The RGGI Opportunity 2.0

RGGI as the Electric Sector Compliance Tool to Achieve 2030 State Climate Targets

Sierra Club, Pace Energy and Climate Center, and Chesapeake Climate Action Network

Updated Version March 4, 2016

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EDITOR'S NOTE

This updated version of *The RGGI Opportunity* considers the gas and oil savings (co-benefits) from electric energy efficiency measures and the electric savings from gas energy efficiency measures. It also includes two new carbon dioxide emission reduction measures that were not considered in our original January 2016 report:

- Gas energy efficiency measures in the residential, commercial, and industrial sectors
- The replacement of aging residential oil heating systems with air-source heat pumps (efficient electric heating units)

In addition, this study:

- revises the methodology for choosing which emission reduction measures to include in the modeling by incorporating the cost of powering electric vehicles with renewables;
- reallocates the installation of onshore wind generators across Northeast states to be more consistent with expected wind speed potential; and
- uses updated levelized costs of energy for onshore wind and utility-scale solar, reflecting the best information available at the time of publishing.

With these measures in effect, lower emission reductions are required of the electric sector to reach the same 40-percent all-sector emissions reduction target for the nine Regional Greenhouse Gas Initiative states.

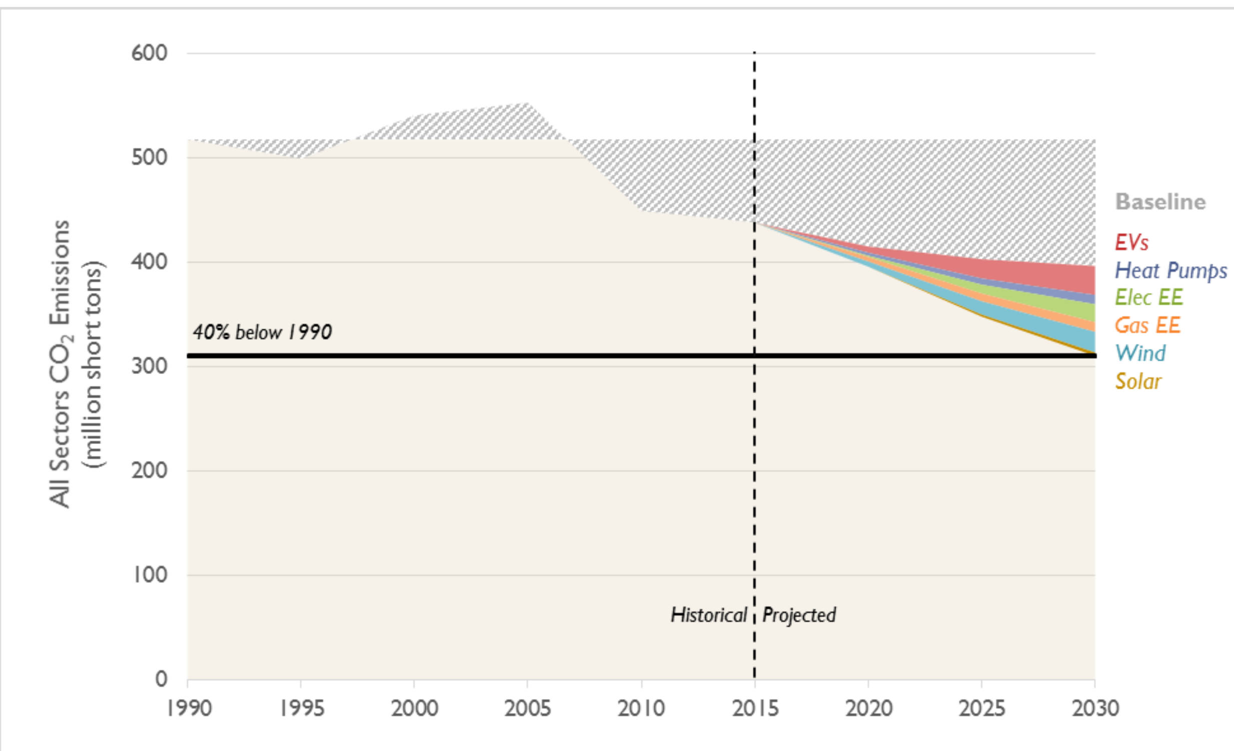
EXECUTIVE SUMMARY

For the past seven years, nine northeastern states have led the country in addressing greenhouse gas emissions from the electric sector. Working together under the Regional Greenhouse Gas Initiative (RGGI), Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont have already cut electric-sector carbon dioxide (CO_2) emissions by 45 percent compared to their 1990 levels and have created a framework to drive deeper electric sector reductions in the future. RGGI's electric sector carbon cap is complemented by individual state renewable portfolio standards (RPS) and energy efficiency resource standards (EERS) that are further helping to transform power generation in the region. The nine RGGI states have also led the country in establishing longer-term economy-wide climate goals, clustering around a 40 percent reduction from 1990 levels by 2030 and an 80 percent reduction by 2050.

Synapse evaluated the most cost-effective approaches for states to meet their 2030 climate goals, while avoiding investments during this time frame that would hinder compliance with states' longer-term 2050 goals. This least-cost strategy achieves a 40 percent CO_2 emission reduction in the nine states by 2030 by lowering the RGGI cap on electric sector emissions from 78 million short tons in 2020 to 39 million short tons in 2030, and adding a new emission reduction measures in the transportation, buildings, and industrial sectors.

In Figure ES-1, the grey area labeled "Baseline" shows the all-sector emission reductions expected without any additional policy measures: 23 percent below 1990 levels by 2030.

Figure ES-1. Emission reductions required to meet 40 percent target in RGGI states



The least-cost strategies modeled by Synapse to achieve an all-sector 40 percent emission reductions in the RGGI region by 2030 include converting one-third of gasoline-powered light-duty vehicles to electric vehicles, replacing 44 percent of the region's residential oil heating consumption with efficient electric-power heat pumps, achieving ambitious electric and gas efficiency savings in all nine states, and investing in new wind generation up to its economic potential. Achieving a 40 percent reduction using these strategies yields $25.7 billion in total savings from 2016 through 2030 and 58,400 new jobs each year in the RGGI region. Asking more from RGGI than its original targets is a win-win for consumers, workers, and the environment.

Achieving a 40 percent CO_2 emission reduction will be driven by reductions in multiple sectors.

While the electric sector will continue to be responsible for nearly half of the incremental emission reductions in 2030, reductions from other sectors are also critical to achieving RGGI states' 2030 climate goals. Synapse's analysis examined the electric, transportation, buildings, and industrial sectors for the least-cost emission reduction combination, and left today's natural gas generating capacity in operation during the transition to renewables. With the 40 percent emission reduction, natural gas generation only runs when it is economic and necessary. In this way it continues to support electric service reliability and plays a role in smoothing out any mismatches between renewable generation and predominantly night-time charging of electric vehicles.

Emission reductions measures save money for customers.

After accounting for the cost of expected damages from climate change, all six emission reduction measures used in this study lower energy sector costs. Even if climate damage costs are omitted, five of the six measures have net negative energy sector costs (that is, benefits). The remaining measure—utility-scale solar, which is not needed to achieve emission reductions—has very low net costs.

Increased adoption of electric vehicles saves money for consumers.

The cost savings of switching from gasoline to electricity to power a car more than make up for electric vehicles' higher purchase price. Our assessment of which emission reduction measures have lower and higher costs includes a value for the climate impacts avoided by lowering CO_2 emissions. But even ignoring the benefits of avoiding damage from climate change, electric vehicles save households money.

Converting aging oil heaters to efficient heat pumps can save money on both heating and cooling.

The Northeast states are unique in their reliance on high-CO_2-emitting oil for home heating. By shifting heating consumption from inefficient, high-emitting oil boilers and furnaces to highly efficient heat pumps, 9 million short tons of CO_2 can be avoided.

Modernizing outdated gas furnaces to more efficient units and adding better insulation to homes reduces both gas utility bills and emissions.

More efficient use of natural gas in homes and businesses has the potential to significantly reduce the RGGI region's greenhouse gas emissions. In 2030, natural gas energy efficiency measures save 159 trillion Btu in the 40 percent emission reduction scenario and avoid 5 percent of total gas consumption between 2015 and 2030.

Robust investment in energy efficiency lowers overall electric sales despite a significant increase in electric vehicles and heat pumps.

In 2030, efficiency measures save 81,000 gigawatt-hours of electricity in the 40 percent emission reduction scenario. Converting one-third of all light-duty vehicles to run on electricity and adding 1.3 million new heat pumps only adds 23,600 gigawatt-hours.

Efficiency measures will continue to lower consumers' bills.

Applying Massachusetts' expected electric energy efficiency savings in terms of percent of sales—based on their current three-year plan—to all RGGI states lowers electric sales by 11 percent by 2030. These efficiency savings have been determined to be cost effective in Massachusetts.

Renewables supply one-half of the RGGI region's electric generation in 2030.

Adding 50,000 gigawatt-hours of new wind and solar in the 40 percent emission reduction scenario results in a future where half of all electricity generation comes from renewable resources in 2030, compared to just 30 percent in the baseline RGGI scenario.

A more stringent RGGI cap works together with state RPS and EERS.

The RGGI allowance auction sets a price signal that is responded to, in part, by state RPS and EERS programs. Together, RGGI and state portfolios are what make emission reductions possible, both today and in the future. Without RPS and EERS programs, the RGGI cap would be achieved by importing an increasing share of the Northeast's electricity from fossil fuel generators outside of the region.

New RGGI policy generates nearly 60,000 jobs per year.

On average from 2016 through 2030, achieving a 40 percent emission reduction creates 58,400 jobs per year. The new policy generates 26,500 jobs in 2020, 91,100 jobs in 2025, and 94,300 jobs in 2030. Of the jobs added, three-quarters come from energy efficiency and resulting savings from reduced energy expenditures, while one-quarter comes from renewables.

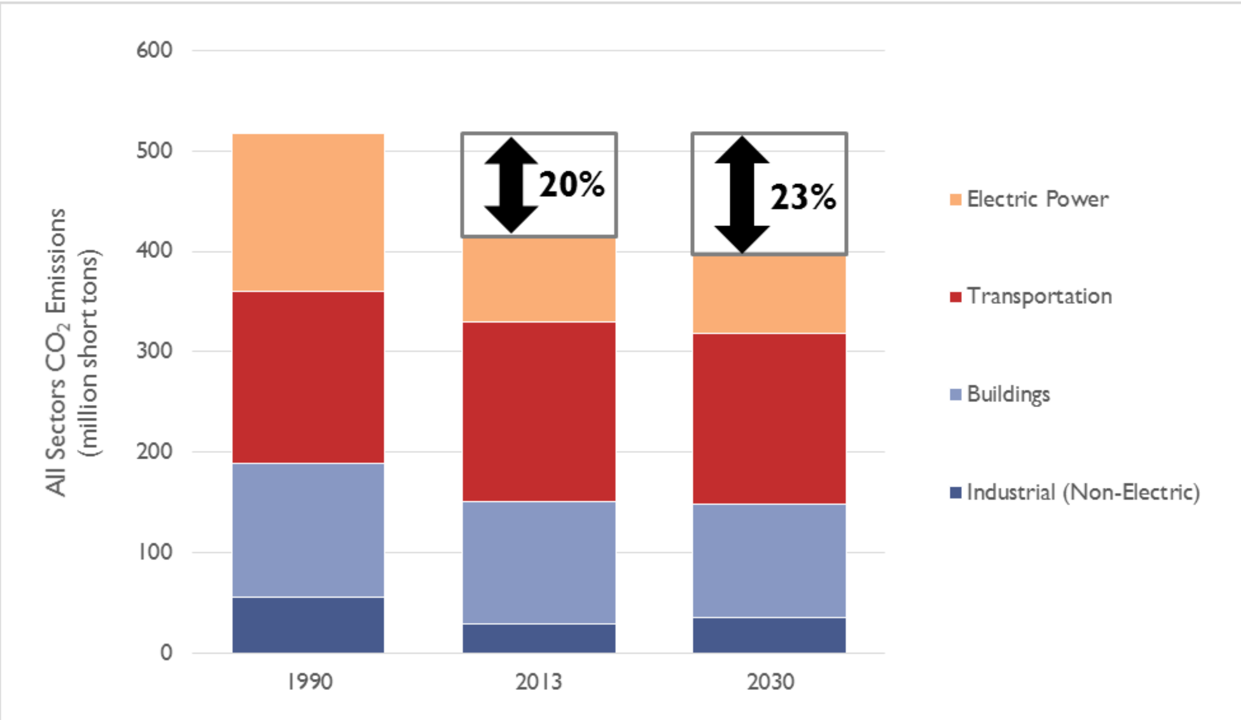
CONTENTS

1. THE RGGI PROGRAM

For the past seven years, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont have worked together to limit the emission of carbon dioxide (CO_2) from their electric sector. The Northeast's Regional Greenhouse Gas Initiative (RGGI) auctions certificates representing states' allowable CO_2 emissions to power generators: For each ton of CO_2 emitted, fossil fuel generators must purchase an allowance. The revenue from these auctions is returned to states and is typically spent on renewable energy and efficiency programs.

RGGI—working in concert with a changing market for fossil fuels, state renewable portfolio standards (RPS) and energy efficiency resource standards (EERS), and other state and federal environmental policies—has lowered total energy-related CO_2 emissions from the nine states 20 percent below 1990 levels (see Figure 1).[1] The RGGI electric-sector emissions cap shrinks from 91 million short tons in 2014 down to 78 million short tons in 2020, and stays constant thereafter. With this lower cap in place—and business-as-usual assumptions that include all current state and federal environment regulations—Synapse estimates that the nine states will achieve an additional 3 percentage point reduction in all sector emissions by 2030.

Figure 1. All-sector CO_2 emission reductions in the RGGI baseline scenario



Source: Synapse Energy Economics.

[1] By 2013, emissions from <u>all sectors</u> had decreased by 20 percent compared to 1990 levels. In the <u>electric sector</u>, emissions decreased by 45 percent.

The U.S. Environmental Protection Agency's (EPA) recently released Clean Power Plan limits CO_2 emissions from electric generators nationwide.[2] However, the combined Clean Power Plan target for Northeast states for 2030 is less stringent (allows higher levels of emissions) than the RGGI cap for 2020: 80 million short tons compared to 78 million short tons of CO_2.[3] With no further electric sector emission reductions between 2020 and 2030, the Northeast states' RGGI agreement already achieves Clean Power Plan compliance for the nine states.

Individual RGGI states have set greenhouse gas emission reduction targets for 2030 that range from 35 to 45 percent, centered around a 40 percent reduction from 1990 levels (see Table 1).

Table 1. State greenhouse gas emission reduction targets, 2030 and 2050

State	2030 Target	2050 Target
Connecticut	35-45% below 1990	80% below 2001
Delaware	36% below 1990*	No target
Maine	35-45% below 1990	75-80% below 2003
Maryland	35% below 1990**	Up to 90% below 2006
Massachusetts	35-45% below 1990	80% below 1990
New Hampshire	35-45% below 1990	80% below 1990
New York	40% below 1990	80% below 1990
Rhode Island	35-45% below 1990	80% below 1990
Vermont	35-45% below 1990	75% below 1990

Note: See Appendix E for citations to state climate statutes.

** Delaware's 2030 target is a non-binding goal recommended in the state's Climate Framework of 30 percent below 2008.*

*** Maryland's 2030 target is framed as 40 percent below 2006.*

To achieve these targets, deeper emission reductions will be needed both within the electric sector, which continues to offer cost-effective emission reductions, and in the rest of the economy. This report compares a "baseline" business-as-usual RGGI scenario to a future in which RGGI states' all-sector energy-related CO_2 emissions are 40 percent lower than their 1990 levels by 2030. The examples of additional emission reductions shown here take place in the electric, transportation, buildings, and industrial sectors. Other policies—not explored here—exist that also have the potential to lower emissions.

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[2] On February 9, 2016, the United States Supreme Court issued a stay on the Clean Power Plan. One week later, on February 16, seven of the RGGI state governors (all but Maine and Maryland) together with 10 other governors signed a Governor's Accord marking their intention to continue implementing a clean energy future (available at http://static1.squarespace.com/static/56704ad6bfe873c2cc9eff73/t/56c3b30c62cd942b3f8c1dc5/1455665943323/Accord) .

[3] All RGGI states' individual Clean Power Plan mass-based targets with new source complement for 2030 are higher than their allocation (by revenue) of the total RGGI emission cap in 2020 with the exception of Maine and Maryland.

2. Getting to 40 Percent Emission Reductions in 2030

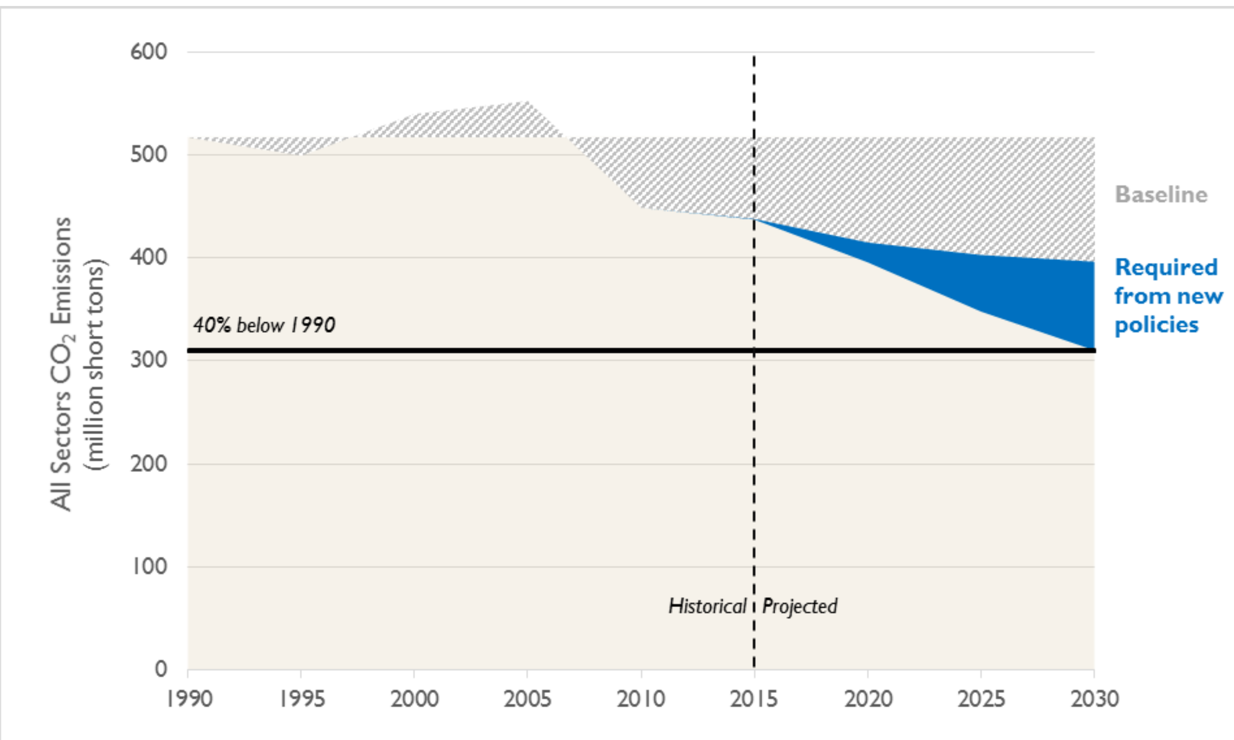
Deeper emission reductions will require efforts in multiple sectors. While there are many potentially successful policies to reduce emissions in all sectors, this analysis focuses on six well-researched, cost-effective emission reduction measures: gas and electric energy efficiency, wind and solar generation in the electric sector, conversion from gas to electric light-duty vehicles in the transportation sector, and conversion of oil heating to electric heat pumps.

