent clean power by 2045. Under Montana's Renewable Resource Standard and Washington State's Energy Independence Act—both of which have renewable energy targets that top out at 15 percent—only the additional

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[359] Idaho, Oregon, Montana, and Washington export power to the Canadian provinces of Alberta, British Columbia, and Saskatchewan, and import power from Alberta and British Columbia. It is notable that each of the focus states paid higher rates for Canadian electricity than Canada paid for its imports from these states in 2019. In fact, the Canada Energy Regulator reports that British Columbia frequently posts a positive electricity trade balance with the United States in terms of revenue, as it is able to import during low-price periods and export during high-price periods. This may be due, in part, to greater system flexibility in Canada and particularly good price forecasting by Canadian power marketer PowerEx. Canada Energy Regulator, "Provincial and Territorial Energy Profiles—British Columbia" (accessed April 3, 2020); industry representative, telephone interview by USITC staff, August 12, 2020.

[360] USITC calculations based on data obtained from EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923), and Canada Energy Regulator, "Commodity Statistics."

power generated through improvements to existing hydroelectric facilities, or at new hydroelectric facilities that meet specific criteria, may qualify as renewable power. Under programs with high targets—i.e., Idaho Power's clean energy initiative, Oregon's renewable portfolio standard, and Washington's more recent Clean Energy Transformation Act—certain types of existing hydroelectricity generation can be used to meet the targets.

Table 4.4 State and utility renewable and clean energy standards in the U.S. Columbia River Basin

Implementing entity	Name	Date	Targets	Eligibility of hydroelectricity
Idaho Power	Clean Today, Cleaner Tomorrow	2019	All power supplied by Idaho Power will be from clean sources by 2045.	Hydroelectricity can be counted towards program targets.
State of Montana	Renewable Resource Standard	2005	Competitive power suppliers and public utilities must source at least 5 percent, 10 percent, and 15 percent of their electricity from eligible sources of renewable energy starting in 2008, 2010, and 2015, respectively.	Additional hydroelectric power can be counted toward targets if it is generated (1) at new facilities that do not exceed 10 MW or involve additional water diversion or appropriation, (2) at new projects that do not exceed 15 MW and are located at existing irrigation facilities or reservoirs without hydroelectric capacity in April 2009; or (3) through the expansion of existing hydroelectric facilities in October 2013 or later.
State of Oregon	Renewable Portfolio Standard	2007	Utilities that account for at least 3 percent of the state's power sales to retail customers must source a gradually increasing share of electricity from qualifying sources, starting at 5 percent by 2011 and reaching 25 percent by 2025. Utilities that account for less than 3 percent have lower obligations.	Power generated at hydroelectric plants that began operations before January 1995, are not located within protected areas, and have received low-impact certification, as well as additional power that is generated through improvements made to existing hydroelectric facilities in January 1995 or later, can be counted towards targets.
State of Oregon	Renewable Portfolio Standard	2016	Utilities that account for at least 3 percent of the state's power sales to retail customers must source a gradually increasing share of electricity from qualifying sources, starting at 25 percent by 2025 and reaching 50 percent by 2040. Utilities that account for less than 3 percent have lower obligations.	Same as in Oregon's 2007 Renewable Portfolio Standard.

Implementing entity	Name	Date	Targets	Eligibility of hydroelectricity
State of Washington	Energy Independence Act	2007	Utilities serving over 25,000 customers must obtain or generate at least 3 percent, 9 percent, and 15 percent of their power from renewable sources by 2012, 2016, and 2020, respectively.	Additional electricity that is generated through improvements to existing hydroelectric facilities or by new hydroelectric facilities in irrigation canals or water pipes can be counted toward the target unless the improvements or new generation predate April 1999.
State of Washington	Clean Energy Transformation Act	2019	By 2045, all power supplied in the state must be from sources that do not emit greenhouse gases.	Hydroelectricity generation that does not entail reservoir expansion or new impoundments or diversions—unless these occurred before the establishment of the legislation or are needed for a facility's operation—can be counted towards the program target.

Sources: National Conference of State Legislatures (NCSL), "State Renewable Portfolio Standards and Goals," April 17, 2020; Washington State Legislature, Energy Independence Act, 2007 c 1 § 11 (Initiative Measure No. 937, approved November 7, 2006); Deyette and Clemmer, "The Washington Clean Energy Initiative: Effects of I-937," October 2006, 11; State of Montana, Montana Renewable Power Production and Rural Economic Development Act; State of Oregon, "Chapter 469A—Renewable Portfolio Standards: 2019 Edition"; 78th Oregon Legislative Assembly, Senate Bill 1547; 74th Oregon Legislative Assembly, Senate Bill 838; Idaho Power, "Idaho Power Sets Goal for 100-percent Clean Energy by 2045," March 26, 2019; Washington State Department of Commerce, "Clean Energy Transformation Act (CETA)" (accessed November 20, 2020); State of Washington, "Engrossed Second Substitute Senate Bill 5116," May 15, 2019.

Other recent energy programs suggest a continuing commitment to clean energy in the Columbia River Basin. The Montana Renewables Development Action Plan—released in June 2018 by the State of Montana and BPA—proposes recommendations for the development of renewable power generation in the state. It aims to complement the region's current renewable power capacity (including hydroelectric) and mentions hydroelectricity as an important element in the power system's black start capabilities.[361] The Joint Clean Grid initiative—which was announced by the governor of Washington and the premier of British Columbia in October 2019—aims to further shift these jurisdictions towards clean and affordable energy. As part of this initiative, the jurisdictions planned to convene a Joint Clean Grid Summit in the fall of 2020, draft an action plan, and form a working group.[362] However, as of December 2020, additional information about this summit and the details of this plan—including what types of electricity generation will be considered "renewable"—are unavailable.

Effects of Hydroelectricity on Efforts to Meet Targets

The region's substantial hydroelectricity capacity has an important impact on individual states' ability to meet clean and renewable energy goals. In general, some of the electricity produced at a limited group of new and existing hydroelectric facilities can be used to meet the focus states' renewable energy standards, while power produced by most hydroelectric facilities can be counted towards clean energy

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[361] BPA and the State of Montana, "Montana Renewables," June 2018, 3, appendix B. Black start capability refers to a power system's ability to resume operations after a complete shutdown. OpenEI, "Blackstart Capability Plan" (accessed August 20, 2020).

[362] British Columbia Utility Commission, "Information Release—BCUC Participates in Clean Grid Initiative," August 13, 2020; Nickelsburg, "Washington State and B.C.," October 3, 2019; Washington Governor's Office, "Inslee and B.C. Premier Horgan" October 3, 2020.

targets (see table 4.4). Hydroelectric facilities also enable the integration of other renewable electricity sources into the grid. The region's hydroelectricity is used to balance variable supply from solar and wind power generators and maintain grid stability.[363] Hydroelectric facilities reportedly will be an increasingly important grid-balancing resource as the region's coal plants are retired.[364] At the same time, hydroelectric facilities' ability to balance variable generation is finite, limiting their ability to singlehandedly support integration of renewables into the system.[365]

Economic Impacts

Trends in Electricity Prices

Throughout 2010–19, commercial and residential power prices in Washington, Oregon, Idaho, and Montana remained lower than U.S.-wide prices (figures 4.4 and 4.5). In 2019, average U.S.-wide prices for one kilowatt-hour (kWh) of electricity in each consumer category were at least 0.5 cents higher than the most expensive rates among the four focus states, and prices in Massachusetts were at least 6 cents higher. At the same time, electricity prices in these states largely increased at a faster rate, or decreased more slowly, than U.S.-wide power prices during the period. For example, while commercial power prices in the United States as a whole decreased at a compound annual growth rate (CAGR) of 0.2 percent from 2010 to 2019, such prices increased at rates ranging between 0.5 percent and 1.2 percent in Idaho, Montana, Oregon, and Washington.[366] The differing trends in Columbia River Basin and U.S.-wide power prices are likely due to a combination of factors. For example, the falling price of natural gas and other fuels has contributed the decrease in U.S.-wide power prices in recent years.[367] Further, one industry expert reports that the cost of compliance with environmental mandates has raised prices for hydroelectric power in the region, making other power sources (such as natural gas facilities) more competitive with hydroelectricity.[368]

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[363] Industry representative, telephone interview by USITC staff, August 12, 2020; BPA, "Hydropower," February 3, 2011; U.S. Department of Energy, "Hydropower Vision," 71, July 25, 2016.

[364] Industry representative, telephone interview by USITC staff, June 9, 2020.

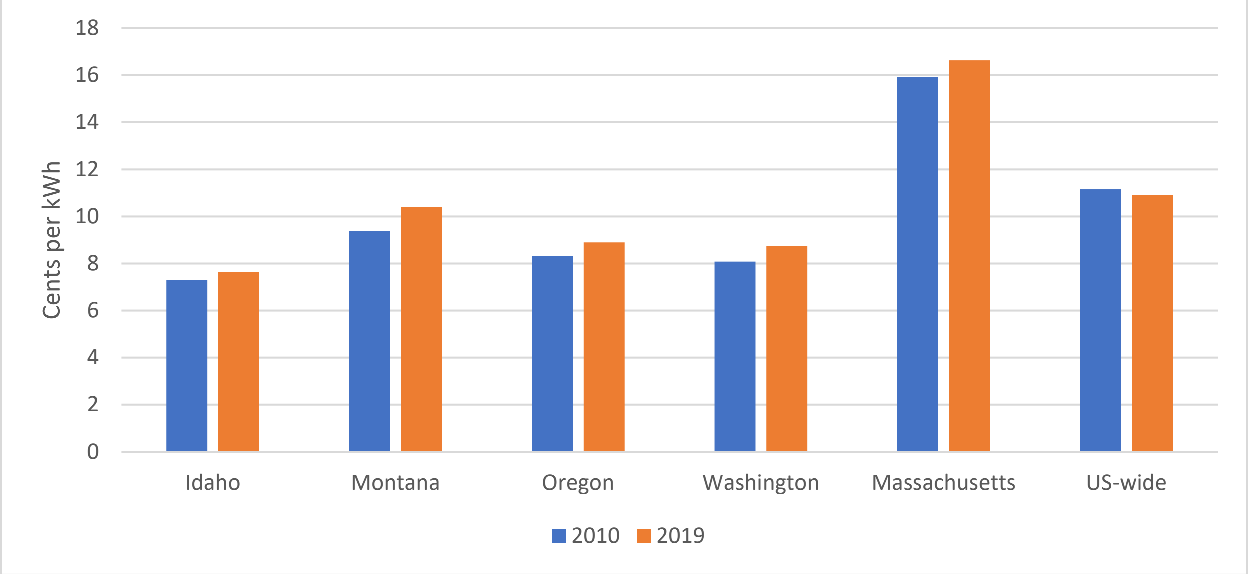
[365] Industry representative, telephone interview by USITC staff, August 12, 2020; Manitoba Hydro, written submission to USITC, August 14, 2020, 11.

[366] During this period, prices charged to commercial customers in Massachusetts increased at a CAGR of 0.5 percent, while prices charged to residential customers in that state increased at a relatively rapid 3.6 percent rate.

[367] EIA, "U.S. Residential Electricity Prices Decline," October 6, 2016.

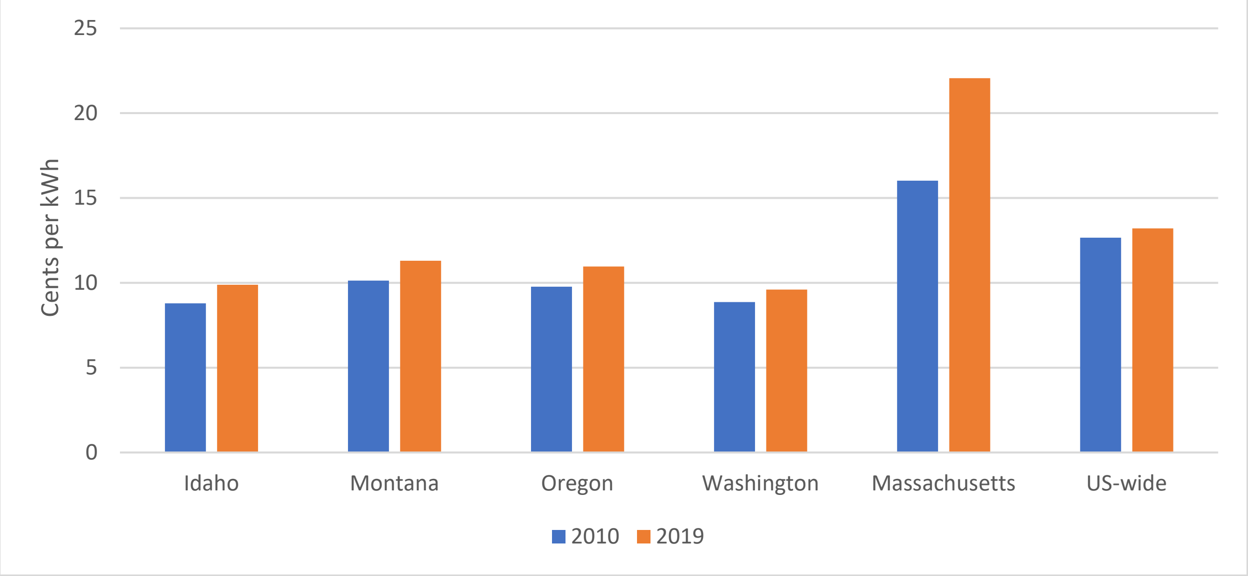
[368] Industry representative, telephone interview by USITC staff, August 12, 2020.

Figure 4.4 Retail power prices for commercial customers in Columbia River Basin states and Massachusetts, 2010 and 2019 (in cents per kilowatt-hour)



Source: BloombergNEF (accessed June 1, 2019).
Note: Underlying data for this figure can be found in appendix table G.23.

Figure 4.5: Retail power prices for residential customers in Columbia River Basin states and Massachusetts, 2010 and 2019 (in cents per kilowatt-hour)



Source: BloombergNEF (accessed June 1, 2019).
Note: Underlying data for this figure can be found in appendix table G.24.

Low electricity prices in Columbia River Basin states are due, in large part, to the region's reliance on relatively inexpensive hydroelectric generation.[369] The operation of hydroelectric facilities entails no fuel

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[369] Industry representative, telephone interview by USITC staff, August 12, 2020; BPA, "Economic Benefits" (accessed June 11, 2020).

costs. Further, while the construction of dams imposes high initial costs, hydroelectric facilities have a relatively long lifespan, and the facilities in the Columbia River Basin were constructed at a time of low building costs.[370]

Effects of Hydroelectricity on Rates and Economic Development

The availability of an inexpensive and stable power supply has attracted electricity-intensive industries to the Pacific Northwest. Aluminum production—which requires a large and steady supply of power—is a notable example of the impact of power prices on the development and continuity of industry operations. Aluminum smelting facilities were first established in the U.S. Northwest in the 1940s, and the region's aluminum industry grew to include 10 aluminum smelters representing 6–7 percent and 40 percent of global and U.S. capacity, respectively.[371] However, due in part to regional power price increases in 1979–81 and 2000–2001, the region's aluminum industry experienced a drop in competitiveness and plant closures and is now largely dormant.[372]

More recently, the low price and large supply of hydroelectricity contributed to BMW and SGL Group's decision to locate a carbon fiber plant in Moses Lake, Washington.[373] Data centers, which are heavy electricity consumers, have also been attracted to the Columbia River Basin, partly due to low-priced and reliable power and—for companies like Amazon, Google, and Microsoft—the ability to meet clean energy preferences and goals.[374] These factors may be particularly appealing to firms that are considering a location for West Coast operations outside of California due to the possibility of rolling outages and power price increases in that state.[375] Currently, there are several large data centers located in Oregon and Washington State.[376]

Agriculture has also benefited from the Northwest's low electricity prices, as certain farm technologies, such as groundwater wells, use a substantial amount of power. Additionally, BPA provides subsidized

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[370] BPA, "Hydropower," February 3, 2011; NHA, "Affordable" (accessed June 17, 2020); industry representative, telephone interview by USITC staff, June 9, 2020.

[371] Northwest Power and Conservation Council, "Aluminum" (accessed June 16, 2020); USITC, *Aluminum*, June 2017, 131–37.

[372] Regional power price increases in 1979–81 resulted from investment in unneeded nuclear plants. In the 1960s, tight electricity supply in the Columbia River Basin led to a 1968 recommendation to build additional infrastructure, including several nuclear plants. This effort—which was based on inaccurate forecasts of future electricity demand—resulted in the completion of only one nuclear plant (the Columbia Generating Station near Richland, Washington) and led BPA to raise electricity prices sharply in order to cover its large debt from two uncompleted nuclear plants. Regional power price increases in 2000–2001 resulted from inadequate investment in power capacity. Northwest Power and Conservation Council, "The State of the Columbia River Basin," September 2019, 36; Northwest Power and Conservation Council, "Northwest Power and Conservation Council" (accessed June 9, 2020); Northwest Power and Conservation Council, "Bonneville Power Administration" (accessed August 21, 2020); Northwest Power and Conservation Council, "Sixth Northwest Conservation and Electric Power Plan," April 29, 2010, 1–7; Northwest Power and Conservation Council, "Aluminum" (accessed June 16, 2020); industry representative, telephone interview by USITC staff, May 27, 2020.

[373] Pryne, "BMW and a German Supplier," April 6, 2010.

[374] Other factors that have attracted data centers to the region include tax breaks, subsea cable access, a knowledgeable workforce, and a temperate climate. Barringer, "Changing Currents," January 29, 2018; industry representatives, telephone interviews by USITC staff, May 27, 2020, and June 9, 2020.

[375] California currently hosts numerous data centers. Miller, "Portland Emerges," May 14, 2020.

[376] Barringer, "Changing Currents," January 29, 2018.

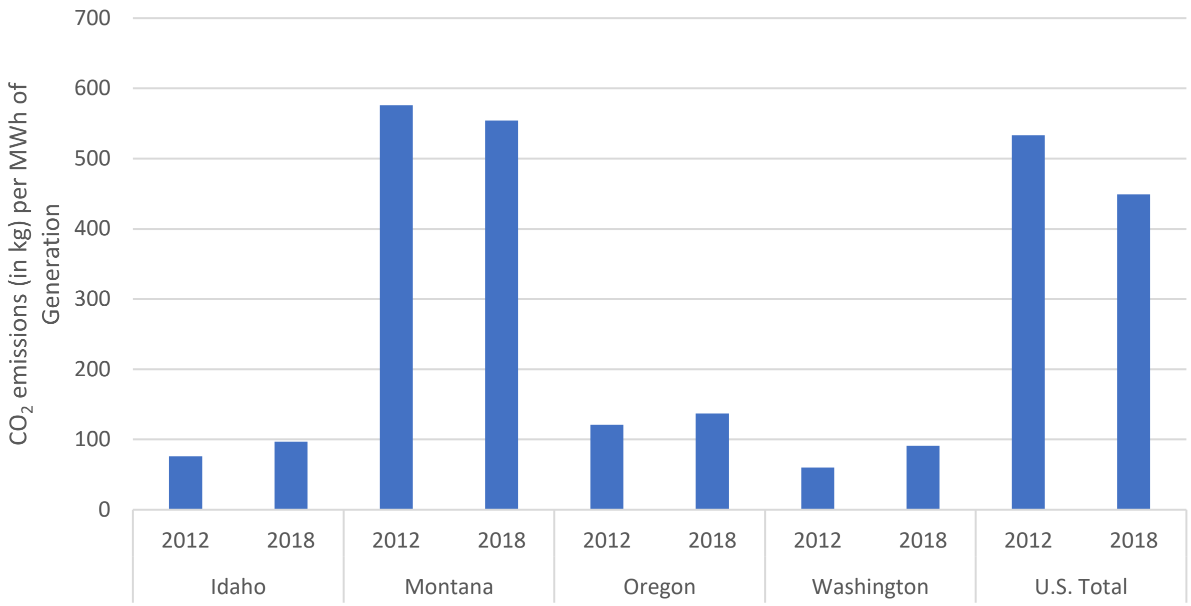
irrigation from the region's dams, which has increased the feasibility of agriculture in the region.[377] BPA reports that irrigation from hydroelectric facilities has created almost 8 million acres of additional farmland in the Northwest.[378] Industry representatives also point to the importance of the Columbia River as a source of irrigation and indicate that hydroelectric facilities support a large amount of agriculture in the Columbia River Basin.[379]

Environmental Impacts

Trends in Greenhouse Gas Emissions

With the exception of Montana—which has a significantly smaller share of hydroelectric generation than Idaho, Oregon, and Washington—each of the Columbia River Basin states posted substantially lower emissions rates from electricity generation than the Unites States as a whole in both 2012 and 2018 (figure 4.6). While power generation emissions rates in Idaho, Oregon, and Washington remain substantially below the U.S. average, the rates in each of these three states increased between 2012 and 2018. This trend contrasts with the significant decrease in emissions rates in the United States as a whole. The increases may be due to growth in natural gas-fueled generation in Idaho and Oregon and in coal- and natural gas-fueled generation in Washington during 2012–18.[380]

Figure 4.6 CO_2 emissions per MWh of generation, 2012 and 2018



Source: EIA, Electric Power Annual 2013, March 2015, and Electric Power Annual 2018, October 2019.
Note: MWh = megawatt-hours. The EIA *Electric Power Annual* does not include state-specific data on CO_2 emissions (in kg) per MWh of generation for years before 2012. Underlying data for this figure can be found in appendix table G.25.

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[377] Barringer, "Changing Currents," January 29, 2018.

[378] BPA, "Economic Benefits" (accessed June 11, 2020).

[379] Industry representatives, telephone interviews by USITC staff, May 27 and June 9, 2020.

[380] Staff calculations based on EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (accessed May 18, 2020).

Effects of Hydroelectricity

As with electricity prices, the region's relatively low emissions rates are likely due to these states' heavy reliance on hydroelectricity. Hydroelectricity generation produces low CO_2 emissions,[381] and its use lessens the need to rely on CO_2-emitting sources of electricity, such as fossil fuel plants.[382] BPA reports that CO_2 emissions from its electricity supply are only 27 lbs. per MWh (as compared to an average of 998 lbs. per MWh in the United States), as hydroelectricity accounts for the vast majority of its power resources.[383] Hydroelectric systems may also emit some methane (CH_4) as a result of biomass decomposition in reservoirs. However, the precise volume of these emissions (both globally and in the Columbia River Basin) is unclear. BPA reports that methane emissions from the reservoirs on the Columbia and Snake Rivers are not substantial.[384]

At the same time, abundant and inexpensive hydroelectricity may have indirectly pushed up emissions levels by attracting certain industries and/or firms—such as the aluminum industry and data centers—to the region. For example, the aluminum industry produces both CO_2 and perfluorocarbon emissions, and data centers may also produce emissions through the use of backup diesel generators.[385]

The presence of hydroelectric facilities also has other environmental impacts. Historical sites, farmland, wildlife habitats, and other areas may be covered in water by the creation of reservoirs.[386] The impact of dams on fish populations is a particularly prominent concern in the Columbia River Basin. Dams can be an obstacle for salmon and steelhead moving up and downstream, and reservoirs can cause water temperature increases that are dangerous to these species.[387] While industry representatives report that the construction of ladders and bypass facilities during the last 30 years has greatly improved fish passage in the Columbia River system, the protection of fish populations remains an ongoing issue.[388] Dam removal has been proposed as a means of protecting salmon in the region. Some of the region's smaller dams have been or may be removed in order to improve salmon migration, and environmental groups have long advocated for the removal of four large Snake River dams in order to protect salmon

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[381] Some industry experts contend that there are substantial CO_2 emissions associated with hydropower reservoirs. Estimates of these emissions vary widely. NAMRA, written submission to USITC, July 15, 2020, 3; WaterPower Canada, written submission to USITC, August 7, 2020, 2; Ocko and Hamburg, "Climate Impacts of Hydropower," October 23, 2019, A–B.

[382] Pacific Northwest Waterways Association, "The Value of Hydropower," February 10, 2017; industry representative, telephone interview by USITC staff, August 12, 2020.

[383] In addition to hydropower, BPA resources include power from one nuclear plant as well as a small amount of purchased power. BPA, "Fact Sheet," January 2019.

[384] BPA, "Fact Sheet," January 2019.

[385] Tyabji and Nelson, "Mitigating Emissions from Aluminum," September 24, 2015; Glanz, "Data Barns in a Farm Town," September 23, 2012.

[386] EIA, "Hydropower Explained," April 9, 2020; industry representatives, telephone interviews by USITC staff, May 27, 2020, and June 9, 2020.

[387] Northwest Power and Conservation Council, "Dams" (accessed June 16, 2020); industry representative, telephone interview by USITC staff, May 27, 2020.

[388] Industry representatives, telephone interviews by USITC staff, May 27, 2020, and June 9, 2020.

populations. In July 2020, the U.S. government decided against the removal of these Snake River dams due to concerns about GHG emissions, grid stability, and power outage risks.[389]

New York State

New York is a net importer of electricity, relying on interstate and international trade along with its own generation to meet its electricity demand. However, different local generation resources, concentration of demand in the downstate market, and transmission constraints have effectively split New York into two electricity markets. As New York's policymakers strive to transition from gas, oil, and nuclear to a market that favors more clean and renewable energy, connecting imports of Canadian hydroelectricity specifically to the downstate market has become an important piece of the system operator's strategy.[390]

New York has a long history of importing hydroelectric power from Canada, a trade that has provided economic and environmental benefits to the state.[391] For example, in 2019, New York's independent system operator (NYISO) estimated that connections to Canada (via a transmission line to Ontario) resulted in about $45 million of production cost savings in the day-ahead market.[392] Additionally, according to Hydro-Québec, in the absence of electricity exports from Quebec, CO_2 emissions in New York would have been almost 1.7 million metric tons higher in 2019.[393]

New York has adopted increasingly ambitious statewide and local commitments to expand the use of renewable and clean energy and to reduce GHG emissions, culminating in a new set of higher commitments for both New York State and New York City in 2019. Existing hydroelectric import arrangements with Canada, as well as planned new arrangements, are expected to be important tools in meeting these commitments.[394]

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[389] U.S. Fish and Wildlife Service, "Why Are Salmon in Trouble?—Dams," (accessed October 16, 2020); Geranios, "Critics Vow to Continue Efforts," October 5, 2020; Geranios, "US: Snake River Dams," July 31, 2020.

[390] NYISO, Reliability and a Greener Grid: Power Trends 2019, 2019, 64.

[391] Imports of electricity from Canada started in 1910 with the construction of the 200 MW Les Cèdres-Dennison intertie, but notably increased with the integration of the Canada and New York power grids in 1978. Upgrades to transmission capacity in Québec in 1984 enabled numerous long-term agreements between Canada and the New York Power Authority to trade energy and capacity services. These agreements included exchanging capacity to meet each region's respective periods of peak demand—winter for Québec and summer for New York. Hydro-Québec, "Exports to New York" (accessed August 2, 2020).

[392] Patton et al., *2019 State of the Market Report*, May 2020, 48.

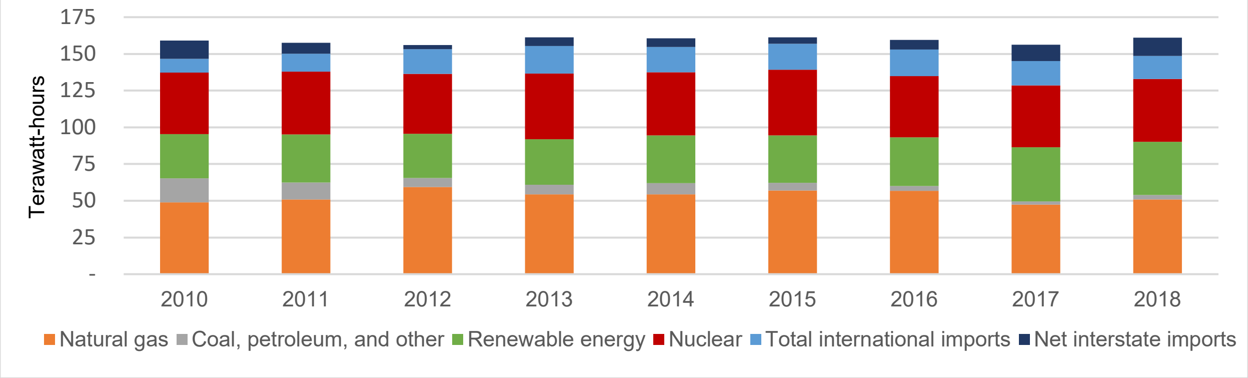
[393] Hydro-Québec, written submission to USITC, July 15, 2020, 10–11.

[394] NYSERDA and New York's Department of Public Service filed a White Paper in June 18, 2020 proposing changes to the Clean Energy Standard to align it with statewide commitments and support meeting the updated targets. The changes included adding a tier designed specifically for resources delivering renewable energy to New York City. This tier allows a broader scope of renewable resources—including large-scale hydropower that is already in existence or under construction—provided that the renewable generation is additional to the supplier's baseline production. On October 15, 2020, New York's Public Service Commission issued an order adopting the White Paper. NYSERDA, White Paper on Clean Energy Standard Procurements to Implement New York's Climate Leadership and Community Protection Act, June 18, 2020, 46-48.
State of New York Public Service Commission, Order Adopting Modifications to the Clean Energy Standard, October 15, 2020, Appendix C (accessed November 20, 2020).

In 2019, the New York State legislature enacted the Climate Leadership and Community Protection Act (CLCPA), which set the state's goal of net zero carbon emissions by 2050. The CLCPA mandates that renewable energy account for 70 percent of power generation by 2030 and calls for total decarbonization of the electricity sector by 2040. It also sets targets of 6,000 MW of solar by 2025 and of 9,000 MW of offshore wind by 2035.[395] Also in 2019, New York City passed Local Law 97, which sets targets for carbon reduction from the commercial retail industry. Impacting over 50,000 buildings, this law aims to reduce building-based emissions 40 percent by 2030 from a 2005 baseline.[396] Since New York City accounts for such a large share of the state's population, the reduction of its carbon footprint will play a significant role in ensuring the state reaches its goals for reducing GHG emissions.[397]

New York State has already made significant progress toward reaching its decarbonization commitments. From 2010 to 2018, New York's electricity generation slowly moved away from fossil fuels and toward nuclear and renewables (mostly hydroelectricity); in 2018 nuclear and renewables accounted for roughly 60 percent of the state's generation (figure 4.7). New York State is also a large net importer of electricity. In 2018, New York State consumed about 161.1 terawatt-hours (TWh) of electricity while generating about 132.5 TWh. Over half of the state's deficit in electric generation (approximately 15.7 TWh) was met by imports from Canada (predominantly hydroelectricity), and the remainder came from other states.[398] In fact, New York's imports of hydroelectricity account for a quarter of Hydro-Québec's total exports.[399]

Figure 4.7 New York State electricity imports and electric generation by source (in terawatt-hours)



Source: EIA, New York Electricity Profile 2018, December 31, 2019, tables 5 and 10. (Excel file).
Note: Underlying data for this figure can be found in appendix table G.26.

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[395] New York State Senate, Senate Bill S6599, June 18, 2019.

[396] City of New York, Local Laws for the City of New York for the Year 2019, No. 97 (accessed March 3, 2020); Urban Green Council, "All about Local Law 97," August 2020.

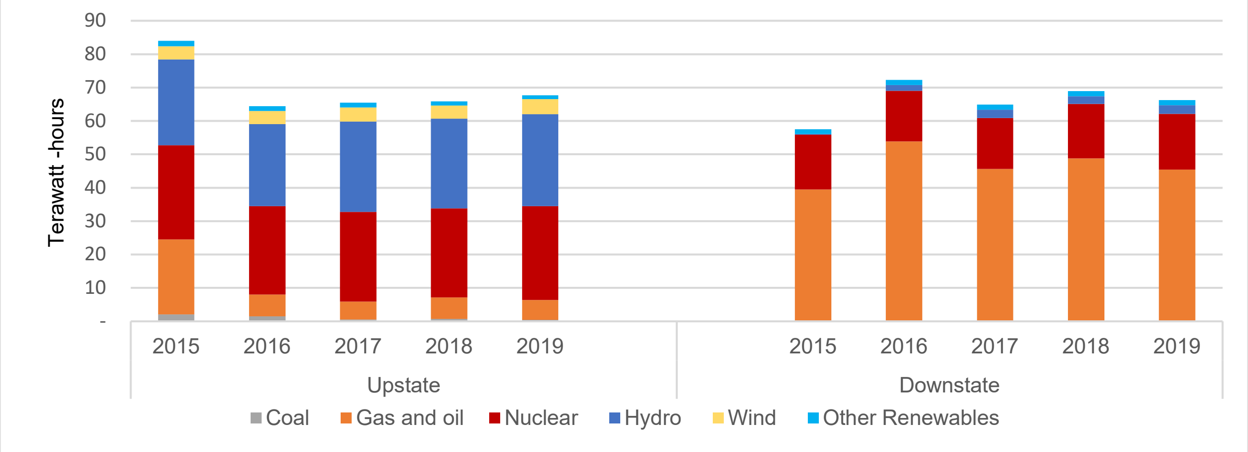
[397] According to the U.S. Census Bureau Population Estimates, New York City (approximately 8.3 million people) accounts for about 43 percent of the population of New York State (approximately 19.4 million people). U.S. Census Bureau, Population Estimates, 2019.

[398] Hydro-Québec states that the vast majority of its electric generation comes from hydroelectric resources. According to Hydro-Québec, it currently has a combined installed hydropower capacity of about 37,000 MW. It also has other sources of clean energy under contract through power purchase agreements, including more than 10,000 MW generated from wind, biomass/biogas, and hydropower. Hydro-Québec, written submission to USITC, August 7, 2020, 6–7.

[399] Hydro-Québec, written submission to USITC, August 7, 2020, 9.

In 2017, NYISO started describing its market as a "Tale of Two Grids" due to the substantial differences in the factors affecting electricity supply in the upstate region versus the downstate region (consisting of New York City, Long Island, the Capital Region, and the Hudson Valley).[400] The geography of upstate New York facilitates significant volumes of generation from hydropower and other renewables (mostly wind) in addition to nuclear and natural gas (figure 4.8). The upstate region also has access to significant imports of hydroelectricity from Canada. As a result, upstate New York is already predominantly powered by clean energy sources. In contrast, downstate New York has historically relied much more heavily on fossil fuel generation. As depicted in figure 4.8, downstate has experienced a gradual increase in renewable generation, though renewables still remain a very small fraction of total generation. For New York State to meet its state-level energy and emissions commitments, much of the transition to renewable resources will need to occur in the downstate region.

Figure 4.8 New York State upstate vs. downstate electricity generation by source, 2015–19 (in terawatt-hours)



Source: NYISO, *Power Trends 2016*, 2016; NYISO, *Power Trends 2017*, 2017; NYISO, *Power Trends 2018*, 2018; NYISO, *Power Trends 2019*, 2019; and NYISO, *Power Trends 2020*, 2020.
Note: Net losses from hydro pumped storage are not included. Underlying data for this figure can be found in appendix table G.27.

New York is pursuing a variety of strategies to help meet its renewable energy targets, including transmission upgrades to increase capacity for imports of hydroelectricity. These upgrades will allow more Canadian hydroelectricity and upstate renewable energy to contribute to the downstate market's supply requirements, offsetting capacity losses from the planned retirement of the last downstate nuclear plant.[401] The transmission upgrades include the creation of the Champlain Hudson Power Express (CHPE), a high-voltage submarine power cable which begins construction in 2021 and will

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[400] NYISO, New York's Evolving Electric Grid: Power Trends 2017, 8.

[401] Entergy announced an agreement with New York in 2017 to retire the Indian Point nuclear plant. One reactor was retired in April 2020 and the other is scheduled to retire in April 2021. The state plans to have renewable hydroelectricity largely offset up to 1,000 MW of nuclear power capacity, with several generation sources online by 2021 to effectively replace the generation capacity of Indian Point. State of New York, "Governor Cuomo Announces 10th Proposal," January 9, 2017; Champlain Hudson Power Express, "Real. Clean. Power." (accessed August 2, 2020); NYISO, Reliability and a Greener Grid: Power Trends 2019, 2019, 59.

reportedly be operational in 2025. It is slated to carry between 1,000 and 1,250 MW of low-cost hydroelectricity directly from Canada to the New York metro area.[402]

The new line will expand the state's power import capacity from Canada by 50 percent, offsetting the loss of generation capacity resulting from the closure of the Indian Point nuclear plant.[403] A report commissioned by the project developer estimates that CHPE will lead to annual reductions of 1.5 million tons of CO_2, as well as yield $12.8 billion in savings to New York State ratepayers over 30 years.[404]

Minnesota-Manitoba

Minnesota Power and Manitoba Hydro have developed a trading relationship demonstrating how power agreements and markets can be structured to leverage the flexibility of hydropower imported from Canada. Minnesota Power and Manitoba Hydro serve neighboring regions but have different generation resource mixes. They both participate in a large regional electricity market with Manitoba and 15 U.S. states in the Midwest and South that is overseen by the Midcontinent Independent System Operator (MISO).[405]

Owned by the government of Manitoba, Manitoba Hydro is mandated not only to supply power to meet the needs of the province, but also to market and supply power to external buyers.[406] About 97 percent of Manitoba Hydro's generation comes from its 15 hydroelectric generation stations, which produce about 30 percent more electricity than is needed within the province.[407] Manitoba has more north-south transmission connections with the U.S. border than east-west connections to other provinces and estimates that it supplies about 10 percent of the electricity consumed in Minnesota.[408]

Minnesota Power is an investor-owned utility serving northeastern Minnesota customers, with some generation resources located in North Dakota.[409] The utility used coal for about 95 percent of its generation in 2005, but has since developed a variety of small and large wind projects which resulted in the reliance on coal-fired generation falling to 75 percent of the utility's mix by 2015.[410] Thus by 2015,

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[402] Champlain Hudson Power Express, "Project Overview" (accessed August 2, 2020).

[403] Seven hundred MW are already in service to offset some of the loss in generation capacity anticipated due to the scheduled shutdown of Indian Point. New York also has planned approximately 350 MW of transmission system upgrades from central to eastern New York and approximately 900 MW of upgrades from the Albany area through the Hudson Valley region to transmit upstate renewable solar, wind, and hydropower downstate by 2023. NYISO, Reliability and a Greener Grid: Power Trends 2019, 2019, 59.

[404] Champlain Hudson Power Express, "Economics," (accessed August 2, 2020); USDOE, OEDER, Final Champlain Hudson Power Express Transmission Line Project, August 2014, S-3.

[405] MISO, "About MISO" (accessed October 20, 2020).

[406] Manitoba Hydro, written submission to USITC, August 14, 2020, 4.

[407] Government of Manitoba, written submission to USITC, August 11, 2020, 2; Manitoba Hydro, written submission to USITC, August 14, 2020, 13.

[408] Government of Manitoba, written submission to USITC, August 11, 2020, 2; Manitoba Hydro, written submission to USITC, August 14, 2020, 3.

[409] Minnesota Power's service territory does not include major population centers like Minneapolis and St. Paul, but large industrial customers in mining and other industries contribute to more than half of its annual electricity sales. Minnesota Power, "Coverage Map" (accessed October 20, 2020); Minnesota Power, 2015 Integrated Resource Plan, September 1, 2015, 1, 8.

[410] Minnesota Power, 2015 Integrated Resource Plan, September 1, 2015, 1–2, 8.

Minnesota Power had already reached its 2025 mandate to supply 25 percent of electricity sales using renewable resources.[411]

Minnesota Power and Manitoba Hydro started discussing the possibility of enhancing transmission between their service areas as early as 2008.[412] In 2011, the two companies negotiated a power purchase agreement (PPA), which includes a "wind storage" provision facilitating electricity exports to Manitoba when wind power production is high or electricity load is low.[413] The agreement required the electricity to be delivered via a new cross-border transmission line, which was completed in June 2020.[414] Minnesota Power announced plans in 2015 to use a large wind farm supported by Manitoba's "storage" to replace and start phasing out one of its major coal generation resources.[415]

Manitoba Hydro participates in the MISO market as a coordinating member; unlike other market participants, Manitoba Hydro's generation is not dispatched by MISO, and demand within the company's service area is not served under MISO's market rules.[416] In a 2013 report, MISO observed that Manitoba Hydro's dynamic participation in the real-time energy market provided a variety of cost savings and reduced wind curtailment.[417]

According to the report, MISO also determined that expanding the mechanism for Manitoba Hydro's participation in real-time energy markets—from only making supply offers to making purchase offers as well—would be mutually beneficial. The expanded mechanism would be bidirectional, allowing Manitoba Hydro to submit a maximum price bid to buy electricity and a minimum price offer to supply electricity (effectively letting Manitoba import electricity and store more water when prices are low, and then sell into MISO when prices spike).[418] As an example, MISO estimated that in 2012, this mechanism would have saved about $8.74 million in production costs and reduced wind energy curtailments by about 21 gigawatt-hours (0.05 percent). MISO concluded that the estimated cost savings within the MISO and increased generation revenue for Manitoba Hydro outweighed the relatively small cost of making the change, and it implemented the expanded mechanism in 2015.[419]

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[411] Minnesota Power, 2015 Integrated Resource Plan, September 1, 2015, 8.
[412] Manitoba Hydro, written submission to USITC, August 14, 2020, 20.
[413] CEA, written submission to USITC, August 7, 2020, 5.
[414] Manitoba Hydro, written submission to USITC, August 14, 2020, 3, 20, 24.
[415] Minnesota Power, 2015 Integrated Resource Plan, September 1, 2015, 2.
[416] Manitoba Hydro, written submission to USITC, August 14, 2020, 14–15.
[417] However, the same study predicted that expanded transmission with Manitoba Hydro would result in a much smaller reduction of wind curtailment if most wind was receiving the federal production tax credit (which expired at the end of 2020) and bidding based on a variable cost of negative $20 per MWh. Bakke, Zhou, and Mudgal, Manitoba Hydro Wind Synergy Study, June 2013, 14–17, 34, 55.
[418] Bakke, Zhou, and Mudgal, Manitoba Hydro Wind Synergy Study, June 2013, 20–21.
[419] Bakke, Zhou, and Mudgal, Manitoba Hydro Wind Synergy Study, June 2013, 23–24; *Power Markets Today*, "MISO Market Enhancements Take Effect," March 3, 2015.

Denmark

Introduction

Denmark is transitioning to a renewable energy-based electricity sector, in line with its goals to reduce GHG emissions 70 percent by 2030. Since 2010, Denmark has increased renewable electricity generation, decreased its use of coal and natural gas, and substantially reduced GHG emissions. Wind power alone rose to represent 49.0 percent of Denmark's electricity generation in 2019, and GHG emissions (in CO_2 equivalent) fell 65.4 percent during 2010–18.[420] This case study discusses Denmark's renewable energy transition with a particular focus on the wind sector, which accounts for the majority of renewable energy production in Denmark, and the role of imports of hydroelectric power.

Denmark's Electricity Market

Denmark participates in the Nord Pool power market, which has historically provided day-ahead and intraday wholesale power markets in Denmark, Estonia, Finland, Latvia, Lithuania, Norway, and Sweden.[421] Within the Nord Pool region, Denmark, Norway, and Sweden are divided into bidding areas, with two areas in Denmark. While there is a common system price, area prices are also set by Nord Pool to account for grid congestion.[422] Denmark is divided into a Western grid (synchronized with continental Europe) and an Eastern grid (synchronized with Nordic countries), which are connected by the Great Belt (Storebælt) transmission line. Denmark West is connected to Germany, the Netherlands, Norway, and Sweden, while Denmark East is connected to Germany and Sweden (figure 4.9).[423] Denmark's high-voltage interconnection lines with Norway and Sweden were first built out in the 1960s and 1970s.[424]

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[420] Greenhouse gas emissions are those from electricity, gas, steam, and air conditioning. BloombergNEF (accessed April–August 2020); Eurostat (accessed March 26, 2020).

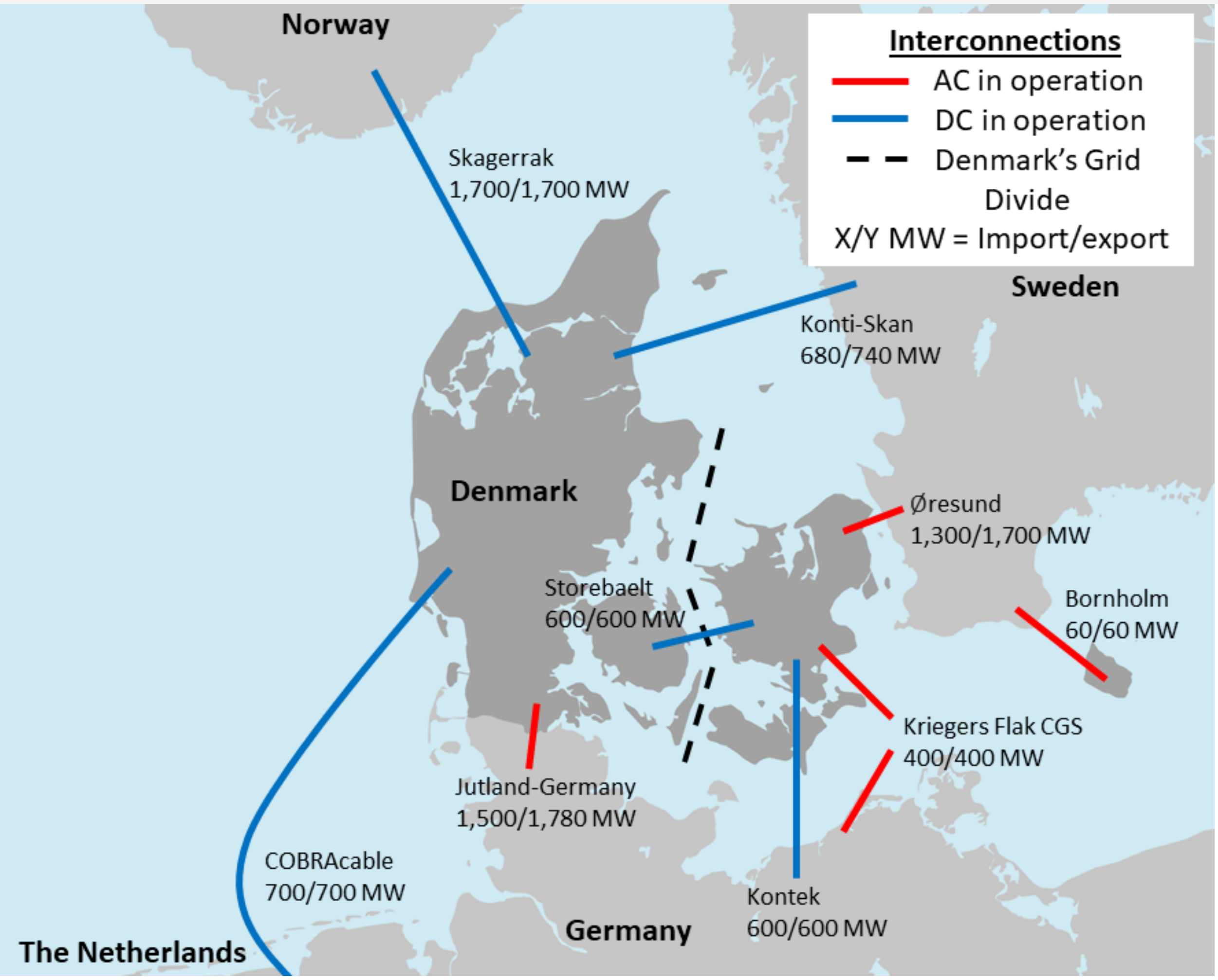
[421] See chapter 1 for a discussion of wholesale power markets. In early 2014, the North-Western Europe Price Coupling was initiated, followed by coupling with markets in Southwest Europe later in the year. In August 2019, Nord Pool launched day-ahead markets in Austria, Belgium, France, Germany, Luxembourg, and the Netherlands. Nord Pool, "Nord Pool Spot," October 2, 2014; Nord Pool, "New Nord Pool," September 2, 2019; Nord Pool, "Euronext Completes," January 15, 2020; Nord Pool, "About Us," (accessed June 1, 2020); Karanfil and Li, "The Role of Continuous Intraday Electricity Markets," 2017, 111; Norwegian Ministry of Petroleum and Energy, *Facts 2015*, December 2014, 52–53.

[422] Norwegian Ministry of Petroleum and Energy, *Facts 2015*, December 2014, 54–55.

[423] Energinet, *Technical Issues*, September 28, 2018, 17.

[424] Windfair, "ABB Is Modernizing," July 13, 2017; Andersson and Hyttinen, "Skagerrak," 2015, 1.

Figure 4.9 Denmark's electricity transmission system



Source: Energinet, *Technical Issues*, September 28, 2018, 17.
Note: MW = megawatts.

Among all electricity generation sources in the Nord Pool region, wind and solar facilities typically have the lowest marginal costs, followed by hydroelectric and nuclear plants.[425] Wholesale prices are generally set by non-combined heat and power producers[426] that rely on a fossil fuel, typically coal, though natural gas may set prices when there is a higher demand.[427] The amount of rain or snow and

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[425] Huisman, Michels, and Westgaard, "Hydro Reservoir," August 2014, 8; Dansk Energi, "Electricity Price," 10 (accessed November 2, 2020).

[426] CHP is the simultaneous generation of electricity and heat that is captured and used, such as for district heating (whereby heat is generated at a central location and piped to individual buildings). CHP producers generally sell electricity at lower prices than non-CHP producers, as they also generate revenue from the sale of heating services. Dansk Energi, "Electricity Price," 10 (accessed November 2, 2020).

[427] Dansk Energi, "Electricity Price," 10 (accessed November 2, 2020); Danish Energy, "Renewable Energy," February 2019, 38–39; Royal Danish Embassy, written submission to USITC, August 13, 2020, 2.

reservoir levels, however, also affect prices, since an increase in the availability of hydroelectric capacity shifts the supply curve.[428]

Denmark's electricity generation mix has historically been dominated by fossil fuels, particularly coal (figure 4.10).[429] Since the early 1980s, combined heat and power (CHP) plants have accounted for most electricity generation, with the heat used for district heating.[430] Over the last decade, however, the country has retired coal and natural gas capacity, replacing it with biomass, solar, and wind capacity. Wind, biomass and waste, and solar grew from 39.2 percent of generation capacity in Denmark in 2010 to 70.2 percent in 2019. Wind, in particular, represented the largest category of new renewable energy, with wind capacity increasing by 63.1 percent during 2010–19.[431] Solar still contributes a relatively small share of electricity capacity and generation, though installations are increasing. Electricity generation from biomass and waste is also growing, as companies convert coal plants to biomass. The country's gross electricity generation declined by about 23.1 percent during 2010–19, which was offset by lower consumption and an increase in imports.[432]

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[428] Hydropower is a limited energy resource, with a tradeoff between reducing reservoir levels by selling energy in the short term versus storing the water in order to sell more in the future. When a storage reservoir is full, the value of storing water falls to zero; however, when a reservoir is low, dam operators will bid at relatively high prices. Bakke, Zhou, and Mudgal, *Manitoba Hydro Wind Synergy Study*, June 2013, 19.

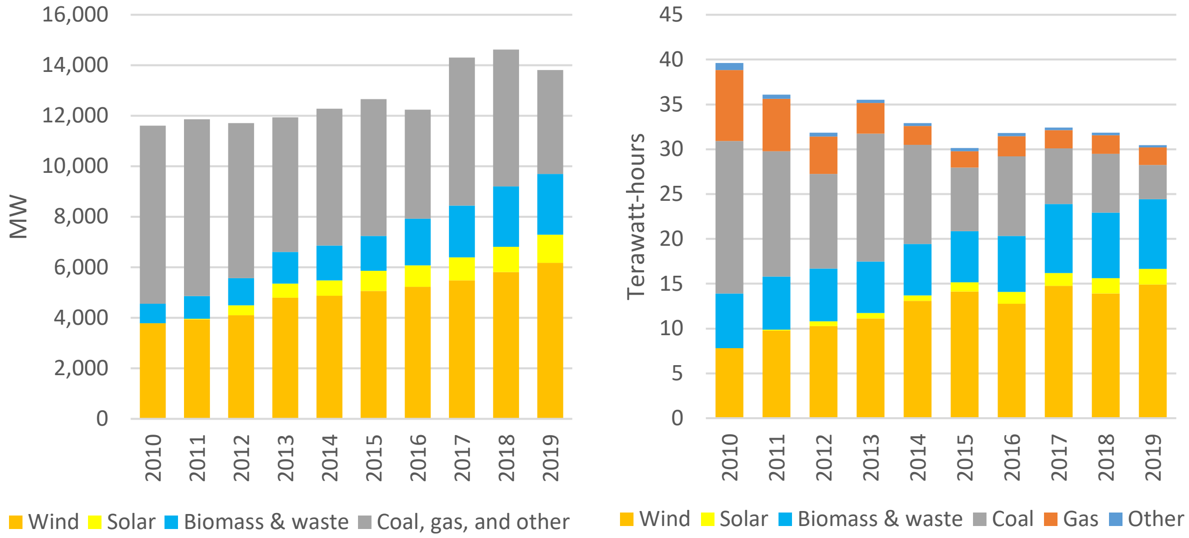
[429] Denmark shifted from primarily using oil in electricity production to primarily using coal due to the oil crises of the 1970s; coal rose from representing 22.1 percent of the fuel used in electricity production in 1972 to its post-1970s peak of 95.8 percent in 1984. Natural gas generation increased substantially in the 1990s and early 2000s, peaking at 24.9 percent of the fuel used in electricity generation in 2005. Danish Energy Agency, "Energy Statistics 2018," February 2020 (Excel file); Rüdiger, "The 1973 Oil Crisis," 2014, 106; Rüdiger, "Designing the Energy Future," 2016, 484.

[430] Data presented in this case study, unless otherwise noted, are only for electricity generation and do not include district heating, whereby heat is generated at a central location and piped to individual buildings (as noted earlier). District heating supplies a substantial share of space and water heating in Denmark, accounting for almost half of final energy consumption for space heating in 2018. The share of district heat production supplied by renewable energy increased from 18.5 percent in 2001 to 34.1 percent in 2010, and then reached 58.5 percent in 2018. Biomass accounts for most heat production from renewable sources, but there was substantial growth in solar thermal production during 2010–19. Danish Energy Agency, "Energy Statistics 2018," February 2020 (Excel file); Epp, "Danish SDH Market," September 1, 2019; Danish Energy Agency, "Regulation and Planning," n.d., 4 (accessed June 9, 2019).

[431] Energinet, "Dansk Elproduktion" (Danish electricity production), April 6, 2020; Gronholt-Pedersen, "Denmark Sources," January 2, 2020; BloombergNEF (accessed April–August 2020).

[432] BloombergNEF (accessed April 11, 2020); Danish Energy Agency, "Electricity Supply" (Excel file, accessed March 26, 2020); Robb, "Phasing Out Coal," March 26, 2019; *State of Green*, "Renewable Energy," November 27, 2018.

Figure 4.10 Electricity capacity (left, in MW) and generation (right, in terawatt-hours) in Denmark by source, 2010–19



Source: BloombergNEF (fee required; accessed April–August 2020).
Note: MW = megawatts. Underlying data for this figure can be found in appendix tables G.28 and G.29.

Denmark is on average a net importer of electricity, though at times it is also a significant exporter, with exports rising during periods of high wind generation (figure 4.11).[433] The country's three primary electricity trading partners during 2010–19 were Germany, Norway, and Sweden, but trade with the Netherlands has begun to increase following the completion of a new transmission line in September 2019.[434] Denmark's net imports of electricity from Norway peaked in 2016, and fell to less than 100 kWh in 2019.[435] This decline in imports from Norway was due to high wind generation in Denmark and low reservoir levels in Norway. In the first four months of 2020, Denmark's imports grew substantially as reservoir levels in Norway recovered.[436] Power imports from Norway are almost entirely hydroelectric, as hydro accounted for 93 percent or more of Norway's annual electricity generation during 2010–19.[437] Hydroelectricity likely also represents a large share of imports from Sweden, where it accounted for more than 40 percent of electricity generation during 2010–18.[438] Denmark also increasingly imports

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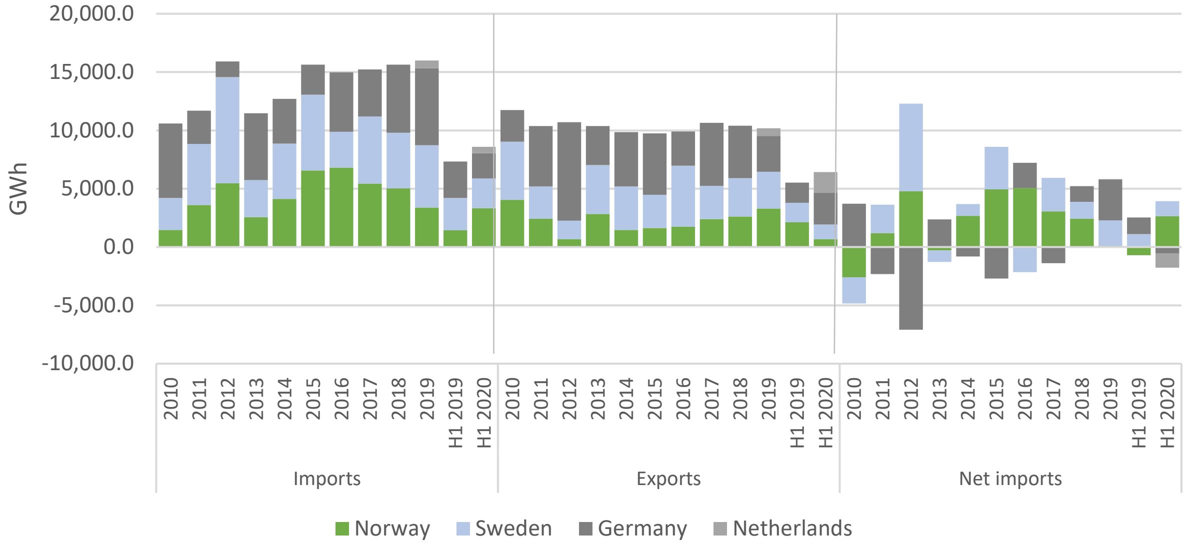
[433] Denmark has a long history of electricity trade; as noted above, its first high voltage interconnections with hydroelectric-intensive electricity systems were completed in the 1960s and 1970s. Mauritzen, "Dead Battery?" September 2011, 12–13, 22; Green and Vasilakos, "Storing Wind," 2012, 17, 19, 24.
[434] Energinet, COBRACable (accessed May 19, 2020); Danish Energy Agency, "Electricity Supply" (Excel file, accessed March 26, 2020).
[435] Danish Energy Agency, "Electricity Supply" (Excel file, accessed March 26, 2020).
[436] Karagiannopoulos, "Rain Pours into Norway's Dams," August 16, 2018; Reuters, "Norway Swings," April 24, 2019; *Local*, "Why Norway," January 3, 2020; IEA, "Key Electricity Trends 2019," April 14, 2020; Nord Pool Website (accessed June 22, 2020); Danish Energy Agency, "Electricity Supply" (accessed June 22, 2020).
[437] BloombergNEF (accessed August 5, 2020).
[438] BloombergNEF (accessed April 11, 2020).

electricity from Germany, due to rising German renewable energy production and grid constraints in Germany that limit transmission from northern to southern Germany.[439]

Figure 4.11 Denmark's electricity trade, January 2010–June 2020 (in GWh)



Source: Danish Energy Agency, "Electricity Supply" (Excel file, accessed March–August 2020).
Note: H1: January to June. GWh = gigawatt-hours. Underlying data for this figure can be found in appendix tables G.30, G.31, and G.32.

Denmark's electricity consumption, like that of the rest of the European Union (EU), declined by about 4 percent during 2010–19. The country's electricity generation declined more substantially than consumption, with the difference offset by an increase in electricity imports (as discussed above). Electricity consumption in Denmark is fairly evenly split between the residential sector (33 percent), the combined commercial and public sectors (36 percent), and the industrial sector (29 percent).[440]

Renewable and Clean Energy Commitments

Overview of Existing Targets

Denmark's large power generation plants are covered under the EU's Emissions Trading System (ETS). The ETS is a cap-and-trade system for CO_2, nitrous oxide, and perfluorocarbons, under which firms receive or purchase tradeable emission allowances for these GHGs. Revisions to the ETS were passed in 2018 to reduce the number of allowances currently on the market and the number issued annually.[441]

Under the 2009 EU Climate and Energy Package, Denmark committed to increasing renewables to 30 percent of final energy consumption by 2020 and reducing GHG emissions from non-ETS sectors by

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[439] Hydroelectricity accounted for more than 4 percent of Germany's electricity generation in 2019. Deign, "Germany's Maxed-Out Grid," March 31, 2020; BloombergNEF (accessed October 2020).
[440] Eurostat (accessed August–October 2020); Danish Energy Agency, "Electricity Supply" (Excel file, accessed August 29, 2020).
[441] The transport sector accounts for the remaining electricity consumption. European Union, "EU Emissions Trading System (EU ETS)" (accessed June 20, 2020).

20 percent by 2020 (from 2005 levels). Under the 2018 EU Winter Energy Package, the EU committed to a 43 percent reduction in GHG emissions within the ETS. Denmark agreed to reduce non-ETS GHG emissions by 39 percent by 2030 (from 2005 levels). The EU's collective share of renewable energy in final energy consumption must be 32 percent by 2030, and countries were mandated to set national contributions to achieving this overall goal. The EU defines renewable energy to include hydroelectric plants of all sizes, but excludes pumped storage.[442] In June 2020, the Danish parliament passed a Climate Act that set a target of reducing GHG emissions from 1990 levels 70 percent by 2030 and moving "towards" net zero emissions by 2050.[443]

Denmark has also implemented a number of policies with the goal of increasing reliance on renewable energy. For example, in March 2012 the Danish Energy Agreement established a number of initiatives which it expected would result in 50 percent of electricity consumption being supplied by wind power in 2020.[444] Most recently, in June 2018, the Danish government reached a new Energy Agreement that it expected would result in renewables accounting for 55 percent of total energy consumption by 2030. Under the agreement, the government expected that renewable energy production would exceed domestic electricity consumption and that non-fossil fuel sources would supply 90 percent of district heating by 2030.[445]

Effects of Hydroelectricity Imports on Efforts to Meet Renewable Energy Targets

Denmark has already surpassed its 2020 goal of 30 percent of final energy consumption from renewables. This is largely due to the high share of renewable energy in electricity consumption (about 70 percent in 2018) and in district heating and cooling production (above 60 percent in 2018). Denmark is also expected to meet its 2020 goal of a 20 percent reduction in GHG emissions.[446]

Transmission capabilities between countries with high levels of hydroelectric capacity, and the flexibility of Denmark's domestic electricity system, have contributed to the high level of wind integration in Denmark and the country's ability to meet its renewable energy targets. In periods of high wind

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[442] As discussed below, most reservoirs in Norway and Sweden rely on natural inflows and do not have pumping options. The EU defines renewable energy as "energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas." However, there are definitions—such as for biomass—that specifically define the meaning of these terms. Final energy consumption is defined as "energy commodities delivered for energy purposes to industry, transport, households, services including public services, agriculture, forestry and fisheries, the consumption of electricity and heat by the energy branch for electricity, heat and transport fuel production, and losses of electricity and heat in distribution and transmission." European Union, Directive (EU) 2018/2001, *Official Journal of the European Union*, L 328/82, December 21, 2018; Danish Energy Agency, *Denmark's Climate and Energy Outlook 2019*, October 2019, 11–12; IEA Wind, *2010 Annual Report*, July 2011, 75; 56; Danish Energy Agency, *Energy Statistics 2018*, February 2020, 56.

[443] Danish Ministry of Climate, Energy, and Utilities, "Danish Climate Act," June 17, 2020; Danish Ministry of Climate, Energy, and Utilities, "During the COP," December 9, 2019; Royal Danish Embassy, written submission to USITC, August 13, 2020, 6.

[444] Danish Ministry of Climate, Energy, and Building, *Accelerating Green Energy*, n.d. (accessed June 23, 2020), 2–5.

[445] Government of Denmark, "Energy Agreement of 29 June 2018," June 29, 2018, 2; Royal Danish Embassy, written submission to USITC, August 13, 2020, 1.