Synapse's analysis applies the least-cost combination of these measures to detailed energy sector models, taking into consideration dynamic interrelations between electric supply and demand, new electric demand for transportation and heating, and each state's power generation and transmission resources.[4] The result is a scenario of the Northeast's future use of energy resources that not only lowers region-wide CO_2 emissions by 40 percent in all sectors by 2030 but also reduces costs to consumers by $25.7 billion over the 2016 to 2030 period.

2.1. 2030 Baseline Emissions are 23 Percent Lower than 1990 Levels

In 2030, all-sector CO_2 emissions in the baseline RGGI scenario are 23 percent lower than 1990 emissions (see Figure 2).

Figure 2. Additional emission reductions required to meet 40 percent target in RGGI states



Source: Synapse Energy Economics.

[4] See the appendices to this report for a detailed description of models and assumptions.

This baseline emission reduction is due not only to RGGI, but also to lower natural gas fuel prices, efficiency gains in the transportation and building sectors, and state and federal environmental policies.

In the RGGI baseline, all-sector emissions are 396 million short tons of CO_2 in 2030 (121 million short tons lower than 1990 levels). A further 86 million short ton reduction is needed to bring all-sector emissions 40 percent below 1990 levels. The RGGI baseline includes the nine states' compliance with the RGGI caps as well as all U.S. states' compliance with state RPS, electric EERS, and federal Clean Power Plan mass-based CO_2 emission caps (including the new source complement).

2.2. Big Ticket Measures Lower Transportation, Buildings, Industrial, and Electric Emissions

Synapse applied six selected "big ticket" emission reduction measures to the RGGI baseline scenario by modeling impacts on the electric and other energy sectors (see Table 2).[5] All six of the selected measures have net negative costs (that is, benefits) for each ton of emission reductions. This means that all six selected shift measures are a net benefit to society when the value of avoiding climate damages is taken into consideration. Moreover, even if climate damage costs are ignored, five of these six emission reduction measures lower costs in the energy sector; the sixth—utility-scale solar—has a very small net cost ($6 per short ton of CO_2 reduction). With small changes in 2030 fuel costs or renewable technology costs, utility-scale solar would join the other measures in providing net benefits to the energy sector.

These net cost estimates include both economic costs and benefits that impact household budgets as well as the benefit of avoiding climate damages estimated as the U.S. federal government's social cost of carbon.[6] (As discussed in Appendix C, we also calculated these emission reduction measures' costs without inclusion of a social cost of carbon and found no change in the resource investment decisions assumed in this study.) Note that this cost-benefit analysis does not include other non-energy benefits, such as improved air and health associated with reducing CO_2 co-pollutants, but does include cross-sector energy efficiency co-benefits (that is, gas and oil savings from electric energy efficiency and vice versa).

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[5] See Appendix C for a more detailed account of emission-reduction measure assumptions and the marginal abatement cost curve methodology used to select these measures. Note that the 2030 emissions reduction potential for solar is greater than the emissions reduction required by and used in this analysis.

[6] U.S. EPA. 2015. "Technical Support Documents: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866." Revised July 2015 by the Interagency Working Group on Social Cost of Carbon. Available at: https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf. Summary also available at: http://www3.epa.gov/climatechange/EPAactivities/economics/scc.html.

Table 2. Selected emission reduction measures in 2030

	Net cost per ton (2014 $ / short ton)	2030 emissions reduction potential (million short tons)	2030 actual emissions reduction used in this analysis (million short tons)
Electric vehicles: Convert one-third of all light-duty vehicles from gas to electric[7]	-$257	28	28
Heat pumps: Convert 44 percent of oil heating to electric heat pumps	-$243	9	9
Electric energy efficiency: Achieve Massachusetts' level of efficiency savings in all RGGI states	-$216	17	17
Gas energy efficiency: Achieve 1 percent annual savings in natural gas used in homes and businesses	-$73	10	10
Wind: Invest in onshore wind generation up to the economically achievable potential	-$70	27	22 (+5)
Solar: Limited investments in utility-scale photovoltaic solar installations	$47	616	0 (+7)

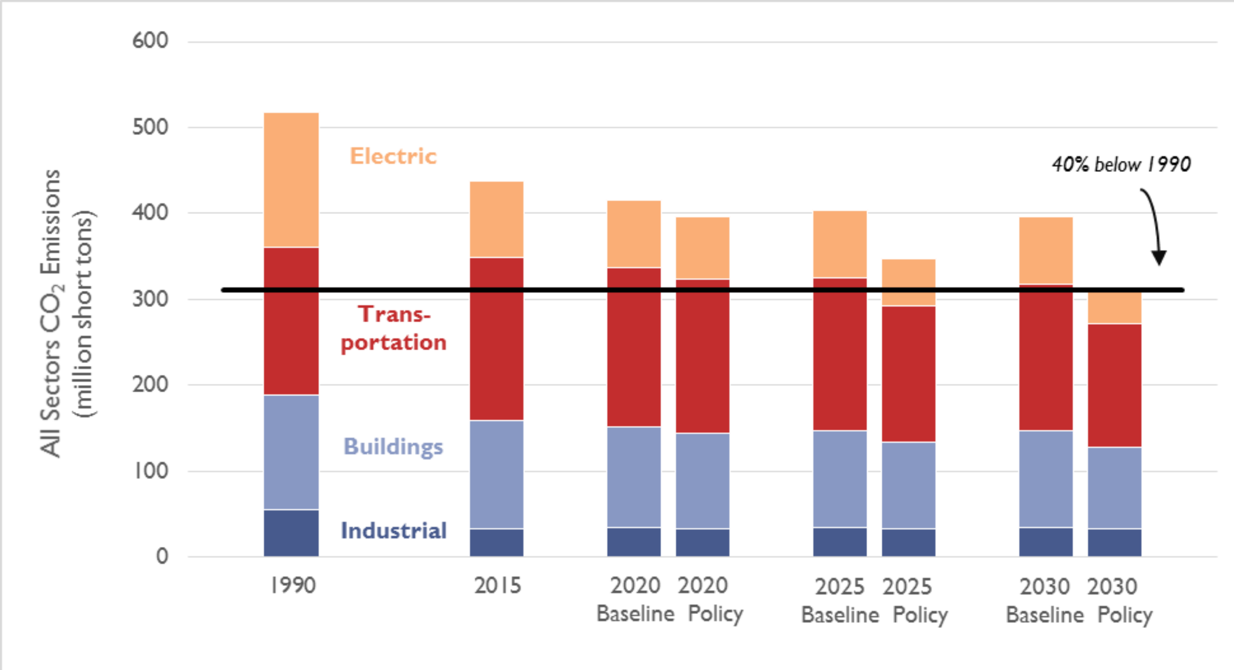
Note: "+" denotes emissions reductions resulting from incremental capacity built to power new electric vehicles and heat pumps. These measures necessitate an increase in electricity consumption requiring additional renewable generation that provides 12 million short tons in emission reductions if compared to supplying this electric demand with the current mix of generators in the region.
Source: Synapse Energy Economics.

Performing detailed electric-sector modeling allows this analysis to take into consideration time of day, time of year, changes in generation by resource type over time, changes in generation technologies themselves over time, federal environmental requirements, and complex interactions of electric supply and demand across state lines.

Figure 3 compares emissions in the RGGI baseline and 40 percent emission reduction policy scenarios. Emission reductions are shared by the electric, transportation and buildings sectors. Electric sector emissions fall from 78 million short tons under the RGGI baseline to 39 million metric tons in the 40 percent emission reduction scenario.

[7] This measure does not include potential emission reductions as a result of plug-in hybrid vehicles or other types of plug-in vehicles.

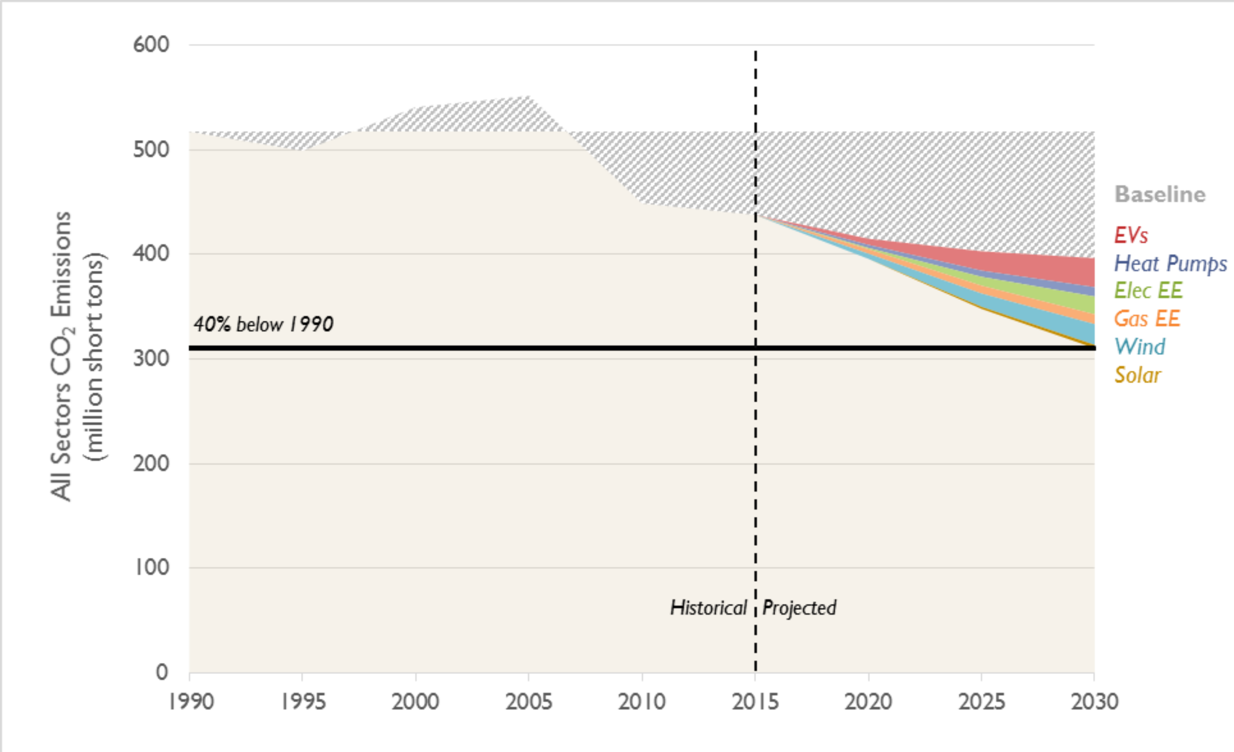
Figure 3. RGGI states' all-sector emissions in the baseline ("Baseline") and 40 percent emission reduction policy ("Policy") scenarios



Source: Synapse Energy Economics.

Figure 4 on the following page displays the estimated emission reductions achieved by each measure. Note that this is an approximation—the measures' actual emission reductions are highly interrelated. The conversion to electric vehicles accounts for 32 percent of total emissions reductions from all four emission reduction measures applied to the RGGI baseline; shifting from oil heating to electric heat pumps, 10 percent; electric energy efficiency, 20 percent; gas energy efficiency, 11 percent; additions of wind, 23 percent; and additions of solar, 4 percent.

Figure 4. Additional emission reductions required to meet 40 percent target in RGGI states, by measure



Source: Synapse Energy Economics.

2.3. Emissions Do Not Leak from the RGGI Region

If RGGI states reduced regional emissions by importing fossil fuel-fired generation, the result would be "emissions leakage": The Northeast's emissions would fall, but emissions in other states would rise. Our modeling demonstrates that this does not occur; emissions leakage is avoided under the scenario examined in this analysis. Our modeling assumptions restrict RGGI states' trading of Clean Power Plan allowances to remain within the RGGI group. This avoids leakage of emission allowances (and emissions) out of the region by (1) restricting RGGI states allowance trading to be within the RGGI region only, and (2) insuring that most new renewable resources are built within the region (instead of importing renewable energy credits and electricity from outside of the region).[8] As a result, RGGI states' electric-sector emissions are lower in the 40 percent emission reduction scenario than in the RGGI baseline. Emissions in the rest of the United States, however, meet Clean Power Plan mass-based targets exactly under both scenarios.

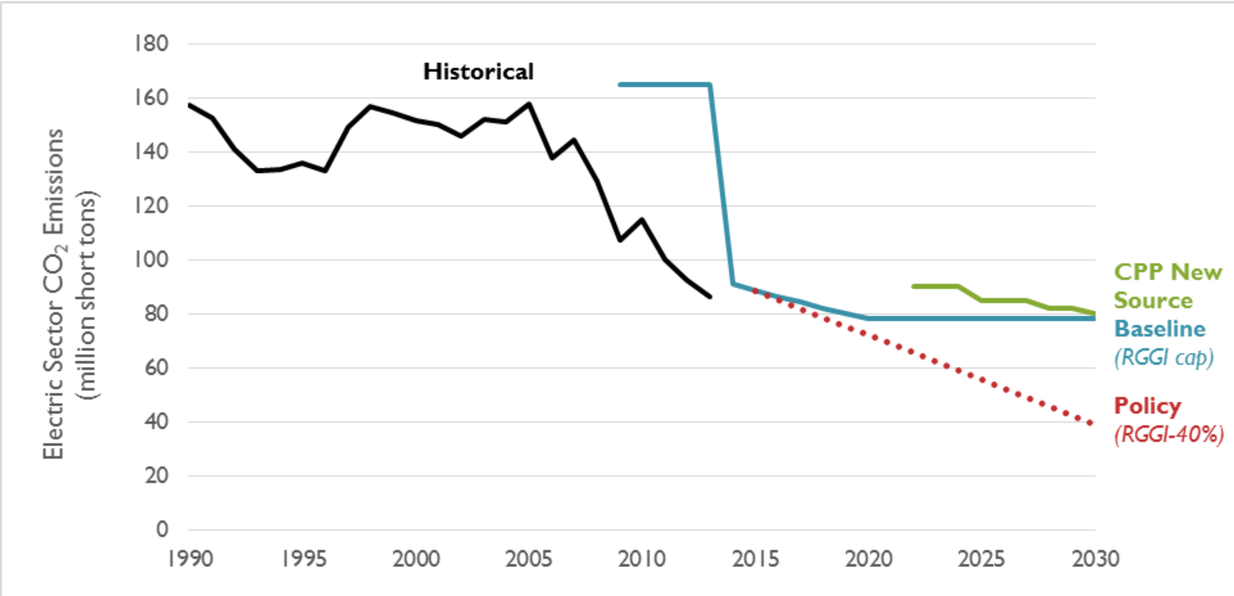
2.4. Half of Emission Reductions Come from the Electric Sector

Electric-sector efficiency and renewables are responsible for nearly half of the additional required reductions in 2030. Figure 5 presents emission reductions in the electric sector for the baseline and 40 percent emission reduction policy scenarios. In the 40 percent emission reduction scenario, Northeast

[8] See Appendix C for further discussion.

states' electric sector emissions are capped at 39 million short tons in 2030 compared to the currently mandated RGGI cap of 78 million short tons in 2020. The RGGI baseline emission caps are themselves 2 percent lower than Clean Power Plan mass-based targets (with the new source complement) for the RGGI states in 2030.

Figure 5. RGGI states' electric-sector emission caps in the baseline and 40 percent emission reduction policy scenarios, relative to historical emissions and requirements in the Clean Power Plan

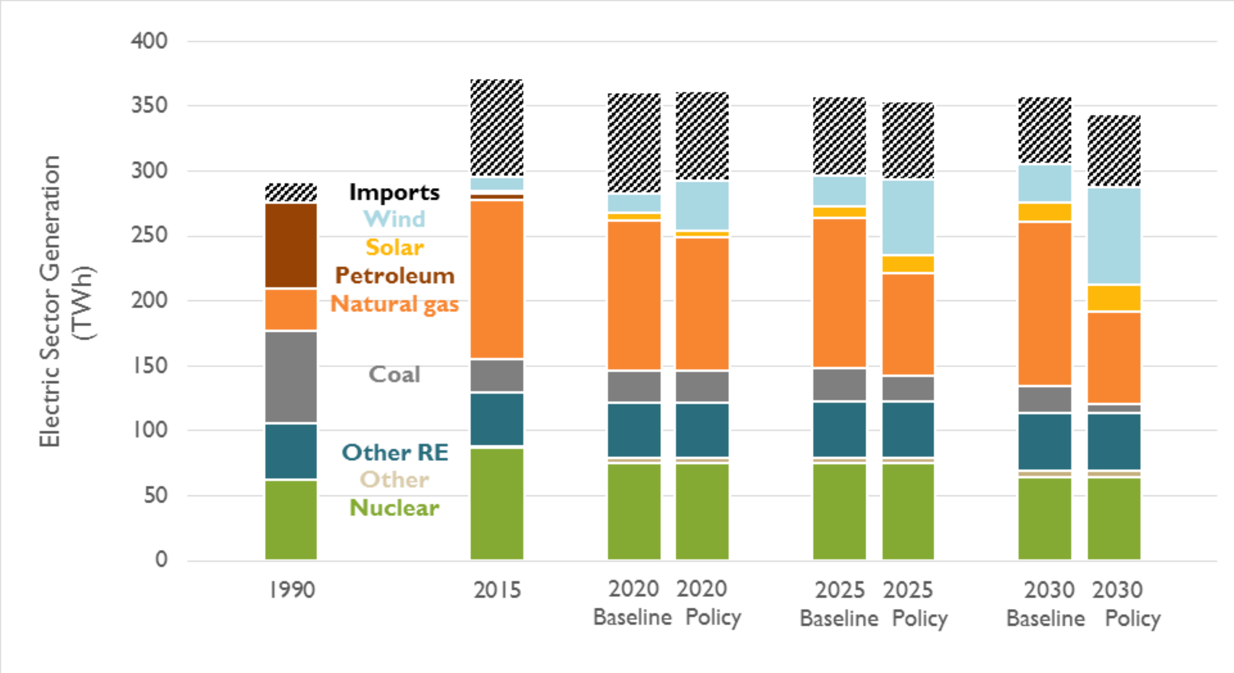


Source: Synapse Energy Economics.