[446] Danish Energy Agency, *Denmark's Climate and Energy Outlook 2019*, October 2019, 19, 20, 61.

generation, Denmark's Nordic neighbors can reduce hydroelectric generation and use imported wind from Denmark. When wind generation is low or demand is high, Denmark can import hydroelectricity. The Nordic hydroelectric system essentially serves as energy "storage" for Denmark's wind power by keeping more water in its reservoirs when wind generation is high.[447] These interconnections, along with the other flexibilities discussed below, have contributed to very low levels of wind curtailment in Denmark.[448]

Denmark's domestic electricity generation is also highly flexible, which helps with the integration of variable renewable energy. Denmark's CHP plants, for example, can switch between CHP and heat-only production, and Denmark's coal power plants have very quick ramp times compared to coal plants in neighboring countries.[449] Denmark's interconnection with Germany provides additional flexibility.[450]

Economic Impacts

Trends in Electricity Prices

Retail electricity prices in Denmark, which are primarily composed of taxes and fees, have declined in recent years. Prices in the most recent years for which data are available were slightly below 2010 levels (2 to 6 percent, depending on the end-use sector) in all end-use sectors except commercial. Prices were below their post-2010 peak (11 to 19 percent, depending on the end-use sector) in all end-use sectors (figure 4.12).[451] Retail prices in Denmark, however, only partially capture the trends occurring in the wholesale power market including the shift to renewable electricity. This is because taxes and fees account for a significant portion of electricity bills in Demark—59.9 percent of residential electricity prices and 71.8 percent of commercial and industrial prices in 2019.[452] The decline in wholesale electricity prices was even steeper than the decline in retail prices, with the base wholesale price declining from 6.9 cents/kWh in 2010 to 4.4 cents/kWh in 2019 (a drop of 35.8 percent).[453]

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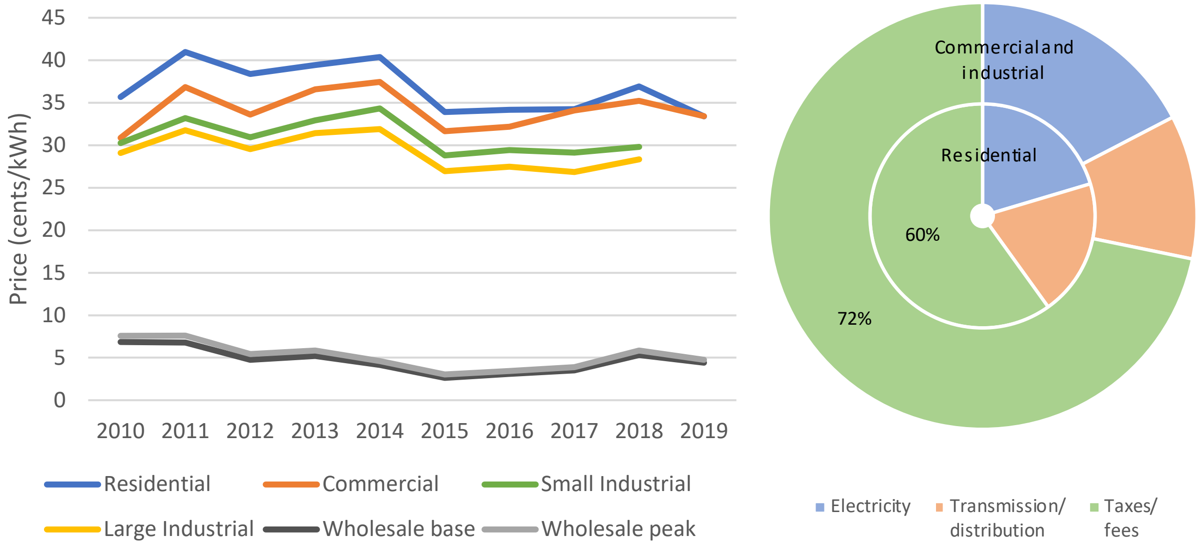
[447] Green and Vasilakos, "Storing Wind," 2012, 24; Ea Energy Analyses, *The Danish Experience*, September 2015, 9, 20–21.
[448] Bird et al., "Wind and Solar Energy Curtailment," 2016, 3; Yasuda et al., "International Comparison," October 2015, 2; Danish Energy Agency, *Flexibility in the Power System*, October 2015, 13.
[449] Danish Energy Agency, *Flexibility in the Power System*, October 2015, 13–18, 36–37; Ea Energy Analyses, *The Danish Experience*, September 2015, 9–10.
[450] Danish Energy Agency, *Flexibility in the Power System*, October 2015, 13.
[451] BloombergNEF (accessed April 11, 2020).
[452] Commercial and industrial users pay slightly higher taxes and fees, but lower prices for electricity, transmission, and distribution, and they have lower total prices. During 2010–19, electricity taxes for the households with high electricity use peaked in 2012. For all other households, electricity taxes peaked in 2017. Eurostat (accessed May 20, 2020 and July 27, 2020).
[453] BloombergNEF (accessed April 11, 2020).

Figure 4.12 Electricity prices in Denmark, 2010–19 (left, in cents/kWh) and components of retail prices in 2019 (right, as a percentage of the total retail price)



Source: BloombergNEF (accessed April 11, 2020); Eurostat (accessed May 20, 2020).
Note: kWh = kilowatt-hours. Residential, commercial, small industrial, and large industrial prices are retail prices. Underlying data for this figure can be found in appendix tables G.33 and G.34.

A number of factors on the supply side combined to put downward pressure on wholesale electricity prices after 2011, including lower fossil fuel prices, a decline in carbon permit prices, higher wind generation (because of wind’s relatively low marginal cost), and an increase in Norway’s reservoir levels (figure 4.13).[454] In addition, electricity consumption, which fell by 4.5 percent during 2010–14, contributed to the decline in electricity prices.[455] By 2019, however, wholesale prices had risen modestly above their 2015 lows due to a reversal of many of the trends that contributed to declines earlier in the decade.[456]

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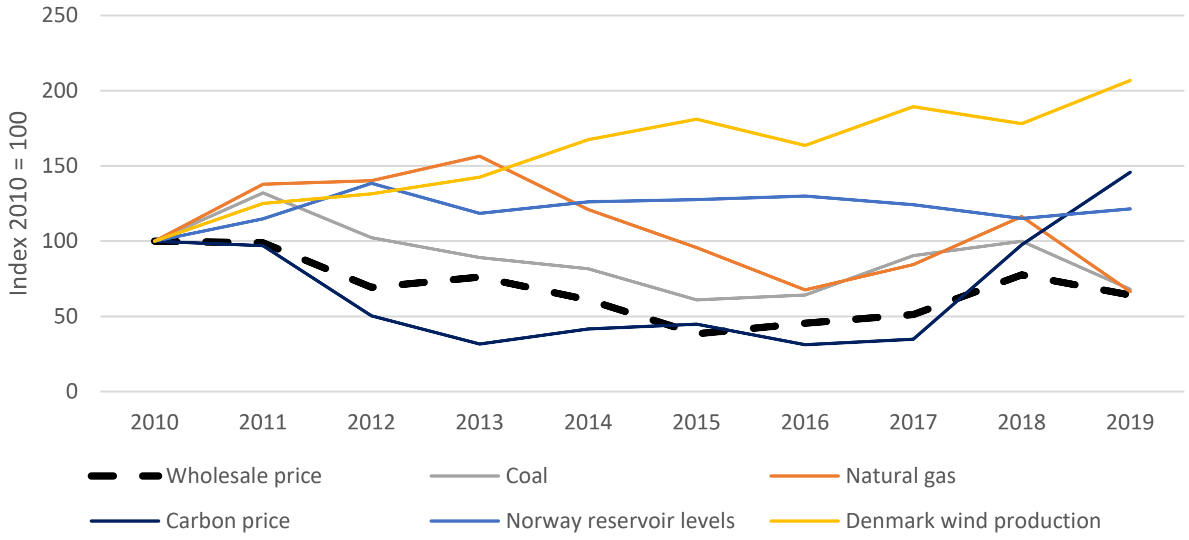
[454] Vattenfall, *Annual and Sustainability Report 2015*, 14; Vattenfall, *Annual and Sustainability Report 2014*, 12–13; Rønningsbakk, “High Snow Levels,” June 8, 2020; Royal Danish Embassy, written submission to USITC, August 13, 2020, 2; BloombergNEF (accessed April–June, 2020); Danish Energy Agency, “Electricity Supply” (Excel file, accessed March 26, 2020); NVE (accessed June 4, 2020).

[455] Eurostat (accessed August 5, 2020).

[456] Carbon prices increased substantially in 2019, but many firms hedged their carbon permit prices. Vattenfall, *Annual and Sustainability Report 2015*, 14; Vattenfall, *Annual and Sustainability Report 2014*, 12–13; Twidale, “What Is Driving a Rally?” August 15, 2018; Karagiannopoulos, “Low on Snow,” June 14, 2018; Karagiannopoulos, “Rain Pours into Norway’s Dams,” August 16, 2018; Reuters, “Norway Swings,” April 24, 2019; Dansk Energi, *Electricity Price Outlook 2018*, 11, 14 (accessed July 21, 2020); Holm, “Low Electricity Prices,” May 31, 2017, 6; BloombergNEF (accessed April–June, 2020); Eurostat (accessed August 5, 2020); Danish Energy Agency, “Electricity Supply” (Excel file, accessed March 26, 2020); NVE (accessed June 4, 2020).

Figure 4.13 Fossil fuel prices, reservoir levels, wind production, and electricity consumption, 2010–19



Source: BloombergNEF (fee required; accessed April–June, 2020); Danish Energy Agency, "Electricity Supply" (Excel file, accessed March 26, 2020); NVE, "Magasinstatistikk" (reservoir statistics), (accessed June 4, 2020).
Note: Underlying data for this figure can be found in appendix table G.35.

Effects of Hydroelectricity Imports on Rates

Nord Pool wholesale power prices were consistently among the lowest in Europe during 2011–19 because a majority of electricity supply in the Nord Pool region came from sources with lower marginal costs, such as wind, hydroelectric, and nuclear.[457] The flexible hydroelectric resources in Norway and Sweden act to support electricity prices during windy periods. When wind generation is high, the abundance of wind on the grid drives down electricity prices. It is more economically attractive during these times, therefore, for hydroelectric plants to limit production. This way they maintain reservoir levels for future use during a period when electricity prices can be expected to be higher.[458] Several studies have found that when these hydroelectric plants come offline, Danish wind facilities receive higher prices for their electricity.[459]

The flexibility of hydroelectric power plants and their storage capability also limit price volatility in the market. In the day-ahead market, Denmark's imports of hydroelectric power have a limiting effect on the hourly price volatility that may otherwise result from an increase in wind generation.[460] In the

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[457] BloombergNEF (accessed June 2020); Huisman, Michels, and Westgaard, "Hydro Reservoir," August 2014, 8–9; Royal Danish Embassy, written submission to USITC, August 13, 2020, 4.

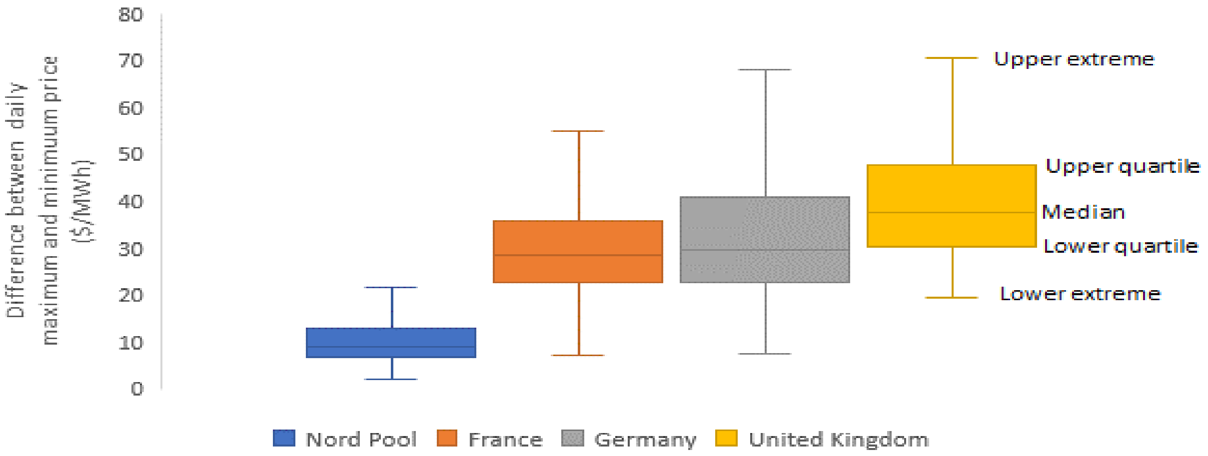
[458] Most of reservoirs in Norway and Sweden rely on natural inflows and do not have pumping options. Therefore, there is only a finite amount of water available in a given year, and firms can maximize their revenue by generating during higher-price periods. Dalla Riva, Hethey, and Vītiņa, "Impacts of Wind," November 2017, 10–12; Huuki, "Wind Value," 4–5; Green and Vasilakos, "Storing Wind," 21.

[459] Wind also benefits in Denmark from higher generation in winter months, when there are higher electricity prices. Dalla Riva, Hethey, and Vītiņa, "Impacts of Wind Turbine Technology," November 2017, 11–12; Huuki, "Wind Value," March 27, 2018, 4, 20; Green and Vasilakos "Storing Wind for a Rainy Day," 21 (accessed November 2, 2020). See also Hirth, "The Benefits of Flexibility," 2016, 213.

[460] Rintamaki, Siddiqui, and Salo, "Does Renewable Energy Generation," December 6, 2016, 22.

intraday market, hydro also has a moderating effect on pricing. If wind forecasts are incorrect and wind facilities are not able to generate enough to supply their contracted amount of electricity, they may need to purchase that electricity on the market. This has the potential to be expensive if firms need to purchase this from more expensive natural gas plants. In Denmark, however, wind operators are able to cover this shortfall by purchasing power from relatively low-cost hydroelectric plants.[461] As illustrated in figure 4.14, there are only small differences between the daily minimum and maximum prices in the Nord Pool region, as compared with neighboring countries.[462]

Figure 4.14 Difference between daily minimum and maximum prices, 2019 (in $/MWh)



Source: BloombergNEF (fee required; accessed June 4, 2020).
Notes: Excludes outliers. Underlying data for this figure can be found in appendix table G.36.

While imported hydroelectricity may limit price volatility, there may still be a cost for using Nordic partners as "energy storage." As excess wind generation tends to reduce market prices, electricity is typically exported at lower market prices and imported at higher market prices.[463] These costs, however, are currently much lower than the cost of using batteries or other energy storage technologies. Norway's wholesale peak price, for example, can serve as a proxy for the cost of importing hydroelectricity from Norway. This price was only $45.0/MWh in 2019.[464] In comparison, utility-scale battery storage costs in Germany (a proxy for price in Denmark) had a levelized cost of electricity of $143.0 to $223.0 per MWh in the first half of 2020.[465]

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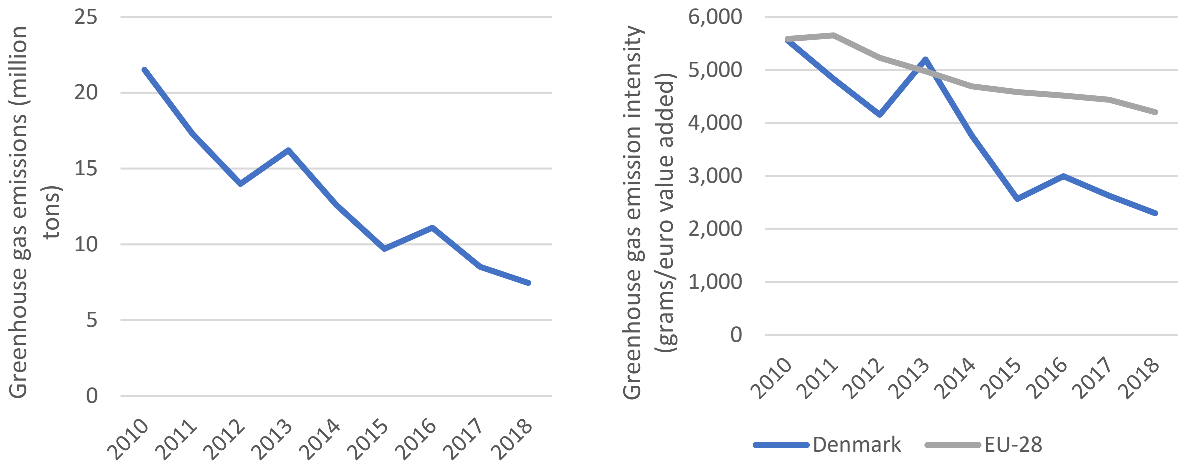
[461] Karanfil and Li, "The Role of Continuous Intraday Electricity Markets," 116, 123–24.
[462] BloombergNEF (accessed June 4, 2020).
[463] Green and Vasilakos, "Storing Wind," 23–24.
[464] BloombergNEF (accessed June 22, 2020).
[465] BloombergNEF (accessed June 22, 2020).

Environmental Impacts

Trends in Greenhouse Gas Emissions

Denmark's GHG emissions from electricity production declined 65.4 percent during 2010–18 (figure 4.15).[466] Emissions continued to decline in 2019.[467] This primarily reflected the rising share of electricity generation accounted for by renewable energy, with the GHG intensity of electricity production (as measured by grams of CO_2 equivalent emissions per euro of value added) falling by 58.7 percent. In addition, emissions declined as a result of lower electricity generation as consumption fell and imports increased.[468] While Denmark's GHG intensity was roughly equivalent to the EU average in 2010, by 2018 it was only 54.6 percent of the EU average.[469]

Figure 4.15 Greenhouse gas emissions (CO_2 equivalent) from electricity, gas, steam, and air conditioning supply, 2010–18 (in million tons, left, and grams/euro value added, right)



Source: Eurostat (accessed March 26, 2020).
Notes: Includes the following GHGs in CO_2 equivalent: CO_2, nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbon, perfluorocarbons, sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Underlying data for these figures can be found in appendix tables G.37 and G.38.

Effects of Hydroelectricity Imports

The rapid decline in Denmark's emissions reflects lower electricity generation from coal, oil, and natural gas. This is a result of both lower electricity generation overall and increasing renewable electricity generation, which is supported by the flexibility of Nordic hydroelectricity and other factors discussed above.[470] Observed CO_2 emissions from coal plants fell by 8.0 million tons (61.3 percent) during 2010–18

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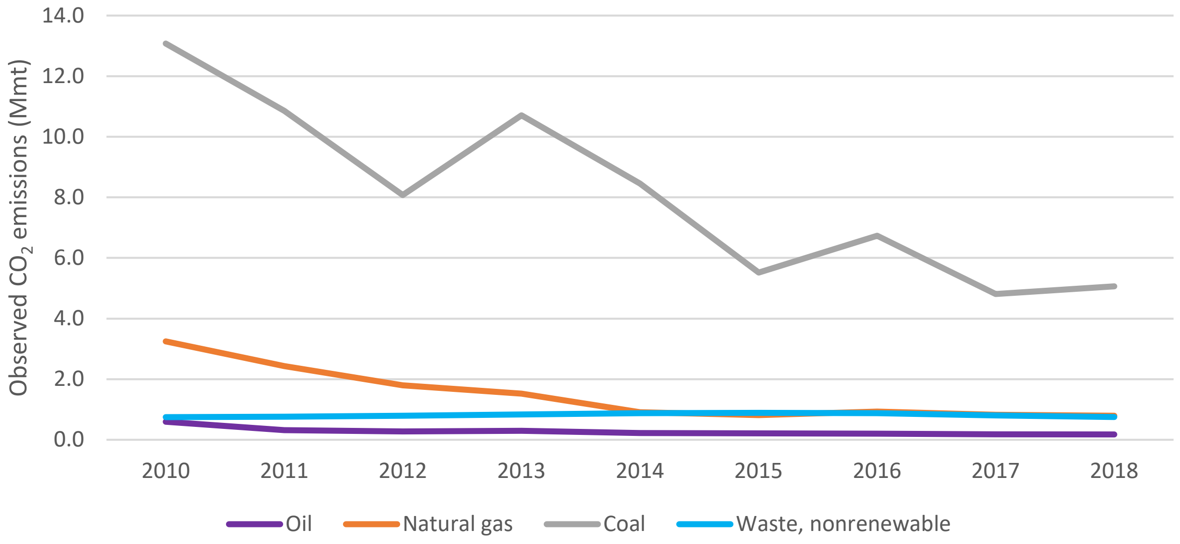
[466] Eurostat (accessed March 26, 2020).
[467] Energinet, "Dansk Elproduktion," June 4, 2020.
[468] BloombergNEF (accessed April 11, 2020); Danish Energy Agency, "Electricity Supply" (Excel file, accessed March 26, 2020); Energinet, "Dansk Elproduktion," June 4, 2020; Eurostat (accessed March 26, 2020); Royal Danish Embassy, written submission to USITC, August 13, 2020, 6.
[469] Eurostat (accessed March 26, 2020).
[470] BloombergNEF (accessed April 11, 2020); Danish Energy Agency, "Electricity Supply" (Excel file, accessed March 26, 2020); Royal Danish Embassy, written submission to USITC, August 13, 2020, 6.

due to the retirements of coal plants and reduced electricity generation from coal, while natural gas plant emissions fell by 2.5 million tons (75.6 percent) (figure 4.16).[471]

Figure 4.16 Observed CO_2 emissions, nonrenewable energy power plants, 2010–18, in million metric tons (Mmt)



Source: Danish Energy Agency, Energy Statistics 2018, February 2020 (Excel file).
Note: Underlying data for this figure can be found in appendix table G.39.

The decline in emissions, as noted above, in part reflects higher imports and lower domestic electricity production during 2015–19 than in 2010–14 (with the exception of 2012). GHG emissions also decline, however, when including electricity imports. On an adjusted basis,[472] CO_2 emissions per kWh of electricity consumption in Denmark fell from 505 grams per kWh in 2010 to 306 grams per kWh in 2018 (39 percent) (figure 4.17).[473] Emissions per kWh of electricity consumed continued to fall in 2019.[474]

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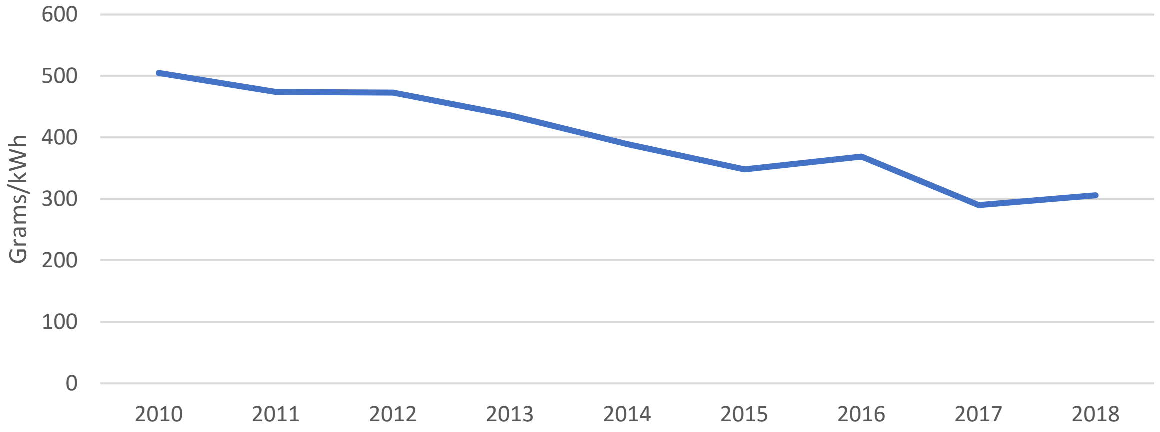
[471] Danish Energy Agency, Energy Statistics 2018, February 2020 (Excel file).

[472] Data are adjusted to take into account trade and temperature fluctuations for comparability of annual basis. Danish Energy Agency, *Energy Statistics 2018*, February 2020, 39–40.

[473] Danish Energy Agency, Energy Statistics 2018, February 2020 (Excel file).

[474] Energinet, “Dansk Elproduktion” (Danish electricity production), June 4, 2020.

Figure 4.17 CO_2 emissions per kWh of electricity consumption in Denmark, 2010–18, adjusted (in grams/kWh)



Source: Danish Energy Agency, Energy Statistics 2018, February 2020 (Excel file); Danish Energy Agency, *Energy Statistics 2018*, February 2020, 39–40.
Note: KWh = kilowatt-hours. Adjusted for weather and trade. Underlying data for this figure can be found in appendix table G.40.

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Appendix A
Request Letter

RICHARD E NEAL,
MASSACHUSETTS,
CHAIRMAN

JOHN LEWIS, GEORGIA
LLOYD DOGGETT TEXAS
MIKE THOMPSON, CALIFORNIA
JOHN B LARSON CONNECTICUT
EARL BLUMENAUER, OREGON
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JIMMY GOMEZ, CALIFORNIA
STEVEN HORSFORD, NEVADA

BRANDON CASEY
MAJORITY STAFF DIRECTOR

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COMMITTEE ON WAYS AND MEANS
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KEVIN BRADY,
TEXAS,
RANKING MEMBER

DEVIN NUNES, CALIFORNIA
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JACKIE WALORSKI, INDIANA
DARIN LAHOOD, ILLINOIS
BRAD R. WENSTRUP OHIO
JODEY ARRINGTON, TEXAS
DREW FERGUSON, GEORGIA
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ARY A DRES,
MI ORITY STAFF DIRECTOR

RECEIVED
JAN 23 2020
OFFICE OF THE SECRETARY
U.S. INTL. TRADE COMMISSION

January 23, 2020

The Honorable David Johanson
Chairman
U.S. International Trade Commission
500 E Street, SW
Washington, DC 20436

Dear Chairman Johanson:

I am writing today to request that the U.S. International Trade Commission (USITC) conduct an investigation and prepare a report under section 332(g) of the Tariff Act of 1930 regarding the potential economic effects of increased renewable energy commitments in New England and Massachusetts and the role of renewable electricity imports in meeting these commitments. Please accept this letter as a replacement for the Committee's letter of December 19, 2019.

Over the past three decades, Massachusetts has seen the retirement of both nuclear and coal-generated power plants across the Commonwealth. With these facilities offline, there has been a growing strain on the ability of New England's bulk power generation and transmission system to meet the demands of consumers. High electricity rates undermine the competitiveness of Massachusetts businesses and make it difficult for residents, particularly low-income households, to afford their utility bills.

At the same time, many New England states have set ambitious goals for seeking alternative renewable means of providing energy while also reducing greenhouse gas emissions. In 2018, Massachusetts enacted greater renewable energy targets. As part of its strategy for meeting this challenge while addressing high electricity rates, the Commonwealth has plans to use hydroelectricity imported from Canada, among other renewable energy resources.

To better understand the potential economic impact of the strategies in place in New England and Massachusetts to increase the use of renewable energy, I request that the USITC conduct an investigation and prepare a report that provides, to the extent practical, the following information:

(1) An overview of the current situation and recent trends in New England and Massachusetts electricity markets with regard to domestic and imported electricity sources and rates for residential and commercial uses, and the status of the transition from nuclear and fossil fuels to renewable sources. This overview will include a description of the Commonwealth's most recent renewable energy goals and commitments as compared to previous commitments and initiatives, as well as the

renewable energy goals and commitments in other New England states, and the potential available resources to meet those goals.

(2) A quantitative analysis of the potential economic effects on the Commonwealth, and broader New England region, of Massachusetts reaching its goals and commitments for renewable electricity sourcing. The analysis should include, for example, the potential economic effects on residential and commercial consumers of electricity.

(3) A quantitative analysis of the likely effects on greenhouse gas emissions of meeting these goals and commitments.

(4) Relevant case studies involving other states, regions, or countries that provide insights into the potential economic effects of imports of hydroelectricity, including on efforts to meet renewable energy targets, the rates paid by commercial and residential customers, and on greenhouse gas emissions.

I request that the analysis not focus on proposed or pending renewable energy transmission projects. I further request that the Commission deliver the report by 12 months from the date of this letter. As I intend to make the report available to the public, please do not include confidential business information. Your assistance in this matter is greatly appreciated.

Sincerely,

Richard E. Neal
Chairman

Appendix B

Federal Register Notices

further determined to issue a limited exclusion order and cease and desist order and to set a bond rate on the entered value of covered products imported during the period of Presidential review.

FOR FURTHER INFORMATION CONTACT: Benjamin S. Richards, Esq., Office of the General Counsel, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436, telephone (202) 708–5453. Copies of non-confidential documents filed in connection with this investigation are or will be available for inspection during official business hours (8:45 a.m. to 5:15 p.m.) in the Office of the Secretary, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436, telephone (202) 205–2000. General information concerning the Commission may also be obtained by accessing its internet server at *https://www.usitc.gov.* The public record for this investigation may be viewed on the Commission's electronic docket (EDIS) at *https://edis.usitc.gov.* Hearing-impaired persons are advised that information on this matter can be obtained by contacting the Commission's TDD terminal on (202) 205–1810.

SUPPLEMENTARY INFORMATION: On February 21, 2018, the Commission instituted this investigation based on a complaint filed by 10X Genomics, Inc. of Pleasanton, CA. 83 FR 7491 (Feb. 21, 2018). The complaint alleges violations of section 337 of the Tariff Act of 1930, as amended, 19 U.S.C. 1337, in the importation into the United States, the sale for importation, or the sale within the United States after importation of certain microfluidic systems and components thereof and products containing same by reason of infringement of one or more claims of U.S. Patent Nos. 9,644,204 ("the '204 patent"); 9,689,024 ("the '024 patent"); 9,695,468 ("the '468 patent"); and 9,856,530 ("the '530 patent"). *Id.* The Commission's notice of investigation named as the sole respondent Bio-Rad Laboratories, Inc. of Hercules, CA. *Id.* The Office of Unfair Import Investigations ("OUII") is participating in this investigation. *Id.*

On July 12, 2019, the administrative law judge ("ALJ") issued the final initial determination ("ID"). The ID found a violation of section 337 by virtue of Bio-Rad's indirect infringement of the '024, the '468, and the '530 patents. The ID found that 10X had not established a violation with respect to the '204 patent. The ID also found that Bio-Rad failed to establish invalidity of any of the asserted claims of any patent. The ID further found that the domestic industry requirement was satisfied for each of the asserted patents. Finally, the ID found that Bio-Rad had not carried its burden with respect to various additional affirmative defenses, including improper inventorship and ownership.

On July 25, 2019, the ALJ issued her recommended determination on remedy and bonding. The ALJ recommended, upon a finding of violation, that the Commission issue a limited exclusion order, issue a cease and desist order, and impose a bond in the amount of twenty-five percent of the entered value of any covered products imported during the period of Presidential review.

On July 29, 2019, 10X, Bio-Rad, and OUII submitted petitions seeking review of the ID. On August 6, 2019, 10X, Bio-Rad, and OUII submitted responses to the others' petitions. On August 26, 2019, 10X and Bio-Rad submitted comments on the public interest pursuant to Commission Rule 210.50(a)(4).

On October 17, 2019, the Commission issued a notice indicating its determination to review the ID with respect to (1) all findings related to a violation based on the '024 patent; (2) all findings related to a violation based on the '468 patent; (3) noninfringement of the '204 patent; (4) all findings related to a violation based on the '530 patent; (5) Bio-Rad's inventorship and ownership defenses; and (6) a typographical error on page 91. The same notice also requested briefing from the parties on certain of those issues, and on remedy, bonding, and the public interest. The notice also included an extension of the target date to December 19, 2019.

The parties filed their initial responses to the Commission's questions on October 31, 2019, and their replies on November 7, 2019.

Upon review of the parties' submissions, the ID, RD, and evidence of record, the Commission has determined that Bio-Rad violated section 337 by reason of infringement of asserted claims 1, 5, 17, 19, and 22 of the '024 patent, claims 1, 6, 7, 9, and 21 of the '468 patent, and claims 1, 4, 11, 14, 19, 26, and 28 of the '530 patent. The Commission found no violation with respect to the '240 patent. The Commission has further determined to issue a limited exclusion order prohibiting further importation of Bio-Rad's infringing microfluidic systems and a cease and desist order against Bio-Rad. The Commission will set a bond of twenty-five percent of entered value on Bio-Rad's infringing microfluidic systems imported during the period of Presidential review.

The authority for the Commission's determination is contained in section 337 of the Tariff Act of 1930, as amended (19 U.S.C. 1337), and in part 210 of the Commission's Rules of Practice and Procedure (19 CFR 210).

By order of the Commission.

Issued: February 12, 2020.

Lisa Barton,

Secretary to the Commission.

[FR Doc. 2020–03192 Filed 2–18–20; 8:45 am]

BILLING CODE 7020–02–P

INTERNATIONAL TRADE COMMISSION

[Investigation No. 332–574]

Renewable Electricity: Potential Economic Effects of Increased Commitments in Massachusetts; Institution of Investigation and Scheduling of Hearing

AGENCY: United States International Trade Commission.

ACTION: Notice of investigation and scheduling of a public hearing.

SUMMARY: Following receipt on January 23, 2020, of a request from the Committee on Ways and Means (Committee) of the U.S. House of Representatives, under section 332(g) of the Tariff Act of 1930, the U.S. International Trade Commission (Commission) instituted Investigation No. 332–574, *Renewable Electricity: Potential Economic Effects of Increased Commitments in Massachusetts,* for the purpose of providing a report regarding the potential economic effects of increased renewable energy commitments in Massachusetts, and the role of renewable electricity imports in meeting these commitments.

DATES:

April 16, 2020: Deadline for filing requests to appear at the public hearing.

April 23, 2020: Deadline for filing prehearing briefs and statements.

May 7, 2020: Public hearing.

May 15, 2020: Deadline for filing post-hearing briefs and statements.

July 28, 2020: Deadline for filing all other written submissions.

January 25, 2021: Transmittal of Commission report to the Committee.

ADDRESSES: All Commission offices, including the Commission's hearing rooms, are located in the U.S. International Trade Commission Building, 500 E Street SW, Washington, DC. All written submissions should be addressed to the Secretary, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436. The public record for this investigation may

be viewed on the Commission's electronic docket (EDIS) at *https://edis.usitc.gov.*

FOR FURTHER INFORMATION CONTACT: Project Leader Diana Friedman (202–205–3433 or *diana.friedman@usitc.gov*) or Deputy Project Leader Patricia Mueller (202–205–2599 or *patricia.mueller@usitc.gov*) for information specific to this investigation. For information on the legal aspects of this investigation, contact William Gearhart of the Commission's Office of the General Counsel (202–205–3091 or *william.gearhart@usitc.gov*). The media should contact Margaret O'Laughlin, Office of External Relations (202–205–1819 or *margaret.olaughlin@usitc.gov*). Hearing-impaired individuals may obtain information on this matter by contacting the Commission's TDD terminal at 202–205–1810. General information concerning the Commission may also be obtained by accessing its website (*https://www.usitc.gov*). Persons with mobility impairments who will need special assistance in gaining access to the Commission should contact the Office of the Secretary at 202–205–2000.

SUPPLEMENTARY INFORMATION:

Background: As requested by the Committee, the Commission will conduct an investigation and prepare a report that provides, to the extent practical, the following information:

(1) An overview of the current situation and recent trends in New England and Massachusetts electricity markets with regard to domestic and imported electricity sources and rates for residential and commercial uses, and the status of the transition from nuclear and fossil fuels to renewable sources. This overview will include a description of the Commonwealth's most recent renewable energy goals and commitments as compared to previous commitments and initiatives, as well as the renewable energy goals and commitments in other New England states, and the potential available resources to meet those goals;

(2) A quantitative analysis of the potential economic effects on the Commonwealth, and broader New England region, of Massachusetts reaching its goals and commitments for renewable electricity sourcing. The analysis should include, for example, the potential economic effects on residential and commercial consumers of electricity;

(3) A quantitative analysis of the likely effects on greenhouse gas emissions of meeting these goals and commitments; and

(4) Relevant case studies involving other states, regions, or countries that provide insights into the potential economic effects of imports of hydroelectricity, including on efforts to meet renewable energy targets, the rates paid by commercial and residential consumers, and on greenhouse gas emissions.

The Committee requested that the analysis not focus on proposed or pending renewable energy transmission projects. The Committee asked that the Commission deliver the report 12 months from the date of the letter, and the Commission expects to transmit its report by January 25, 2021. The Committee stated that it intends to make the Commission's report available to the public and asked that the report not include any confidential business information. The Committee noted that it had sent an earlier version of this letter and asked that the Commission accept the January 23, 2020 letter as a replacement for the Committee's letter of December 19, 2019.

Public Hearing: A public hearing in connection with this investigation will be held at the U.S. International Trade Commission Building, 500 E Street SW, Washington, DC, beginning at 9:30 a.m. on May 7, 2020. Requests to appear at the public hearing should be filed with the Secretary no later than 5:15 p.m., April 16, 2020, in accordance with the requirements in the "Written Submissions" section below. All prehearing briefs and statements should be filed not later than 5:15 p.m., April 23, 2020, and all post-hearing briefs and statements should be filed not later than 5:15 p.m., May 15, 2020. Post-hearing briefs and statements should address matters raised at the hearing. In the event that, as of the close of business on April 23, 2020, no witnesses are scheduled to appear at the hearing, the hearing will be canceled. Any person interested in attending the hearing as an observer or nonparticipant should contact the Office of the Secretary at 202–205–2000 after April 23, 2020, for information concerning whether the hearing will be held.

Written Submissions: In lieu of or in addition to participating in the hearing, interested parties are invited to file written submissions concerning this investigation. All written submissions should be addressed to the Secretary, and should be received not later than 5:15 p.m., July 28, 2020. All written submissions must conform to the provisions of section 201.8 of the Commission's *Rules of Practice and Procedure* (19 CFR 201.8). Section 201.8, as further explained in the Commission's Handbook on Filing Procedures, requires that interested parties file documents electronically on or before the filing deadline. Interested parties must submit eight (8) true paper copies by 12:00 p.m. Eastern Time on the next business day. In the event that confidential treatment of a document is requested, interested parties must file, at the same time as the eight paper copies, at least four (4) additional true paper copies in which the confidential information must be deleted (see the following paragraphs for further information regarding confidential business information). Persons with questions regarding electronic filing should contact the Office of the Secretary, Docket Services Division (202–205–1802).

Confidential Business Information. Any submissions that contain confidential business information must also conform to the requirements of section 201.6 of the Commission's *Rules of Practice and Procedure* (19 CFR 201.6). Section 201.6 of the rules requires that the cover of the document and the individual pages be clearly marked as to whether they are the "confidential" or "non-confidential" version, and that the confidential business information is clearly identified by means of brackets. All written submissions, except for confidential business information, will be made available for inspection by interested parties.

As requested by the Committee, the Commission will not include any confidential business information in the report that it sends to the Committee. However, all information, including confidential business information, submitted in this investigation may be disclosed to and used: (i) By the Commission, its employees and Offices, and contract personnel (a) for developing or maintaining the records of this or a related proceeding, or (b) in internal investigations, audits, reviews, and evaluations relating to the programs, personnel, and operations of the Commission including under 5 U.S.C. Appendix 3; or (ii) by U.S. government employees and contract personnel (a) for cybersecurity purposes or (b) in monitoring user activity on U.S. government classified networks. The Commission will not otherwise disclose any confidential business information in a way that would reveal the operations of the firm supplying the information.

Summaries of Written Submissions: Persons wishing to have a summary of their position included in the report should include a summary with their written submission and should mark the summary as having been provided for that purpose. The summary should be clearly marked as "summary for inclusion in the report" at the top of the page. The summary may not exceed 500 words, should be in MS Word format or a format that can be easily converted to MS Word, and should not include any confidential business information. The summary will be published as provided if it meets these requirements and is germane to the subject matter of the investigation. The Commission will list the name of the organization furnishing the summary and will include a link to the Commission's Electronic Document Information System (EDIS) where the full written submission can be found.

By order of the Commission.

Issued: February 12, 2020.

Lisa Barton,

Secretary to the Commission.

[FR Doc. 2020–03191 Filed 2–18–20; 8:45 am]

BILLING CODE 7020–02–P

DEPARTMENT OF JUSTICE

[OMB Number 1110–0052]

Agency Information Collection Activities; Proposed eCollection eComments Requested; Extension of a Currently Approved Collection; Applicant Information Form (1–783)

AGENCY: Criminal Justice Information Services Division, Federal Bureau of Investigation, Department of Justice.

ACTION: 60-Day notice.

SUMMARY: Department of Justice (DOJ), Federal Bureau of Investigation, Criminal Justice Information Services Division, will be submitting the following information collection request to the Office of Management and Budget (OMB) for review and approval in accordance with the Paperwork Reduction Act of 1995.

DATES: The Department of Justice encourages public comment and will accept input until April 20, 2020.

FOR FURTHER INFORMATION CONTACT: If you have additional comments especially on the estimated public burden or associated response time, suggestions, or need a copy of the proposed information collection instrument with instructions or additional information, please contact Gerry Lynn Brovey, Supervisory Information Liaison Specialist, Federal Bureau of Investigation, Criminal Justice Information Services Division, 1000 Custer Hollow Road; Clarksburg, West Virginia 26306; phone: 304–625–4320 or email *glbrovey@fbi.gov.* Written comments and/or suggestions can also be sent to the Office of Management and Budget, Office of Information and Regulatory Affairs, Attention Department of Justice Desk Officer, Washington, DC 20503 or sent to *OIRA_submissions@omb.eop.gov.*

SUPPLEMENTARY INFORMATION: Written comments and suggestions from the public and affected agencies concerning the proposed collection of information are encouraged. Your comments should address one or more of the following four points:

- —Evaluate whether the proposed collection of information is necessary for the proper performance of the functions of the Bureau of Justice Statistics, including whether the information will have practical utility;
- —Evaluate the accuracy of the agency's estimate of the burden of the proposed collection of information, including the validity of the methodology and assumptions used;
- —Evaluate whether and if so how the quality, utility, and clarity of the information to be collected can be enhanced; and
- —Minimize the burden of the collection of information on those who are to respond, including through the use of appropriate automated, electronic, mechanical, or other technological collection techniques or other forms of information technology, *e.g.,* permitting electronic submission of responses.

Overview of This Information Collection

1. *Type of Information Collection:* Extension of a currently approved collection.

2. *The Title of the Form/Collection:* Applicant Information Form.

3. *The agency form number, if any, and the applicable component of the Department sponsoring the collection:* 1–783. The applicable component within the Sponsoring component: Department of Justice, Federal Bureau of Investigation, Criminal Justice Information Services Division.

4. *Affected public who will be asked or required to respond, as well as a brief abstract:* Primary: Individuals. This collection is necessary for individuals to request a copy of their personal identification record to review it or to obtain a change, correction, or an update to the record.

5. *An estimate of the total number of respondents and the amount of time estimated for an average respondent to respond:* Annually, the FBI receives 125,000 identification requests, therefore there are 125,000 respondents. The form requires 5 minutes to complete.

6. *An estimate of the total public burden (in hours) associated with the collection:* There are an estimated 10,417 total annual burden hours associated with this collection.

If additional information is required contact: Melody Braswell, Department Clearance Officer, United States Department of Justice, Justice Management Division, Policy and Planning Staff, Two Constitution Square, 145 N Street NE, 3E.405B, Washington, DC 20530.

Dated: February 12, 2020.

Melody Braswell,

Department Clearance Officer for PRA, U.S. Department of Justice.

[FR Doc. 2020–03174 Filed 2–18–20; 8:45 am]

BILLING CODE 4410–CW–P

DEPARTMENT OF JUSTICE

[OMB Number 1103–0016]

Agency Information Collection Activities: Proposed Collection; Comments Requested: Certification of Identity

AGENCY: Office of Information Policy, Department of Justice.

ACTION: 60-Day notice.

SUMMARY: The Department of Justice (DOJ), Justice Management Division, will be submitting the following information collection request to the Office of Management and Budget (OMB) for review and approval in accordance with the Paperwork Reduction Act of 1995. The proposed information collection is published to obtain comments from the public and affected agencies.

DATES: Comments are encouraged and will be accepted for 60 days until April 20, 2020.

FOR FURTHER INFORMATION CONTACT: If you have additional comments especially on the estimated public burden or associated response time, suggestions, or need a copy of the proposed information collection instrument with instructions or additional information, please contact Evie Sassok, 145 N Street NW, Washington, DC 20530. Phone: 202–514–0022.

SUPPLEMENTARY INFORMATION: Written comments and suggestions from the public and affected agencies concerning the proposed collection of information are encouraged. Your comments should address one or more of the following four points:

- —Evaluate whether the proposed collection of information is necessary for the proper performance of the information concerning the Commission may also be obtained by accessing its website (*https://www.usitc.gov*).

Background: As requested by the Committees, the Commission will conduct an investigation and prepare a report that, to the extent practical, identifies imported goods related to the response to COVID–19, their source countries, tariff classifications, and applicable rates of duty. For each product that the Commission so identifies, the Commission will seek to provide:

1. The 10-digit HTS code for the article;
2. its legal description;
3. general duty rate;
4. any special or additional rates of duty imposed on the article, the dates on which the rates were imposed, and the authorities under which they were imposed;
5. whether any such duties have been suspended and, if so, the date of suspension as well as how long the suspension is scheduled to last;
6. the total rate of duty imposed on such article, including any special or additional rate of duty; and
7. the major countries of origin for each such article, and the import value of each such article from each country for the years 2017–2019.

The Committees asked that the Commission deliver the report as soon as possible, but no later than April 30, 2020. The Committees further requested that the Commission provide any relevant updated data runs on its website through June 30, 2020. The Committees stated that they intend to make the Commission's report available to the public and asked that the report not include any confidential business information.

Confidential Business Information. As requested by the Committees, the Commission will not include any confidential business information in the report that it sends to the Committees. However, all information, including confidential business information, submitted in this investigation may be disclosed to and used: (i) By the Commission, its employees and Offices, and contract personnel (a) for developing or maintaining the records of this or a related proceeding, or (b) in internal investigations, audits, reviews, and evaluations relating to the programs, personnel, and operations of the Commission including under 5 U.S.C. Appendix 3; or (ii) by U.S. government employees and contract personnel (a) for cybersecurity purposes or (b) in monitoring user activity on U.S. government classified networks. The Commission will not otherwise disclose any confidential business information in a way that would reveal the operations of the firm supplying the information.

By order of the Commission.

Issued: April 13, 2020.

William Bishop,

Supervisory Hearings and Information Officer.

[FR Doc. 2020–08144 Filed 4–16–20; 8:45 am]

BILLING CODE 7020–02–P

INTERNATIONAL TRADE COMMISSION

[Investigation No. 332–574]

Renewable Electricity: Potential Economic Effects of Increased Commitments in Massachusetts; Notice of Postponement of Public Hearing, Dates for Filing Written Submissions

AGENCY: United States International Trade Commission.

ACTION: Notice of postponement of public hearing.

SUMMARY: Notice is hereby given that the U.S. International Trade Commission has postponed, to dates to be determined, the public hearing and the filing dates for written submissions in Investigation No. 332–574, *Renewable Electricity: Potential Economic Effects of Increased Commitments in Massachusetts* due to COVID–19.

SUPPLEMENTARY INFORMATION: The Commission published notice of institution of the above referenced investigation in the **Federal Register** on February 19, 2020 (85 FR 9479, February 19, 2020). In that notice, the Commission announced that it would hold a public hearing on May 7, 2020, and it also set dates by which requests to appear at the hearing, briefs, and other written submissions should be filed. However, due to COVID–19, the Commission has postponed the hearing to a date to be determined. The Commission will publish notice in the **Federal Register**, when circumstances permit, of a new date for the public hearing as well as new dates by which requests to appear at the hearing, briefs, and other written submissions should be filed. Pending publication of new dates, the Commission welcomes the filing of any written submissions relevant to this investigation. Such submissions must be filed in electronic form; the Commission cannot accept paper filings at this time.

FOR FURTHER INFORMATION CONTACT: Project Leader Diana Friedman (202–205–3433 or *diana.friedman@usitc.gov*) or Deputy Project Leader Patricia Mueller (202–205–2599 or *patricia.mueller@usitc.gov*) for information specific to this investigation. For hearing-related information, contact Lisa R. Barton, Secretary to the Commission, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436, telephone (202) 205–2000. For information on the legal aspects of this investigation, contact William Gearhart of the Commission's Office of the General Counsel (202–205–3091 or *william.gearhart@usitc.gov*). The media should contact Margaret O'Laughlin, Office of External Relations (202–205–1819 or *margaret.olaughlin@usitc.gov*). Hearing-impaired individuals may obtain information on this matter by contacting the Commission's TDD terminal at 202–205–1810. General information concerning the Commission may also be obtained by accessing its internet server (*http://www.usitc.gov*). Persons with mobility impairments who will need special assistance in gaining access to the Commission should contact the Office of the Secretary at 202–205–2000.

By order of the Commission.

Issued: April 13, 2020.

Lisa Barton,

Secretary to the Commission.

[FR Doc. 2020–08104 Filed 4–16–20; 8:45 am]

BILLING CODE 7020–02–P

INTERNATIONAL TRADE COMMISSION

[Investigation No. 332–575]

Seafood Obtained via Illegal, Unreported, and Unregulated Fishing: U.S. Imports and Economic Impact on U.S. Commercial Fisheries; Notice of Postponement of Public Hearing, Dates for Filing Written Submissions

AGENCY: United States International Trade Commission.

ACTION: Notice of postponement of public hearing.

SUMMARY: Notice is hereby given that the U.S. International Trade Commission has postponed, to dates to be determined, the public hearing and filing dates for written submissions in Investigation No. 332–575, *Seafood Obtained via Illegal, Unreported, and Unregulated Fishing: U.S. Imports and Economic Impact on U.S. Commercial Fisheries* due to COVID–19.

SUPPLEMENTARY INFORMATION: The Commission published notice of institution of the investigation in the **Federal Register** on January 31, 2020

Appendix C
Calendar of Hearing Witnesses

CALENDAR OF PUBLIC HEARING

Those listed below appeared as witnesses at the United States International Trade Commission's hearing:

Subject: Renewable Electricity: Potential Economic Effects of Increased Commitments in Massachusetts

Inv. No.: 332-574

Date & Time: July 29, 2020 – 9:30 a.m.

Sessions were be held in connection with this investigation via videoconference and/or through written testimony.

EMBASSY APPEARANCE:

Embassy of Canada
Washington, DC

Craig Weichel, Counsellor

Andre Bernier, Senior Director for Electricity, Natural Resource Canada in Ottawa

INDUSTRY PANEL #1

ORGANIZATION AND WITNESSES:

Executive Office of Energy and Environmental Affairs
Massachusetts Department of Energy Resources ("DOER")
Boston, MA

The Honorable Patrick C. Woodcock, Commissioner

Arent Fox LLP
Washington, DC
on behalf of

Government of Québec

Patrick McSweeney, Director of Trade Disputes, Ministry of Economy and Innovation, Government of Québec

Louis-Philippe Coulombe, Legal Counsel, Government of Québec

INDUSTRY PANEL #1 (continued)

ORGANIZATION AND WITNESSES:

Marie-Claude Francoeur, Québec Delegate to New England,
Québec Government Office in Boston

Matthew J. Clark)
Nancy A. Noonan) – OF COUNSEL
Jessica R. DiPietro)

Arnold & Porter Kaye Scholer LLP
Washington, DC
on behalf of

Hydro-Québec

Sophie Brochu, President and Chief Executive Officer,
Hydro-Québec

Martin Imbleau, Vice President, Corporate Strategy and
Business Development, Hydro-Québec

Gary Sutherland, Director, Strategic Affairs, Northeast
Markets, Hydro-Québec

Francois Ramsay, General Counsel, Hydro-Québec

Lynn M. Fischer Fox)
) – OF COUNSEL
Michael Gerrard)

ISO New England
Holyoke, MA

Anne George, Vice President, External Affairs & Corporate
Communications

Jeff Turcotte, Senior Advisor, External Affairs

INDUSTRY PANEL #2

ORGANIZATION AND WITNESSES:

Dentons US LLP
Washington, DC
on behalf of

Canadian Electricity Association ("CEA")

Francis Bradley, President and Chief Executive Officer

Gordon D. Giffin, Partner

Andrew Shaw) – OF COUNSEL

Sierra Club
Washington, DC

Mark Kresowik, Deputy Regional Director

North American Megadam Resistance Alliance ("NAMRA")
Buffalo, NY

Margaret E. Sheehan, Coordinator

-END-

Appendix D
Summary of Views of Interested Parties

Views of Interested Parties

Interested parties had the opportunity to file written submissions to the Commission in the course of this investigation and to provide summaries of the positions expressed in the submissions for inclusion in this report. This appendix contains these written summaries, provided that they meet certain requirements set out in the notice of investigation. The Commission has not edited these summaries. This appendix also contains the names of other interested parties who filed written submissions during investigation but did not provide written summaries. A copy of each written submission is available in the Commission's Electronic Docket Information System (EDIS), https://www.edis.usitc.gov. The Commission also held a public hearing in connection with this investigation on July 29, 2020. The full text of the transcript of the Commission's hearing is also available on EDIS.

Written Submissions

AVANGRID

No written summary. Please see EDIS for full submission.

Canadian Electricity Association

No written summary. Please see EDIS for full submission.

Center for Climate and Energy Solutions

No written summary. Please see EDIS for full submission.

Gordon Giffin

No written summary. Please see EDIS for full submission.

Government of Canada

No written summary. Please see EDIS for full submission.

Government of Manitoba

No written summary. Please see EDIS for full submission.

Government of Quebec

On behalf of the Government of Québec, an interested party in this proceeding, we hereby submit the attached Executive Summary, for inclusion in the Commission's report, in accordance with U.S. International Trade Commission's scheduling notice (85 Fed. Reg. 35329 (June 9, 2020)) and hearing held on July 29, 2020, in the above-referenced proceedings.
Québec is on the forefront of renewable energy and reductions in greenhouse gas emissions. With over three million bodies of water holding 3 percent of the Earth's freshwater reserves, Québec has access to abundant, reliable, and affordable hydroelectric power.

Hydroelectric power generated in Québec has long been exported to other provinces and U.S. states. The Government of Québec has created a policy framework, most recently through its 2030 Energy

Policy, that promotes and facilitates reliable, renewable energy to reduce greenhouse gas emissions and deliver on its promises of a green economy for all Québecers. Hydroelectricity, defined by law as renewable, is a major component of the decarbonization of Québec. Hydro-Québec is the regulated power utility in Québec that operates within this policy framework. The success of Québec's renewable energy policies and reductions in greenhouse gas emissions positively impacts Québec's economic viability.

The Government of Québec has been responsibly developing its vast hydraulic resources, working with local populations to expand its distribution network. This push in favor of the development of hydroelectric assets ensured that, today, Québecers have access to a reliable supply of energy, composed almost exclusively of hydroelectricity transmitted from an already- installed base.

The Government of Québec is a long-standing and reliable partner of the United States, particularly in the North East. In 1996, as part of a wider energy policy announcement, Québec adjusted its regulatory system, creating the Régie de l'Énergie. The Régie ensures that there is sufficient energy for the residents of Québec, at fair and reasonable prices. The creation of the Régie ensured Québec's compliance with Federal Energy Regulatory Commission orders, allowing for reliable interconnection with the United States.

Looking ahead, Québec's commitment to a sustainable future is achieved with innovative projects contributing to sustainable reliance on renewable clean energy, focused on individual communities and their economic growth. Québec's energy policies respect domestic laws requiring careful assessment of such projects, including analysis of environmental and social impacts, direct and indirect market impacts, greenhouse gas reduction, ensuring that energy projects have a positive impact, that prices are fair to consumers and competitive in the market. These projects are specific to and involve the communities impacted.

The involvement of communities includes involvement and agreement with indigenous peoples, consistent with Quebec's constitutional obligations and the nation-to-nation relationships between the government and indigenous peoples. For example, the 1975 James Bay and Northern Québec Agreement, the 2002 Agreement Respecting a New Relationship Between the Cree Nation and the Government of Québec, the 2012 Agreement on Governance in the Eeyou Istchee James Bay Territory, and the 2020 Québec and the Cree Nation Memorandum of Understanding, create new opportunities for their populations. Québec's collaborative development process enables long-term solutions for all.

Hydro-Quebec

The United States and Canada have a long history of mutually beneficial trade in electricity. For decades, Hydro-Québec has been an active participant in the regional electric power system, exporting power to New England, New York, and neighboring Canadian provinces. Hydro-Québec's exports provide affordable, clean power to customers in the Northeastern United States and contribute to the reliability and stability of the regional electrical grid.

Hydro-Québec has hydropower capacity to meet its obligations to export customers as well as new long-term contracts with Massachusetts. The company's installed hydropower capacity is approximately 37,000 MW, of which 5000 MW has been added since 2003. The expansion—planned in the early

2000s—was done in anticipation of growing demand for clean energy with low greenhouse gas emissions in Québec and other Canadian provinces, as well as New England and New York.

New long-term commitments to Massachusetts and New England will not require other Hydro-Québec customers to shift to other sources of electricity—particularly not fossil fuels. Hydro-Québec's capacity is sufficient to meet its obligations. Furthermore, any new sources of supply that Hydro-Québec might acquire would not include fossil fuels. The company already has more than 10,000 MW of wind and other non-hydro renewables under contract in its portfolio.

Hydro-Québec's reservoirs have among the lowest life-cycle greenhouse gas emissions, with an average emissions rate on par with nuclear or wind, and much lower than natural gas and other forms of thermal generation. Hydropower is widely recognized as a renewable resource and satisfies the Massachusetts Clean Energy Standard (CES) for electricity needed to meet the state's strict greenhouse gas emissions reduction requirements.

Imports from Hydro-Québec through long-term contracts with Massachusetts will provide reliable, firm energy and environmental attributes at a predictable, affordable price. The recent New England Clean Energy Connect (NECEC) long-term contracts are expected to:

1. provide savings to consumers of 4 cents/kWh, or $40/MWh, over the term of the contract, with total net benefits of $4 billion;
2. result in approximately 2-4% reduction in customers' monthly bills; and
3. provide an average 1.5 cents/kWh of direct savings for ratepayers over buying the same amount of energy and CES compliance in the market over the life of the contracts.

The contract price includes not only the price of electricity but also the value of the environmental attributes required to meet Massachusetts' greenhouse gas emissions reduction obligations. Evaluations of the contracts conclude the NECEC will provide electricity to Massachusetts ratepayers at low prices and reduce energy costs for the entire region by increasing regional supply.

Long-term contracts for hydropower complement the development of intermittent renewables in New England. As solar and wind power development increases, Hydro-Québec's easily dispatchable power can flow energy to the grid when intermittent renewables cannot, and, when supply is abundant, "store" power in its reservoirs. The NECEC power line, financed by long-term contracts, is necessary to expand transmission capacity and allows hydropower to function as a "battery" for intermittent renewables in the future.

ISO New England

No written summary. Please see EDIS for full submission.

Massachusetts Department of Energy Resources

No written summary. Please see EDIS for full submission.

New England Power Generators Association

No written summary. Please see EDIS for full submission.

North American Megadam Resistance Alliance

We have ten years to prevent irreversible damage from climate change. In the words of U.N. General Assembly President Garces of Ecuador "we are the last generation that can prevent irreparable damage to our planet" and must act for future generations guided by principles of climate justice. Continued Canadian hydropower development perpetuates colonialism and injustice forcing Indigenous and local communities to suffer the negative impacts of energy production that does not deliver the benefits promised.

"Rivers are essential sources of environmental health, economic wealth and human well- being" and river connectivity extends in four dimensions: longitudinally, laterally, vertically and temporally.[1] The Canadian Government's myopic view is that rivers are merely "hydroelectricity capacity" with "only" 40 percent developed, an additional four gigawatts currently under construction and with 60% remaining available to be exploited for profits and disguised as clean energy. Canada's hydropower energy policy is a death knell for rivers, communities and the planet. It is a shameful example of what 21st century renewable energy is not. Canadian hydropower does not deliver promised economic benefits to its own citizens as the financially disastrous Site C, Keeyask and Muskrat Falls demonstrate and in fact harms communities.

Canadian's regulatory review process for hydropower development is a sham. Projects are routinely exempted from review. When review does occur, it fails to meet basic standards for accountability as documented at Site C and Muskrat Falls. U.S. regulators do not undertake their own independent review of the impacts of this hydropower production allowing projects to be segmented, thereby escaping scrutiny under U.S. environmental protection laws. U.S. hydropower energy policy is outdated and at odds with climate science and international principles of equity and justice.

NAMRA urges the ITC to review all aspects of impacts of Canadian hydroelectricity imports and recommend:

1. Bilateral renegotiation of the 2018 side letter to the USMCA/CUSMA on energy matters to replace the current flawed definition "renewable energy"[2] on hydropower;
2. A carbon accounting of greenhouse gas emissions of existing and proposed Canadian hydropower imports;
3. A directive to end all greenwashing of existing and proposed Canadian hydroelectricity imports;
4. A bilateral truth and reconciliation process to redress past and present harms to Indigenous people caused by Canada's hydropower development and the U.S. consumption of that hydropower; and

A recommendation that Massachusetts incorporate principles of climate justice, equity and inclusion into its energy policy for Canadian hydroelectricity imports.

Royal Danish Embassy

No written summary. Please see EDIS for full submission.

Dr. Mary Jane McCallum, Member of the Senate, Parliament of Canada

No written summary. Please see EDIS for full submission.

Sierra Club

No written summary. Please see EDIS for full submission.

WaterPower Canada

WaterPower Canada (WPC) is the national, not-for-profit trade association dedicated to representing the waterpower industry in Canada. “Waterpower” (or “hydropower”) converts kinetic energy in falling or flowing water, into mechanical energy, and then into electrical energy (or “hydroelectricity”). While there are a number of ways to generate power from moving water, in all cases the energy is “renewable” (“derived from a natural process that is replenished at a rate that is equal to or faster than the rate at which they are consumed”). Water is not consumed, depleted or wasted in the process.

Canada has one of the largest renewable supplies of freshwater in the world. Probably no country in the world has as much of its surface area covered by freshwater as does Canada, and Canadian rivers discharge close to 9% of the world’s renewable water supply on an annual basis (while Canada has less than 1% of the world’s population). Due to the abundance of this renewable energy resource, hydropower now produces approximately 60 per cent of Canada’s total electricity annually.

Further growth in annual hydropower generation in Canada can continue to be achieved through new transmission capacity to increase market access; efficiency enhancements and generation capacity additions during refurbishment and redevelopment of existing units and sites; and development of new hydropower generation projects.

Canadian hydropower can play a significant role supporting New England and other U.S. states to achieve their clean and renewable energy goals and commitments for the following two reasons:

1. Canadian hydropower has ultra-low greenhouse gas emissions. The lifecycle GHG emissions from Canadian hydroelectricity are minimal in comparison to fossil-fueled electricity generation. While there are variances from facility to facility, a range of 2 – 17 t CO2e / GWh is representative of the majority Canadian hydroelectricity generation fleet. This is comparable to those from wind-powered electricity generation, for example, which is 12 t CO2e / GWh, and significantly lower than fossil fuel generation, which is in the range of 461 – 1,001 t CO2e / GWh.
2. The flexible energy dispatchability and reserves, dependable capacity and long-duration energy storage that the Canadian hydropower generation fleet can provide can support supply adequacy, and grid reliability and resilience, as the penetration of variable renewable energy resources (such as wind and solar energy) increases in the electricity supply-mix.

Across the world, regions with abundant hydroelectricity supply regularly support their neighbors to decarbonize their electricity sectors. Due to the abundance of Canada’s hydroelectricity and its proximity to U.S. populations and electricity demand, there remains significant potential for it to play a larger and more important role in future.

WIRES

No written summary. Please see EDIS for full submission.

Appendix E
Details of the Economic Model

Introduction

This appendix describes in more technical detail the economic model and data underlying the estimates in chapter 3. The appendix begins with a review of two studies which also examine some aspects of Massachusetts's recent goals and commitments that are the focus of this report. The rest of the appendix is divided into four broad sections, which discuss model inputs, model outputs, data sources, and additional results.