2.5. Efficiency, Wind, and Solar Drive Down Electric-Sector Emissions

Under the 40 percent emission reduction scenario new, lower RGGI caps drive deeper, more wide-spread changes in the RGGI states' electric system. Figure 6 reports the impact of these measures in terms of generation by resource. Coal, oil, and natural gas-fired generation are replaced by efficiency and renewables. Note that electric sector generation is lower in the 40 percent emission reduction scenario than in the RGGI baseline even though substantial generation is needed to power electric vehicles and heat pumps: savings from energy efficiency outweigh additional electricity sold to owners of electric vehicles and heat pumps.

Figure 6. RGGI states' electric generation by resource type in the baseline ("Baseline") and 40 percent emission reduction policy ("Policy") scenarios



Source: Synapse Energy Economics.

Table 3 below shows a summary of the increase in wind and solar capacity in the 40 percent emission reduction scenario compared to existing capacity. Total capacity values for all resources in the 40 percent emission reduction scenario are provided in Appendix F.

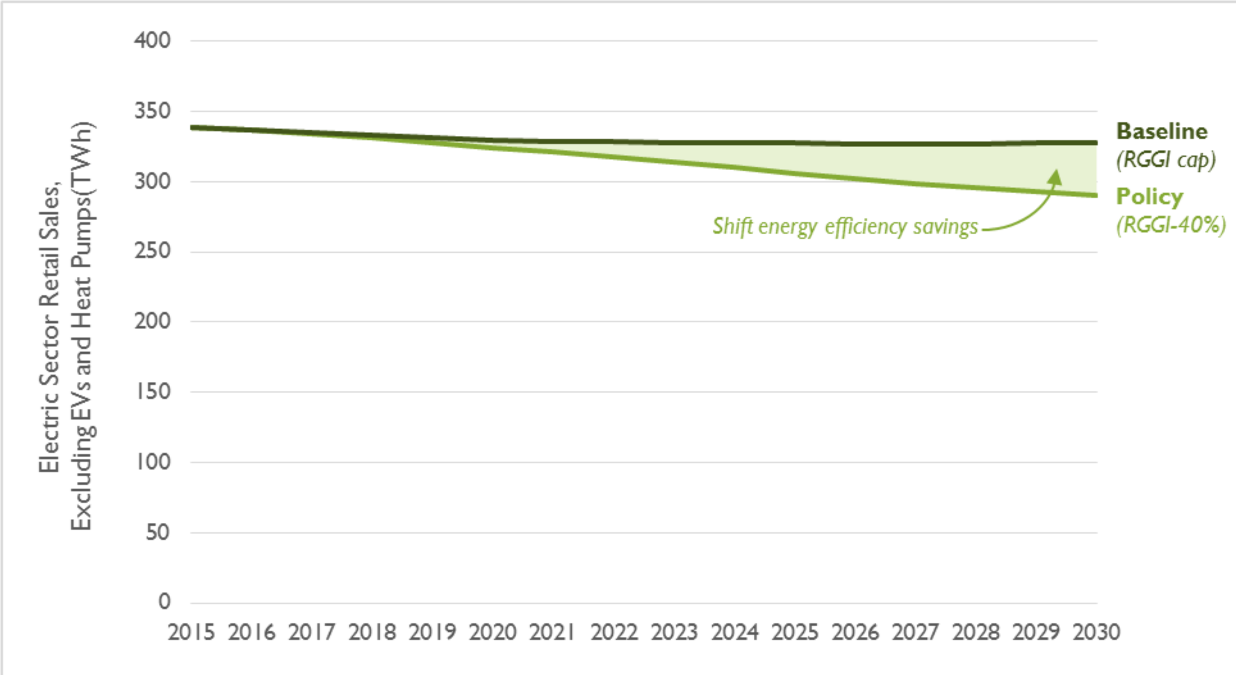
Table 3. 2030 increase in capacity in the 40 percent emission reduction policy scenario compared to existing capacity (GW)

	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Wind	0.2	0.0	1.2	0.8	5.0	1.7	7.1	0.0	3.5	19.5
Solar	1.0	1.1	1.0	2.8	2.4	0.8	2.7	0.5	0.4	12.8

2.6. Energy Efficiency Savings Are One-Third of Total Emission Reductions

Together, electric and gas energy efficiency measures are responsible for nearly one-third of RGGI states' 2030 all-sector emission reductions. Electric-sector energy efficiency measures alone contribute 20 percent of RGGI states' 2030 all-sector emission reductions between the baseline and policy scenarios. While baseline RGGI electric efficiency is expected to avoid 45 TWh of required electric sales in 2030, the efficiency measures in the 40 percent emission reduction scenario provide an additional 37 TWh of savings in 2030 (see Figure 7).

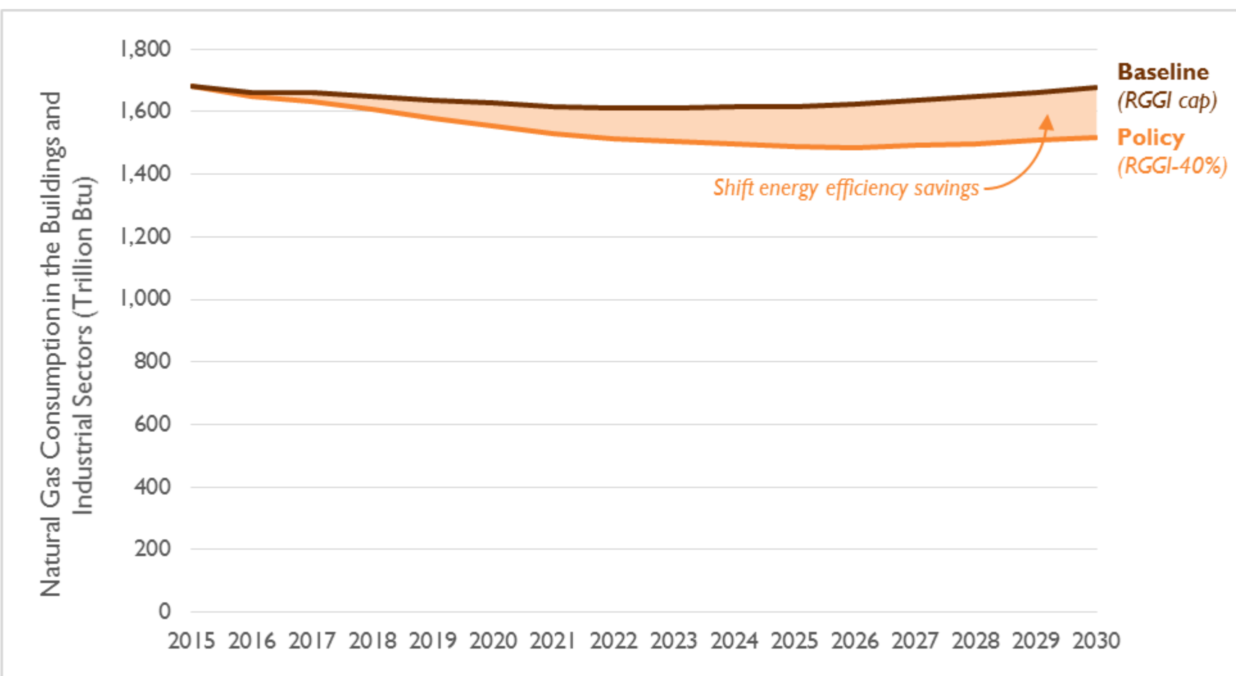
Figure 7. RGGI states' sales in the baseline and 40 percent emission reduction policy scenarios



Source: Synapse Energy Economics.

Gas energy efficiency measures in the residential, commercial, and industrial sectors are responsible for 11 percent of RGGI states' 2030 all-sector emission reductions. The efficiency measures in the 40 percent emission reduction scenario provide 159 trillion Btu of savings in 2030 (see Figure 8).

Figure 8. RGGI states' natural gas consumption in the baseline and 40 percent emission reduction policy scenarios



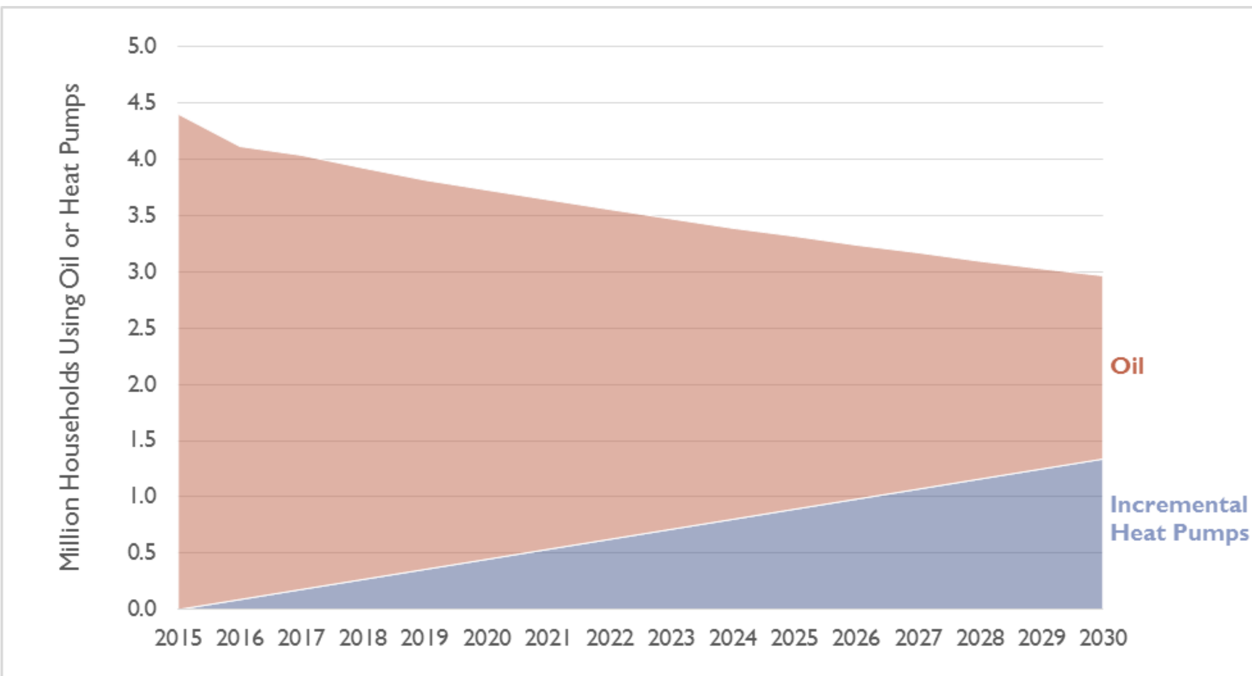
Source: Synapse Energy Economics.

2.7. About 1.3 Million Electric Heat Pumps Replace Oil Heaters

In 2015, over 4 million families in the RGGI region were still heating their homes with oil. By 2030, this number is expected to shrink to 3 million households in the RGGI baseline scenario as households move to more efficient forms of heating. These oil furnaces and boilers would release 20.4 million short tons of CO_2 into the atmosphere in 2030.

The 40 percent emission reduction scenario shifts 1.3 million of the remaining 3 million households from oil to air-source heat pumps by 2030 (see Figure 9). Heat pumps are appliances that use electricity to absorb heat energy in cold areas (i.e., outside) and transfer it to indoor areas. Heat pumps have the advantage of being able to work in reverse—not only can they provide heating in winter months, but they take the place of a central air conditioning systems in the summer months. Heat pump technology has existed for decades, and these units are commonplace in Europe and Asia, but high-performing systems that function well in cold-weather climates as in many of the Northeast states have just recently begun to make inroads in the United States. By shifting heating consumption from inefficient, high-emitting oil boilers and furnaces to highly efficient heat pumps, 9 million short tons of CO_2 are avoided.

Figure 9. Residential households in the RGGI states continuing to use oil or switch to heat pumps

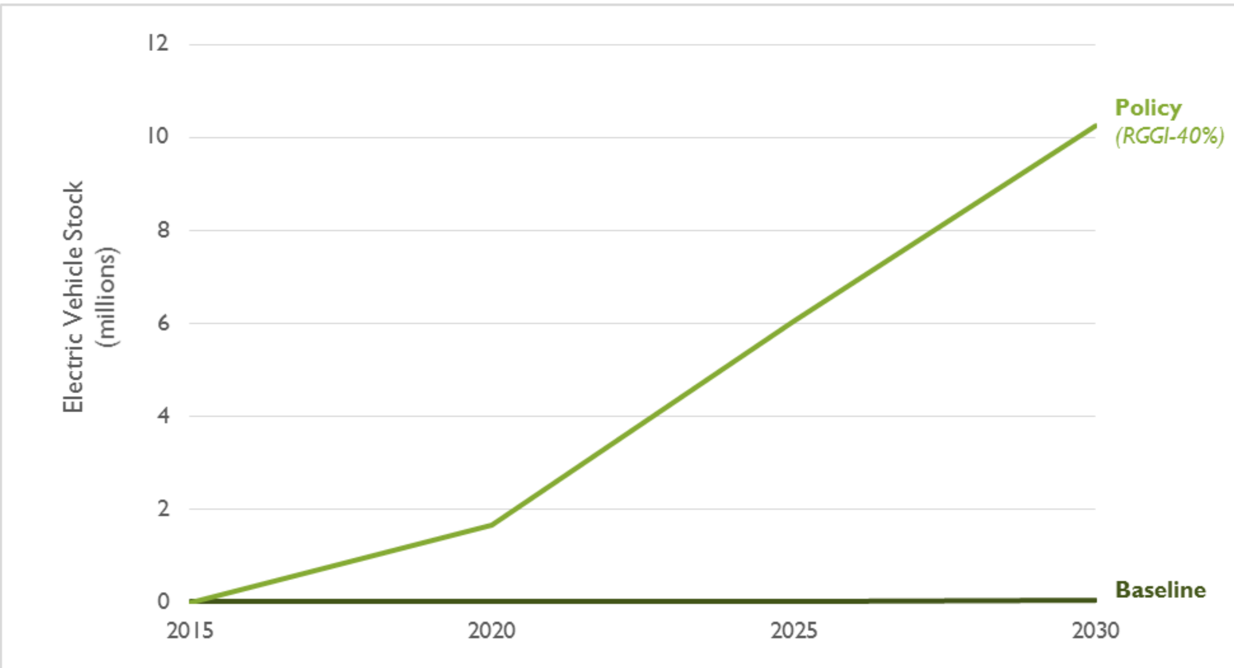


Note: This figure does not include heat pumps assumed to be installed in the RGGI baseline scenario. Source: Synapse Energy Economics.

2.8. Ten Million Electric Vehicles Offset 28 Million Short Tons of CO_2

The 40 percent emission reduction scenario adds 10 million battery electric vehicles in the nine RGGI states by 2030, above what is currently in place and expected in the baseline forecast (see Figure 10).[9] The stock of electric vehicles in the RGGI baseline is based on the Energy Information Administration's 2015 projections and reaches 46,000 vehicles in the RGGI region in 2030. In contrast, Synapse's 40 percent emission reduction scenario assumes that one-third of the RGGI region's light-duty vehicles run on electricity by 2030 based on the Federal Highway Administration's projection of the potential for electric vehicle adoption. These new electric vehicles reduce total RGGI state emissions by 28 million short tons of CO_2 in 2030.

Figure 10. Total electric vehicle stock in the RGGI states, 2030



Source: Synapse Energy Economics.

2.9. Forty Percent Emission Reduction Policy Saves Customers $25.7 billion

The 40 percent emission reduction scenario reduces costs to energy customers by $7.8 billion in 2030 alone. This savings represents the difference between the RGGI baseline and 40 percent emission reduction scenario net spending on the electric system, customer out-of-pocket costs for gas and electric energy efficiency measures, new subsidies for electric vehicles and heat pumps, and avoided gasoline, natural gas, and oil consumption.

[9] This scenario does not include potential emission reductions as a result of plug-in hybrid vehicles or other types of plug-in vehicles.

There are, however, additional benefits to the 40 percent emission reduction scenario beyond just economic costs and benefits. Table 4 and Figure 11 present not only the out-of-pocket costs and benefits of this change, but also the additional co-benefit of avoiding climate damages (estimated here using the U.S. federal government's social cost of carbon).[10] When the avoided social cost of carbon is included, savings from the 40 percent emission reduction scenario increases to $12.2 billion in 2030.