The section on model inputs provides more specifics about the calculation of model inputs, including details of how the load shares of the goals and commitments and of hydroelectricity are calculated; how the model calculates the way electricity sourcing shifts to meet the clean and renewable standards; how the compliance credits are modeled; and some background information on the five scenarios taken from the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO).

The model outputs section supplies additional details on the calculations of the key model results: effects on the price of wholesale generation, effects on the costs to Massachusetts consumers, effects on the costs to New England consumers, and effects on Massachusetts emissions.

The data sources section provides details about the sources for the data in the model, including more detail on calculations used throughout.

The additional results section presents results to supplement the analysis in chapter 3. First, it reports additional estimates of the greenhouse gas emissions, giving model projections for the four alternative scenarios. Then, it presents a sensitivity analysis of the modeling assumptions outlined in table 3.2. These three sensitivity analyses focus on (1) changing the marginal resource used to satisfy renewable portfolio standard (RPS) and clean energy standard (CES) demand; (2) changing how much access Massachusetts has to clean energy imports; and (3) changing the assumption about the number of residential and commercial customers.

As was the case in chapter 3, for this appendix, "renewable" refers specifically to resources that qualify for Massachusetts's RPS commitment and "clean" refers to resources that qualify for Massachusetts's CES commitment, unless otherwise specified.

Related Studies of Massachusetts's Recent Goals and Commitments

Two other studies have considered the potential effects of certain aspects of Massachusetts's renewable and clean energy commitments on ratepayers and greenhouse gas emissions in the past five years. The first ("Massachusetts Energy study") was prepared by Synapse Energy Economics and Sustainable Energy Advantage at the request of Northeast Clean Energy Council Institute and Massachusetts Energy Consumers Alliance. Published in May 2017, the study compares a baseline case to potential modifications to Massachusetts's and Connecticut's RPS commitments. For Massachusetts, the baseline case includes the 2016 Act to Promote Energy Diversity, which committed Massachusetts to acquiring long-term contracts for both offshore wind and for clean energy;[475] the Global Warming Solutions Act (GWSA) emissions commitments, which set economy-wide targets to reduce greenhouse gas emissions by 80 percent of their 1990 levels by 2050; and Massachusetts's prior commitment to increasing its RPS by 1 percentage points per year through 2050. The study then considers, among other things, the effect of altering Massachusetts's and Connecticut's RPS commitments three ways: (1) an increase of 2 percentage points per year in Massachusetts's RPS; (2) an increase of 2 percentage points per year in Massachusetts's RPS and an increase of 1.5 percentage points per year of Connecticut's RPS; and (3) an increase of 3 percentage points per year in Massachusetts's RPS and an increase of 1.5 percentage points per year in Connecticut's RPS.[476]

The second study ("Massachusetts Senate study"), published in June 2018, was prepared by the Applied Economics Clinic and Sustainable Energy Advantage at the request of the Massachusetts Senate Committee on Global Warming and Climate Change. This study analyzes the effect of provisions proposed in drafts of the 2018 Act to Promote Clean Energy: (1) an acceleration to Massachusetts's RPS from 1 percentage point per year to 3 percentage points per year, (2) a commitment to building 5,000 megawatts of offshore wind by 2035, (3) reaching 1,766 MW of battery storage in-state by 2025, and (4) removing the cap on net metering of electricity (the selling of electricity back to the grid) from small solar installations.[477] The 2018 Act ultimately included an acceleration of 2 percentage points per year, rather than the 3 percent acceleration examined in this study. Additionally, the 2018 Act set a goal for potential offshore wind procurement at an additional 1,600 megawatts, instead of the full 5,000 megawatts modeled in the report.[478]

Both the 2017 Massachusetts Energy and 2018 Massachusetts Senate reports are built using multiple proprietary models developed by private organizations: the EnCompass model, which models electricity sector capacity buildout and generation dispatch, and the Renewable Energy Market Outlook model, which models renewable energy buildout and forecasts REC prices. These are large electricity system models that simulate the effect of renewable energy sourcing commitments on a variety of economic indicators, including the impact on greenhouse gas emissions and on retail electricity rates. Their models project the effects of the respective commitments out to 2030 under several alternative scenarios to reflect uncertainty over future market conditions.

The 2017 Massachusetts Energy study found that increasing the RPS in Massachusetts to 2 percentage points per year would result in an increase in in-region renewable electricity capacity of between 300 and 1,100 megawatts (MW).[479] The study also found that increasing Massachusetts's RPS commitment to 2 percentage points per year is projected to reduce wholesale electricity prices by an average 0.3 percent per year between 2025 and 2030.[480] As for retail prices, the study found an additional monthly cost to consumers of between $0.10 and $0.20 from 2018 to 2030 when the RPS was increased to 2 percentage points per year.[481] This study also projected a baseline decrease in electricity sector

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[475] Summarized in more detail in a footnote at the beginning of chapter 3.
[476] Knight et al., An Analysis of the Massachusetts Renewable Portfolio Standard, May 2017, iii, v.
[477] Stanton et al., An Analysis of the Massachusetts 2018 'Act,' June 21, 2018, i.
[478] An Act to Advance Clean Energy, 2018 Mass. Acts 227, § 12, 21.
[479] Knight et al., An Analysis of the Massachusetts Renewable Portfolio Standard, May 2017, 24. More information on the supply-side commitments of the 2016 Act are available in a footnote at the beginning of this chapter.
[480] Knight et al., An Analysis of the Massachusetts Renewable Portfolio Standard, May 2017, 26.
[481] Knight et al., An Analysis of the Massachusetts Renewable Portfolio Standard, May 2017, 30.

emissions by 2030 of 60 percent over 1990 levels, while the increase in Massachusetts's RPS to 2 percentage points per year would result in a reduction in emissions of 62 percent of the 1990 levels.[482]

The 2018 Massachusetts Senate study, by contrast, found that the commitments modeled would result in additional renewable generation capacity buildout of approximately 1,500 MW in Massachusetts.[483] This study predicted a reduction in emissions due to the commitments equal to 0.6 million metric tons of greenhouse gas emissions.[484] Finally, the study predicted an increase in Massachusetts's average household electricity bills of 44 cents per month (or 0.25 cents per kWh) for the first three years of the forecast, with prices falling below their initial value thereafter. On average, this would result in a reduction of consumer bills by about 1.5 percent over the 2018 to 2030 window.[485]

Model Inputs

Calculation of Load Shares for Goals and Commitments, Hydroelectricity

The Commission's model focuses on the effects of Massachusetts's updated Class I renewable portfolio standards.[486] These standards do not mandate that a certain share of electricity generation in Massachusetts or New England come from clean or renewable sources.[487] Rather, they require that Massachusetts utilities purchase or earn enough compliance credits to cover a mandated share of the electricity load that they serve. Massachusetts's RPS can be satisfied by renewable resources, including wind and solar, located in New England or interconnected regions. The Class I RPS commitment increases to 55 percent of Massachusetts's load by 2050. Massachusetts's CES commitment is higher, rising to 80 percent of Massachusetts load by 2050. It can be satisfied by hydroelectric generation (built after 2010) or nuclear generation (built after 2010), as well as by any Class I renewable resources.

In the tables and formulas below, S_o represents the initial (or "old") RPS share of Massachusetts's load, S_u represents the updated RPS share, and S_c represents the CES share. In each year, $S_c < S_u < S_c$. Table E.1 reports the shares for 2030, 2035, 2040, 2045, and 2050.[488]

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[482] Knight et al., An Analysis of the Massachusetts Renewable Portfolio Standard, May 2017, 30.
[483] Stanton et al., An Analysis of the Massachusetts 2018 'Act,' June 21, 2018, 6.
[484] Stanton et al., An Analysis of the Massachusetts 2018 'Act,' June 21, 2018, i.
[485] Stanton et al., An Analysis of the Massachusetts 2018 'Act,' June 21, 2018, 9.
[486] The Class II RPS did not change after 2016, so Class II commitments are not part of the estimated effects of the policy changes in 2017–19. For more information about Massachusetts's Class II commitments, see chapter 2 of this report.
[487] References to "renewable" and "clean" in this appendix refer to resources eligible for the Massachusetts commitments specifically. This means, for example, that large-scale hydroelectricity is considered clean but not renewable. See chapter 2 of this report for more details on qualifying sources of electricity under Massachusetts's commitments.
[488] Again, note that the old RPS commitments, S_o, and the updated RPS commitments, S_u, represent the Class I commitments by Massachusetts, which also qualify for the CES commitments. Massachusetts's Class II commitments, which account for approximately 6 percent of total sales, do not qualify to fill the clean energy commitments in the CES, which is why the modeling examines the resources that will potentially fill the share $S_c - S_u$. For further discussion of the classes of resources in Massachusetts's commitments, see chapter 2 of this report.

Table E.1 Renewable and clean energy requirements (as a percentage of total load)

Share	2030	2035	2040	2045	2050
S_o	25	30	35	40	45
S_u	35	40	45	50	55
S_c	40	50	60	70	80
$S_c – S_u$	5	10	15	20	25

Source: State of Massachusetts, "Program Summaries: Summaries of all the Renewable and Alternative Energy Portfolio Standard Programs," (accessed September 16, 2020); "Clean Energy Standard," 310 CMR 7.75 (2017), 509, 513–14; "Act to Advance Clean Energy (H4857)," 2018,; "Renewable Energy Portfolio Standard for Retail Electricity Suppliers," Mass. Gen. Laws ch. 25A, § 11 F.

As discussed in a footnote in the "Massachusetts's Recent Goals and Commitments" section of chapter 3, the renewable and clean energy commitments modeled in this report generally apply to investor-owned utilities, not municipally owned utilities. Municipally owned utilities account for about 14.1 percent of Massachusetts's total electricity demand.[489]

Table E.2 reports S_h, the share of non-municipally provided load supplied by hydroelectric power in each year in the AEO Reference case, including imports from Canada and New York. Given that the AEO does not break imports down by generation source, the share of total imports coming from hydroelectric generation is calculated using reported shares of hydroelectricity in New England imports available on the NEPOOL (New England Power Pool) General Information System. The NEPOOL information shows that for the most recent available data, 24.8 percent of electricity imports from New York State and 96.0 percent of electricity imports from Quebec were from hydroelectric generation.[490] Hydroelectricity generated in New England is not counted in the calculation of S_h due to a simplifying assumption that all New England hydroelectric facilities came online before 2011 and would not qualify to fill Massachusetts's CES commitments.

Table E.2 Projected share from hydroelectric power, Reference case (as a percentage of total load)

Share	2019	2030	2035	2040	2045	2050
S_h	16.2	14.6	14.0	14.3	14.2	14.2

Source: USITC calculations.

Note that although table E.2 shows a decrease in the share of hydroelectric power (hydro) in total load over the 2019 to 2050 timeframe, the projected levels of hydro are relatively stable, starting at 7.5 TWh in 2019, initially falling slightly, and ending at 7.8 TWh in 2050.

Shift in the Electricity Sourcing to Meet the Standards

Since hydroelectric generation qualifies for Massachusetts's CES, hydroelectricity satisfies most, and in some years all, of the gap between S_u and S_c. For the first two periods of the model, tables E.1 and E.2 show that the entire commitment of Massachusetts's CES above its RPS would be satisfied by imported hydroelectricity, since $S_h > S_c – S_u$. The gap between S_h and $S_c – S_u$ would be less than 1 percent in 2040 and would then rise to become closer to 5 and 10 percent in 2045 and 2050, respectively.

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[489] "Act to Advance Clean Energy (H4857)" (2018); "Clean Energy Standard," 310 CMR 7.75 (2017), 509, 513–14; EIA, Table 9: Retail Electricity Sales Statistics, (accessed September 16, 2020).

[490] NEPOOL General Information System, System Mix (accessed November 3, 2020).

The model assumes that any difference between Massachusetts's CES and RPS commitment that is not satisfied by hydroelectricity would be satisfied by building additional RPS-eligible generation in New England. It is not likely that imports of hydroelectricity would increase to fill this gap, since there are international transmission constraints that would likely persist for decades into the future.[491] Furthermore, building new nuclear or hydroelectric generation in New England is not projected to be cost effective when compared to building renewables like wind and solar.[492]

Tables E.3 and E.4 report the projected generation mix in the New England region in the AEO 2020 Reference case as supporting evidence for the argument that wind and solar, not hydroelectricity, will meet the additional demand for clean energy. Electricity generation in AEO projections is divided into two major categories: generation by the electric power sector (table E.3), which is generation by utility-scale providers that then distribute electricity to the end users, and generation by the end-use sector (table E.4), which is generation by the end users themselves. For generation in the electric power sector, the greatest growth is projected in production from onshore and offshore wind, while hydroelectric power and other renewable sources remain relatively constant. Growth in offshore wind is projected to occur rapidly over the next 10 years and then level off. A similar pattern is projected in onshore wind. For generation in the end-use sector, most of the projected increase beyond 2030 is in solar generation, representing on-site solar installations (including rooftop solar generation).[493] The AEO projects that other renewable and clean energy sources will remain relatively constant.

Table E.3 Projected renewable generation mix in the electric power sector in the New England region, Reference case (in terawatt-hours)

Type of generation	2019	2030	2035	2040	2045	2050
All renewable and clean	10.6	43.3	45.1	45.5	45.6	48.0
Solar (photovoltaic)	1.5	2.0	2.0	2.0	2.1	2.4
Offshore wind	0.1	7.1	8.8	8.8	8.8	8.8
Onshore wind	3.3	26.7	26.7	27.1	27.1	28.9
Wood and other biomass	3.3	3.6	3.6	3.6	3.6	3.6
Municipal waste	2.4	4.0	4.0	4.0	4.0	4.3

Source: Compiled from AEO 2020, Reference Case estimates.

Note: The AEO defines the electric power industry as "stationary and mobile generating units that are connected to the electric power grid and can generate electricity. The electric power industry includes the 'electric power sector' (utility generators and independent power producers) and industrial and commercial power generators, including combined-heat-and-power producers, but excludes units at single-family dwellings." EIA, "Glossary" (accessed September 21, 2020).

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[491] International transmissions connections have historically been very stable. For example, the last transmission line between New York or New England and Quebec was constructed 30 years ago (though it is worth noting there are plans underway to expand transmission between the regions). Hydro-Québec, written submission to USITC, August 7, 2020, 39. Again, our model is not considering the effects of any existing or potential contracts to expand transmission. However, such contracts could increase Massachusetts's access to imports.

[492] EIA projects that the LCOE will be far greater for hydroelectricity and nuclear than for wind and solar in 2025 in the United States. EIA, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020," February 2020, 7.

[493] EIA, Commercial Demand Module, October 2018, 200; EIA, Residential Demand Module, June 2020, 120.

Table E.4 Projected renewable generation mix in the end-use sector in the New England region, Reference case (in terawatt-hours)

Type of generation	2019	2030	2035	2040	2045	2050
All renewable and clean	6.6	12.7	14.4	16.3	18.1	19.9
Solar (photovoltaic)	4.9	10.8	12.5	14.4	16.1	17.9
Onshore wind	0.1	0.1	0.1	0.1	0.1	0.1
Wood and other biomass	1.4	1.4	1.5	1.5	1.6	1.6
Municipal waste	0.2	0.2	0.2	0.2	0.2	0.2

Source: Compiled from AEO 2020, Reference Case estimates.

Given the anticipated size of solar as a generation resource and that solar and wind are the renewable resources which require the smallest incentives in the projection periods, the model assumes that solar will be the marginal resource meeting demand for new renewables.[494]

Modeling the Value of Compliance Credits

The renewable and clean energy standards are designed to incentivize new energy production through the payment of compliance credits. The value of these incentives depends on how profitable new energy plants would be absent the credits. A plant's profitability per megawatt-hour (MWh) of electricity generated is the difference between the average cost and average revenue over the full life cycle of the plant.

Massachusetts's increased commitments only create compliance costs to the extent that they are needed to incentivize additional generation to meet the standards. If average revenue is less than average cost, the renewable or clean energy credit (or more generally "compliance credit") covers the difference in order to make the investment in renewable or clean energy resources profitable, and the commitments are "incentivizing" new renewable or clean generation. If the standards are incentivizing, then the value of compliance credits is greater than zero and Massachusetts utilities pay the cost of the credits, which they then pass on to Massachusetts retail electricity consumers. For the model scenarios and years where the standards are not incentivizing, the value of the credits is zero. In these years the commitments have no effect on generation or other market outcomes and no effect on costs to consumers.

The model estimates the future values of the credits based on the economic fundamentals that underlie the profitability of new renewable generation. These fundamentals suggest that credit values should incorporate future technological innovations, revenue opportunities, and all other factors that determine the profitability of new generation.

For any share of renewables S, a new generation plant's profits per MWh, π, are equal to the difference between its average revenue, AR, and its average cost, AC:

$$\pi(S) = AR(S) - AC(S) \tag{E1}$$

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[494] EIA, Annual Energy Outlook 2020: LACE (available from EIA on request; accessed October 2, 2020); EIA, Annual Energy Outlook 2020: LCOE (available from EIA on request; accessed October 2, 2020). As discussed in chapter 3, and in box 3.2 specifically, the RPS Sunset case provides an additional rationale to assume that solar will grow to meet Massachusetts's commitments.

Table E.5 provides the AEO's projections for average revenue and average cost for solar photovoltaic (PV) generation for each of the model years.

Table E.5 Average revenue and average cost of the marginal solar generation plant, Reference case (in 2019 dollars per megawatt-hour)

Measure	2030	2035	2040	2045	2050
AR	33.70	33.11	35.30	34.79	33.69
AC	37.56	35.34	33.40	31.75	30.48
AR minus AC	-3.87	-2.23	1.94	3.03	3.21

Source: EIA, Annual Energy Outlook 2020: LACE (available from EIA on request; accessed October 2, 2020); EIA, Annual Energy Outlook 2020: LCOE (available from EIA on request; accessed October 2, 2020).

Although these estimates are generally low, REC prices in Massachusetts have been declining since they reached a peak in 2014.[495] At their highest, Class I RECs reached around $65 per MWh in 2014. The average monthly closing price of RECs for Class I renewables in Massachusetts was listed as low as approximately $5 per MWh in the third quarter of 2018, reaching around $20 per MWh in the second quarter of 2019.[496]

To account for diminishing profitability of renewables as their market share increases, the model adjusts the estimate of the profitability (in terms of 2019 dollars per MWh) of additional renewable generation at different levels of renewables penetration, using the profitability curve defined in equation (E2):

$$\pi(S_2) = \pi(S_1) + 1 - \left(\frac{1-S_1}{1-S_2}\right) \tag{E2}$$

where S_1 and S_2 represent any two shares of renewable generation in the market. If share S_2 is greater than share S_1, then $\pi(S_2)$ will be less than $\pi(S_1)$. This curve is almost flat when S_2 is close to S_1, decreasing S_2 as increases, and becomes very negative as S_2 approaches one. This diminishing profitability of new generation as renewable penetration increases in a particular year reflects the likely exhaustion of the best revenue opportunities and least-cost projects.

The model estimates the equilibrium value of the credit (VOC) required to incentivize enough additional renewable and clean generation to meet the updated standards in equilibrium, based on equation (E3):

$$VOC(S) = MAX[-\pi(S), 0] \tag{E3}$$

The compliance credit represents an equilibrium outcome: if the value of the credit were smaller, the standards would not be met; if the value of the credit were larger, excess investments would drive down the value of the credit.

The model defines VOC_0 as the value of compliance credits under the initial RPS, and VOC_1 as the value of compliance credits under Massachusetts's updated RPS and its CES. These are not values at different points in time; they are values at the same point in time for different levels of electricity sourcing coming from renewables, so it is always the case that VOC_1 is greater than or equal to VOC_0. Starting from $\pi(S_u)$, the profitability projection from the AEO, and defining $S_x = MAX[0, S_c - S_u - S_h]$, the profitability measures at the updated and initial RPS are given in equations (E4) and (E5):

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[495] Barbose, *U.S.* Renewables Portfolio Standards, 2019, 33.

[496] Barbose, *U.S.* Renewables Portfolio Standards, 2019, 33.

[496] Barbose, *U.S.* Renewables Portfolio Standards, 2019, 33.

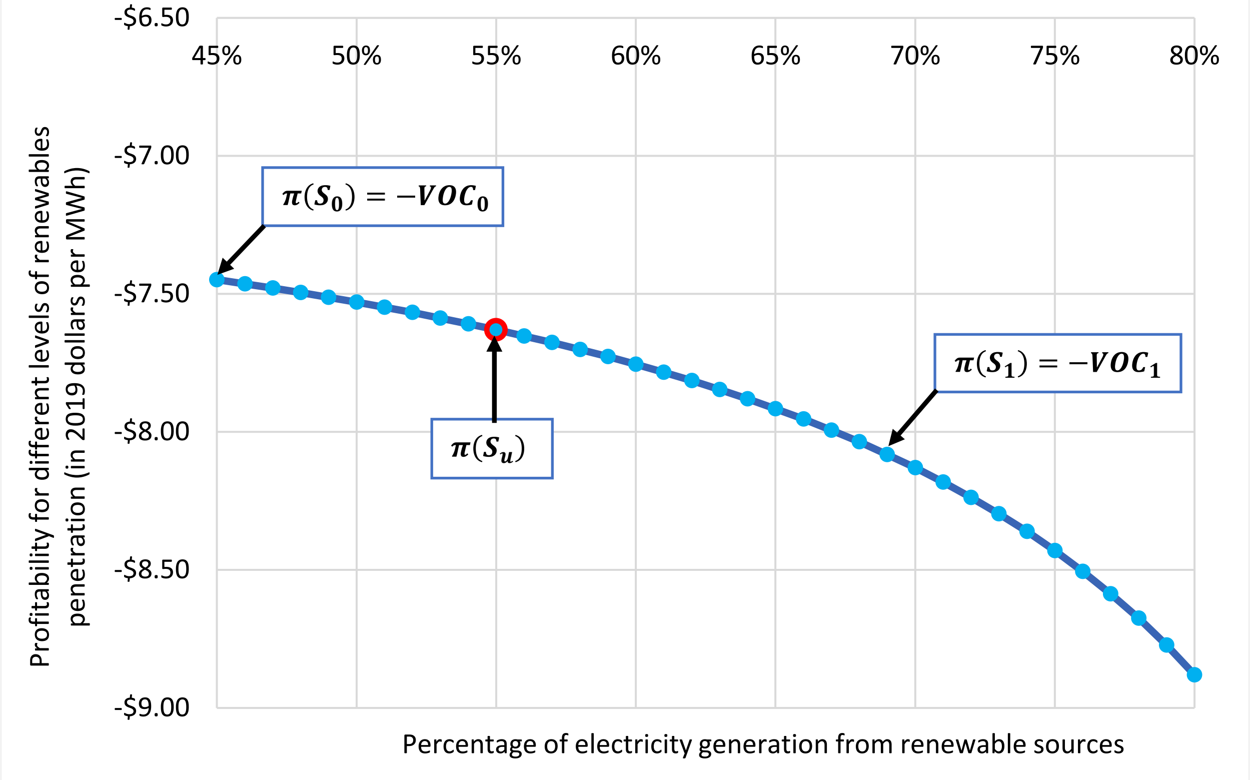
$$VOC_1 = MAX\left[-\left(\pi(S_u) + 1 - \left(\frac{1-S_u}{1-S_u-S_x}\right)\right), 0\right] \tag{E4}$$

$$VOC_0 = MAX\left[-\left(\pi(S_u) + 1 - \left(\frac{1-S_u}{1-S_o}\right)\right), 0\right] \tag{E5}$$

If $S_h > S_c – S_u$ (no additional renewable sources are required beyond those that meet the updated RPS), then VOC_1 can be calculated as the difference between average revenue and average cost of the marginal renewable source, equal to $MAX[0, – \pi(S_u)]$. This is the case in 2030 and 2035 for all five AEO cases. If $S_h < S_c – S_u$ (additional renewable sources are required beyond those that meet the updated RPS), then there is an upward adjustment in VOC_1 as the profitability of the marginal renewable resource falls. This is the case in the illustrative example provided in figure E.1, which shows that VOC_1 is found by a rightward movement along the diminishing profitability curve from $\pi(S_u)$ for 2050 for the AEO High Renewables Cost case as new renewable generation becomes less profitable.

Figure E.1 provides an illustration of the relationship between VOC_0, equal to $– \pi(S_0)$, and VOC_1, equal to $– \pi(S_1)$, when $S_h < S_c – S_u$ using the profitability curve for the year 2050 in the High Renewables Cost case of the model. The figure shows that at the red point, labeled $\pi(S_u)$, the difference between AR and AC generated by the AEO's general equilibrium model is approximately −$7.63 per MWh of generation. The numbers used for the value of the credits in the Commission's modeling, however, are the points labeled VOC_0, the value of the credit with the old RPS commitment in place, and VOC_1, the value of the credit with the updated RPS and the new CES in place. These values are approximately $7.45 per MWh for the old commitment levels and $8.08 per MWh for the new commitment levels, resulting in an additional credit of $0.63 per MWh. The increased saturation of renewable and clean energy to meet the higher commitments results in lower profitability per MWh, driving up the required credit size to incentivize new renewable generation.

Figure E.1 Average revenue minus average cost estimates, 2050 High Renewables Cost case example



Source: USITC calculations.
Note: Underlying data for this figure can be found in appendix table G.41.

The model assumes that the residual of Massachusetts's CES over its updated RPS and imported hydroelectricity is met by new renewable generation in New England, rather than clean nonrenewables. This is a reasonable assumption, because (1) large nuclear facilities would take decades to permit and construct and high construction costs, and (2) this report is not considering how additional transmission from Canada to Massachusetts would affect Massachusetts's ability to meet its commitments.[497] Given this assumption, the value of the credit will be the same for both renewable and clean sources, as the model equalizes the return to new renewable generation being used to fill either the RPS or CES commitment. However, if adding hydroelectric power becomes a less expensive way to meet the residual of Massachusetts's CES over its updated RPS, then the model estimates may overstate the effects of Massachusetts's CES on compliance costs.

For context, the estimated share of Massachusetts's CES commitments met by additional renewables is given in table E.6. The table only reports shares in 2040, 2045, and 2050; for all earlier years of the model there is enough imported hydroelectricity to satisfy the entirety of the difference between Massachusetts's CES and RPS commitments.

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[497] Biello, "Nuclear Reactor Approved," February 9, 2012.

Table E.6 Additional renewable generation necessary to meet CES commitment (as a percentage of total Massachusetts load)

Year	CES minus RPS share	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2040	15.0	0.7	0.4	0.1	0.0	0.0
2045	20.0	5.8	5.1	5.1	3.1	4.0
2050	25.0	10.8	10.9	10.2	9.5	10.0

Source: USITC calculations.

Background on AEO Scenarios

As mentioned in chapter 3, the AEO uses a comprehensive general equilibrium model of the U.S. economy to build projections for the energy sector through 2050. To account for the uncertainty of long-term projections, the AEO includes several alternative scenarios. The modeling makes use of data from five of the AEO's cases: the Reference case, the High Renewables Cost case, the Low Renewables Cost case, the High Oil and Gas Supply case, and the Low Oil and Gas Supply case. Due to the uncertainty inherent in developing a model with projections 30 years into the future, these cases provide insights for several possible states of the world over the next three decades.

The Reference case represents the EIA's "best assessment of how the U.S. and world energy markets will operate through 2050, based on key assumptions intended to provide a base for exploring long-term trends."[498] The alternative cases then present specific adjustments to allow for potential departures from the Reference case.

First, consider the High and Low Renewables Cost cases. Recall that in table 3.2, in the High Renewables Cost case, overnight capital cost for renewables is assumed to remain at 2019 levels, where overnight capital cost is a hypothetical measure equal to the cost of building a new power plant, assuming no interest accrues during the process.[499] For the Low Renewables Cost Case, the model assumes that overnight capital cost, operating and maintenance costs, and fuel costs (where applicable) for renewables fall 40 percent lower than the Reference case equivalents by 2050.[500] From the AEO's 2020 data release, figure E.2 shows how these two cases change the forecast capital costs associated with solar photovoltaic (PV), wind, and combined-cycle natural gas generation.

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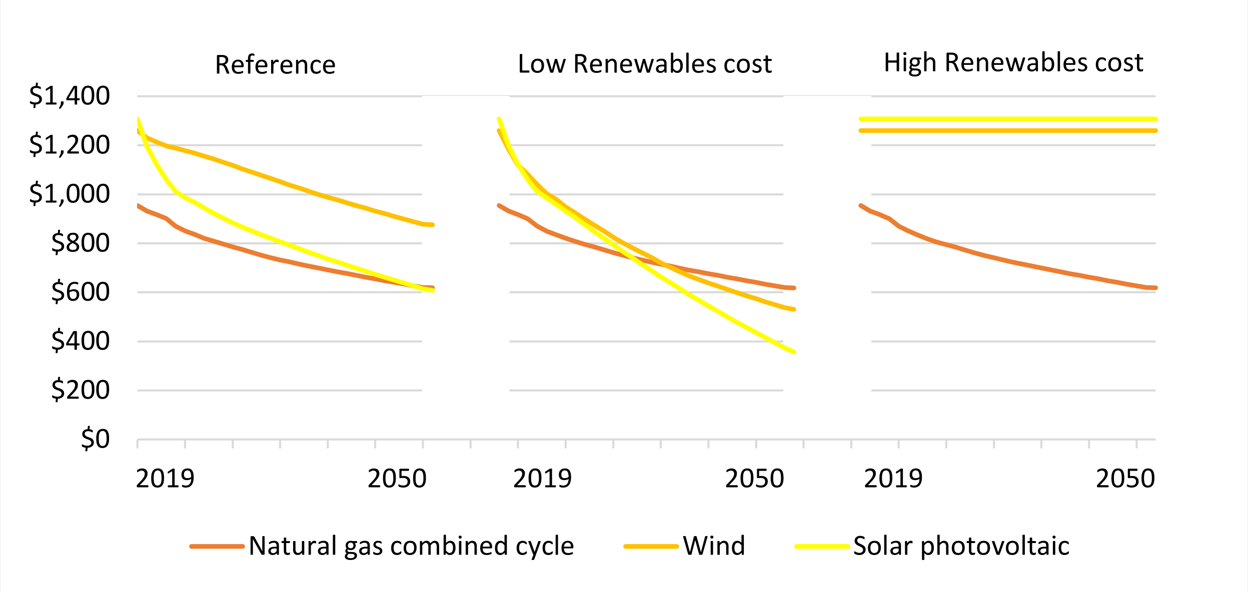
[498] U.S. Energy Information Administration, "Annual Energy Outlook 2020, Full Report," January 29, 2020, 5.

[499] EIA, "Annual Energy Outlook 2020: Case Descriptions," January 2020, 6; EIA "Capital Cost Estimates for Utility Scale Electricity Generating Plants," 1.

[500] EIA, "Annual Energy Outlook 2020: Case Descriptions," January 2020, 6.

Figure E.2 Overnight installed capital cost in the United States by technology, Reference and alternative Renewables Cost scenarios (in 2019 dollars per kilowatt)



Source: EIA, AEO2020 Full Report, January 29, 2020, 21.
Note: Underlying data for this figure can be found in appendix tables G.42, G.43, and G.44.

The AEO's Reference case depicts a higher overnight capital cost for wind for almost the entirety of the forecast window, with the cost of solar also declining far more rapidly than the cost of wind. In the Low Renewables Cost Case, however, the cost of wind and solar are very similar initially, with the overnight capital cost of solar eventually falling below the cost of wind. In the High Renewables Cost case, the overnight capital costs of solar and wind are frozen at their 2019 levels. This means even though solar is forecast to drop below wind very quickly in the Reference case, this does not occur in the High Renewables Cost case, and solar remains more expensive than wind throughout the forecast window.

Next, consider the High Oil and Gas Supply and Low Oil and Gas Supply scenarios. The High Oil and Gas Supply scenario assumes 50 percent higher well output and 50 percent higher technological improvements than the Reference case.[501] The Low Oil and Gas Supply case assumes 50 percent lower well output and 50 percent lower technological improvement than the Reference case.[502] The resulting forecasts for natural gas production are given in figure E.3.

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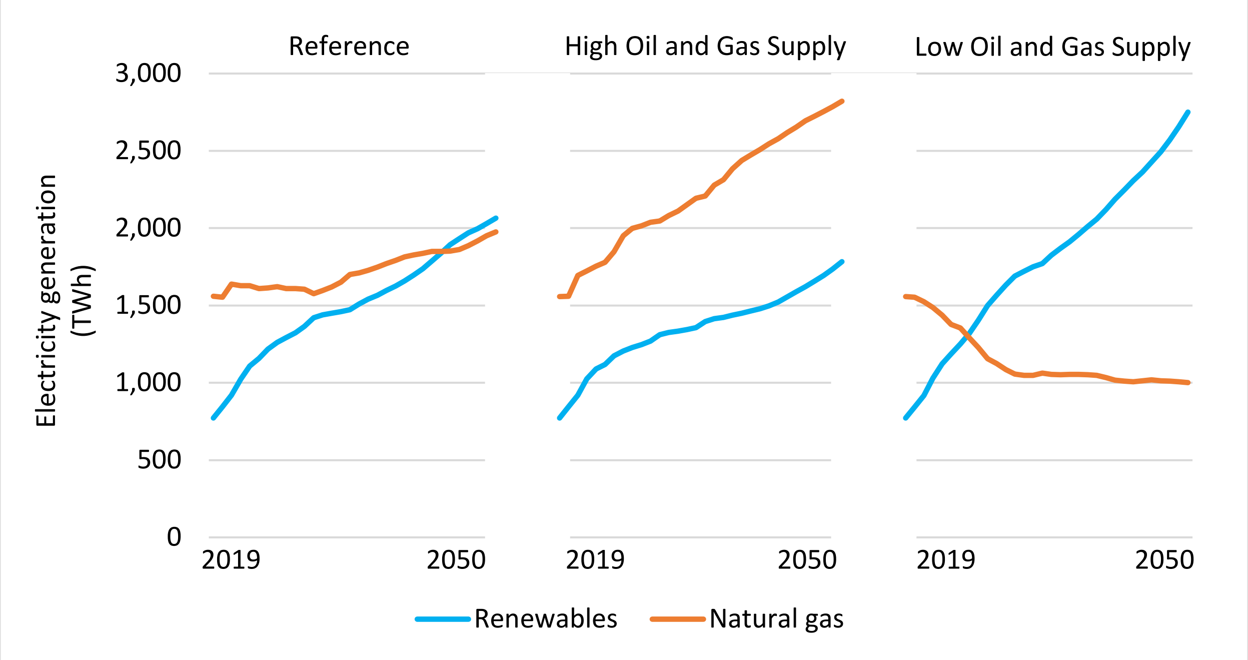
[501] EIA, "Annual Energy Outlook 2020: Case Descriptions," January 2020, 5–6. EIA defines technological improvements here as improvements that may lead to the development of crude oil and natural gas resources that have not yet been identified.

[502] EIA, "Annual Energy Outlook 2020: Case Descriptions," January 2020, 5.

Figure E.3 U.S. electricity generation from selected fuels, Reference, and alternative Oil and Gas Supply scenarios (in terawatt-hours)



Source: EIA, AEO2020 Full Report, January 29, 2020, 58.
Note: Underlying data for this figure can be found in appendix tables G.45, G.46, and G.47.

The AEO's graphs of electricity generation in the Reference case show that generation from renewables is projected to pass generation from natural gas by around 2045. In the High Oil and Gas Supply case, however, natural gas is projected to remain the primary source of electricity generation throughout the forecast window, and the projected output of electricity from renewables is projected to be below the Reference case projections. In the Low Oil and Gas Supply case, electricity generation from renewables is projected to be much greater than in the Reference case by the end of the forecast window, with generation from natural gas dropping by about a third compared to its 2019 level before leveling off around 2030.

Model Outputs

Effects on the Price of Wholesale Generation

Massachusetts's new commitments lead to additional generation when they are incentivizing. As a result, the commitments increase electricity supply in New England, lowering the price of generation available to Massachusetts utilities. The model estimates future reductions in the price of generation in New England using projections of future prices of electricity in New England for a case with the updated RPS in place and another case, the RPS Sunset case, with no RPS or CES.[503] The difference between these two price projections, prorated by the difference between Massachusetts's initial and updated RPS plus

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[503] Box 3.2 provides additional discussion of the RPS Sunset case, including how its projections compare to the Reference case results.

the part of Massachusetts's CES share above the updated RPS that is not met by hydroelectric resources in the baseline, is the estimated negative price effect of the updated RPS.

The estimated policy-induced reductions in the price of generation are small, and the effects of the additional CES are zero in most years or very small in 2050. The model applies the ratio of the changes in commitment shares to adjust the estimated reduction in the price of generation in New England observed going from the RPS Sunset case to the Reference case. Equation (E6) defines the wholesale price effect (WPE):

$$WPE = \left(P_{Ref} - P_{Sunset}\right) \frac{(S_u - S_o) + I_h\left((S_c - S_u) - S_h\right)}{(S_u - 0)} (S_{NE}) \tag{E6}$$

where I_h is one if $S_h < S_c - S_u$ and is zero otherwise; where the prices P_{Ref} and P_{Sunset} are the AEO's projected prices for New England in the Reference case and RPS Sunset case, respectively; and where S_{NE} is equal to Massachusetts's share of total New England load (45.6 percent). The first term of equation (E6) is the estimated price effect of the RPS commitments of all 30 policies nationwide as compared to the situation if there were no state-level RPS commitments. The second term of the equation is the prorating factor, which prorates the total effect by the amount of renewables required to meet Massachusetts's RPS and CES commitments, $(S_c - S_u) + I_h ((S_c - S_u) - S_h)$, divided by the increase in Massachusetts's commitment going from the Reference case to the RPS Sunset case (equal to zero), $S_u - 0$. The final term further prorates the New England price effect by multiplying it by Massachusetts's share of New England's total load.

Effects on the Costs to Massachusetts Consumers

The effects of the standards on costs to residential and commercial electricity customers in Massachusetts will be determined mostly by the increased cost of compliance credits. Equation (E7) estimates the change in the costs of the credits, ΔCredit, to Massachusetts consumers, in 2019 constant dollars per MWh:

$$\Delta Credit = (VOC_1 - VOC_0)\, S_o + (S_u - S_o)\, VOC_1 + I_h\, (S_c - S_u)\, VOC_1 \tag{E7}$$

where I_h is one if $S_h < S_c - S_u$ and is zero otherwise. The effects of the standards on the total costs to consumers also include the small estimated policy-induced reduction in the price of generation discussed above. Equation (E8) defines the total cost to consumers inclusive of the credit and the price reduction in 2019 constant dollars per MWh:

$$\Delta Cost_{Mass} = \Delta Credit + I_v \left((1 - I_h)\,(1 - S_u) + I_h\left(1 - (S_c - S_h)\right)\right) WPE \tag{E8}$$

where ΔCredit is defined in equation (E7); I_v is one if $VOC_1 > 0$ (i.e., the policy is incentivizing) and is zero otherwise; and WPE is defined in equation (E6). For the share of load covered by the standard, any reduction in the price of generation will require an increase in the value of the compliance credits in order to maintain the profitability of the new generation, so this price reduction has no net effect on Massachusetts consumers. The reduction in the price of generation will likely mitigate some of the increased costs from compliance credits, but this effect will likely be relatively minor. From equation (E8), WPE is applied to the share of generation that is not satisfied by renewable generation. Simplifying the second term of the equation, if the share of hydro is large enough that no clean energy needs to be incentivized, then the wholesale price effect equals (1 – S_u) WPE. If the share of hydro is not large enough to satisfy Massachusetts's CES, then all of the new renewables built to satisfy Massachusetts's RPS also receive credits, so the price effect is applied to the share of generation not satisfied by renewables, now equal to (1 – (S_c – S_h)) WPE.

The model then calculates the total dollar value of the change in costs to consumers for each of the future years by multiplying the estimated change per MWh by the estimated Massachusetts non-municipal load in the year.

Effects on the Costs to New England Consumers

As discussed in chapter 3 of this report, the costs for the Massachusetts RPS and CES commitments from the compliance credits would be paid only by Massachusetts consumers; the economic effects of the commitments for the rest of New England would be limited to impacts on the price of generation in the region.

The model calculates the total dollar value of the change in costs to New England consumers for each of the future years by multiplying the estimated effect on the price of generation per MWh, as defined in the equation (E6), by the estimated New England load net of Massachusetts in the year.

Effects on Massachusetts Emissions

To the extent that the standards lead to more renewable or clean generation, they will reduce the greenhouse gas emissions associated with Massachusetts electricity loads. The model approximates the reduction in carbon dioxide (CO_2) emissions based on the estimated increase in renewable and clean sourcing by assuming that the renewable and clean sources replace natural gas generation, since natural gas generation is the next-lowest-cost resource.[504] Table E.7 lists these CO_2 emissions rates.

Table E.7 Carbon dioxide (CO_2) emissions rate of natural gas generation in New England, Reference case (in million metric tons per megawatt-hour)

Measure	2030	2035	2040	2045	2050
CO_2 emissions rate	0.411	0.392	0.429	0.437	0.447

Source: USITC calculations.

If clean generation is profitable absent incentives from Massachusetts's CES or RPS, then although new production from clean resources will reduce emissions, those reductions will not count toward the estimated policy-induced reductions in emissions. This is why in some years the model does not project any policy-induced reductions in emissions.

Equation (E9) estimates the policy-induced change in emissions associated with Massachusetts's load, in millions of metric tons per MWh:

$$\Delta EM = I_v \quad erng \quad (S_o - MAX[S_u, \quad S_c - S_h]) \tag{E9}$$

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[504] Note that this is reflected in table 2.5 in chapter 2, which shows that natural gas supplies the largest share of generation in Massachusetts.

I_v is equal to one if $VOC_1 > 0$ and zero otherwise. erng is the CO_2 emissions rate for displaced natural gas generation in New England (table E.7). The model calculates the total policy-induced change in CO_2 emissions in each of the future years by multiplying the estimated change per MWh by the estimated non-municipal load in Massachusetts in a given year.

Data Sources

The model includes data from many different sources.

- The data on the renewable and clean energy commitment shares in table E.1 are from the Massachusetts state implementing legislation.
- The model takes into account the fact that the aspects of Massachusetts's RPS and CES modeled in this report generally apply only to investor-owned utilities and not to municipal providers by netting out the share of electricity sales coming from municipal providers. Data on the share of electricity from municipal providers are pulled from the EIA's state electricity profile for Massachusetts table on Retail Electricity Sales Statistics for 2018 (the most recent available data).[505] The model assumes this rate remains stable over the span of the model at its 2018 level of approximately 14.1 percent.
- The data on future loads in Massachusetts are calculated using EIA's AEO projections on net energy for New England load in the future years, adjusted for the share of Massachusetts load in total New England load reported by ISO New England and also for the share of Massachusetts load served by municipal utilities.
- The share of Massachusetts in New England's total load is assumed to remain constant at the levels in the most recent data available (2018), equal to 45.6 percent. Massachusetts's share is found by dividing the Massachusetts load estimates from EIA by ISO New England's estimates of total load.[506]
- The data on the share of Massachusetts non-municipal load served by imported hydroelectric resources in table E.2 are calculated from the EIA's AEO projections for New England's international and interregional imports (prorated for the share of these international and interregional imports that are hydroelectric generation), assuming that the shares serving Massachusetts are the same as the shares in total New England load. The share of New England's imports coming from hydroelectric generation is extrapolated from the most recent available NEPOOL estimates. In September 2018, 24.8 percent of imports from New York State were from hydroelectric generation. In October 2018, 96.0 percent of imports from Quebec were from hydroelectric generation.[507]
- The average revenue estimates for the marginal new renewable generation in New England are based on EIA's levelized avoided cost of electricity (LACE) for the five AEO 2020 cases. The

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[505] EIA, Table 9: Retail Electricity Sales Statistics (accessed Sept 16, 2020).

[506] ISO New England, "Net Energy and Peak Load by Source" (accessed March 24, 2020); EIA, "State Electricity Profiles" (accessed March 24, 2020).

[507] NEPOOL General Information System, System Mix (accessed November 3, 2020).

model uses EIA projections at the regional level, defined by ISO New England. Detailed data for each year, plant type, and case for the New England region were provided by EIA. LACE measures the revenue available to a new generator over a 30-year cost recovery period. EIA estimates revenue opportunities for the additional generation on an hour-by-hour basis over the full life cycle of the generation plant. LACE accounts for variation in daily and seasonal electricity demand and for the characteristics of the existing generation fleet to which new capacity will be added.

- The average cost estimates for the marginal new renewable generation in New England are based on EIA's levelized cost of electricity (LCOE) estimates for the five AEO 2020 cases. Additional underlying data for each year, plant type, and case for the New England region are provided by EIA. LCOE measures the revenue required to build and operate a new generator over a 30-year cost recovery period. It is calculated by EIA based on engineering estimates of building, operating, and maintenance costs over the full life cycle of the generation plant. It incorporates projections of future technology, fuel costs, and many other factors.[508]
- The model estimates future reductions in the price of generation in New England using simulation results reported in the 2020 AEO. EIA projects future prices of electricity in the New England region for its Reference case (which includes Massachusetts's pre-2016 RPS but not its CES or the 2018 update of its RPS) and the RPS Sunset case (with no RPS).
- Estimates of the cost to residential consumers per household per month are calculated by first finding the average consumption per household per month in Massachusetts. This is calculated using AEO's forecasts for residential electrical energy use for New England, adjusting by the share of electricity load in New England going to Massachusetts (about 45.6 percent), and then dividing by the number of residential customers in Massachusetts according to the AEO's state electricity profile. This makes the estimate potentially on the higher end, as it does not allow an increase in the number of residential consumers over the time period but instead assumes the number of retail customers remains constant from the 2018 levels. An alternative cost estimate in which the number of residential consumers grows according to a linear trend is included later in this appendix.[509]
- Emissions rates are calculated using AEO forecasts. Specifically, for each of the five cases considered in the Commission model, AEO forecasts the level of generation and carbon emissions by resource type over the span of the model. Taking the projected emissions from natural gas generation in a given year (the lowest-cost displaced resource) and dividing by the projected generation from natural gas in that same year yields the projected emissions per megawatt-hour of electricity coming from non-clean resources.

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[508] Calculations for LCOE (and LACE) include state and federal tax incentives, state-level renewable energy targets. EIA, "Levelized Cost and Levelized Avoided Cost," February 2020, 4–5.

[509] EIA, Table 8: Retail Sales (accessed September 15, 2020).

Additional Results

Alternative Scenarios: Cost to New England Consumers and Greenhouse Gas Estimates

In chapter 3, table 3.9 reports the estimated cost saving for the rest of New England (excluding Massachusetts) resulting from Massachusetts's recent commitments. The corresponding estimates for the High and Low Renewables Cost cases and the High and Low Oil and Gas Supply cases are presented in table E.8.

Table E.8 Estimated savings for New England, excluding Massachusetts, due to Massachusetts's commitments (in 2019 dollars)

Year	Price effect if incentivizing (cents per kWh)	Total annual savings, High Renewables Cost case (million $)	Total annual savings, Low Renewables Cost case (million $)	Total annual savings, High Oil and Gas Supply case (million $)	Total annual savings, Low Oil and Gas Supply case (million $)
2030	-0.0013	0.87	0.87	0.87	0
2035	-0.0044	3.00	0	3.00	0
2040	-0.0021	1.50	0	1.49	0
2045	-0.0044	3.22	0	0	0
2050	-0.0031	2.44	0	0	0

Source: USITC calculations.

Note: The price effect is calculated using the comparison of AEO estimated prices in the Reference case and the RPS Sunset case. The model assumes the same cent per kWh price effect in the other cases but zeroes out the total price effect when the policy is not incentivizing the addition of renewables. The calculation of the price effect is discussed further with equation (E6).

The total annual savings are calculated using the AEO projections for net energy for load for each scenario multiplied by the price effect per kWh. Because the price effect does not change between cases, the total annual savings are relatively constant across all five scenarios (including the Reference case).

In chapter 3, table 3.10 reports the estimated reduction in carbon dioxide emissions rates associated with the shift in electricity consumed within Massachusetts due to the new RPS and CES commitments, in million metric tons per MWh, and total carbon dioxide emissions reductions for each of the model years using data from the AEO 2020 Reference case. The corresponding estimates for the High and Low Renewables Cost cases and the High and Low Oil and Gas Supply cases are presented here in both millions of metric tons (Mmt), table E.9, and millions of metric tons per MWh (Mmt per MWh), table E.10.

Table E.9 Estimated effect of commitments on carbon dioxide emissions per MWh in Massachusetts, alternative scenarios (in million metric tons, Mmt, per MWh)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	-0.041	-0.041	-0.041	-0.042	0
2035	-0.039	-0.042	0	-0.043	0
2040	0	-0.044	0	-0.043	0
2045	0	-0.065	0	0	0
2050	0	-0.089	0	0	0

Source: USITC calculations.

Table E.10 Estimated effect of commitments on total carbon dioxide emissions in Massachusetts, alternative scenarios (in million metric tons, Mmt)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	-1.94	-1.95	-1.94	-1.99	0
2035	-1.91	-2.06	0	-2.10	0
2040	0	-2.23	0	-2.19	0
2045	0	-3.42	0	0	0
2050	0	-4.93	0	0	0

Source: USITC calculations.

Because the alternative cases are only adjusting underlying costs and supplies of resources, the reductions in emissions do not vary significantly from scenario to scenario for the years in which the policies are incentivizing. This is evident across the estimates in tables E.9 and E.10, with the Reference case estimates in 2030 and 2035 being very similar to those estimates in the alternative cases.

For the High Renewables Cost case, the reduction in emissions is forecast to increase over the timeframe of the commitments, both on a per-MWh basis and in total emissions reductions. The reduction in carbon dioxide emissions increases over time as the commitments become more ambitious through 2050. For the Low Renewables Cost case, on the other hand, the commitments are only incentivizing in the earliest projection year. For the High Oil and Gas Supply case, reductions in carbon emissions are very similar to the estimates for the High Renewables Cost case in the years in which the commitments are incentivizing (through 2040).

Sensitivity Analysis of Assumptions

In this section, the some of the model's underlying assumptions are modified to provide sensitivity analysis for the results. Table 3.2 outlines the key assumptions used in the modeling that are relaxed in the following section. First, the chapter 3 estimates assume that marginal new renewable generation is from solar PV facilities; in the first subsection below, the cost to consumers is calculated for when wind is the marginal resource. Second, chapter 3 estimates assume that Massachusetts's access to imports is proportional to its load as a share of total New England load; the second subsection below calculates the cost to consumers in the Reference case when Massachusetts has moderate, low, and no access to these imports. Finally, chapter 3 calculations of the monthly cost to consumers assume there is no growth in the number of residential and commercial customers in Massachusetts; the final subsection below presents the monthly cost to consumers when the number of customers is allowed to grow following a linear trend.

Wind as the Marginal Resource

The following set of estimates present an alternative scenario in which, instead of solar PV resources being the marginal resource filling Massachusetts's RPS and CES commitments, onshore wind generation is the marginal resource. Tables E.11 and E.12 show the cost to consumers of the commitments, assuming the marginal commitments are filled by new onshore wind construction.

Table E.11 Estimated increase in per-unit cost to Massachusetts consumers with onshore wind as the marginal resource (in 2019 cents per kWh)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	0.072	0.089	0.012	0.082	0.009
2035	0.050	0.082	0	0.061	0
2040	0.020	0.192	0	0.047	0
2045	0	0.235	0	0.070	0
2050	0	0.184	0	0	0

Source: USITC calculations.

Table E.12 Estimated increase in total cost to Massachusetts consumers with onshore wind as the marginal resource (in millions of 2019 dollars)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	34.2	42.4	5.8	39.0	4.3
2035	24.5	40.5	0	30.1	0
2040	10.0	97.9	0	24.0	0
2045	0	124.4	0	36.9	0
2050	0	102.0	0	0	0

Source: USITC calculations.

Comparing tables E.11 and E.12 to tables 3.5 and 3.6, the results for wind show a significant departure from the predicted costs to consumers if solar is the marginal resource. Compared to the Reference case, wind being the marginal resource results in a cost to consumers about 75 percent higher than if solar is the marginal resource in 2030, and about 110 percent greater in 2035. Additionally, Massachusetts's increased commitments continue to be costly to consumers in 2040, while if solar is the marginal resource they are not. These increasing differences between the cost to consumers when the marginal demand is satisfied by wind reflect the fact that the rate of overnight capital cost reductions from wind is slower than the rate of cost reductions for solar PV energy generation.[510]

For the alternative cases, however, the cost to consumers is lower when wind is the marginal resource both for the High Renewables Cost case and the Low Renewables Cost case. For the High Renewables Cost case, this is a result of the way that the AEO constructs the overnight cost of capital, as was discussed in the "Background on AEO Scenarios" section of this appendix (the High Renewables Cost case freezes the capital costs for solar and wind, leading to the price of solar never falling below the price of wind). For the Low Renewables Cost case, solar is less expensive to build than wind by around 2022 (see figure E.2), but the profitability of wind is still forecast to be greater through 2040 (see tables E.13 and E.14). As a result, the cost of the commitments is about 50 percent lower in 2030 with wind as

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[510] See discussion of figure E.2 or table 3.2.

the marginal resource. For the High Renewables Cost scenario, the commitments cost between 20 and 40 percent less over the projected time frame if wind is the marginal resource rather than solar.

Similar to the Reference case, commitments in the High Oil and Gas Supply and Low Oil and Gas Supply cases are higher across the board when wind is the marginal resource. The underlying structures of the Oil and Gas Supply scenarios do not make changes to the profitability of renewables, so it is unsurprising that the ranking of the resources does not change. The Oil and Gas Supply scenarios affect only the next-best resource.

Table E.13 and E.14 include the AEO's projected profitability for the wind and solar as reference for the discussion in this section.

Table E.13 Profitability (average revenue minus average cost) of solar (photovoltaic) in New England for all scenarios (in 2019 dollars per megawatt-hour)

Scenario	2030	2035	2040	2045	2050
Reference	-3.87	-2.23	1.94	3.03	3.21
High Renewables Cost	-11.62	-11.04	-9.76	-9.51	-7.63
Low Renewables Cost	-2.43	1.09	4.32	5.94	6.95
High Oil and Gas Supply	-4.15	-1.73	-0.06	0.61	3.19
Low Oil and Gas Supply	0.30	4.59	7.80	8.71	9.01

Source: EIA, Annual Energy Outlook 2020: LACE (available from EIA on request; accessed October 2, 2020); EIA, Annual Energy Outlook 2020: LCOE (available from EIA on request; accessed October 2, 2020).

Table E.14 Profitability (average revenue minus average cost) of onshore wind in New England for all scenarios (in 2019 dollars per megawatt-hour)

Scenario	2030	2035	2040	2045	2050
Reference	-6.97	-4.87	-0.60	0.53	1.55
High Renewables Cost	-8.65	-8.08	-7.51	-7.41	-4.33
Low Renewables Cost	-0.98	2.52	4.94	5.73	6.08
High Oil and Gas Supply	-7.91	-5.96	-4.31	-2.03	0.53
Low Oil and Gas Supply	-0.68	1.37	4.86	6.06	6.09

Source: EIA, Annual Energy Outlook 2020: LACE (available from EIA on request; accessed October 2, 2020); EIA, Annual Energy Outlook 2020: LCOE (available from EIA on request; accessed October 2, 2020).

Varying Access to Imports

As discussed previously, the modeling elsewhere in the report assumes that Massachusetts receives 45.6 percent of New England's total imports, since Massachusetts accounts for 45.6 percent of New England's load. For this section, that assumption is relaxed, and the model examines how the results change if Massachusetts's access to imports is lowered. This case reflects the fact that Massachusetts is geographically farther from Canada and New York State than the majority of other New England states.[511]

Lowering Massachusetts's access to imports impacts the model through the CES commitments: when access to imports is low, Massachusetts will be filling a larger share of its CES commitments with the

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[511] Massachusetts does not share a border with Canada and borders the downstate portion of New York's electricity grid (which has significantly less hydropower than the upstate portion; see chapter 4 for more discussion of New York's electricity market).

lowest-cost resource that fits into the clean or renewable category. As discussed earlier, the model uses solar PV generation as this resource.

For the Reference case, recall that the commitments are costly only to consumers for 2030 and 2035. In these periods, the difference between Massachusetts's RPS and CES is small—5 percent in 2030 and 10 percent in 2035. Therefore, in those years, access to imports does not need to be large for hydroelectricity to be able to satisfy the entirety of the clean energy commitment.

The effect of varying access to imports for the High Renewables Cost case is provided as an illustration of the effect that imports have on the costs to consumers (tables E.15 and E.16). For the High Renewables cost case, reducing access to imports does not affect costs in the early years, as was also true for the Reference case. For the High Renewables Cost case with the baseline level of imports, recall that a small share of Massachusetts's CES was met by renewables (reflected by the jump in the cost to consumers in 2040). If Massachusetts has moderate or low access to imports, then renewables are needed to meet CES commitments as early as 2040.

Table E.15 Estimated increase in per-unit cost to consumers of Massachusetts's increased commitments, varying levels of access to imports, High Renewables Cost Case (in 2019 cents per kWh)

Year	Baseline imports (45.6 percent)	Moderate access (30 percent)	Low access (20 percent)
2030	0.119	0.119	0.119
2035	0.112	0.222[a]	0.225[a]
2040	0.249[a]	0.254[a]	0.259[a]
2045	0.298[a]	0.308[a]	0.315[a]
2050	0.299[a]	0.317[a]	0.331[a]

[a] A share of the Clean Energy Standard commitment above the Renewable Portfolio Standard is being met by renewable generation.

Source: USITC calculations.

Table E.16 Estimated increase in total cost to consumers of Massachusetts's increased commitments, varying levels of access to imports, High Renewables Cost Case (in millions of 2019 dollars)

Year	Baseline imports (45.6 percent)	Moderate access (30 percent)	Low access (20 percent)
2030	56.5	56.5	56.5
2035	55.0	109.2[a]	110.3[a]
2040	126.6[a]	129.5[a]	131.7[a]
2045	157.7[a]	162.8[a]	166.9[a]
2050	165.9[a]	175.5[a]	183.5[a]

[a] A share of the Clean Energy Standard commitment above the Renewable Portfolio Standard is being met by renewable generation.

Source: USITC calculations.

As discussed in chapter 3 of this report, assuming Massachusetts has no access to imports results in a significant increase in the cost to consumers of Massachusetts's increased commitments in many of the years of the model projections. The complete results of this estimation of cost to consumers are in tables E.17 and E.18.

Table E.17 Estimated increase in per-unit cost to consumers of Massachusetts's increased commitments if Massachusetts has no access to imported hydroelectricity (in 2019 cents per kWh)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	0.064	0.180	0.042	0.068	0
2035	0.057	0.231	0	0.045	0
2040	0	0.270	0	0.024	0
2045	0	0.336	0	0.001	0
2050	0	0.374	0	0	0

Source: USITC calculations.

Table E.18 Estimated increase in total cost to consumers of Massachusetts's increased commitments if Massachusetts has no access to imported hydroelectricity (in millions of 2019 dollars)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	30.2	85.6	19.9	32.4	0
2035	27.6	113.3	0	21.9	0
2040	0	137.4	0	12.1	0
2045	0	177.9	0	0.7	0
2050	0	207.2	0	0	0

Source: USITC calculations.

A discussion of the changes in costs as compared to the model estimates with access to imports (detailed in table 3.11) is in chapter 3.

Residential and Commercial Customer Growth

The following table reports the cost to consumers if instead of holding constant the number of retail and commercial customers at the 2018 levels, these numbers are allowed to increase following a linear trend based on Massachusetts retail and commercial customer growth observed between 1990 and 2018. This set of estimates would present a likely lower bound for the cost to consumers, whereas the estimates in tables 3.7 and 3.8 are an upper bound, as they assume a lower number of customers in each category. Tables E.19 and E.20 depict the results when residential customers and commercial customers grow according to the linear trend for completeness.

Table E.19 Estimated increase in the cost to residential consumers for high population growth, monthly cost per customer (in 2019 dollars)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	0.24	0.70	0.16	0.26	0
2035	0.14	0.67	0	0.11	0
2040	0	1.50	0	0.01	0
2045	0	1.82	0	0	0
2050	0	1.85	0	0	0

Source: USITC calculations.

Table E.20 Estimated increase in the cost to commercial consumers for high population growth, monthly cost per customer (in 2019 dollars)

Year	Reference case	High Renewables Cost case	Low Renewables Cost case	High Oil and Gas Supply case	Low Oil and Gas Supply case
2030	1.60	4.71	1.04	1.73	0
2035	0.90	4.29	0	0.72	0
2040	0	9.34	0	0.05	0
2045	0	11.12	0	0	0
2050	0	11.25	0	0	0

Source: USITC calculations.