Table 4. Cost and benefits by cost type in the 40 percent emission reduction scenario (billions)

	2020	2025	2030
Net system costs	$0.2	-$4.3	-$7.8
Social cost of carbon	-$0.8	-$2.5	-$4.4
Total	**-$0.6**	**-$6.8**	**-$12.2**

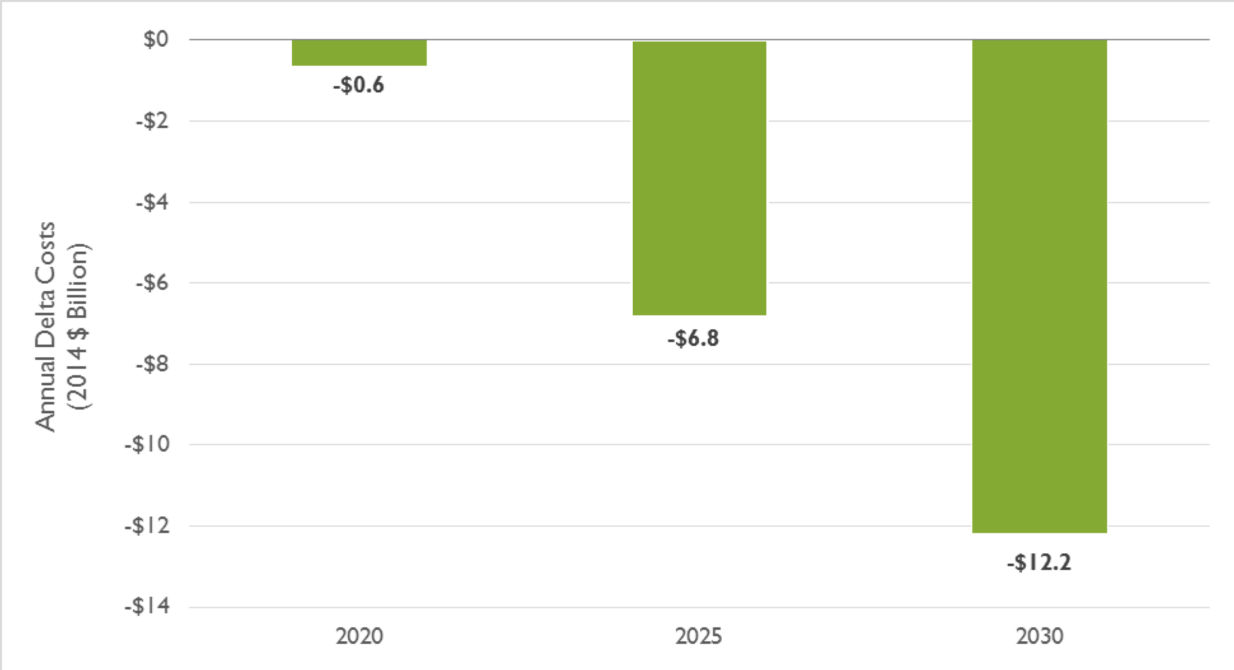
Note: Positive numbers represent increased costs in the 40 percent emission reduction scenario. Negative numbers represent savings in the 40 percent reduction scenario. Source: Synapse Energy Economics.

While electric system costs increase over the study period, as more electric vehicles, heat pumps, and energy efficiency measures are introduced over time, the savings from avoided gasoline, natural gas, petroleum, and electricity overwhelms the incremental costs experienced in other sectors. Altogether, the discounted change in costs for 2016 through 2030 results in a net present value of $25.7 billion in savings to energy customers before the inclusion of the social cost of carbon, and a net present value of $47.9 billion in savings to all customers once the social cost of carbon is included.[11]

[10] U.S. EPA. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*.

[11] Net present value calculated using a discount rate of 3 percent and reported in 2014 dollars.

Figure 11: Annual changes in net costs in the 40 percent emission reduction scenario (billions)

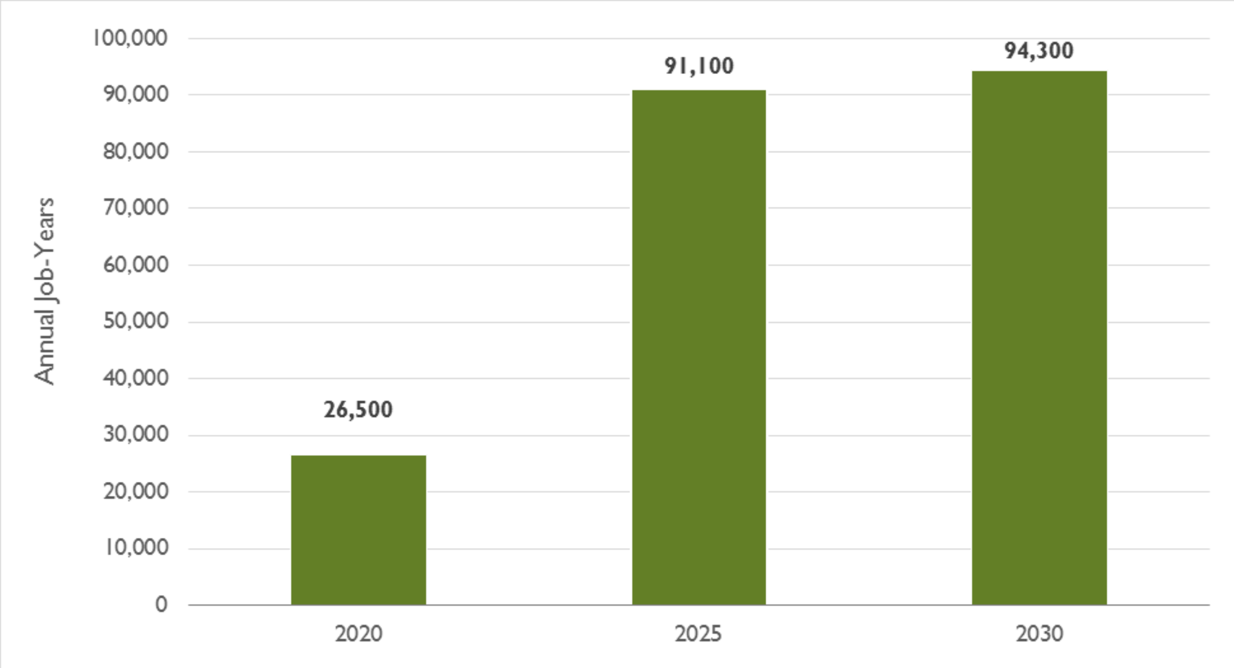


Note: Positive numbers represent increased costs in the 40 percent emission reduction scenario compared to the RGGI baseline. Negative numbers represent savings in the 40 percent reduction scenario. Source: Synapse Energy Economics.

2.10. Emission Reductions Generate 58,400 Jobs per Year

On average from 2016 through 2030, the 40 percent emission reduction scenario creates 58,400 "job-years", or jobs per year (see Figure 12). The new policy generates 26,500 jobs in 2020, 91,100 jobs in 2025, and 94,300 jobs in 2030.

Figure 12: Annual job impacts in the 40 percent emission reduction scenario



Source: Synapse Energy Economics.

The employment impacts show the "net" economic effect from the 40 percent emission reduction scenario; that is, the jobs created by the policy less the jobs created in the RGGI baseline scenario. For the electric sector, the net jobs depend on the differences in capital and operating costs between scenarios. Additional jobs are created when new resources are installed under the 40 percent emission reduction policy, and fewer jobs are identified when the resources only exist in the RGGI baseline. Similarly, electric vehicles generate job impacts resulting from new electric service and charging infrastructure but also include losses from reduced gasoline usage. In the buildings and industrial sectors, jobs are created through saved spending on natural gas and petroleum and installations of new energy efficiency measures.

Table 5 shows the breakdown of jobs by the source of impact through 2030. The largest gain in jobs comes from energy efficiency (over 29,000 average jobs per year from both gas and electric), re-spending (25,300 average jobs per year), and renewable energy resources (over 14,000 average jobs per year). The only sectors that would have fewer jobs under the baseline than in the 40 percent emission reduction scenario are coal, natural gas, biomass, heat pumps, and oil delivery.[12] "Re-spending" impacts refer to households and businesses spending savings from the new 40 percent emission reduction policy relative to the RGGI baseline. For instance, if households are financially better off from purchasing the combination of an electric vehicle and more electricity for battery charging (as opposed to a conventional gas-powered car and gasoline) then they can spend that savings elsewhere in the regional economy.

[12] Heat pump installations replaces the need to install both an oil heating system and a separate electric cooling system and therefore results in fewer jobs. In effect, customers get two systems (heating and cooling) for the price of one installation.

Table 5: Annual and cumulative job-year impacts by resource in the 40 percent emission reduction scenario

Resource	2020	2025	2030	Average Annual Jobs	Cumulative Jobs through 2030
Coal	100	-400	-1,300	-400	-6,100
Biomass	0	-100	-300	-100	-1,100
Natural Gas	-2,200	-6,500	-16,600	-5,700	-86,100
Electric Energy Efficiency	13,300	26,900	29,000	19,300	290,000
Renewable	8,700	22,700	2,000	14,100	211,100
Nuclear	0	0	0	0	0
Hydro	0	-100	100	0	0
Transmission	600	3,600	6,200	2,500	37,500
Transportation	-100	200	-200	100	1,800
Re-spending	2,400	41,100	72,200	25,300	379,400
Gas Energy Efficiency	10,000	10,500	10,400	9,900	148,000
Heat Pumps	-6,000	-6,000	-6,000	-6,000	-89,300
Oil Delivery	-400	-800	-1,400	-600	-9,700
Total	**26,500**	**91,100**	**94,300**	**58,400**	**875,500**

Note: Columns may not sum to total due to rounding. Values represent differences between single-year "job-years" in different hypothetical futures and do not necessarily show gains or losses from existing jobs. Source: Synapse Energy Economics.

The result that the 40 percent emission reduction scenario creates new jobs is not surprising. Renewable energy and energy efficiency typically create more jobs for the same amount of capacity provided by coal and natural gas generation. More of the cost of clean energy sources is spent on labor than on capital and fuel. The electrification of transportation also displaces fossil fuels. Compounding this effect, fossil fuels consumed by the RGGI states come almost entirely from outside the region. Thus the 40 percent emission reduction scenario leads to a shift from spending on extractive industries outside the region to more labor-intensive industries inside the region.

3. Key Policy Take-Aways

Both lowering the RGGI cap in the electric sector and expanding emission reductions in the transportation, building and industrial sectors are critical to Northeast states achieving their state greenhouse gas emission reduction targets. To achieve 40 percent CO_2 emission reductions in RGGI states by 2030, Synapse made a few critical modeling assumptions that point to important policy considerations for a new, expanded RGGI policy.

Achieving a 40 percent CO_2 emission reduction will be driven by reductions in multiple sectors.

While the electric sector will continue to be responsible for nearly half of the incremental emission reductions in 2030, reductions from other sectors are also critical to achieving RGGI states' 2030 climate goals. Synapse's analysis examined the electric, transportation, buildings, and industrial sectors for the least-cost emission reduction combination, and left today's natural gas generating capacity in operation during the transition to renewables. With the 40 percent emission reduction, natural gas generation only runs when it is economic and necessary. In this way it continues to support electric service reliability and plays a role in smoothing out any mismatches between renewable generation and predominantly night-time charging of electric vehicles.

Emission reductions measures save money for customers.

After accounting for the cost of expected damages from climate change, all six emission reduction measures used in this study lower energy sector costs. Even if climate damage costs are omitted, five of the six measures have net negative energy sector costs (that is, benefits). The remaining measure—utility-scale solar, which is not needed to achieve emission reductions—has very low net costs.

Increased adoption of electric vehicles saves money for consumers.

The cost savings of switching from gasoline to electricity to power a car more than make up for electric vehicles' higher purchase price. Our assessment of which emission reduction measures have lower and higher costs includes a value for the climate impacts avoided by lowering CO_2 emissions. But even ignoring the benefits of avoiding damage from climate change, electric vehicles save households money.

Converting aging oil heaters to efficient heat pumps can save money on both heating and cooling.

The Northeast states are unique in their reliance on high-CO_2-emitting oil for home heating. By shifting heating consumption from inefficient, high-emitting oil boilers and furnaces to highly efficient heat pumps, 9 million short tons of CO_2 can be avoided.

Modernizing outdated gas furnaces to more efficient units and adding better insulation to homes reduces both gas utility bills and emissions.

More efficient use of natural gas in homes and businesses has the potential to significantly reduce the RGGI region's greenhouse gas emissions. In 2030, natural gas energy efficiency measures save 159 trillion Btu in the 40 percent emission reduction scenario and avoid 5 percent of total gas consumption between 2015 and 2030.

Robust investment in energy efficiency lowers overall electric sales despite a significant increase in electric vehicles and heat pumps.

In 2030, efficiency measures save 81,000 gigawatt-hours of electricity in the 40 percent emission reduction scenario. Converting one-third of all light-duty vehicles to run on electricity and adding 1.3 million new heat pumps only adds 23,600 gigawatt-hours.

Efficiency measures will continue to lower consumers' bills.

Applying Massachusetts' expected electric energy efficiency savings in terms of percent of sales—based on their current three-year plan—to all RGGI states lowers electric sales by 11 percent by 2030. These efficiency savings have been determined to be cost effective in Massachusetts.

Renewables supply one-half of the RGGI region's electric generation in 2030

Adding 50,000 gigawatt-hours of new wind and solar in the 40 percent emission reduction scenario results in a future where half of all electricity generation comes from renewable resources in 2030, compared to just 30 percent in the baseline RGGI scenario.

A more stringent RGGI cap works together with state RPS and EERS.

The RGGI allowance auction sets a price signal that is responded to, in part, by state RPS and EERS programs. Together, RGGI and state portfolios are what make emission reductions possible, both today and in the future. Without RPS and EERS programs, the RGGI cap would be achieved by importing an increasing share of the Northeast's electricity from fossil fuel generators outside of the region.

New RGGI policy generates nearly 60,000 jobs per year.

On average from 2016 through 2030, achieving a 40 percent emission reduction creates 58,400 jobs per year. The new policy generates 26,500 jobs in 2020, 91,100 jobs in 2025, and 94,300 jobs in 2030. Of the jobs added, three-quarters come from energy efficiency and resulting savings from reduced energy expenditures, while one-quarter comes from renewables.

APPENDIX A: ENERGY SECTOR MODELS

Synapse's purpose-built Excel-based model of the nine RGGI states' electric, transportation, buildings, and industrial sectors estimates emission and cost differences between the RGGI baseline and the 40 percent reduction policy scenarios. The baseline and the 40 percent emission reduction policy scenario capacity, generation, emissions and costs for the electric sector are modeled in Synapse's adapted version of the National Renewable Energy Laboratory's (NREL) Regional Energy Deployment System (ReEDS) model. The results are then imported into the Excel-based model.[13]

Multi-Sector Emissions Model (M-SEM)

Synapse has developed the Multi-sector Emissions Model (M-SEM), a state-specific model used for tracking historical energy use and emissions, and for projecting future energy use and emission based on a set of policy changes.[14] This dynamic spreadsheet model includes information on the electric, transportation, building, and industrial sectors. For all four sectors, energy use and its associate emissions differ between the RGGI baseline and 40 percent reduction policy scenarios.

Electric-sector ReEDs model

ReEDS is a long-term capacity expansion and dispatch model of the electric power system in the lower 48 states. Synapse has adapted its in-house version of the ReEDS model to allow for more detailed outputs by state and sector, and to permit differentiation of energy efficiency expectations by state.

Compliance with the Clean Power Plan is modeled as achieving the state-level mass-based targets that include estimated emissions from new sources (the "new source complement") on a biennial basis. We assume that emission allowances are traded both within and across state borders among two separate groups of states: the nine RGGI states, and all other states modeled. The price of allowances is set endogenously within the model as a shadow price. For the RGGI states, Clean Power Plan emission caps are replaced with more stringent (lower) RGGI caps in both scenarios.

Temporal scope

The time period of this analysis is 2015-2030. ReEDS modeling is performed at two-year intervals starting in 2014. Historical data through 1990 has been included in the spreadsheet model to serve as a point of comparison for future emissions. The Excel-based model projects emissions and costs at five-year intervals for the years 2015, 2020, 2025, and 2030.

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[13] ReEDS version used is ReEDS_v2015.2(r25). More information is available at: http://www.nrel.gov/analysis/reeds.

[14] More information on M-SEM is available at http://www.synapse-energy.com/MSEM.

Geographic scope

The nine RGGI states are modeled both independently and as a group. In the ReEDS model, all states in the continental United States are represented. ReEDS divides the United States into 134 power control areas that are consistent with state boundaries and can be aggregated to model state impacts. Each power control area is modeled as having a single aggregated "unit" of each resource type, the size of which is equal to the sum of the capacities of the actual units in that territory. For this analysis, Synapse modeled the country as a whole to capture interactions between states.

APPENDIX B: BASELINE SCENARIO

The RGGI baseline scenario is a business-as-usual case in which (a) the currently mandated RGGI caps for each year are in place (staying constant at the 2020 level in years thereafter), (b) states comply with their RPS and electric EERS requirements,[15] and (c) states outside of RGGI comply with their mass-based Clean Power Plan targets, including the new source complement. States' RGGI emission caps are more stringent (lower) than their Clean Power Plan mass-based targets. For this reason, only the RGGI caps (and not the Clean Power Plan targets) apply to RGGI states and—to avoid emission leakage out of the RGGI region—we have restricted RGGI states to only trade allowances among themselves while remaining states may trade throughout the non-RGGI region.

Note that inputs used in this analysis were finalized in December 2015. As such, they do not incorporate changes to the electric system such as new capacity cleared in recent forward capacity market auctions, revisions to unit retirements, or updates to renewable portfolio standards and energy efficiency resource standards that have been announced since that date.

Baseline state-specific emissions data

Historical years, 1990 to 2013

State-specific baseline energy consumption is based on the U.S. Energy Information Administration's (EIA) State Energy Data System (SEDS). SEDS contains historical time series of state-level estimates of energy production, consumption, prices, and expenditures by source and sector.[16] State-specific emissions are based on EIA's State Carbon Dioxide Emissions database.[17] These energy-related data do not include agriculture, land-use change, or upstream (life-cycle) emissions.

Future years, 2015-2030

Synapse based projections for the transportation, buildings, and industrial sectors on regional sector-specific growth rates derived from the EIA's Annual Energy Outlook (AEO) 2015 Reference case.[18] Electric-sector projections were based on detailed ReEDS modeling runs. ReEDS modeling assumptions specific to the RGGI baseline scenario are discussed in more detail in the subsequent sub-sections.

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[15] Gas energy efficiency in the baseline is as assumed by U.S. Energy Information Administration's in its Annual Energy Outlook 2015 Reference case. AEO 2015 gas efficiency assumptions are described below in Appendix B.

[16] U.S. Energy Information Administration (EIA). 2015. "About SEDS." Available at: http://www.eia.gov/state/seds/.

[17] EIA. 2015. "State Carbon Dioxide Emissions." Available at: http://www.eia.gov/environment/emissions/state/.

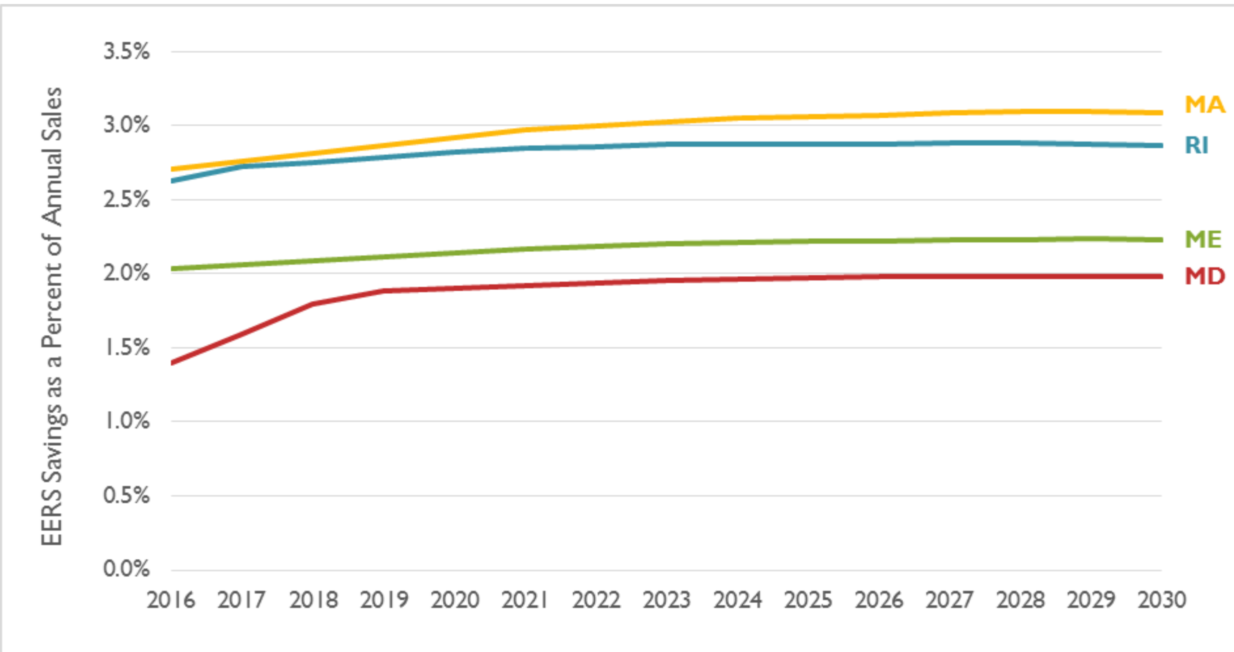
[18] EIA. 2015. "Annual Energy Outlook 2015." Available at: http://www.eia.gov/forecasts/aeo/index.cfm.

Electric sales and energy efficiency

Annual retail electric sales for the nine RGGI states are projected by applying regional growth rates from the AEO 2015 Reference case to state-specific EIA historical data. On average, the AEO 2015 Reference case assumes an annual growth rate of about 0.5 percent per year for the nine RGGI states. From this we "back out" the AEO representation of ongoing savings—estimated at 0.29 percent of 2012 sales—from new energy efficiency measures and replace it with more detailed forecasts.[19] Overall, energy efficiency in the RGGI baseline replaces 10.5 percent of regional electric sales in 2030.[20]

Four of the nine RGGI states (Massachusetts, Maryland, Maine, and Rhode Island) have electric energy efficiency resource standards (EERS) that require utilities to meet a state-specific share of retail electric sales through energy efficiency measures. The RGGI states' EERS requirements are summarized in Figure 13.

Figure 13. RGGI states' EERS requirements



Note: EERS levels are modeled based on state and utility filings of projected energy efficiency, rather than on percentage-based state statutes.

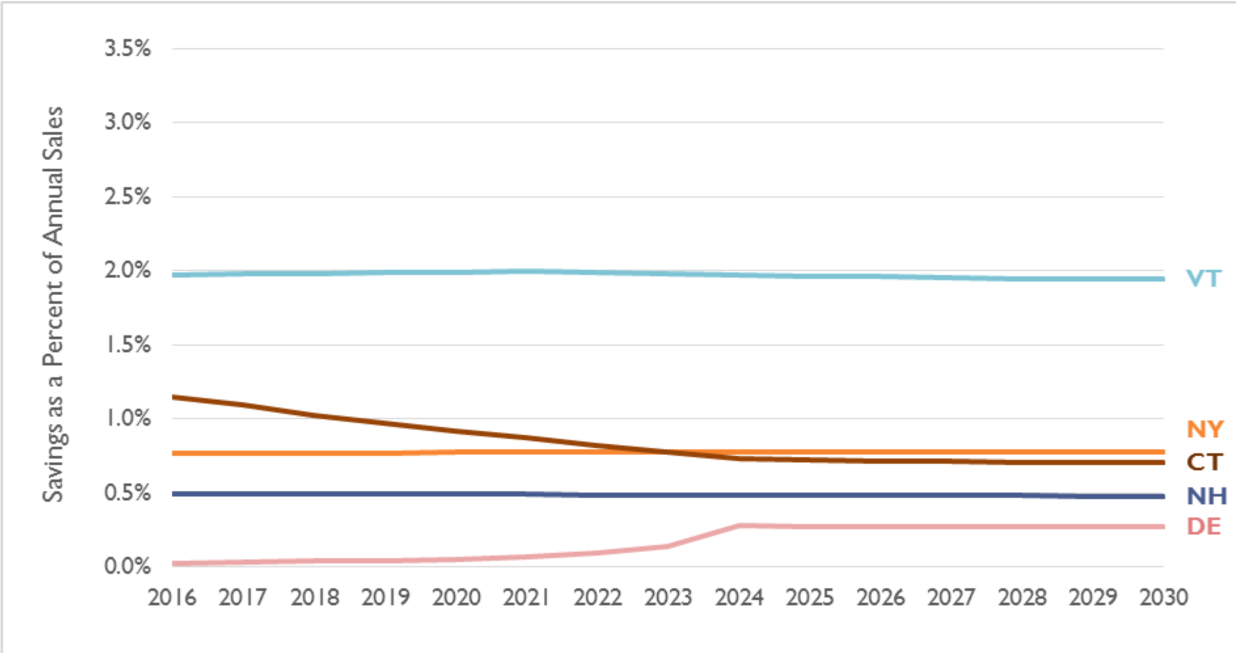
For states without electric EERS policies, Synapse estimates future baseline energy efficiency savings according to state-specific program plans and utility- or state-specific integrated resource planning

[19] White, D., et al. 2013. "State Energy Efficiency Embedded in Annual Energy Outlook Forecasts: 2013 Update." Synapse Energy Economics. Available at http://synapse-energy.com/sites/default/files/SynapseReport.2013-11.0.EE-in-AEO-2013.12-094-Update_0.pdf.

[20] In both the baseline and policy cases we have modeled the cross-sectoral co-benefits of electric energy efficiency savings on gas and oil usage in the buildings sector and vice versa. We describe the assumptions and methodology used to develop these co-benefits below in this section, and in Appendix C.

documents (see Figure 14). Where data are otherwise unavailable, we assume that the savings level in the last year of each individual forecast continues through 2030.

Figure 14. Efficiency savings assumptions for RGGI states without EERS requirements



Sources: Connecticut Department of Energy and Environmental Protection's 2014 Integrated Resource Plan; Delmarva Power & Light Company's 2014 Integrated Resource Plan; 2016 New Hampshire Statewide Core Energy Efficiency Plan from NH Public Utilities Commission Docket DE14-216; 2014 NY incremental savings from EIA Form 861; Vermont Energy Investment Corporation's 2015-2017 Triennial Plan, prepared for the Vermont Public Service Board.

Fossil fuel sales and gas energy efficiency

Annual natural gas and petroleum consumption for the nine RGGI states in the buildings and industrial sectors are projected by applying regional growth rates from the AEO 2015 Reference case to state-specific EIA historical data. In addition, we calculate "co-benefits" from the energy efficiency in the baseline scenario. "Co-benefits" are energy—and emissions—that are avoided from reduced end-use fuel consumption as a result of installing measures meant to reduce electricity consumption.[21] Based on Massachusetts energy efficiency program data, we assume that for every TWh of retail sales avoided in the electric sector as a result of installing electric energy efficiency measures, 0.27 percent of natural gas and petroleum consumption are avoided as a result of reduced end-use fuel consumption.[22]

[21] In most cases, these co-benefits are positive: for example, oil use can be reduced as a result of weatherization designed to achieve more efficient air conditioning. In some cases, these co-benefits can be negative: for example, installing more efficient lighting can actually lead to an increase in consumption of end-use fuels.

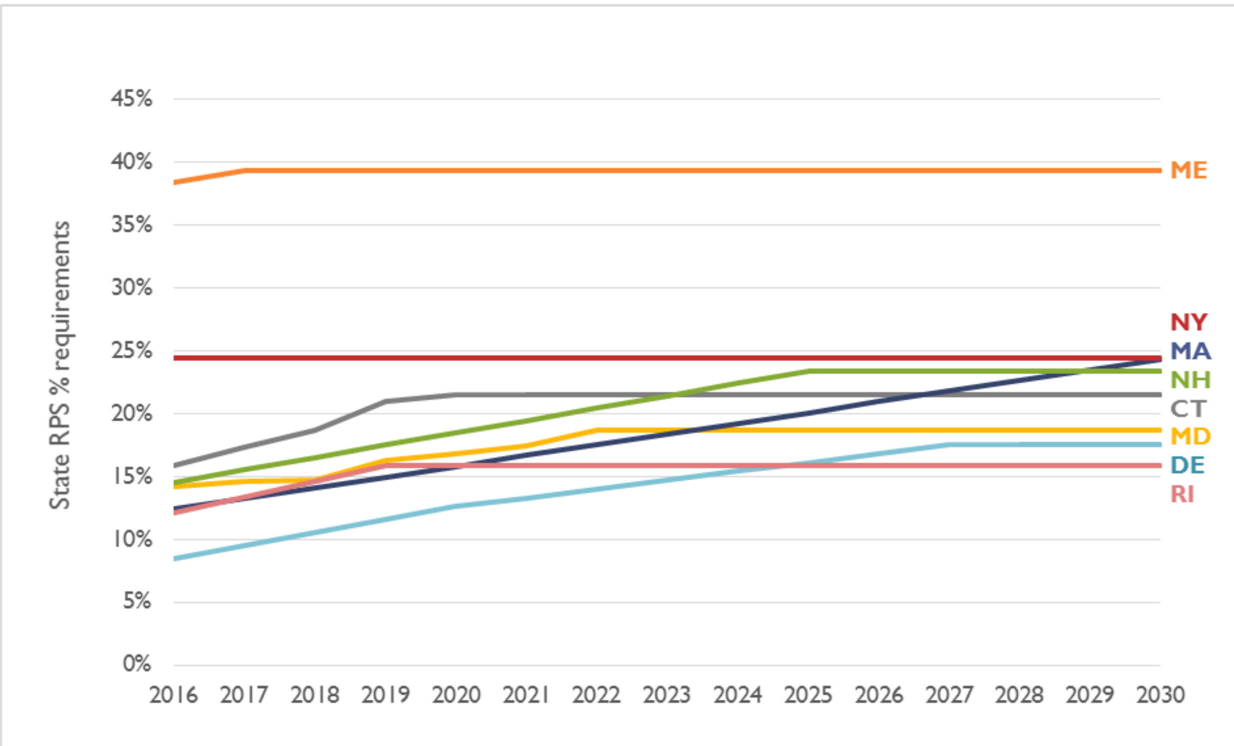
[22] Analysis of 2013-2015 data for Massachusetts electric energy efficiency program administrators, available at http://ma-eeac.org/wordpress/wp-content/uploads/2015-Q4-Report-Statewide-Final.xlsx. For states other than Massachusetts, we scale gas and oil savings to their respective sectors in the relevant state.

For the nine RGGI states, the RGGI baseline scenario assumes an annual growth rate for natural gas consumption of about -0.02 percent per year and an annual growth rate for petroleum consumption of about -1.1 percent per year in the buildings and industrial sectors.[23]

Renewable energy

All nine RGGI states have RPS policies that require utilities to procure a percentage of their electric retail sales in qualified forms of renewable generation. The share of renewables required and types of resources acceptable for classification as renewable varies from state to state. The RGGI states' total RPS requirements for all renewable resource types are summarized in Figure 15. Overall, renewable energy (including from existing generators) will account for 24 percent of sales from the RGGI region by 2030 in the baseline.

Figure 15. RGGI states' RPS requirements



Notes: This figure displays total RPS-required share of sales for each state after adjusting for the sales in each state unaffected by the RPS requirement. For example, Massachusetts utilities' 2030 RPS requirement is 25 percent but affected utilities represent only 97 percent of the Commonwealth's retail sales. In this table, the RPS share of sales for Massachusetts as a whole is 24 percent in 2030. The trends shown in this figure do not account for any existing renewables already constructed. Vermont's RPS of 55 percent in 2017 and 75 percent in 2032 is assumed to be primarily met with existing energy supplied from Hydro Québec, and is not shown on this figure.

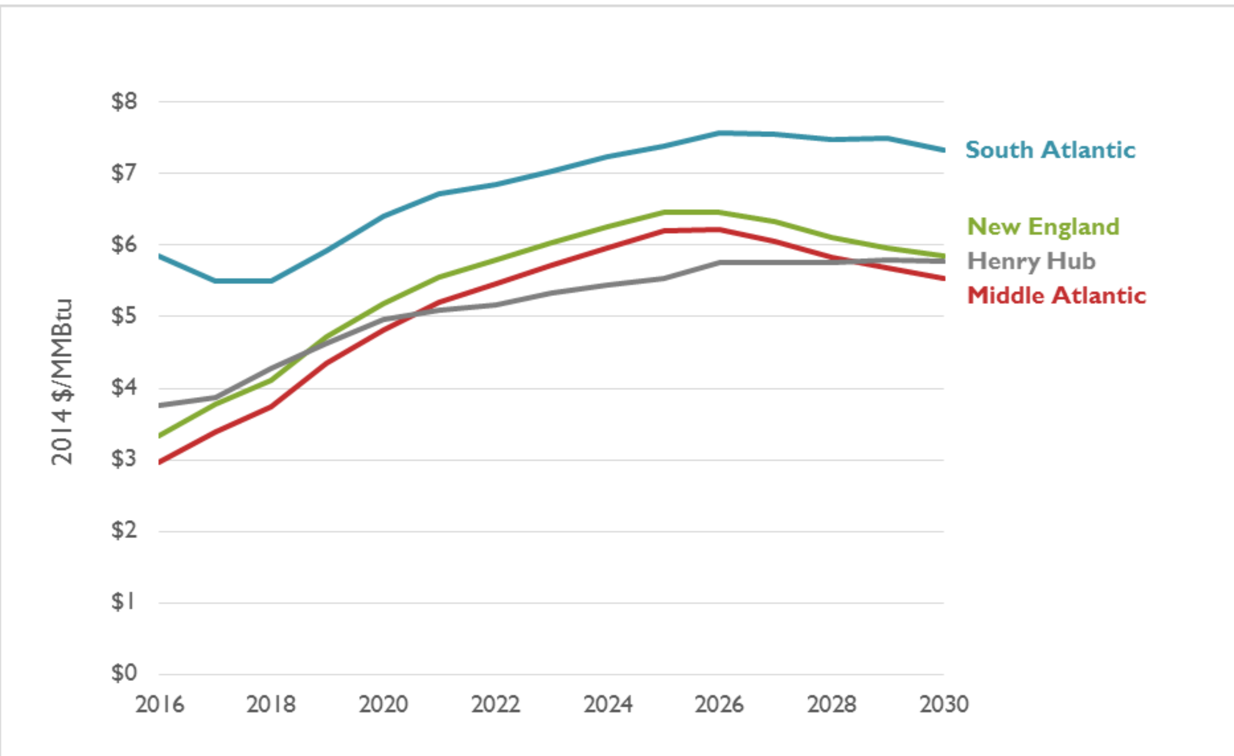
[23] In this analysis "petroleum" includes consumption of distillate fuel oil, residual fuel oil, propane, kerosene, and other miscellaneous petroleum products.

For New York, in addition to modeling the existing RPS (approximately 24 percent of retail electric sales by 2015), we modeled an additional 3,000 MW of utility-scale photovoltaic (PV) solar added by 2023 and an additional 1,600 MW of wind added by 2029, in line with the New York State Energy Research and Development Authority's (NYSERDA) projections for capacity that will come online as a result of the *NY-Sun* and *Large-Scale Renewables* programs.[24,25]

Electric sector natural gas prices

Projected natural gas prices for the electric sector were derived from the AEO 2015 Reference case for the New England, Middle Atlantic, and South Atlantic regions. Figure 16 presents the projected price of natural gas in this region out to 2030 and, for comparison, the projected Henry Hub spot-price from the same source. Note that ReEDS uses natural gas prices based on an endogenous supply-curve formulation, in which cost is a function of the quantity demanded with underlying supply curves calibrated to AEO Reference case forecasts.

Figure 16. Electric sector natural gas prices for the RGGI state regions



Source: Synapse Energy Economics, based on AEO 2015, Tables 3.1, 3.2, and 3.5.

[24] New York State Energy Planning Board. 2015. *2015 New York State Energy Plan*. Available at: http://energyplan.ny.gov/-/media/nysenergyplan/2015-state-energy-plan.pdf.

[25] New York State Energy Research and Development Authority. 2015. *Large-Scale Renewable Energy Development in New York: Options and Assessment*. Available at: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={26BD68A2-48DA-4FE2-87B1-687BEC1C629D}.

Unit additions

A number of new natural gas units have been announced for the nine RGGI states. Table 6 on the following pages presents a summary that includes: the state in which the units are coming online; the associated plant and utility; and each unit's capacity, anticipated in-service year, and generation technology. This list was developed by Sierra Club, Pace Energy and Climate Center, and Chesapeake Climate Action Network using sources that included the following:

- Unit additions reported in the 2014 edition of the EIA 860 database of generators currently under construction.
- Natural gas generators listed as currently under construction in the PJM Interconnection Queue. Where possible, data for these units was cross-checked with the EIA 860 2014 (even in cases where those generators have not yet begun construction, according to that dataset).
- New generators that have obligations in the New England capacity market for the periods of 2016-2017, 2017-2018, and 2018-2019.
- Generators that have completed the Class Year Facilities Study according to the 2015 NYISO Gold Book.
- Estimated incremental solar and wind capacity according to the 2015 NY State Energy Plan (NY-Sun initiative) and the 2015 NYSERDA Large-scale Renewables Report (LSR-incentivized wind).