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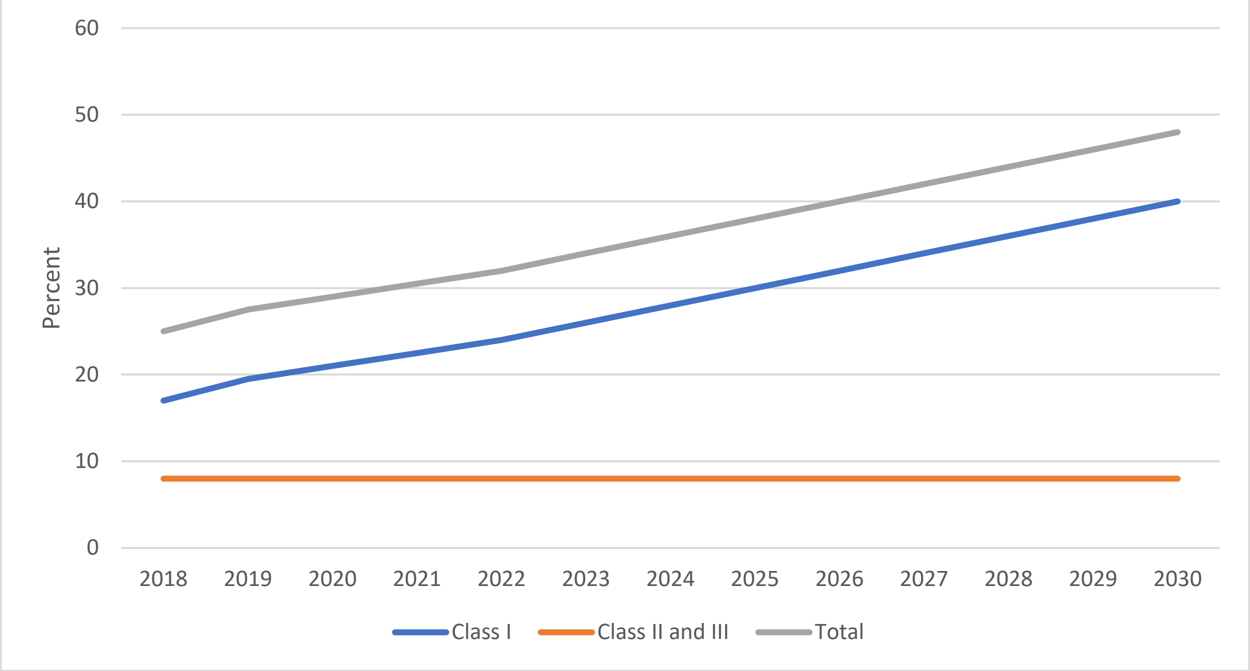
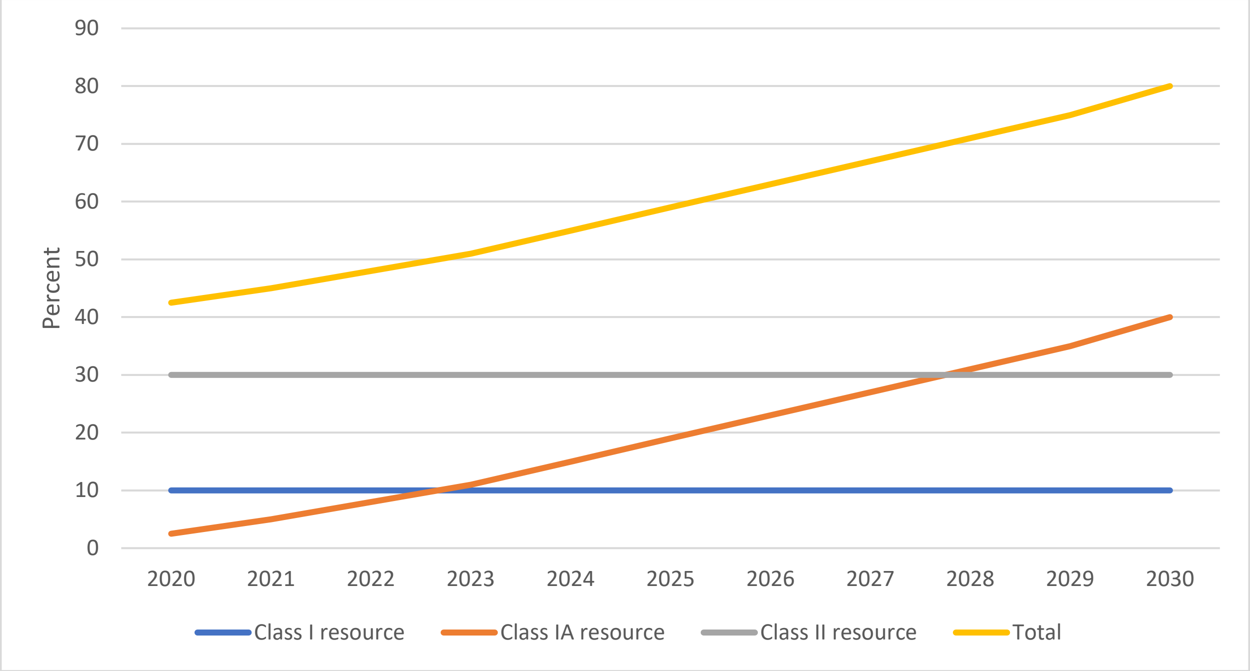
Appendix F
Supplementary Figures and Tables

Figure F.1 Connecticut RPS by class (percent of electricity consumption), 2018–30



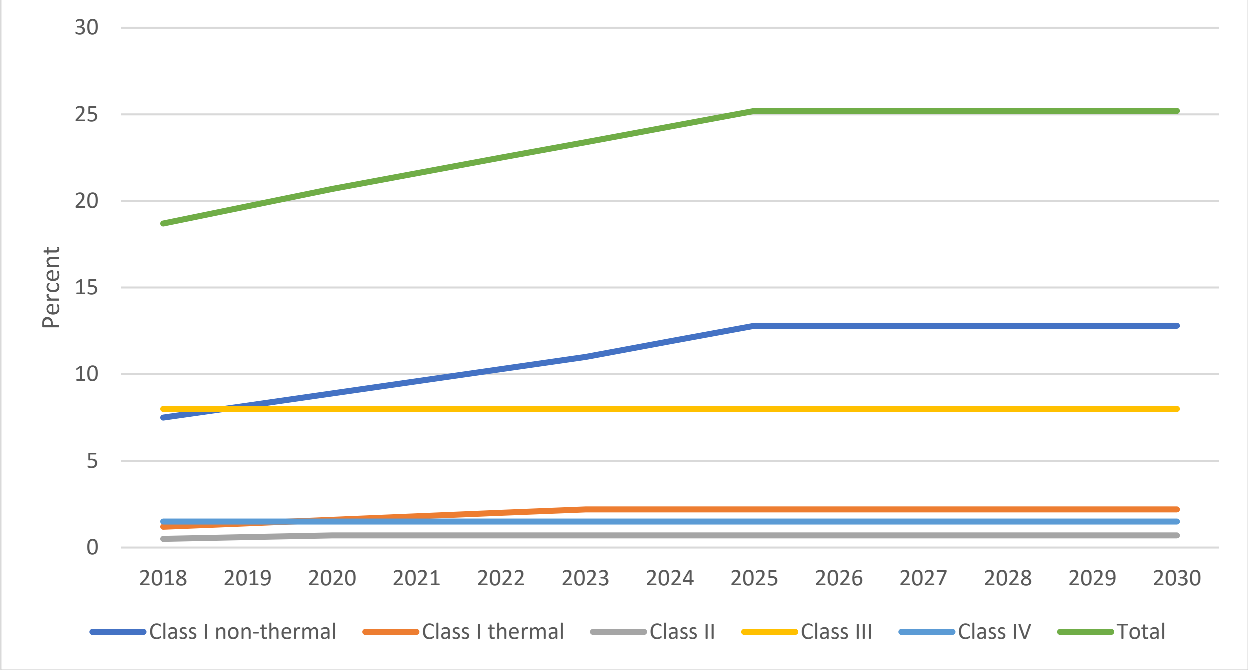
Source: DOE and EPA, Public Utilities Regulatory Authority. Connecticut Renewable Portfolio Standard, March 2020.
Note: Underlying data for this figure can be found in appendix table G.48.

Figure F.2 Maine RPS by class (percent of electricity consumption), 2020–30



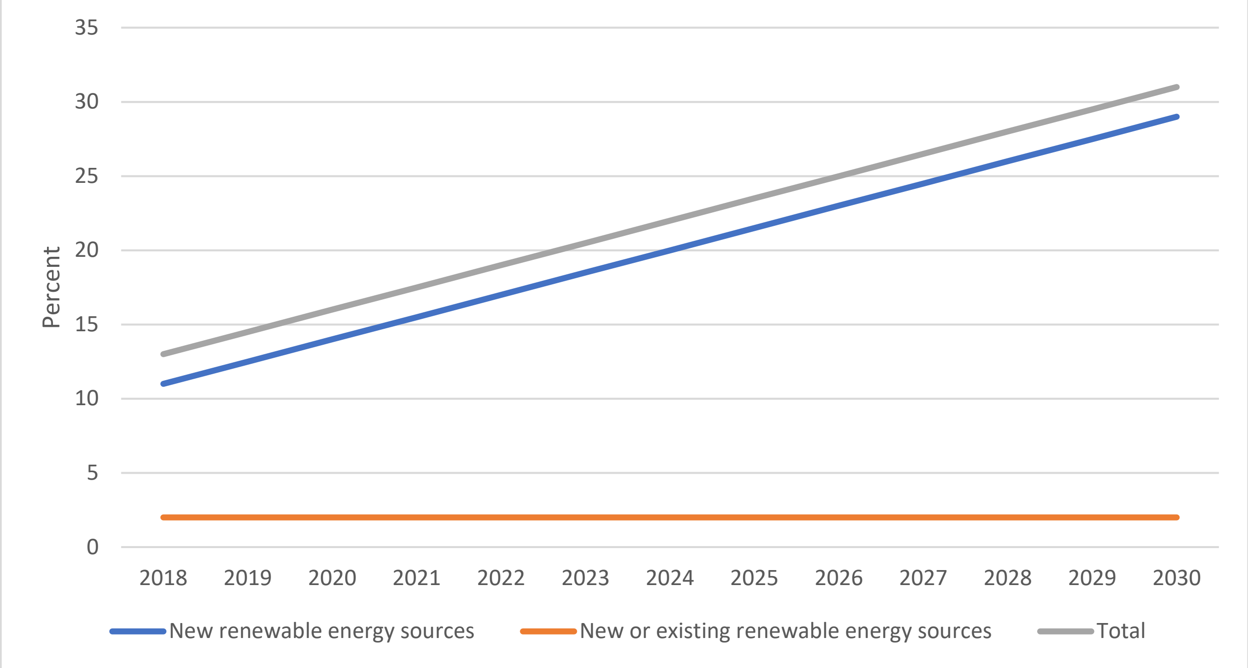
Source: Maine Legislature, LD 1494, An Act to Reform Maine's Renewable Portfolio Standard, Sec. 1. 35-A MRSA §3210 (2) (B), June 2019.
Note: Underlying data for this figure can be found in appendix table G.49.

Figure F.3 New Hampshire RPS by class (percent of electricity consumption), 2018–30



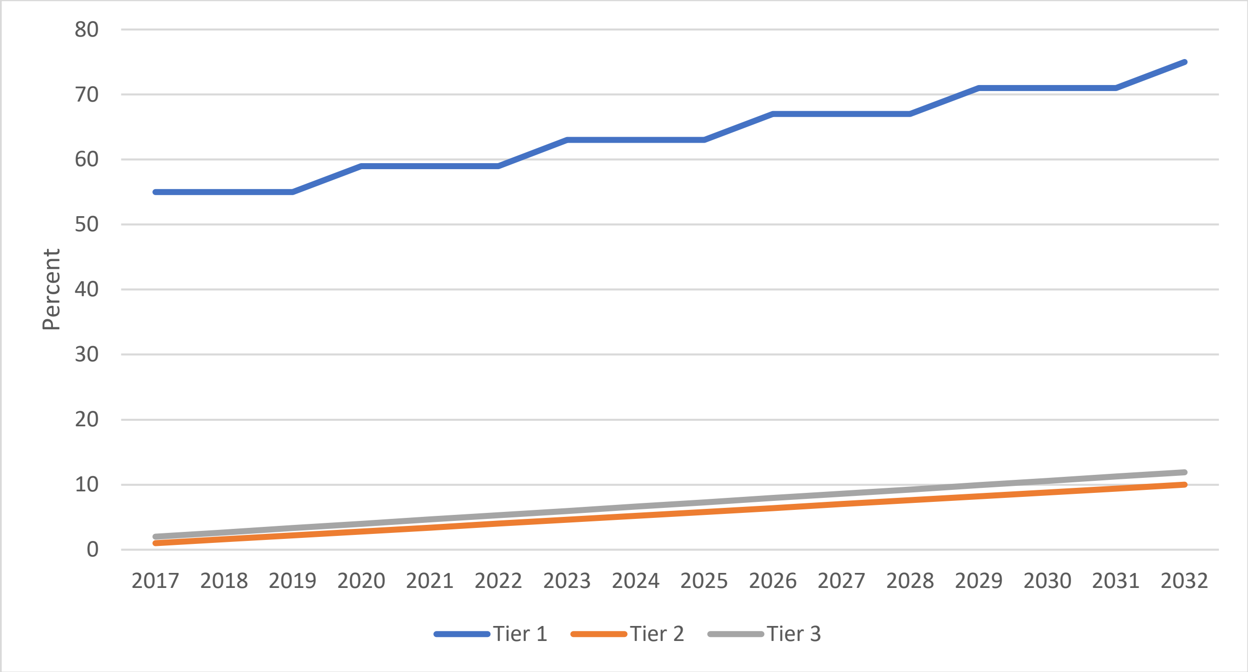
Source: New Hampshire Public Utility Commission, Electric Renewable Portfolio Standard (RPS) n.d. (accessed May 12, 2020).
Note: Underlying data for this figure can be found in appendix table G.50.

Figure F.4 Rhode Island RPS by new and existing sources (percent of electricity consumption), 2018–30



Source: State of Rhode Island, Public Utilities Commission and Division of Public Utilities and Carriers, “RES Obligation Targets, by Compliance Year, for Both New and Existing Resources.”
Note: Underlying data for this figure can be found in appendix table G.51.

Figure F.5 Vermont RPS by tier (percent of electricity consumption), 2017–32



Source: State of Vermont, Public Utility Commission, Renewable Energy Standard (accessed June 17, 2020).
Notes: Tier 2 qualified renewable energy sources can qualify as Tier 1 and should not be viewed as a cumulative mandate. Underlying data for this figure can be found in appendix table G.52.

Table F.1 Renewable energy credits in Connecticut (CT), 2019, by tier and location

Eligibility	Certificates count by eligibility	New York	Maritime provinces	Quebec	ISO New England settlement certificates	Behind-the-meter certificates
CT Class I	9,894,039	2,184,289	151,596	467,034	6,112,681	978,439
CT Class I FERC	0	0	0	0	0	0
CT Class II	1,116,851	0	0	0	1,116,851	0
CT Class III – CHP	1,042,927	0	0	0	144,921	898,006
CT Class III – CLM	47,028	0	0	0	0	0
CT Class III – DRP	0	0	0	0	0	0
CT LREC	213,453	0	0	0	0	213,453

Source: New England Power Pool Generation Information System (NEPOOL GIS), Certificates by Eligibility and Location (accessed November 4, 2020).
Notes: The Maritime provinces include portions of Maine not in the control area. For purposes of these data, New York is defined as the New York ISO control area. FERC = Federal Energy Regulatory Commission. CHP = combined heat and power. CLM = conservation and load management program. DRP = demand-response provider.

Table F.2 Renewable energy credits in Maine (ME), 2019, by tier and location

Eligibility	Certificates count by eligibility	New York	Maritime provinces	Quebec	ISO New England settlement certificates	Behind-the-meter certificates
ME Class I	5,466,935	462,217	72,018	117,584	3,605,662	1,209,454
ME Class II	12,916,841	389,352	311,436	855,281	9,981,066	1,379,706
ME Community Based Renewable Energy	0	0	0	0	0	0

Source: New England Power Pool Generation Information System (NEPOOL GIS), Certificates by Eligibility and Location (accessed November 4, 2020)

Notes: The Maritime provinces include portions of Maine not in the control area. For purposes of these data, New York is defined as the New York ISO control area.

Table F.3 Renewable energy credits in New Hampshire (NH), 2019, by tier and location

Eligibility	Certificates count by eligibility	New York	Maritime provinces	Quebec	ISO New England settlement certificates	Behind-the-meter certificates
NH Class I	4,212,229	986,250	0	0	3,178,934	47,045
NH Class I Biodiesel Producer	0	0	0	0	0	0
NH Class I Thermal	83,620	0	0	0	0	83,620
NH Class II	156,794	0	0	0	73,378	83,416
NH Class III	833,612	134,226	0	0	669,721	29,665
NH Class IV	181,922	0	0	0	155,223	26,699

Source: New England Power Pool Generation Information System (NEPOOL GIS), Certificates by Eligibility and Location (accessed November 4, 2020).

Notes: The Maritime provinces include portions of Maine not in the control area. For purposes of this data, New York is defined as the New York ISO control area.

Table F.4 Renewable energy credits in Rhode Island (RI), 2019, by tier and location

Eligibility	Certificates count by eligibility	New York	Maritime provinces	Quebec	ISO New England settlement certificates	Behind-the-meter certificates
RI existing renewable energy resource	1,889,998	11,007	0	0	1,862,813	16,178
RI new renewable energy resource	6,293,466	1,932,713	0	0	4,161,606	199,147

Source: New England Power Pool Generation Information System (NEPOOL GIS), Certificates by Eligibility and Location (accessed November 4, 2020)

Notes: The Maritime provinces include portions of Maine not in the control area. For purposes of these data, New York is defined as the New York ISO control area.

Table F.5 Renewable energy credits in Vermont (VT), 2019, by tier and location

Eligibility	Certificates count by eligibility	New York	Maritime provinces	Quebec	ISO New England settlement certificates	Behind-the-meter certificates
VT Tier I	12,306,518	0	0	0	11,302,257	1,004,261
VT Tier II	224,534	0	0	0	0	224,534

Source: New England Power Pool Generation Information System (NEPOOL GIS), Certificates by Eligibility and Location (accessed November 4, 2020)

Notes: The Maritime provinces include portions of Maine not in the control area. For purposes of these data, New York is defined as the New York ISO control area.

Table F.6 Net electricity generation for Columbia River Basin states, 2010 and 2018 (as a percentage of total generation)

Electricity generation source	Idaho, 2010	Idaho, 2018	Montana, 2010	Montana, 2018	Oregon, 2010	Oregon, 2018	Wash., 2010	Wash., 2018
Total	100	100	100	100	100	100	100	100
Coal	0.73	0.11	62.44	47.35	7.49	2.30	8.24	4.61
Hydroelectric conventional	76.13	60.67	31.60	40.42	55.40	55.28	66.00	69.28
Natural gas	14.05	18.04	0.19	1.69	28.39	27.95	10.01	9.02
Nuclear	[a]	[a]	[a]	[a]	[a]	[a]	8.93	8.32
Petroleum	0	0	1.37	1.58	0.01	0.01	0.03	0.02
Pumped storage	[a]	[a]	[a]	[a]	[a]	[a]	0.05	0.02
Wind	3.67	14.61	3.12	7.63	7.11	11.62	4.59	6.77
Wood and wood derived fuels	3.97	2.17	0.33	0.08	1.15	1.06	1.62	1.35
Geothermal	0.60	0.46	[a]	[a]	[a]	0.27	[a]	[a]
Solar thermal and photovoltaic	[a]	3.06	[a]	0.12	[a]	0.89	[a]	0
Other gases	[a]	[a]	0.01	0.04	[a]	[a]	0.28	0.37
Other biomass	0.20	0.53	[a]	[a]	0.37	0.56	0.19	0.20
Other	0.65	0.35	0.94	1.08	0.08	0.05	0.06	0.05

Source: EIA, "Table 5. Generation," updated March 23, 2020, State Electricity Profiles for Idaho, Montana, Oregon, and Washington.

[a] No value reported.

Appendix G
Data Tables for Selected Figures

In compliance with section 508, an amendment to the United States Workforce Rehabilitation Act of 1973, alternative text is used by screen readers to provide people with disabilities text equivalent for non-text elements. The tables in this appendix are referenced in the notes to the figures contained in this report.

Executive Summary Data Tables

Table G.1 New England and Massachusetts electricity generation by source (in terawatt-hours), 2010 and 2018

Electricity generation source	Massachusetts, 2010	Massachusetts, 2018	New England, 2010	New England, 2018
Renewable energy	2.3	3.5	15.8	19.6
Coal, petroleum, and other	9.0	0.8	14.7	2.3
Nuclear	5.9	4.4	38.4	31.4
Natural gas	25.6	18.4	57.6	50.5
Imports	19.3	29.9	5.5	21.5

Source: U.S. Energy Information Administration (EIA), “Massachusetts Electricity Profile,” table 5 and table 10, (Excel file, accessed March 24, 2020); ISO New England, Net Energy and Peak Load by Source (accessed March 24, 2020)

Notes: Coal-powered generation in Massachusetts in 2018 is zero. Renewable energy in this figure includes all forms of hydroelectric generation and generation from biomass. However, state-level renewable portfolio standards have varying eligibility requirements and may not qualify all of these as renewable generation sources. Table corresponds to figure ES.1.

Table G.2 Massachusetts’s clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50

Year	Total RPS obligations	Total CES obligations
2018	19.1	16.0
2019	20.2	18.0
2020	22.7	20.0
2021	24.7	22.0
2022	26.7	24.0
2023	28.7	26.0
2024	30.7	28.0
2025	32.7	30.0
2026	34.7	32.0
2027	36.7	34.0
2028	38.7	36.0
2029	40.7	38.0
2030	41.7	40.0
2031	42.7	42.0
2032	43.7	44.0
2033	44.7	46.0
2034	45.7	48.0
2035	46.7	50.0
2036	47.7	52.0
2037	48.7	54.0
2038	49.7	56.0
2039	50.7	58.0
2040	51.7	60.0
2041	52.7	62.0
2042	53.7	64.0
2043	54.7	66.0

Year	Total RPS obligations	Total CES obligations
2044	55.7	68.0
2045	56.7	70.0
2046	57.7	72.0
2047	58.7	74.0
2048	59.7	76.0
2049	60.7	78.0
2050	61.7	80.0

Source: Lawrence Berkeley National Laboratory, "RPS Targets (Percent of Applicable Retail Electricity Sales)," July 2019 (Excel file); State of Massachusetts, Global Warming Solutions Act 10-Year Progress Report, 2017, 30, 56.

Notes: Large-scale hydroelectricity is a qualifying resource for the Clean Energy Standard obligations only. Table corresponds to figure ES.2.

Table G.3 New England and U.S. average retail price of electricity, for residential and commercial customers in cents per kilowatt-hour (cents/kWh), 2010–19

Location and customer type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
New England residential	16.2	15.9	15.7	16.2	17.8	19.4	18.8	19.4	20.6	21.1
New England commercial	14.7	14.3	13.7	14.0	14.7	15.5	15.2	15.5	16.5	16.2
U.S. residential	11.5	11.7	11.9	12.1	12.5	12.7	12.6	12.9	12.9	13.0
U.S. commercial	10.2	10.2	10.1	10.3	10.7	10.6	10.4	10.7	10.7	10.7

Source: U.S. Energy Information Administration (EIA), "Electric Sales, Revenue, and Average Price," table 4 (Excel file, accessed March 24, 2020).

Note: Table corresponds to figure ES.3.

Table G.4 New England and Massachusetts electricity generation industry CO_2 emissions rate in pounds per megawatt-hour (lbs/MWh), 2010–18

Region	2010	2011	2012	2013	2014	2015	2016	2017	2018
New England	733.0	672.2	632.6	637.2	611.0	637.8	593.6	571.2	569.5
Massachusetts	1,043.0	948.0	887.0	986.0	913.0	920.0	876.0	846.0	808.0

Source: U.S. Energy Information Administration (EIA), "Massachusetts Electricity Profile," table 7 (Excel file, accessed March 24, 2020).

Notes: MWh = megawatt-hour. Table corresponds to figure ES.4.

Chapter 2 Data Tables

Table G.5 New England net electricity generation by source and imports (in terawatt-hours), 2010–19

Electricity generation source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Natural gas	57.6	62.3	61.1	51.1	47.6	53.6	52.1	49.2	50.5	47.4
Coal, petroleum, and other	14.7	7.4	3.9	6.6	5.9	4.7	3.1	2.4	2.3	0.7
Renewable energy	15.8	16.7	15.8	17.1	18.1	17.8	17.7	19.4	19.6	20.0
Nuclear	38.4	34.3	36.1	37.2	36.8	31.9	32.7	31.5	31.4	29.8
Imports	5.5	10.1	12.6	19.0	20.7	20.9	20.8	20.4	21.5	23.0

Source: ISO-NE, Net Energy and Peak Load by Source (accessed March 24, 2020).

Note: Table corresponds to figure 2.1.

Table G.6 New England net renewable electricity generation by energy source (in terawatt-hours), 2010–19

Energy source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Solar	0.0	0.0	0.0	0.1	0.3	0.5	0.7	0.9	1.2	1.7
Wind	0.5	0.8	1.2	1.8	1.9	2.2	2.5	3.3	3.4	3.5
Other biomass	3.4	3.2	3.4	3.3	3.1	3.0	3.9	3.7	3.6	3.5
Wood and wood-derived fuels	3.8	3.3	3.4	3.6	4.0	4.2	3.2	3.0	2.7	2.5
Hydroelectric	8.1	9.4	7.8	8.4	8.7	8.1	7.5	8.6	8.7	8.8

Source: ISO-NE, Net Energy and Peak Load by Source (March 24, 2020).
Notes: Hydroelectric generation in this chart includes both run-of-the-river hydroelectric as well as large-scale hydro. In this discussion, all forms of hydroelectric generation and generation from biomass are considered renewable. However, state-level renewable portfolio standards have varying eligibility requirements and may not qualify all of these as renewable generation sources. Table corresponds to figure 2.2.

Table G.7 New England electricity generation and net imports (in terawatt-hours), 2018

State	Generation	Net imports
Connecticut	39.5	-8.0
Maine	11.3	3.8
Massachusetts	27.2	29.9
New Hampshire	17.1	-5.3
Rhode Island	8.4	-0.1
Vermont	2.2	3.7

Source: EIA, state electricity profiles, tables 5 and 10 (accessed March 24, 2020).
"Massachusetts Electricity Profile," table 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Connecticut Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Maine Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "New Hampshire Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Rhode Island Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Vermont Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020).
Note: Table corresponds to figure 2.3.

Table G.8 New England electricity generation by state and energy source (percentage of total generation),2018

State	Renewable energy	Coal	Nuclear	Natural gas	Other
Connecticut	3.6	0.8	42.8	50.7	2.0
Maine	73.7	0.6	0.0	20.7	5.0
Massachusetts	12.9	0.0	16.3	67.7	3.1
New Hampshire	18.4	3.9	58.9	17.5	1.3
Rhode Island	4.8	0.0	0.0	94.3	0.9
Vermont	99.8	0.0	0.0	0.1	0.1

Source: EIA, "Massachusetts Electricity Profile," table 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Connecticut Electricity Profile," tables 5 and 10, (Excel file, accessed March 24, 2020); EIA, "Maine Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020); EIA, "New Hampshire Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020); EIA, "Rhode Island Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020); EIA, "Vermont Electricity Profile," tables 5 and 10 (Excel file, accessed March 24, 2020).
Note: Table corresponds to figure 2.4.

Table G.9 Massachusetts electricity generation by energy source and net imports (in terawatt-hours), 2010–18

Energy source	2010	2011	2012	2013	2014	2015	2016	2017	2018
Renewable energy	2.3	2.4	2.2	2.4	2.6	2.7	2.7	3.2	3.5
Coal	8.3	4.1	2.1	4.0	2.8	2.3	1.9	1.1	0.0
Nuclear	5.9	5.1	5.9	4.3	5.8	5.0	5.4	5.0	4.4
Natural gas	25.6	25.9	24.7	21.3	18.5	21.0	21.1	22.2	18.4
Other	0.7	0.6	0.7	0.9	1.4	1.2	0.8	0.6	0.8
Imports	19.3	21.9	24.9	27.3	28.0	27.3	26.0	24.6	29.9

Source: EIA, "Massachusetts Electricity Profile," table 5 and table 10 (Excel file, accessed March 24, 2020).
Note: Table corresponds to figure 2.5.

Table G.10 Massachusetts renewable electricity generation by energy source (in terawatt-hours), 2010–18

Energy source	2010	2011	2012	2013	2014	2015	2016	2017	2018
Hydroelectric	1.0	1.1	0.9	1.0	0.9	0.8	0.7	1.0	1.1
Other biomass	1.1	1.0	1.1	1.1	1.1	1.0	1.1	1.0	1.1
Solar	0.0	0.0	0.0	0.1	0.3	0.5	0.6	0.8	1.0
Wind	0.0	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Wood and wood-derived fuels	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: EIA, "Massachusetts Electricity Profile," table 5 (Excel file, accessed March 24, 2020).
Note: Table corresponds to figure 2.6.

Table G.11 New England (NE) and U.S. average retail price of electricity, residential and commercial customers in cents per kilowatt-hour (cents/kWh), 2010–19

Location and customer type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NE residential	16.2	15.9	15.7	16.2	17.8	19.4	18.8	19.4	20.6	21.1
NE commercial	14.7	14.3	13.7	14.0	14.7	15.5	15.2	15.5	16.5	16.2
U.S. residential	11.5	11.7	11.9	12.1	12.5	12.7	12.6	12.9	12.9	13.0
U.S. commercial	10.2	10.2	10.1	10.3	10.7	10.6	10.4	10.7	10.7	10.7

Source: EIA, "Electric Sales, Revenue, and Average Price," table 4 (Excel file, accessed March 24, 2020).
Note: Table corresponds to figure 2.7.

Table G.12 New England and Massachusetts electric power industry carbon dioxide (CO_2) emissions rate in pounds per MWh (lbs/MWh), 2010–18

Region	2010	2011	2012	2013	2014	2015	2016	2017	2018
New England	733.0	672.2	632.6	637.2	611.0	637.8	593.6	571.2	569.5
Massachusetts	1,043.0	948.0	887.0	986.0	913.0	920.0	876.0	846.0	808.0

Source: EIA, "Massachusetts Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Connecticut Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Maine Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "New Hampshire Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Rhode Island Electricity Profile," table 7 (Excel file, accessed March 24, 2020); EIA, "Vermont Electricity Profile," table 7 (Excel file, accessed March 24, 2020).
Note: Table corresponds to figure 2.8.

Table G.13 Massachusetts Class I RPS obligation, before and after the 2018 Massachusetts Act to Advance Clean Energy (percentage of electricity consumption)

Year	Pre-2018 RPS	2018 RPS
2010	5	5
2011	6	6
2012	7	7
2013	8	8
2014	9	9
2015	10	10
2016	11	11
2017	12	12
2018	13	13
2019	14	14
2020	15	16
2021	16	18
2022	17	20
2023	18	22
2024	19	24
2025	20	26
2026	21	28
2027	22	30
2028	23	32
2029	24	34
2030	25	35
2031	26	36
2032	27	37
2033	28	38
2034	29	39
2035	30	40
2036	31	41
2037	32	42
2038	33	43
2039	34	44
2040	35	45
2041	36	46
2042	37	47
2043	38	48
2044	39	49
2045	40	50
2046	41	51
2047	42	52
2048	43	53
2049	44	54
2050	45	55

Source: An Act to Advance Clean Energy, 2018 Mass. Acts 227; "Renewable Energy Portfolio Standard for Retail Electricity Suppliers," Mass. Gen. Laws ch. 25A, § 11 F.

Note: Table corresponds to figure 2.9.

Table G.14 Massachusetts renewable portfolio standard obligation (percent of electricity consumption), 2018–50

Year	Total CES obligations	Total RPS obligations	Class I (solar carve-out)	Class I (non-solar)	Class II existing RE	Class II municipal solid waste (MSW)
2018	16.0	19.1	6.6	6.4	2.6	3.5
2019	18.0	20.2	7.0	7.0	2.7	3.5
2020	20.0	22.7	8.4	7.6	3.2	3.5
2021	22.0	24.7	9.7	8.3	3.2	3.5
2022	24.0	26.7	11.1	8.9	3.2	3.5
2023	26.0	28.7	11.8	10.2	3.2	3.5
2024	28.0	30.7	11.8	12.2	3.2	3.5
2025	30.0	32.7	11.8	14.2	3.2	3.5
2026	32.0	34.7	11.7	16.3	3.2	3.5
2027	34.0	36.7	11.7	18.3	3.2	3.5
2028	36.0	38.7	11.7	20.3	3.2	3.5
2029	38.0	40.7	11.6	22.4	3.2	3.5
2030	40.0	41.7	11.6	23.4	3.2	3.5
2031	42.0	42.7	11.5	24.5	3.2	3.5
2032	44.0	43.7	11.5	25.5	3.2	3.5
2033	46.0	44.7	11.5	26.5	3.2	3.5
2034	48.0	45.7	11.4	27.6	3.2	3.5
2035	50.0	46.7	11.4	28.6	3.2	3.5
2036	52.0	47.7	11.3	29.7	3.2	3.5
2037	54.0	48.7	11.3	30.7	3.2	3.5
2038	56.0	49.7	11.2	31.8	3.2	3.5
2039	58.0	50.7	11.2	32.8	3.2	3.5
2040	60.0	51.7	11.1	33.9	3.2	3.5
2041	62.0	52.7	11.1	34.9	3.2	3.5
2042	64.0	53.7	11.0	36.0	3.2	3.5
2043	66.0	54.7	11.0	37.0	3.2	3.5
2044	68.0	55.7	10.9	38.1	3.2	3.5
2045	70.0	56.7	10.8	39.2	3.2	3.5
2046	72.0	57.7	10.8	40.2	3.2	3.5
2047	74.0	58.7	10.7	41.3	3.2	3.5
2048	76.0	59.7	10.6	42.4	3.2	3.5
2049	78.0	60.7	10.6	43.4	3.2	3.5
2050	80.0	61.7	10.5	44.5	3.2	3.5

Source: Lawrence Berkeley National Laboratory, “RPS Targets (Percent of Applicable Retail Electricity Sales),” July 2019, (Excel file).
Note: Table corresponds to figure 2.10.

Table G.15 Massachusetts clean energy standard and renewable portfolio standard obligations (as a percentage of electricity consumption), 2018–50

Year	Total RPS obligations	Total CES obligations
2018	19.1	16.0
2019	20.2	18.0
2020	22.7	20.0
2021	24.7	22.0
2022	26.7	24.0
2023	28.7	26.0
2024	30.7	28.0
2025	32.7	30.0
2026	34.7	32.0
2027	36.7	34.0
2028	38.7	36.0
2029	40.7	38.0
2030	41.7	40.0
2031	42.7	42.0
2032	43.7	44.0
2033	44.7	46.0
2034	45.7	48.0
2035	46.7	50.0
2036	47.7	52.0
2037	48.7	54.0
2038	49.7	56.0
2039	50.7	58.0
2040	51.7	60.0
2041	52.7	62.0
2042	53.7	64.0
2043	54.7	66.0
2044	55.7	68.0
2045	56.7	70.0
2046	57.7	72.0
2047	58.7	74.0
2048	59.7	76.0
2049	60.7	78.0
2050	61.7	80.0

Source: Lawrence Berkeley National Laboratory (Excel file); State of Massachusetts, Global Warming Solutions Act 10-Year Progress Report, 2017, 30, 56.
Note: Table corresponds to figure 2.11.