Table 6. RGGI states' assumed unit additions

State	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Prime Mover	Unit Type
CT	Bridgeport Energy 1	Unknown	22	2018	Gas	GT	ISO-NE FCM
CT	CPV_Towantic	Unknown	725	2018	Gas	CC	ISO-NE FCM
CT	Subase Microgrid Project	CT Muni Electric Energy Coop	2	2016	Petroleum	IC	EIA 860
CT	Subase Microgrid Project	CT Muni Electric Energy Coop	2	2016	Petroleum	IC	EIA 860
CT	Subase Microgrid Project	CT Muni Electric Energy Coop	2	2016	Petroleum	IC	EIA 860
CT	Subase Microgrid Project	CT Muni Electric Energy Coop	2	2016	Petroleum	IC	EIA 860
CT	Wallingford 6 and 7	Unknown	90	2018	Gas	GT	ISO-NE FCM
DE	Garrison Energy Center	Garrison Energy Center	126	2015	Gas	CA	EIA 860
DE	Garrison Energy Center	Garrison Energy Center	235	2015	Gas	CT	EIA 860
MA	Belchertown SEd	Unknown	1	2018	Solar	PV	ISO-NE FCM
MA	Dartmouth Solar	Unknown	1	2018	Solar	PV	ISO-NE FCM
MA	East Bridgewater Solar Energy Project	Unknown	1	2016	Solar	PV	ISO-NE FCM
MA	Fisher Road Solar I	Unknown	2	2018	Solar	PV	ISO-NE FCM
MA	Harrington Street PV Project	Unknown	1	2016	Solar	PV	ISO-NE FCM
MA	Holliston	Unknown	0	2018	Solar	PV	ISO-NE FCM
MA	Indian Orchard Photovoltaic Facility	Unknown	1	2018	Solar	PV	ISO-NE FCM
MA	Indian Orchard Solar PV	Unknown	1	2016	Solar	PV	ISO-NE FCM
MA	Indian River Power Supply# LLC	Unknown	0	2018	Hydro	HY	ISO-NE FCM
MA	Landcraft	Unknown	1	2018	Solar	PV	ISO-NE FCM
MA	LSRHS	Unknown	0	2018	Solar	PV	ISO-NE FCM

State	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Prime Mover	Unit Type
MA	MAT-2 (MATEP Combined Cycle)	Unknown	14	2017	Gas	CC	ISO-NE FCM
MA	Medway Peaker – SEMARI	Unknown	195	2018	Gas	GT	ISO-NE FCM
MA	N/A	TerraForm Solar XVII	2	2015	Solar	PV	EIA 860
MA	N/A	TerraForm Solar XVII	3	2015	Solar	PV	EIA 860
MA	NFM Solar Power, LLC	Unknown	1	2016	Solar	PV	ISO-NE FCM
MA	Northfield Mountain 1	Unknown	12	2016	Hydro	PS	ISO-NE FCM
MA	Northfield Mountain 2	Unknown	12	2016	Hydro	PS	ISO-NE FCM
MA	Northfield Mountain 3	Unknown	12	2016	Hydro	PS	ISO-NE FCM
MA	Northfield Mountain 4	Unknown	12	2016	Hydro	PS	ISO-NE FCM
MA	Plymouth	Unknown	2	2018	Solar	PV	ISO-NE FCM
MA	Salem Harbor	NAES Salem Harbor	340	2017	Gas	CC	EIA 860
MA	Salem Harbor	NAES Salem Harbor	340	2017	Gas	CC	EIA 860
MA	Silver Lake Photovoltaic Facility	Unknown	0	2018	Solar	PV	ISO-NE FCM
MA	Southbridge Landfill Gas to Energy 17-18	Unknown	1	2017	Landfill Gas	IC	ISO-NE FCM
MA	Southbridge Landfill Gas to Energy 17-18	Unknown	1	2018	Landfill Gas	IC	ISO-NE FCM
MA	Treasure Valley- SE	Unknown	2	2018	Solar	PV	ISO-NE FCM
MA	Uxbridge	Unknown	1	2018	Solar	PV	ISO-NE FCM
MA	West Brookfield Solar	Unknown	0	2016	Solar	PV	ISO-NE FCM
MA	Westford Solar	Unknown	2	2018	Solar	PV	ISO-NE FCM
MA	WMA Chester Solar 1	Unknown	2	2018	Solar	PV	ISO-NE FCM
MD	Baltimore Ravens Facility	Baltimore Ravens	1	2015	Gas	IC	PJM Queue

State	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Prime Mover	Unit Type
MD	CNE at Cambridge MD	Constellation Solar Maryland	3	2015	Solar	PV	EIA 860
MD	CPV St Charles Energy Center	CPV Maryland LLC	215	2017	Gas	CT	PJM, EIA 860
MD	CPV St Charles Energy Center	CPV Maryland LLC	215	2017	Gas	CT	PJM, EIA 860
MD	CPV St Charles Energy Center	CPV Maryland LLC	316	2017	Gas	CA	PJM, EIA 860
MD	Keys Energy System	Genesis Power	736	2018	Gas	CC	PJM Queue
MD	Keys Energy System	Genesis Power	65	2018	Gas	GT	PJM Queue
MD	Mattawoman Energy Center	Mattawoman Energy, LLC	286	2018	Gas	CC	PJM, EIA 860
MD	Mattawoman Energy Center	Mattawoman Energy, LLC	286	2018	Gas	CC	PJM, EIA 860
MD	Mattawoman Energy Center	Mattawoman Energy, LLC	436	2018	Gas	CC	PJM, EIA 860
MD	Perryman	Constellation Power Source Generation	141	2015	Gas	GT	EIA 860
MD	Rockfish Solar	Rockfish Solar	10	2016	Solar	PV	EIA 860
MD	Wildcat Point Generation Facility	Old Dominion Electric Coop	310	2017	Gas	CT	PJM, EIA 860
MD	Wildcat Point Generation Facility	Old Dominion Electric Coop	310	2017	Gas	CT	PJM, EIA 860
MD	Wildcat Point Generation Facility	Old Dominion Electric Coop	493	2017	Gas	CA	PJM, EIA 860
ME	Saddleback Ridge Wind	Unknown	6	2017	Wind	WT	ISO-NE FCM
NH	Berlin Biopower	Unknown	7	2017	Biomass	ST	ISO-NE FCM
NH	Jericho Power	Jericho Power	14	2015	Wind	WT	EIA 860
NY	Berrians GT	NRG Energy	200	2017	Gas	CC	NY Gold Book
NY	Berrians GT II	NRG Energy, Inc.	79	2017	Gas	CC	NY Gold Book
NY	Berrians GT III	NRG Energy, Inc.	279	2019	Gas	CC	NY Gold Book
NY	CPV Valley Energy Center	CPV Valley, LLC	820	2016	Gas	CC	NY Gold Book

State	Plant	Utility	Nameplate Capacity (MW)	First Year of Operation	Fuel Type	Prime Mover	Unit Type
NY	Millbrook School	SolarCity Corporation	1	2015	Solar	PV	EIA 860
NY	Roaring Brook Wind	PPM Roaring Brook, LLC / PPM	78	2015	Wind	WT	NY Gold Book
NY	Taylor Biomass	Taylor Biomass Energy Mont., LLC	21	2017	MSW	Unk	NY Gold Book
NY	NY-Sun Initiative I	None	1,500	2020	Solar	PV	NY SEP
NY	NY-Sun Initiative I	None	1,500	2023	Solar	PV	NY SEP
NY	Wind-LSR I	None	800	2024	Wind	WT	NYSERDA
NY	Wind-LSR II	None	800	2029	Wind	WT	NYSERDA
RI	Central Power Plant	State of Rhode Island	2	2015	Gas	IC	EIA 860
RI	Johnston Solar	Half Moon Ventures	1	2015	Solar	PV	EIA 860
RI	Tiverton Power	Unknown	11	2018	Gas	GT	ISO-NE FCM

Sources: 2014 Form EIA-860 data, schedule 3, 'Generator Data' (Proposed, under construction units); PJM Interconnection Queue, accessed November 2015; ISO-NE Forward Capacity Market obligations 2016-2019; 2015 NYISO Gold Book; NY 2015 State Energy Plan; 2015 NYSERDA Large-scale Renewables Report.

Unit retirements and environmental retrofits

Table 7 on the following pages lists all announced unit retirements for the nine RGGI states. Retirement data is based on the 2014 edition of EIA's Form 860, supplemented by ongoing Synapse research. This table also indicates control technologies projected to be required at coal generators that will continue to operate through the study period. The cost of control technologies that will be installed at coal plants under existing federal environmental regulations other than the Clean Power Plan were estimated using the Synapse Coal Asset Valuation Tool (CAVT) (see Table 7 on the following page).[26] These expected new retrofits are only added in years in which specific units have not yet been retired. Note that all retirements and retrofits are assumed as inputs to both the baseline and the 40 percent reduction policy scenario scenarios.

[26] For more information, see also: Knight, P. and J. Daniel. 2015. "Forecasting Coal Unit Competitiveness – 2015 Update." Synapse Energy Economics. Available at: http://www.synapse-energy.com/sites/default/files/Forecasting-Coal-Unit-Competitiveness-14-021.pdf. CAVT is available at http://synapse-energy.com/tools/coal-asset-valuation-tool-cavt.

Table 7. RGGI states' anticipated unit retirements.

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retiring?	Moth-balling?	Re-powering?	Dry FGD	SCR	Baghouse	ACI	Cooling	CCR	Effluent
CT	Bridgeport Station 2	163	Coal	0%	2014									
CT	Bridgeport Station 3	400	Coal	24%								2019		
CT	Bridgeport Station 4	19	Oil	1%	2017									
CT	CJTS Energy Center UNIT1	0.2	Gas	23%	2014									
CT	CJTS Energy Center UNIT2	0	Gas	23%	2014									
CT	CJTS Energy Center UNIT3	0.2	Gas	23%	2014									
CT	CJTS Energy Center UNIT5	0	Gas	23%	2014									
CT	Covanta Wallingford Energy GEN1	11	Other	41%	2015									
CT	New Milford Gas Recovery GEN4	1	Other	50%	2015									
CT	South Norwalk Electric 6	1	Oil	0%	2014									
CT	Versailles Mill NO1	20	Gas	0%	2014									

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retiring?	Moth-balling?	Re-powering?	Dry FGD	SCR	Baghouse	ACI	Cooling	CCR	Effluent
DE	Indian River Generating Station 3	176.8	Coal	0%	2014									
DE	Indian River Generating Station 4	446	Coal	22%								2015	2019	2019
DE	McKee Run 1	18.8	Gas	0%	2017									
DE	McKee Run 2	19	Gas	0%	2017									
MA	Brayton Point 1	241	Coal	30%	2017									
MA	Brayton Point 2	241	Coal	35%	2017									
MA	Brayton Point 3	642.6	Coal	22%	2017									
MA	Brayton Point 4	476	Gas	2%	2017									
MA	Harris Energy Realty ALBA	0.3	Hydro	0%	2015									
MA	Harris Energy Realty ALBD	1	Hydro	0%	2015									
MA	Harris Energy Realty NONO	0.5	Hydro	0%	2015									
MA	Mass Inst Tech Cntrl Utilities/Cogen Plt CTG1	21	Gas	71%	2019									

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retiring?	Moth-balling?	Re-powering?	Dry FGD	SCR	Baghouse	ACI	Cooling	CCR	Effluent
MA	Mount Tom 1	136	Coal	0%	2014									
MA	Pilgrim Nuclear Power Station 1	670	Nuclear	98%	2019									
MA	Salem Harbor 1	81.9	Coal	0%	2014									
MA	Salem Harbor 2	82	Coal	0%	2014									
MA	Salem Harbor 3	165.7	Coal	15%	2014									
MA	Salem Harbor 4	476	Oil	1%	2014									
MD	Brandon Shores 1	685	Coal	42%									2019	2019
MD	Brandon Shores 2	685	Coal	37%									2019	2019
MD	C P Crane 1	190.4	Coal	11%	2020									
MD	C P Crane 2	209	Coal	17%	2020									
MD	Chalk Point LLC ST1	364	Coal	36%	2019									
MD	Chalk Point LLC ST2	364	Coal	43%	2019									

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retiring?	Moth-balling?	Re-powering?	Dry FGD	SCR	Baghouse	ACI	Cooling	CCR	Effluent
MD	Dickerson 2	196	Coal	23%	2019									
MD	Dickerson 3	196	Coal	23%	2019									
MD	Dickerson ST1	196	Coal	23%	2019									
MD	Goddard Steam Plant 1	6	Coal	19%	2014									
MD	Goddard Steam Plant 2	6.2	Coal	26%	2014									
MD	Herbert A Wagner 2	136	Coal	19%	2020									
MD	Herbert A Wagner 3	359	Coal	33%								2019	2019	2019
MD	Morgantown Generating Plant ST1	626	Coal	55%								2019	2019	2019
MD	Morgantown Generating Plant ST2	626	Coal	57%								2019	2019	2019
MD	Riverside 4	72	Gas	0%	2016									
MD	Riverside GT6	135	Gas	0%	2014									
ME	Bar Harbor 2	2	Oil	0%	2014									

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retiring?	Moth-balling?	Re-powering?	Dry FGD	SCR	Baghouse	ACI	Cooling	CCR	Effluent
ME	Bar Harbor 4	2	Oil	0%	2014									
ME	Medway IC1	2	Oil	0%	2015									
ME	Medway IC2	2	Oil	0%	2015									
ME	Medway IC3	2	Oil	0%	2015									
ME	Medway IC4	2	Oil	0%	2015									
NH	Merrimack 1	114	Coal	34%								2019		
NH	Merrimack 2	345.6	Coal	27%								2019		
NH	Nashua Plant UNT1	2	Other	20%	2014									
NH	Schiller 4	50	Coal	22%								2019		2019
NH	Schiller 5	50	Coal	71%								2019		2019
NH	Schiller 6	50	Coal	21%								2019		2019
NY	Al Turi 3010	1	Other	47%	2017									

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retiring?	Moth-balling?	Re-powering?	Dry FGD	SCR	Baghouse	ACI	Cooling	CCR	Effluent
NY	Auburn LFG Energy Facility 2	1.1	Other	35%	2014									
NY	C R Huntley Generating Station 67	200	Coal	29%	2016									
NY	C R Huntley Generating Station S68	200	Coal	40%	2016									
NY	Cayuga Operating Company 1	155	Coal	30%								2019	2019	2019
NY	Cayuga Operating Company 2	167.2	Coal	35%			2018		2018					
NY	Danskammer Generating Station 3	147	Coal	0%			2014							
NY	Danskammer Generating Station 4	239.4	Coal	0%			2014							
NY	Dunkirk Generating Plant 1	96	Coal	0%				2020			2016	2019	2019	2019
NY	Dunkirk Generating Plant 2	96	Coal	44%		2015								
NY	Dunkirk Generating Plant 3	218	Coal	0%		2015								
NY	Dunkirk Generating Plant ST4	217.6	Coal	0%		2015								
NY	Entenmanns Energy Center 1	1	Gas	15%	2014									

State	Plant Name	Nameplate Capacity (MW)	Fuel Type	2014 Capacity Factor	Retiring?	Moth-balling?	Re-powering?	Dry FGD	SCR	Baghouse	ACI	Cooling	CCR	Effluent
NY	Entenmanns Energy Center 2	1.3	Gas	15%	2014									
NY	Entenmanns Energy Center 3	1	Gas	15%	2014									
NY	Entenmanns Energy Center 4	1.3	Oil	15%	2014									
NY	Hawkeye Energy Greenport LLC U-01	54	Oil	3%	2018									
NY	James A Fitzpatrick 1	882	Nuclear	75%	2017									
NY	Monroe Livingston Gas Recovery GEN2	1	Other	61%	2016									
NY	Oceanside Energy OS3	0.7	Other	32%	2015									
NY	Rochester 9 2	19	Gas	0%	2014									
NY	S A Carlson 5	24.5	Coal	2%										
NY	S A Carlson 6	25	Coal	21%										
NY	Somerset Operating Co LLC 1	655.1	Coal	31%								2019	2019	2019
NY	WPS Power Niagara GEN1	56	Coal	18%				2020			2016		2019	2019
VT	Gilman Mill GEN5	4	Biomass	0%	2014									
VT	Vermont Yankee 1	563	Nuclear	103%	2014									

Note: Some capacity factors may exceed 100 percent based on discrepancies in utility reporting to EIA. Source: Synapse Energy Economics, based on EIA Form 860 data.

APPENDIX C: THE RGGI 40 PERCENT EMISSION REDUCTION POLICY SCENARIO

To design a policy scenario that would achieve 2030 all-sector energy-related CO_2 emissions that are 40 percent lower than 1990 levels, Synapse examined a discrete set of emission reduction measures for which previous research has demonstrated a potential for significant emission reduction and that are known to be among the most cost-effective strategies for achieving remission reductions. For each measure, Synapse estimated the net costs per ton of CO_2 reduction in 2030 and the potential for emission reductions in tons in 2030. From these measures were chosen—in order of cost—just enough emission reductions to achieve the target.

After accounting for expected emission reductions in the transportation, buildings, and industrial sectors, ReEDS was programmed to achieve the remaining reductions in the electric sector by (1) setting new, more stringent (lower) RGGI caps, and (2) setting minimum additions (with respect to 2015) of onshore wind and utility-scale PV that ReEDS must build within the RGGI states. This second constraint—together with the limitation in both scenarios that RGGI states may only trade emissions allowances within their group—avoids leakage of emissions out of RGGI region. Note that these two constraints, taken together, interact in the same way that current day RGGI caps work together with state RPS and EERS policies to achieve emission reductions.

Shift measures

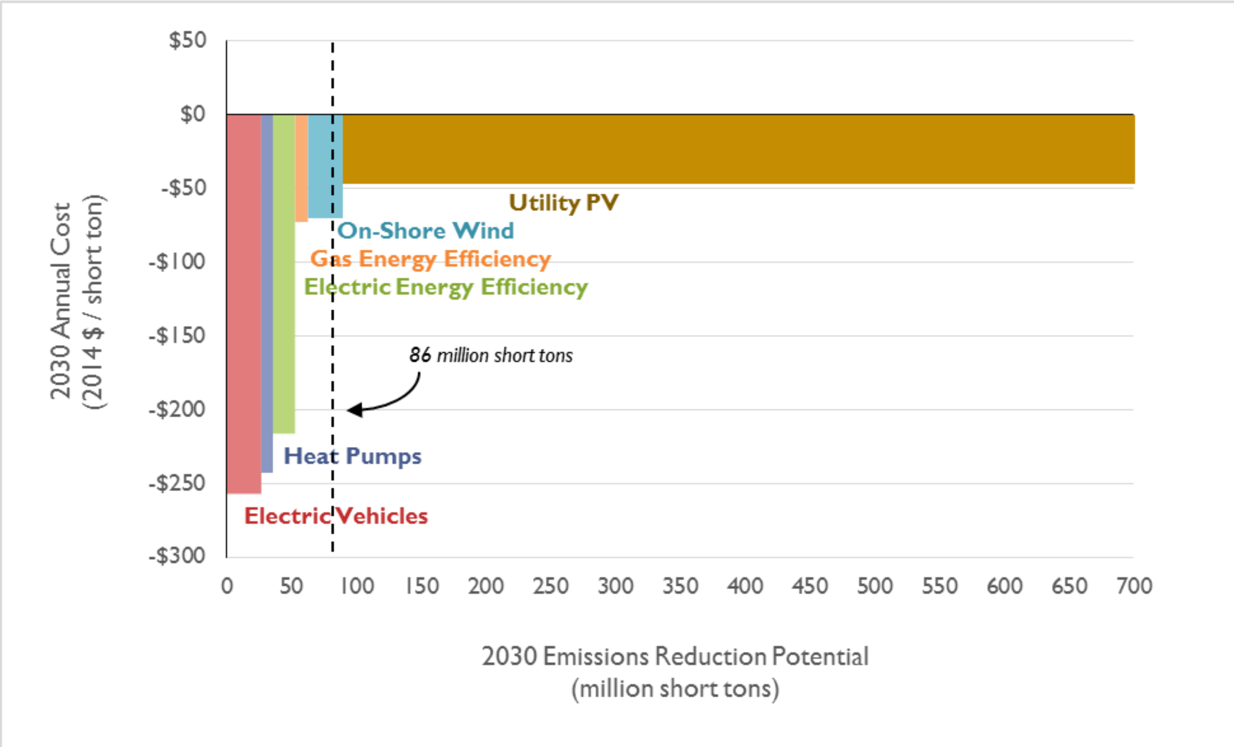
To determine the lowest-cost emission reduction to achieve the incremental 86 million short tons of reductions needed beyond the RGGI baseline, Synapse used a supply—or "marginal abatement"—curve methodology. A supply curve analysis sets out potential emission reduction measures—or "shifts"—in order according to each measure's cost-per-ton of avoided CO_2. Shift measures are then selected for inclusion in the 40 percent reduction policy scenario in order of their costs, from least to most expensive, until their potential emission reductions are sufficient to meet the target. The per-ton cost of each shift measure includes both the costs of achieving the new measure and the costs avoided by not taking the same actions as in the RGGI baseline. (For example, the cost of a shift to electric vehicles is offset by savings from gasoline not purchased.) The per-ton costs of each shift also include a value of avoided climate damages equal to the federal social cost of carbon: $51 per short ton in 2030.[27]

Figure 17 presents the supply curve used to compare these shift measures in terms of relative costs per ton and relative emission reduction potentials. Note that all six of the shifts have negative net costs.

[27] U.S. EPA. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*.

Even after accounting for the construction and operation of these new low-carbon technologies, their benefits outweigh their costs.

Figure 17. Supply curve of emission reduction shift measures in 2030



Source: Synapse Energy Economics.

Synapse researched seven potential shift measures for use in this analysis, and ultimately brought six of these measures into our supply curve:

- **Electric vehicles:** By 2030, 35 percent of existing light-duty vehicle trips under 100 miles are assumed to be replaced with trips taken in plug-in battery electric vehicles.[28] Emissions are reduced by avoiding gasoline consumption. Electric vehicles are assumed to be powered by additions of new onshore wind and utility-scale PV generation; for each new kWh shifted from the transportation sector to the electric sector, an incremental kWh of renewable generation is also added. One hundred percent of this shift's emission reduction potential was applied to the 40 percent emissions reduction policy scenario, providing 28 million short tons of emission reductions. This shift follows Scenario 8 from the Federal Highway Administration's EV project and includes an assumed 80 percent of charging occurring at home and gas tax revenues remaining

[28] This shift measure does not include potential emission reductions as a result of plug-in hybrid vehicles or other types of plug-in vehicles.

unaffected.[29] For comparison, a recent Georgetown University study of potential electric vehicle adoption in 12 Northeast states found transportation emission reductions of 29-40 percent by 2030 and consumer savings of $3.6-18 billion over 15 years.[30]

- **Costs:** Incremental electricity consumption at the AEO 2015 wholesale price of energy,[31] state-level subsidies associated with direct incentives for electric vehicles at the level of current RGGI states are phased out by 2020, state-level subsidies associated with spurring public charging stations at the level of current RGGI states are continued through 2030,[32] and the levelized cost of the new renewable generation needed to support this measure[33]
- **Avoided Costs:** Gasoline purchases,[34] social cost of carbon[35]

- **Heat pumps:** By 2030, 44 percent of residential consumption of petroleum is assumed to be replaced with ductless minisplit heat pump systems.[36] Emissions are avoided by decreasing the direct consumption of distillate fuel oil in residential buildings. Heat pumps are assumed to be powered by additions of new onshore wind and utility-scale PV generation; for each new kWh added to the electric sector from heat pumps, an incremental kWh of renewable generation is added. One hundred percent of this shift's emission reduction potential was applied to the 40 percent emissions reduction policy scenario, providing 9 million short tons of emission reductions. This shift follows the "High State Support" scenario from Massachusetts Department of Energy Resource's 2014 study "Commonwealth Accelerated Renewable Thermal Strategy."[37]

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[29] U.S. Federal Highway Administration. 2015. "Feasibility and Implications of Electric Vehicle (EV) Deployment and Infrastructure Development." Available at: http://www.fhwa.dot.gov/environment/climate_change/mitigation/publications/ev_deployment/es.cfm.

[30] Pacyniak, G., K. Zyla, V. Arroyo, M. Goetz, C. Porter, and D. Jackson. 2015. "Reducing Greenhouse Gas Emissions from Transportation: Opportunities in the Northeast and Mid-Atlantic." Georgetown Climate Center with Cambridge Systematics. Available at: http://www.georgetownclimate.org/five-northeast-states-and-dc-announce-they-will-work-together-to-develop-potential-market-based-poli.

[31] EIA. "Annual Energy Outlook 2015." Tables 3.1, 3.2, and 3.5.

[32] Additional information on current EV subsidies is available from the International Council on Clean Transportation at http://www.theicct.org/sites/default/files/publications/SupportEVsUScities_201510.pdf.

[33] For the purpose of the supply curve we assume that the new renewable built to supply electricity to incremental electric vehicles is supplied by onshore wind and utility-scale PV in equal measure.

[34] EIA. "Annual Energy Outlook 2015." Tables 3.1, 3.2, and 3.5.

[35] U.S. EPA. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*.

[36] In this analysis "petroleum" includes consumption of distillate fuel oil, residual fuel oil, propane, kerosene, and other miscellaneous petroleum products, and consumption includes use of energy for both water heating and space heating.

[37] Navigant and Meister Consulting Group. 2014. "Commonwealth Accelerated Renewable Thermal Strategy." Prepared for Massachusetts Department of Energy Resources. Available at http://www.mass.gov/eea/docs/doer/renewables/thermal/carts-report.pdf.

- **Costs:** Incremental costs of installing a heat pump system versus a replacement oil-fired furnace or boiler (including the cost of oil tank removal), net of a new central cooling system; incremental costs of electricity consumption.
- **Avoided Costs:** Social cost of carbon; avoided cost of purchasing distillate fuel oil per AEO 2015

- **Electric energy efficiency:** Electric savings in MWh from energy efficiency measures reduce emissions by displacing the same amount of MWh of fossil fuel-fired generation. Electric energy efficiency savings in the 40 percent emission reduction policy scenario are assumed to be equal to each RGGI state achieving the savings assumed for Massachusetts in the RGGI baseline,[38] or a region-wide average of 3 percent annual incremental savings by 2030. Emissions are assumed to be avoided at the emission rate of the marginal generator. In addition to emissions reductions in the electric sector, this shift also includes "co-benefits"—emissions avoided from reduced end-use fuel consumption as a result of installing measures meant to reduce electricity consumption. One-hundred percent of this shift's emission reduction potential (or 37 TWh by 2030) was applied to the 40 percent emission reduction policy scenario, providing an estimated 17 million short tons of emission reductions.
  - **Costs:** Utility-side energy efficiency program costs (including costs covering administration, marketing, incentives, and other utility-side costs)[39]
  - **Avoided Costs:** Social cost of carbon; avoided capacity, transmission, and distribution per AESC 2015[40]

- **Gas energy efficiency:** Energy savings from natural gas efficiency measures in the residential, commercial, and industrial sectors reduce emissions by directly eliminating the use of fossil fuels. Non-electric energy efficiency savings in the policy scenario are assumed to be equal to the savings resulting from implementing natural gas energy efficiency spending from a 2013 Lawrence Berkeley National Laboratory study at historical costs for natural gas energy efficiency based on recent data from Massachusetts.[41, 42] This assumption results in each state reducing its baseline natural gas consumption across the residential, commercial, and industrial sectors by 9 percent in 2030. CO_2 emissions are assumed to be avoided at a region-, fuel-, and sector-specific rate that is derived from AEO projections of natural gas consumption and emissions. In

38 MassSave. 2015. "2016-2020 Massachusetts Joint Statewide Three-Year Electric and Gas Energy Efficiency Plan." Massachusetts Energy Efficiency Advisory Council. Available at http://ma-eeac.org/wordpress/wp-content/uploads/Exhibit-1-Gas-and-Electric-PAs-Plan-2016-2018-with-App-except-App-U.pdf.

39 Program costs are $0.40 per kilowatt-hour based on the average program cost for RGGI states historically.

40 Hornby, R. et al. 2015. "Avoided Energy Supply Costs in New England: 2015 Report - Revised." Avoided Energy Supply Component Study Group. Available at: http://www.ct.gov/deep/lib/deep/energy/aescinnewengland2015.pdf.

41 Barbose, G. et al. 2013. "The Future of Utility Customer-Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025." Lawrence Berkeley National Lab (LBNL). Available at: https://emp.lbl.gov/sites/all/files/lbnl-5803e.pdf.

42 MA Energy Efficiency Advisory Council. Analysis of 2013-2015 plan data for Massachusetts gas energy efficiency program administrators, available at http://ma-eeac.org/wordpress/wp-content/uploads/2015-Q4-Report-Statewide-Final.xlsx

addition to emissions reductions associated with decreased use of natural gas within buildings, this shift includes the cross-sector co-benefits of emission reductions associated with decreased electricity consumption resulting from natural gas efficiency measures. We estimate that for every trillion Btu avoided through natural gas efficiency measures, there is a corresponding 0.004 percent reduction in electricity sales.[43] One hundred percent of this shift's emission reduction potential (or 160 trillion Btu by 2030) was applied to the 40 percent emission reduction policy scenario, providing an estimated 9 million short tons of emission reductions.

- **Costs:** Utility-side energy efficiency program costs (including costs covering administration, marketing, incentives, and other utility-side costs)[44]
- **Avoided Costs:** Social cost of carbon; avoided end-use natural gas cost per AESC 2015[45]

- **Wind:** Electric generation from economically achievable onshore wind displaces generation from existing fossil resources. Emissions are assumed to be avoided at the emission rate of the marginal generator in the baseline scenario. 82 percent of this shift's emission reduction potential (or 49 TWh) was applied to the 40 percent emission reduction policy scenario, providing an estimated 22 million short tons of emission reductions. An additional 11 TWh was included in the 40 percent emission reduction policy scenario to support new demand for electricity to power electric vehicles and heat pumps. This shift is based on generation potential included in NREL's July 2015 study *Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results*[46] but its costs are based on the more recent *Lazard's Levelized Cost of Energy Analysis—Version 9.0*. In the Lazard November 2015 analysis the current levelized cost of onshore wind in the Northeast is lower than NREL's projected 2030 cost of onshore wind.[47]
    - **Costs:** Levelized production cost of onshore wind generation[48]
    - **Avoided Costs:** Social cost of carbon; avoided energy, capacity, transmission, and distribution per AESC 2015

[43] MA Energy Efficiency Advisory Council. Analysis of 2013-2015 data for Massachusetts electric energy efficiency program administrators, available at http://ma-eeac.org/wordpress/wp-content/uploads/2015-Q4-Report-Statewide-Final.xlsx.

[44] Program costs are $48 per MMBtu based on the average program cost for Massachusetts historically.

[45] Hornby, R. et al. "Avoided Energy Supply Costs in New England: 2015 Report - Revised."

[46] Brown A. et al. 2015. "Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results." National Renewable Energy Laboratory (NREL). Available at: http://www.nrel.gov/docs/fy15osti/64503.pdf.

[47] Lazard. 2015. "Lazard's Levelized Cost of Energy Analysis – Version 9.0." Available at https://www.lazard.com/media/2390/lazards-levelized-cost-of-energy-analysis-90.pdf.

[48] The cost of onshore wind in the supply curve analysis is $54 per MWh—the 2015 Northeast levelized cost from the Lazard study at NREL's assumed capacity factor for the region, 35-40 percent. Our ReEDS analysis and system cost results include NREL's original resource cost assumptions without these changes ($76 per MWh in 2030).

- **Solar:** Electric generation from economically achievable utility-scale PV units displaces generation from existing fossil resources. Emissions are assumed to be avoided at the emission rate of the marginal generator in the baseline scenario. While no solar was required to be built in the policy scenario to get to a 40 percent reduction in all-sector emissions, 15 TWh of utility-scale PV potential was included in the 40 percent emission reduction policy scenario to support new demand for electricity to power electric vehicles and heat pumps. Furthermore, an additional 4 TWh were constructed by 2030 as a result of this resource being yet more economic than other traditional utility-scale resources (such as coal, nuclear, or natural gas generators). This shift is based on costs and generation potential included in NREL's July 2015 study *Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results* but its costs are based on the more recent *Lazard's Levelized Cost of Energy Analysis—Version 9.0*. In the Lazard November 2015 analysis the current levelized cost of utility-scale PV in the Northeast is lower than NREL's projected 2030 cost of utility-scale PV.[49]
    - **Costs:** Levelized production cost of utility-scale PV generation[50]
    - **Avoided Costs:** Social cost of carbon; avoided energy, capacity, transmission, and distribution per AESC 2015
- **Increased long-distance rail usage:** By 2030, 14.4 million miles of long-distance light-duty vehicle trips have the potential to be replaced by trips taken on Amtrak's Northeast Corridor. This shift's cost was several orders of magnitude higher than the other potential shifts and was not included in the supply curve analysis. This shift is based on Alternative I in the November 2015 "NEC Futures" report.[51]

Impact of the Social Cost of Carbon

The costs and order of measures used in the above supply curve assume the federal social cost of carbon of $36 per short ton in 2015, rising to $51 per short ton in 2030 and $70 per short ton in 2050.[52] The social cost of carbon is an estimate of the economic damages associated with a small increase in CO_2 emissions. An externality value, it incorporates costs associated with changes in net agricultural productivity, human health, property damages from flood risk, and changes in heating and cooling costs. However, there is uncertainty in this value: the IPCC Fifth Assessment report observed that the federal

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[49] Lazard. "Lazard's Levelized Cost of Energy Analysis – Version 9.0."

[50] The cost of utility-scale PV in the supply curve analysis is $80 per MWh—the 2015 Northeast levelized cost from the Lazard study for crystalline, utility-scale PV fixed-tilt (Lazard does not provide regional results for thin-film PV). Our ReEDS analysis and system cost results include NREL's original resource cost assumptions without these changes ($104 to $111 per MWh in 2030).

[51] U.S. Department of Transportation Federal Railroad Administration. 2015. "NEC Future: Tier 1 Draft Environmental Impact Statement." Available at: http://www.necfuture.com/tier1_eis/deis/.

[52] U.S. EPA. *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*.

value for the social cost of carbon omits a number of impacts that would increase damages.[53] Other reports, such as AESC 2015, use other values for the potential damages associated with carbon emissions ($100 per short ton).

If, however, decisions about resource investments were made without consideration of the social cost of carbon (a de facto assumption that climate damage has no cost to society) the resultant supply curve would lead to a set of emission reduction measure choices identical to those made with climate damages included: electric vehicles, heat pumps, electric energy efficiency, gas energy efficiency, and onshore wind continue to have net negative costs even with a social cost of carbon of zero dollars per short ton, while utility-scale solar has a very small net positive cost that would be erased with a slightly lower levelized cost of energy (one that, for example, took into consideration of the availability of less expensive thin-film technology).