Table G.16 RGGI allowances for New England states, 2009–20 (by MmtCO$_2$ equivalent)

State	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Connecticut	10.7	10.7	10.7	10.7	10.7	5.9	5.7	5.6	5.5	5.3	5.2	5.1
Maine	5.9	5.9	5.9	5.9	5.9	3.3	3.2	3.1	3	3	2.9	2.8
Massachusetts	26.7	26.7	26.7	26.7	26.7	14.5	14.1	13.7	13.6	13.1	12.8	12.4
New Hampshire	8.6	8.6	8.6	8.6	8.6	4.8	4.6	4.5	4.4	4.3	4.2	4.1
Rhode Island	2.7	2.7	2.7	2.7	2.7	2.3	2.2	2.2	1.3	1.5	2	2
Vermont	1.2	1.2	1.2	1.2	1.2	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Source: RGGI, “Allowance Distribution,” September 2020.
Note: Table corresponds to figure 2.12.

Table G.17 Economy-wide emissions targets by New England state, 2010–50 (by MmtCO$_2$ equivalent)

State	1990	2010	2020	2030	2035	2050
Connecticut	45.3	45.3	40.8	27.1	27.1	9.8
Maine	19.4	19.4	17.4	10.7	10.7	3.9
Massachusetts	94.4	94.4	70.8	70.8	70.8	18.9
New Hampshire	16.0	13.6	11.6	8.8	8.8	8.8
Rhode Island	12.5	12.5	11.2	11.2	6.9	2.5
Vermont	8.4	8.4	8.4	4.2	4.2	2.1

Source: Compiled by USITC.

Notes: There is no statutory requirement in New Hampshire that economy-wide greenhouse gas emissions be reduced or reported. However, the state has an unofficial target of reducing emissions to 45 percent below 1990 levels by 2030. National Council of State Legislatures (NCSL), "State Renewable Portfolio Standards and Goals: New Hampshire," April 17, 2020. Table corresponds to figure 2.13.

Table G.18 Estimated installed solar photovoltaic capacity in New England, 2018–25 (commercial, residential, and utility, MW)

Year	Residential	Commercial	Utility
2018	1624	1188	1226
2019	1917	1325	1423
2020	2047	1534	1558
2021	2190	1764	1873
2022	2411	2158	2257
2023	2601	2470	2616
2024	2790	2772	2929
2025	2994	3089	3092

Source: BloombergNEF (accessed June 9, 2020).

Note: Table corresponds to figure 2.14.

Table G.19 Estimated installed wind capacity in New England, 2018–25 (onshore and offshore, MW)

Year	Offshore	Onshore
2018	30	1400
2019	30	1438
2020	30	1438
2021	430	1622
2022	842	1903
2023	2342	2167
2024	2342	2396
2025	3142	2515

Source: BloombergNEF (accessed June 9, 2020).

Note: Table corresponds to figure 2.15.

Chapter 3 Data Tables

Table G.20 Mandated share of load from renewable and clean sources under Massachusetts's recent goals and commitments (percentage of electricity consumption)

Year	Initial Renewable Portfolio Standard (pre-2018)	Clean Energy Standard (2017, includes hydropower)	Updated Renewable Portfolio Standard (Act to Advance Clean Energy, 2018)
2020	15	20	16
2021	16	22	18
2022	17	24	20
2023	18	26	22
2024	19	28	24
2025	20	30	26
2026	21	32	28
2027	22	34	30
2028	23	36	32
2029	24	38	34
2030	25	40	35
2031	26	42	36
2032	27	44	37
2033	28	46	38
2034	29	48	39
2035	30	50	40
2036	31	52	41
2037	32	54	42
2038	33	56	43
2039	34	58	44
2040	35	60	45
2041	36	62	46
2042	37	64	47
2043	38	66	48
2044	39	68	49
2045	40	70	50
2046	41	72	51
2047	42	74	52
2048	43	76	53
2049	44	78	54
2050	45	80	55

Source: Government of Massachusetts, "Program Summaries: Summaries of All" (accessed September 16, 2020); "Clean Energy Standard," 310 CMR 7.75 (2017); "Act to Advance Clean Energy (H4857)" (2018).

Note: Table corresponds to figure 3.1.

Chapter 4 Data Tables

Table G.21 Power generation in Idaho, Montana, Oregon, and Washington by energy source, in terawatt hours (TWh)

Energy source	2010	2011	2012	2013	2014	2015	2016	2017	2018
Hydroelectric	117	160	151	129	135	123	132	142	139
Natural gas	28	15	19	30	27	34	30	29	32
Coal	31	24	20	25	26	24	21	21	20
Wind	10	14	16	19	20	18	20	18	20
Nuclear	9	5	9	8	9	8	10	8	10
Other	5	5	5	5	5	6	5	6	6

Source: EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923), (accessed May 18, 2020).
Note: Table corresponds to figure 4.2.

Table G.22 Conventional hydroelectricity as a share of total net generation, 1990–2018 (percent)

Year	Idaho	Montana	Oregon	Washington	U.S. total
1990	94	41	82	86	10
1991	93	42	87	87	9
1992	89	32	75	79	8
1993	92	40	86	76	9
1994	91	32	81	74	8
1995	93	41	90	81	9
1996	94	51	88	83	10
1997	94	47	89	85	10
1998	93	39	78	78	9
1999	94	44	80	83	9
2000	92	36	74	74	7
2001	77	27	64	66	6
2002	90	38	73	76	7
2003	80	33	68	72	7
2004	78	33	64	70	7
2005	79	34	63	71	7
2006	84	36	71	76	7
2007	79	32	61	74	6
2008	78	34	58	70	6
2009	80	36	58	70	7
2010	76	32	55	66	6
2011	81	42	71	80	8
2012	71	41	65	77	7
2013	56	35	55	68	7
2014	59	38	59	68	6
2015	56	34	54	67	6
2016	58	36	57	69	7
2017	61	39	61	71	7
2018	61	40	55	69	7

Source: EIA, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) (accessed May 18, 2020).
Note: Table corresponds to figure 4.3.

Table G.23 Retail power prices for commercial customers in Columbia River Basin states and Massachusetts, 2010 and 2019 (in cents per kilowatt-hour)

State	2009	2019
Idaho	7.16	7.64
Montana	9.18	10.4
Oregon	8.28	8.89
Washington	7.69	8.73
Massachusetts	16.94	16.63
U.S.-wide	11.19	10.91

Source: BloombergNEF (accessed June 1, 2019).

Note: Table corresponds to figure 4.4.

Table G.24 Retail power prices for residential customers in Columbia River Basin states and Massachusetts, 2010 and 2019 (in cents per kilowatt-hour)

State	2009	2019
Idaho	8.63	9.89
Montana	9.93	11.3
Oregon	9.62	10.96
Washington	8.49	9.61
Massachusetts	18.62	22.07
US-wide	12.69	13.21

Source: BloombergNEF (accessed June 1, 2019).

Note: Table corresponds to figure 4.5.

Table G.25 CO_2 emissions per MWh of generation, 2012 and 2018

State	2012	2018
Idaho	76	97
Montana	576	554
Oregon	121	137
Washington	60	91
U.S. total	533	449

Source: EIA, Electric Power Annual 2013, March 2015, and Electric Power Annual 2018, October 2019.

Notes: The EIA *Electric Power Annual* does not include state-specific data on CO_2 emissions (in kg) per MWh of generation for years before 2012. Table corresponds to figure 4.6.

Table G.26 New York State electricity imports and electric generation by source (in terawatt-hours)

Electricity generation source	2010	2011	2012	2013	2014	2015	2016	2017	2018
Natural gas	48.92	50.81	59.46	54.35	54.38	56.92	56.79	47.27	50.81
Coal, petroleum, and other	16.42	11.52	6.10	6.59	7.66	5.19	3.31	2.29	3.15
Renewable energy	30.06	32.93	29.99	30.86	32.49	32.41	33.17	36.84	36.08
Nuclear	41.87	42.70	40.78	44.76	43.04	44.60	41.57	42.17	42.92
Total international imports	9.37	12.09	16.89	18.71	17.13	17.79	18.03	16.50	15.69
Net interstate imports	12.49	7.58	2.76	6.07	5.83	4.36	6.64	11.19	12.29

Source: EIA, New York Electricity Profile 2018, tables 5 and 10, December 31, 2019. (Excel file).

Note: Table corresponds to figure 4.7.

Table G.27 New York State upstate vs. downstate electricity generation by source, 2015–19 (in terawatt-hours)

Year	New York State region	Coal	Gas and oil	Nuclear	Hydro	Hydro pumped storage	Wind	Other renewables
2015	Upstate	2.05	22.45	28.20	25.70	0.83	3.98	1.66
2016	Upstate	1.49	6.51	26.51	24.58	0.46	3.94	1.36
2017	Upstate	0.57	5.32	26.87	27.11	0.44	4.22	1.39
2018	Upstate	0.69	6.49	26.67	26.81	0.40	3.99	1.21
2019	Upstate	0.43	6.02	28.09	27.53	0.35	4.45	1.20
2015	Downstate	0	39.46	16.42	0.18	0	0	1.42
2016	Downstate	0	53.87	15.13	1.74	0.37	0	1.57
2017	Downstate	0	45.59	15.30	2.44	0.35	0	1.58
2018	Downstate	0	48.78	16.33	2.23	0.41	0	1.57
2019	Downstate	0	45.43	16.70	2.62	0.23	0	1.50

Source: NYISO, *Power Trends 2016*, 2016; NYISO, *Power Trends 2017*, 2017; NYISO, *Power Trends 2018*, 2018; NYISO, *Power Trends 2019*, 2019; and NYISO, *Power Trends 2020*, 2020.

Notes: Net losses from hydro pumped storage are not included. Table corresponds to figure 4.8.

Table G.28 Electricity capacity in Denmark by source, 2010–19 (in MW)

Electricity generation type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wind	3,787	3,936	4,096	4,803	4,871	5,061	5,230	5,478	5,806	6,177
Solar	4	21	394	556	607	800	853	912	1,008	1,110
Biomass & waste	762	904	1,081	1,253	1,384	1,377	1,843	2,055	2,389	2,414
Coal, gas, and other	7,052	6,996	6,134	5,329	5,423	5,422	4,312	5,855	5,423	4,115
Total	11,605	11,857	11,705	11,941	12,285	12,660	12,238	14,300	14,626	13,816

Source: BloombergNEF (fee required; accessed April–August 2020).

Note: MW = megawatts. Table corresponds to figure 4.10.

Table G.29 Electricity generation in Denmark by source, 2010–19 (in terawatt-hours)

Electricity generation type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wind	7,809	9,774	10,270	11,123	13,079	14,133	12,782	14,780	13,899	14,923
Solar	15	104	518	596	604	1,031	1,293	1,407	1,720	1,720
Biomass & waste	6,087	5,931	5,906	5,744	5,743	5,685	6,254	7,710	7,306	7,791
Coal	17,006	13,976	10,539	14,292	11,064	7,110	8,865	6,209	6,570	3,795
Gas	7,906	5,841	4,192	3,417	2,096	1,824	2,255	2,017	2,072	1,959
Other	795	470	420	364	331	336	343	298	280	273
Total	39,618	36,096	31,845	35,536	32,917	30,119	31,792	32,421	31,847	30,461

Source: BloombergNEF (fee required; accessed April–August 2020).

Note: Table corresponds to figure 4.10.

Table G.30 Denmark's imports of electricity, January 2010–June 2020 (in GWh)

Year	Norway	Sweden	Germany	Netherlands
2010	1,452.3	2,747.1	6,399.9	n/a
2011	3,598.0	5,227.6	2,867.6	n/a
2012	5,454.5	9,104.3	1,361.4	n/a
2013	2,553.2	3,189.5	5,715.9	n/a
2014	4,120.4	4,755.9	3,826.1	n/a
2015	6,570.8	6,499.7	2,574.3	n/a
2016	6,807.4	3,071.6	5,097.4	n/a
2017	5,430.8	5,758.2	4,029.1	n/a
2018	5,034.8	4,750.1	5,848.8	n/a
2019	3,383.9	5,355.9	6,587.1	655.4
H1 2019	1,434.0	2,780.0	3,124.0	n/a
H1 2020	3,325.0	2,540.0	2,177.0	549.0

Source: Danish Energy Agency, "Electricity Supply" (Excel file, accessed March–August 2020).

Notes: H1: January to June. n/a = not applicable. GWh = gigawatt-hours. The transmission line between Denmark and the Netherlands did not come online until September 2019. Table corresponds to figure 4.11.

Table G.31 Denmark's exports of electricity, January 2010–June 2020 (in GWh)

Year	Norway	Sweden	Germany	Netherlands
2010	4,049.4	4,985.4	2,699.7	n/a
2011	2,411.1	2,781.1	5,182.5	n/a
2012	673.2	1,590.0	8,443.0	n/a
2013	2,840.4	4,190.4	3,346.6	n/a
2014	1,453.1	3,744.6	4,649.4	n/a
2015	1,616.5	2,851.1	5,265.5	n/a
2016	1,749.4	5,225.7	2,944.3	n/a
2017	2,386.2	2,858.0	5,411.2	n/a
2018	2,617.1	3,288.0	4,504.1	n/a
2019	3,299.9	3,165.8	3,069.5	636.0
H1 2019	2,126.0	1,671.0	1,710.0	n/a
H1 2020	675.0	1,254.0	2,727.0	1,775.0

Source: Danish Energy Agency, "Electricity Supply" (Excel file, accessed March–August 2020).

Notes: H1: January to June. n/a = not applicable. GWh = gigawatt-hours. The transmission line between Denmark and the Netherlands did not come online until September 2019. Table corresponds to figure 4.11.

Table G.32 Denmark's net exports of electricity, January 2010–June 2020 (in GWh)

Year	Norway	Sweden	Germany	Netherlands
2010	2,597.0	2,238.3	-3,700.2	n/a
2011	-1,186.9	-2,446.4	2,314.9	n/a
2012	-4,781.4	-7,514.4	7,081.6	n/a
2013	287.2	1,000.9	-2,369.2	n/a
2014	-2,667.3	-1,011.3	823.3	n/a
2015	-4,954.2	-3,648.6	2,691.2	n/a
2016	-5,058.1	2,154.0	-2,153.0	n/a
2017	-3,044.6	-2,900.2	1,382.1	n/a
2018	-2,417.6	-1,462.1	-1,344.7	n/a
2019	-84.0	-2,190.1	-3,517.7	-19.4
H1 2019	692.0	-1,109.0	-1,414.0	n/a
H1 2020	-2,650.0	-1,286.0	550.0	1,226.0

Source: Danish Energy Agency, "Electricity Supply" (Excel file, accessed March–August 2020).

Notes: H1: January to June. n/a = not applicable. GWh = gigawatt-hours. The transmission line between Denmark and the Netherlands did not come online until September 2019. Table corresponds to figure 4.11.

Table G.33 Electricity prices in Denmark, 2010–19 (in cents/kWh)

Consumer type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Residential	35.7	41.0	38.4	39.4	40.4	33.9	34.2	34.2	36.9	33.4
Commercial	30.9	36.8	33.6	36.6	37.5	31.6	32.2	34.1	35.2	33.4
Small Industrial	30.3	33.2	30.9	32.9	34.3	28.8	29.4	29.1	29.8	
Large Industrial	29.1	31.8	29.6	31.4	31.9	27.0	27.5	26.9	28.3	
Wholesale base	6.9	6.8	4.8	5.2	4.2	2.6	3.1	3.5	5.3	4.4
Wholesale peak	7.6	7.6	5.4	5.8	4.6	3.0	3.5	3.9	5.8	4.8

Source: BloombergNEF (accessed April 11, 2020).

Notes: KWh = kilowatt-hours. Residential, commercial, small industrial, and large industrial prices are retail prices. Table corresponds to figure 4.12.

Table G.34 Components of retail prices in 2019 (as a percentage of the total retail price)

Retail price component	Residential	Commercial and industrial
Electricity	6.0	4.7
Transmission/distribution	5.8	2.9
Taxes/fees	17.7	19.4

Source: Eurostat (accessed May 20, 2020).

Note: Table corresponds to figure 4.12.

Table G.35 Fossil fuel prices, reservoir levels, wind production, and electricity consumption, 2010–19 (Index, 2010 = 100)

Series	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wholesale electricity price	100.0	99.0	69.3	76.2	60.9	38.4	45.4	51.2	77.7	64.2
Coal	100.0	132.1	102.2	89.2	81.7	60.9	64.2	90.4	99.9	67.9
Natural gas	100.0	137.9	140.3	156.5	121.1	95.7	67.6	84.5	116.3	66.5
Carbon price	100.0	97.0	50.4	31.6	41.5	44.7	31.1	34.7	97.6	145.8
Norway reservoir levels	100.0	114.8	138.4	118.6	126.1	127.6	130.0	124.1	115.1	121.4
Denmark wind production	100.0	125.2	131.5	142.4	167.5	181.0	163.7	189.4	178.2	206.8

Source: BloombergNEF (fee required; accessed April–June, 2020); Danish Energy Agency, "Electricity Supply" (Excel file, accessed March 26, 2020); NVE, "Magasinstatistikk" (reservoir statistics), (accessed June 4, 2020).

Note: Table corresponds to figure 4.13.

Table G.36 Difference between daily minimum and maximum prices, 2019 (in $/MWh)

Quantile	Nord Pool	France	Germany	United Kingdom
Upper extreme	21.6	55.0	68.1	70.7
Upper quartile	12.7	35.8	40.9	47.7
Median	9.0	28.5	29.5	37.6
Lower quartile	6.7	22.8	22.6	30.4
Lower extreme	1.9	7.1	7.4	19.5

Source: BloombergNEF (fee required; accessed June 4, 2020).

Notes: Excludes outliers. Table corresponds to figure 4.14.

Table G.37 Greenhouse gas emissions (CO_2 equivalent) from electricity, gas, steam and air conditioning supply, 2010–18 (in million tons)

Year	Denmark
2010	21,512,750.40
2011	17,285,794.30
2012	13,980,119.90
2013	16,192,520.80
2014	12,587,541.90
2015	9,701,215.90
2016	11,096,830.20
2017	8,519,138.10
2018	7,449,614.00

Source: Eurostat (accessed March 26, 2020).

Notes: Includes the following greenhouse gas (GHG) emissions in CO_2 equivalent: CO_2, nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbon, perfluorocarbons, sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Table corresponds to figure 4.15.

Table G.38 Greenhouse gas emissions (CO_2 equivalent) from electricity, gas, steam and air conditioning supply, 2010–18 (in grams/euro value added)

Year	Denmark	EU-28
2010	5,553.70	5,581.00
2011	4,826.10	5,650.60
2012	4,151.20	5,229.10
2013	5,196.60	4,975.10
2014	3,768.30	4,689.70
2015	2,563.30	4,583.20
2016	2,992.40	4,516.70
2017	2,622.00	4,437.90
2018	2,294.50	4,201.90

Source: Eurostat (accessed March 26, 2020).

Notes: Includes the following GHGs in CO_2 equivalent: CO_2, nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbon, perfluorocarbons, sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Table corresponds to figure 4.15.

Table G.39 Observed CO_2 emissions, nonrenewable energy power plants, 2010–18, in million metric tons (Mmt)

Year	Oil	Natural gas	Coal	Waste, nonrenewable
2010	594.7	3,247.20	13,077.30	747
2011	322.7	2,435.80	10,853.60	759.4
2012	276.8	1,801.90	8,081.20	795.7
2013	292.7	1,526.30	10,705.70	831.8
2014	220.4	905.4	8,458.30	876.4
2015	210.9	816.2	5,517.40	888.9
2016	205	929	6,729.70	878.2
2017	180.7	827.1	4,810.60	803.9
2018	175.9	793.3	5,063.20	751

Source: Danish Energy Agency, Energy Statistics 2018, February 2020. (Excel file).

Note: Table corresponds to figure 4.16.

Table G.40 CO2 emissions per kWh of electricity consumption in Denmark, 2010–18, adjusted (in grams/kWh)

Region	2010	2011	2012	2013	2014	2015	2016	2017	2018
Denmark	505	474	473	436	389	348	369	290	306

Source: Danish Energy Agency, Energy Statistics 2018, February 2020 (Excel file); Danish Energy Agency, *Energy Statistics 2018*, February 2020, 39–40.

Notes: KWh = kilowatt-hours. Adjusted for weather and trade. Table corresponds to figure 4.17.

Appendix E Data Tables

Table G.41 Average revenue minus average cost estimates, 2050 High Renewables Cost case example

Share of electricity generation from renewable sources	Profitability for different levels of renewables penetration
0.45	-7.45
0.46	-7.46
0.47	-7.48
0.48	-7.50
0.49	-7.51
0.50	-7.53
0.51	-7.55
0.52	-7.57
0.53	-7.59
0.54	-7.61
0.55	-7.63
0.56	-7.65
0.57	-7.68
0.58	-7.70
0.59	-7.73
0.60	-7.76
0.61	-7.78
0.62	-7.81
0.63	-7.85
0.64	-7.88
0.65	-7.92
0.66	-7.95
0.67	-7.99
0.68	-8.04
0.69	-8.08
0.70	-8.13
0.71	-8.18
0.72	-8.24
0.73	-8.30
0.74	-8.36
0.75	-8.43
0.76	-8.51
0.77	-8.59
0.78	-8.68
0.79	-8.77
0.80	-8.88

Source: USITC calculations.

Note: Table corresponds to figure E.1.

Table G.42 Overnight installed capital cost in the United States by technology, Reference case (in 2019 dollars per kilowatt)

Year	Natural gas combined cycle	Wind	Solar photovoltaic
2019	954	1260	1307
2020	931	1231	1195
2021	917	1214	1123
2022	901	1198	1061
2023	871	1189	1013
2024	851	1178	986
2025	837	1168	967
2026	821	1157	944
2027	809	1145	923
2028	798	1132	903
2029	786	1118	884
2030	775	1104	866
2031	764	1090	850
2032	752	1077	836
2033	742	1064	821
2034	733	1051	807
2035	724	1038	792
2036	716	1025	778
2037	707	1013	764
2038	699	1000	750
2039	691	988	737
2040	684	977	724
2041	677	965	711
2042	670	954	699
2043	662	943	686
2044	655	932	674
2045	647	921	661
2046	641	910	650
2047	634	900	638
2048	627	889	626
2049	620	878	615
2050	618	875	608

Source: EIA, AEO2020 Full Report, January 29, 2020, 19.
Note: Table corresponds to figure E.2.

Table G.43 Overnight installed capital cost in the United States by technology, Low Renewables Cost case (in 2019 dollars per kilowatt)

Year	Natural gas combined cycle	Wind	Solar photovoltaic
2019	954	1260	1307
2020	932	1183	1197
2021	917	1119	1122
2022	901	1082	1061
2023	870	1040	1012
2024	849	1002	985
2025	835	979	958
2026	820	949	932
2027	808	924	905
2028	796	899	877
2029	785	874	849
2030	774	851	821
2031	763	825	794
2032	752	803	767
2033	742	782	741
2034	732	762	714
2035	723	742	688
2036	715	721	664
2037	707	702	639
2038	698	684	614
2039	691	668	590
2040	684	652	567
2041	676	638	544
2042	669	625	522
2043	662	612	500
2044	655	599	478
2045	647	586	457
2046	640	574	435
2047	633	562	415
2048	627	550	394
2049	620	538	374
2050	618	531	357

Source: EIA, AEO2020 Full Report, January 29, 2020, 19.
Note: Table corresponds to figure E.2.

Table G.44 Overnight installed capital cost in the United States by technology, High Renewables Cost case (in 2019 dollars per kilowatt)

Year	Natural gas combined cycle	Wind	Solar photovoltaic
2019	954	1260	1307
2020	932	1260	1307
2021	917	1260	1307
2022	901	1260	1307
2023	870	1260	1307
2024	850	1260	1307
2025	833	1260	1307
2026	818	1260	1307
2027	805	1260	1307
2028	795	1260	1307
2029	784	1260	1307
2030	772	1260	1307
2031	761	1260	1307
2032	750	1260	1307
2033	741	1260	1307
2034	732	1260	1307
2035	723	1260	1307
2036	715	1260	1307
2037	707	1260	1307
2038	699	1260	1307
2039	691	1260	1307
2040	684	1260	1307
2041	677	1260	1307
2042	669	1260	1307
2043	662	1260	1307
2044	655	1260	1307
2045	647	1260	1307
2046	640	1260	1307
2047	634	1260	1307
2048	627	1260	1307
2049	620	1260	1307
2050	618	1260	1307

Source: EIA, AEO2020 Full Report, January 29, 2020, 19.

Note: Table corresponds to figure E.2.

Table G.45 U.S. electricity generation from selected fuels, Reference case (in terawatt-hours)

Year	Renewables	Natural gas
2019	772.0	1558.5
2020	844.1	1552.8
2021	918.7	1638.7
2022	1023.8	1627.8
2023	1108.9	1627.3
2024	1158.1	1609.5
2025	1217.9	1613.8
2026	1260.7	1621.9
2027	1292.0	1609.1
2028	1322.8	1608.5
2029	1363.9	1605.1
2030	1420.6	1577.0
2031	1438.9	1596.1
2032	1449.1	1619.3
2033	1460.6	1650.8
2034	1471.5	1699.8
2035	1510.4	1710.3
2036	1541.0	1727.5
2037	1566.5	1748.7
2038	1596.7	1771.4
2039	1625.8	1791.8
2040	1658.8	1814.9
2041	1695.7	1826.9
2042	1737.6	1836.4
2043	1786.8	1849.3
2044	1838.7	1848.9
2045	1893.0	1852.2
2046	1932.9	1862.8
2047	1968.9	1886.5
2048	1997.5	1918.0
2049	2029.0	1951.3
2050	2064.0	1976.0

Source: EIA, AEO2020 Full Report, January 29, 2020, 58.
Note: Table corresponds to figure E.3.

Table G.46 U.S. electricity generation from selected fuels, High Oil and Gas Supply case (in terawatt-hours)

Year	Renewables	Natural gas
2019	772.0	1557.6
2020	844.3	1560.1
2021	919.1	1693.5
2022	1024.3	1723.1
2023	1089.8	1754.1
2024	1118.0	1778.6
2025	1173.5	1847.6
2026	1205.7	1951.1
2027	1228.9	1998.2
2028	1247.0	2014.9
2029	1269.2	2038.9
2030	1311.2	2046.6
2031	1326.0	2081.4
2032	1334.6	2110.1
2033	1344.2	2150.8
2034	1355.9	2193.0
2035	1394.9	2207.3
2036	1414.0	2278.5
2037	1422.9	2313.4
2038	1436.4	2383.7
2039	1449.0	2437.1
2040	1463.6	2472.0
2041	1477.8	2508.0
2042	1497.2	2546.0
2043	1523.2	2577.6
2044	1555.5	2617.5
2045	1587.9	2653.0
2046	1621.4	2694.2
2047	1656.2	2722.9
2048	1694.0	2754.4
2049	1736.5	2785.7
2050	1783.9	2821.0

Source: EIA, AEO2020 Full Report, January 29, 2020, 58.
Note: Table corresponds to figure E.3.

Table G.47 U.S. electricity generation from selected fuels, Low Oil and Gas Supply case (in terawatt-hours)

Year	Renewables	Natural gas
2019	772.0	1557.8
2020	843.0	1552.5
2021	917.3	1524.7
2022	1029.6	1486.4
2023	1121.6	1437.7
2024	1186.4	1376.2
2025	1250.5	1354.0
2026	1320.2	1289.9
2027	1404.4	1227.6
2028	1499.8	1155.8
2029	1565.8	1124.0
2030	1632.9	1085.2
2031	1689.1	1056.4
2032	1721.7	1047.3
2033	1749.2	1048.1
2034	1771.2	1061.6
2035	1824.3	1053.3
2036	1869.9	1052.2
2037	1912.2	1053.1
2038	1959.2	1053.3
2039	2010.8	1051.8
2040	2059.3	1048.3
2041	2121.4	1033.0
2042	2187.7	1016.8
2043	2246.8	1011.6
2044	2306.3	1006.9
2045	2362.7	1012.5
2046	2426.4	1018.4
2047	2492.7	1012.9
2048	2571.0	1009.9
2049	2655.3	1006.8
2050	2750.5	1001.0

Source: EIA, AEO2020 Full Report, January 29, 2020, 58.
Note: Table corresponds to figure E.3.

Appendix F Data Tables

Table G.48 Connecticut RPS by class (percent of electricity consumption), 2018–30

Year	Class I	Class II and III	Total
2018	17	8	25
2019	19.5	8	27.5
2020	21	8	29
2021	22.5	8	30.5
2022	24	8	32
2023	26	8	34
2024	28	8	36
2025	30	8	38
2026	32	8	40
2027	34	8	42
2028	36	8	44
2029	38	8	46
2030	40	8	48

Source: Department of Energy and Environmental Protection, Public Utilities Regulatory Authority. Connecticut Renewable Portfolio Standard, March 2020.
Note: Table corresponds to figure F.1.

Table G.49 Maine RPS by class (percent of electricity consumption), 2020–30

Year	Class I resource	Class IA resource	Class II resource	Total
2020	10	2.5	30	42.5
2021	10	5	30	45
2022	10	8	30	48
2023	10	11	30	51
2024	10	15	30	55
2025	10	19	30	59
2026	10	23	30	63
2027	10	27	30	67
2028	10	31	30	71
2029	10	35	30	75
2030	10	40	30	80
2031	10	40	30	80
2032	10	40	30	80

Source: Maine Legislature, LD 1494, An Act to Reform Maine's Renewable Portfolio Standard, Sec. 1. 35-A MRSA §3210 (2) (B), June 2019.
Note: Table corresponds to figure F.2.

Table G.50 New Hampshire RPS by class (percent of electricity consumption), 2018–30

Year	Class I non-thermal	Class I thermal	Class II	Class III	Class IV	Total
2018	7.5	1.2	0.5	8	1.5	18.7
2019	8.2	1.4	0.6	8	1.5	19.7
2020	8.9	1.6	0.7	8	1.5	20.7
2021	9.6	1.8	0.7	8	1.5	21.6
2022	10.3	2	0.7	8	1.5	22.5
2023	11	2.2	0.7	8	1.5	23.4
2024	11.9	2.2	0.7	8	1.5	24.3
2025	12.8	2.2	0.7	8	1.5	25.2
2026	12.8	2.2	0.7	8	1.5	25.2
2027	12.8	2.2	0.7	8	1.5	25.2
2028	12.8	2.2	0.7	8	1.5	25.2
2029	12.8	2.2	0.7	8	1.5	25.2
2030	12.8	2.2	0.7	8	1.5	25.2

Source: New Hampshire Public Utility Commission, Electric Renewable Portfolio Standard (RPS) n.d. (accessed May 12, 2020).
Note: Table corresponds to figure F.3.

Table G.51 Rhode Island RPS by new and existing sources (percent of electricity consumption), 2018–30

Year	New renewable energy sources	New or existing renewable energy sources	Total
2018	11	2	13
2019	12.5	2	14.5
2020	14	2	16
2021	15.5	2	17.5
2022	17	2	19
2023	18.5	2	20.5
2024	20	2	22
2025	21.5	2	23.5
2026	23	2	25
2027	24.5	2	26.5
2028	26	2	28
2029	27.5	2	29.5
2030	29	2	31

Source: Rhode Island Public Utilities Commission and Division of Public Utilities and Carriers, "RES Obligation Targets, by Compliance Year, for Both New and Existing Resources."
Note: Table corresponds to figure F.4.

Table G.52 Vermont RPS by tier (percent of electricity consumption), 2017–32

Year	Tier 1	Tier 2	Tier 3
2017	55	1	2
2018	55	1.6	2.66
2019	55	2.2	3.32
2020	59	2.8	3.98
2021	59	3.4	4.64
2022	59	4	5.3
2023	63	4.6	5.96
2024	63	5.2	6.62
2025	63	5.8	7.28
2026	67	6.4	7.94
2027	67	7	8.6
2028	67	7.6	9.26
2029	71	8.2	9.92
2030	71	8.8	10.58
2031	71	9.4	11.24
2032	75	10	11.9

Source: State of Vermont Public Utility Commission, Renewable Energy Standard (accessed June 17, 2020).

Note: This figure can be found in appendix table F.5.