Changes to ReEDS assumptions

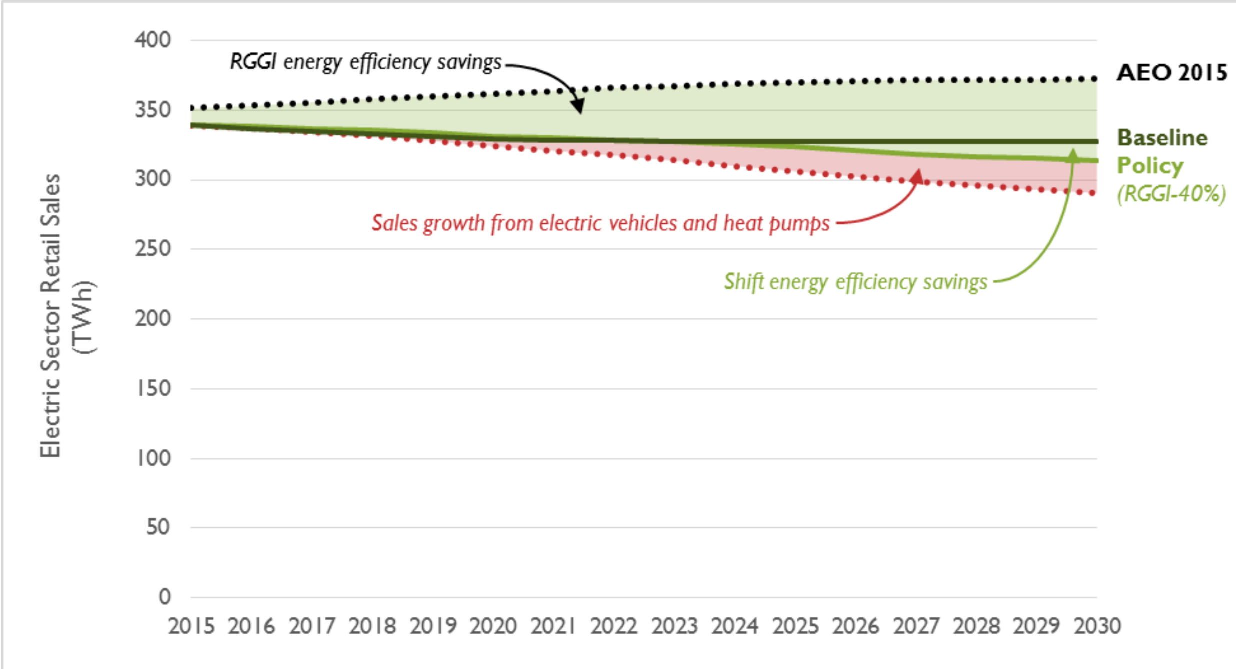
ReEDS modeling of the 40 percent emission reduction policy scenario begins with the RGGI baseline scenario in ReEDS and makes just a few changes to it in order to achieve the emission reduction goal. Note that ReEDS' build out of new renewables and emission impacts differs from that presented in the supply curve analysis. The supply curve analysis is a rough approximation. The ReEDS analysis is more complex and detailed, considering economic dispatch of electric generators and interaction among state both within and outside of the RGGI region.

ReEDS modeling inputs to the 40 percent emission reduction policy scenario are identical to the RGGI baseline scenario with three exceptions:

1. Retail electric sales are lower throughout the modeling period (see Figure 18). In 2030, the combination of energy efficiency savings (reducing sales), new electric demand to power light-duty vehicles and heat pumps (increasing sales), and electric co-benefits from gas and oil energy efficiency measures (decreasing sales) lowers retails sales in the 40 percent emission reduction policy scenario by 4 percent, compared to the RGGI baseline.

[53] U.S. EPA. "The Social Cost of Carbon." Accessed March 2016. Available at http://www3.epa.gov/climatechange/EPAactivities/economics/scc.html.

Figure 18. Retail electric sales in the RGGI baseline and 40 percent emission reduction policy scenario



Source: Synapse Energy Economics.

2. The model is instructed to build additional new renewables in RGGI states. These inputs are minimum additions of onshore wind and utility-scale PV in the 40 percent emission reduction policy case with respect to 2015 and includes the requirements of the electric vehicle, heat pump, and wind shifts. Table 8 displays the combined effect of inputs determined by our supply curve analysis and the model's dynamic additions of capacity based on the economics of each resource's expected costs. The ReEDS model chooses a build out of new resources that is both consistent with the constraints entered by the modeler and provides the lowest system costs.

Table 8. 2030 incremental renewable capacity in the 40 percent emission reduction policy scenario compared to the RGGI baseline (GW)

	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Wind	0.0	0.0	0.3	0.0	4.2	1.1	5.1	0.0	2.7	13.4
Solar	0.6	0.9	0.9	-0.3	2.3	0.8	-2.3	0.3	0.4	3.7

Source: Synapse Energy Economics.

3. RGGI electric sector emission caps are more stringent (lower) than in the RGGI baseline. RGGI caps in the 40 percent emission reduction policy scenario are gauged to meet the all-sector 2030 reduction target of 40 percent, after taking into consideration the emission reductions achieved in the transportation sector from the transition to electric vehicles. This results in a 2030 cap on CO_2 emissions from the electric sector of 39 million short tons, compared to the current RGGI cap of 78 million short tons that is in place for 2020 and thereafter.

APPENDIX D: ECONOMIC AND EMPLOYMENT MODEL

We estimated the job impacts using IMPLAN for each RGGI state and the region as a whole.[54] For each state, this modeling captures the impacts from spending in state and on the rest of the region. The assumed spending in each RGGI state comes from following activities:

- Construction of generating resources, transmission, energy efficiency installations, and new electric vehicle charging infrastructure
- Operations of energy resources
- Avoided gas station activity displaced by electric vehicles
- Avoided natural gas and petroleum consumption
- Consumer and business re-spending of electricity, natural gas, petroleum, and transportation cost savings

For the electric sector, we developed customized inputs for the IMPLAN model relying in part on NREL's JEDI model.[55] For each resource, we estimated the portion of the investment spent on materials versus labor. Impacts from household spending and gas stations were more straightforward since these industries directly correspond to IMPLAN sectors. The analysis results in impacts of the following types:

- **Direct impacts** include jobs for contractors, construction workers, plant operators and automobile manufacturers. We developed these estimates using the amount of investment, the share of that investment spent on labor for each resource, and industry-specific wages.

- **Indirect impacts** include jobs that support the direct activities. For instance, an investment in a new wind farm not only creates jobs at the wind farm, but also down the supply chain, increasing jobs for turbine and other component manufacturers. We adjusted the IMPLAN model's base resource spending allocation assumptions for the entire electric industry based on NREL data on requirements for each individual resource.

- **Induced impacts** result from employees in newly created direct and indirect jobs spending their paychecks locally on restaurants, car repairs, and countless other consumer goods and services. Induced impacts also come from customer savings on energy spending, which are spent on the same broad range of goods and services.

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[54] IMPLAN is a commercial model developed by IMPLAN Group PLC. Information on IMPLAN is available at: http://implan.com/

[55] NREL. *Jobs and Economic Development Impact (JEDI) Models.* Last accessed December 16, 2015. Available at: http://www.nrel.gov/analysis/jedi/about_jedi.html.

APPENDIX E: STATE EMISSION REDUCTION TARGETS

Table 9. State greenhouse gas emission reduction targets with citations, 2030 and 2050

State	2030 Target	2050 Target	Sources
Connecticut	35-45% below 1990	80% below 2001	2030: Conf. of New England Govs. Resolution 39-1 2050: C.G.S. 22a-200a (enacted by H.B. 5600) (https://www.cga.ct.gov/2008/ACT/PA/2008PA-00098-R00HB-05600-PA.htm)
Delaware	30% below 2008*	No target	*Recommended target. See Climate Framework for Delaware (Dec. 31, 2014) (http://www.dnrec.delaware.gov/energy/Documents/The%20Climate%20Framework%20for%20Delaware.pdf)
Maine	35-45% below 1990	75-80% below 2003	2030: Conf. of New England Govs. Resolution 39-1 "Long-term" target; date not specified: Maine Rev. Stat. ch. 3-A § 576(3) (enacted by PC 2003, C. 237) (http://legislature.maine.gov/statutes/38/title38sec576.html).
Maryland	40% below 2006	Up to 90% below 2006	2030: Recommendation of the Maryland Commission on Climate Change (Oct. 29, 2015) 2050: Md. Env. Code § 2-1201 (2009) (http://law.justia.com/codes/maryland/2013/article-gen/section-2-1201/)
Massachusetts	35-45% below 1990	80% below 1990	2030: Conf. of New England Govs. Resolution 39-1 2050: Mass.Gen.L. ch. 21N § 3(b) (https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter21N/Section3)
New Hampshire	35-45% below 1990	80% below 1990	2030: Conf. of New England Govs. Resolution 39-1 2050: 2009 New Hampshire Climate Action Plan (http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/documents/nhcap_final.pdf)
New York	40% below 1990[b]	80% below 1990	2030: 2015 New York State Energy Plan (http://energyplan.ny.gov/Plans/2015). "Energy Sector" only—excludes agriculture 2050: Executive Order No. 24 (2009) (http://www.dec.ny.gov/energy/71394.html)
Rhode Island	35-45% below 1990	80% below 1990	2030: Conf. of New England Govs. Resolution 39-1 2050: Resilient Rhode Island Act of 2014, Sec. 42-6.2-2 (http://webserver.rilin.state.ri.us/Statutes/TITLE42/42-6.2/42-6.2-2.HTM)
Vermont	35-45% below 1990	75% below 1990	2030: Conf. of New England Govs. Resolution 39-1 2050: 10 V.S.A. § 578 (enacted by S. 259) (http://www.leg.state.vt.us/docs/legdoc.cfm?URL=/docs/2006/acts/ACT168.HTM)

Appendix F: Detailed Result Tables

Table 10. Difference in job-years by state and resource between the 40 percent emission reduction policy and baseline scenarios

2020	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0	0	0	14	0	0	64	0	0	77
Biomass	0	0	0	0	0	0	0	0	-6	-6
Natural Gas	-284	0	-207	-62	-714	-451	-423	-24	-2	-2,167
Electric Energy Efficiency	2,091	563	213	1,048	573	684	7,761	77	304	13,314
Renewables	271	574	1,694	304	6,233	1,162	-4,279	219	2,527	8,705
Nuclear	0	0	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	0	0	0	0
Transmission	9	0	10	-18	0	0	201	0	396	597
Transportation	-2	-3	-12	-6	-3	-4	-34	-2	-1	-67
Savings	1,986	-148	2,496	1,883	-1,326	287	-790	431	-2,405	2,415
Gas Energy Efficiency	738	265	1,928	1,048	239	145	5,269	294	29	9,955
Heat Pumps	-994	-88	-1,260	-367	-550	-450	-1,709	-275	-259	-5,951
Oil Delivery	-56	-5	-71	-17	-42	-32	-97	-15	-18	-353
Total	3,758	1,158	4,791	3,827	4,409	1,341	5,963	705	565	26,517

2025	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0	-32	0	-307	0	-1	-107	0	0	-447
Biomass	-62	0	0	-26	0	0	0	0	-15	-103
Natural Gas	-503	-32	-904	-498	-1,077	-992	-2,267	-260	5	-6,528
Electric Energy Efficiency	4,312	1,069	-42	3,143	537	1,443	15,995	45	357	26,859
Renewables	813	1,000	1,857	2,112	7,120	1,791	5,192	406	2,386	22,676
Nuclear	0	0	0	0	0	0	0	0	0	0
Hydro	0	0	0	-34	0	0	0	0	-30	-63
Transmission	0	0	47	0	32	2,330	21	0	1,182	3,612
Transportation	46	4	50	79	20	12	-4	2	7	216
Savings	5,997	247	12,895	9,665	-3,324	1,765	15,590	2,080	-3,787	41,127
Gas Energy Efficiency	785	283	2,052	1,123	257	154	5,462	313	31	10,460
Heat Pumps	-994	-88	-1,260	-367	-550	-450	-1,709	-275	-259	-5,951
Oil Delivery	-127	-12	-154	-41	-93	-73	-230	-33	-40	-803
Total	10,266	2,441	14,540	14,850	2,921	5,978	37,943	2,277	-163	91,053

2030	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0	-159	0	-908	0	-3	-261	0	0	-1,331
Biomass	-21	0	0	-173	-5	0	0	0	-53	-252
Natural Gas	-749	-1	-1,203	-491	-571	-1,357	-12,842	-210	833	-16,591
Electric Energy Efficiency	4,126	1,615	75	2,734	504	1,852	17,678	63	348	28,995
Renewables	500	453	817	-11,675	6,606	1,969	918	266	2,198	2,049
Nuclear	0	0	0	0	0	0	0	0	0	0
Hydro	0	0	0	0	0	0	44	-10	28	62
Transmission	181	0	1,244	1	10	1,510	2,873	0	371	6,191
Transportation	11	-9	-30	14	-6	-11	-139	-6	-3	-179
Savings	10,043	729	21,495	19,719	-5,858	2,301	25,383	3,160	-4,737	72,237
Gas Energy Efficiency	785	277	2,052	1,121	255	154	5,407	313	31	10,394
Heat Pumps	-994	-88	-1,260	-367	-550	-450	-1,709	-275	-259	-5,951
Oil Delivery	-214	-21	-257	-69	-155	-123	-394	-55	-66	-1,355
Total	13,668	2,796	22,933	9,905	229	5,842	36,958	3,246	-1,308	94,268

Source: Synapse Energy Economics.

Table 11. Difference in million short tons CO_2 emissions by state and resource between the 40 percent emission reduction policy and baseline scenarios

2020	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0	0	0	-1	0	0	0	0	0	0
Natural Gas	0	0	-1	0	-2	-1	-1	0	0	-6
Petroleum	0	0	0	0	0	0	0	0	0	0
Other Electric	0	0	0	0	0	0	0	0	0	0
Transportation	-1	0	-1	-1	0	0	-2	0	0	-6
Buildings	-1	0	-1	-1	0	0	-3	0	0	-6
Industrial	0	0	0	0	0	0	0	0	0	-1
Total	-2	0	-3	-2	-3	-2	-6	0	0	-19

2025	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0	0	0	-4	0	0	-2	0	0	-6
Natural Gas	-1	0	-2	-2	-2	-2	-6	-1	0	-17
Petroleum	0	0	0	0	0	0	0	0	0	0
Other Electric	0	0	0	0	0	0	0	0	0	0
Transportation	-2	-1	-3	-4	-1	-1	-6	0	0	-18
Buildings	-2	0	-2	-1	-1	-1	-5	0	0	-12
Industrial	0	0	0	0	0	0	-1	0	0	-2
Total	-4	-1	-8	-11	-4	-3	-20	-2	-1	-55

2030	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0	-2	0	-10	0	0	-2	0	0	-14
Natural Gas	-2	0	-3	-3	-2	-3	-12	-1	0	-25
Petroleum	0	0	0	0	0	0	0	0	0	0
Other Electric	0	0	0	0	0	0	0	0	0	0
Transportation	-3	-1	-5	-6	-1	-1	-9	-1	-1	-28
Buildings	-2	0	-3	-1	-1	-1	-7	-1	0	-17
Industrial	0	0	0	0	0	0	-1	0	0	-2
Total	-7	-3	-12	-20	-4	-5	-32	-2	-1	-86

Source: Synapse Energy Economics.

Table 12. Difference in total costs (2014 $ million) by region and resource between the 40 percent emission reduction policy and baseline scenarios.

2020	New England	New York	DE + MD	Total
Coal	$0	$22	$5	$27
Biomass	$0	$0	$0	$0
Natural Gas	-$504	-$136	-$110	-$750
Electric Energy Efficiency	$75	$152	$25	$252
Renewables	$1,367	$704	$99	$2,170
Nuclear	$0	$0	$0	$0
Hydro	$0	$0	$0	$0
Transmission	$7	$4	$0	$11
Electric system subtotal	$945	$746	$18	$1,709
Transportation	-$351	-$281	-$170	-$803
RGGI collections	$21	$6	$4	$31
Elec. EE Participant Spendi	$74	$141	$21	$236
Buildings and Industrial	-$700	-$478	-$141	-$1,319
Gas EE Participant Spendin	$115	$168	$49	$332
Total	$103	$303	-$219	$187

2025	New England	New York	DE + MD	Total
Coal	$0	-$36	-$108	-$145
Biomass	-$4	$0	-$1	-$5
Natural Gas	-$1,083	-$728	-$332	-$2,143
Electric Energy Efficiency	$260	$581	$144	$985
Renewables	$2,977	$463	$422	$3,862
Nuclear	$0	$0	$0	$0
Hydro	-$2	$0	-$2	-$3
Transmission	$138	-$7	$0	$130
Electric system subtotal	$2,286	$272	$124	$2,681
Transportation	-$2,471	-$2,009	-$1,351	-$5,832
RGGI collections	$114	$105	$70	$290
Elec. EE Participant Spendi	$241	$586	$145	$973
Buildings and Industrial	-$1,548	-$1,105	-$325	-$2,977
Gas EE Participant Spendin	$205	$287	$87	$579
Total	-$1,173	-$1,863	-$1,250	-$4,286

2030	New England	New York	DE + MD	Total
Coal	$0	-$88	-$345	-$433
Biomass	-$10	$0	-$12	-$22
Natural Gas	-$1,165	-$1,548	-$436	-$3,149
Electric Energy Efficiency	$397	$1,052	$257	$1,706
Renewables	$4,238	$888	$139	$5,265
Nuclear	$0	$0	$0	$0
Hydro	-$1	$0	$0	-$1
Transmission	$279	$50	$0	$329
Electric system subtotal	$3,738	$354	-$398	$3,694
Transportation	-$4,117	-$3,335	-$2,377	-$9,829
RGGI collections	$108	$174	$189	$472
Elec. EE Participant Spendi	$381	$1,064	$258	$1,703
Buildings and Industrial	-$2,427	-$1,657	-$488	-$4,572
Gas EE Participant Spendin	$258	$358	$108	$725
Total	-$2,059	-$3,042	-$2,707	-$7,808

Note: Negative values indicate net savings in the 40 percent emission reduction policy scenario
Source: Synapse Energy Economics.

Table 13. Total electric generating capacity in gigawatts by state and resource in the 40 percent emission reduction policy scenario

2020	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0.4	0.4	0.0	3.5	0.0	0.5	1.2	0.0	0.0	6.1
Natural Gas	4.7	1.9	6.5	6.4	1.4	1.3	13.8	1.7	0.1	37.8
Nuclear	2.1	0.0	0.0	1.7	0.0	1.2	4.4	0.0	0.0	9.4
Other	1.7	0.9	4.4	3.3	1.9	1.3	13.9	0.0	0.4	27.7
Solar	0.3	0.3	0.8	0.8	0.5	0.2	0.6	0.1	0.2	3.7
Wind	0.1	0.0	0.6	0.7	2.2	0.8	4.8	0.0	1.6	11.0
Total	9.3	3.6	12.3	16.4	6.0	5.3	38.7	1.9	2.2	95.7

2025	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0.0	0.4	0.0	3.4	0.0	0.0	1.1	0.0	0.0	4.9
Natural Gas	4.5	1.9	6.4	6.0	1.4	1.2	12.8	1.7	0.1	35.9
Nuclear	2.1	0.0	0.0	1.7	0.0	1.2	4.4	0.0	0.0	9.4
Other	1.9	0.7	3.8	3.3	1.9	1.3	13.4	0.0	0.4	26.7
Solar	0.6	0.9	1.3	1.9	1.7	0.6	1.6	0.4	0.4	9.3
Wind	0.2	0.0	0.9	0.9	3.7	1.4	7.0	0.0	2.6	16.7
Total	9.4	3.9	12.4	17.1	8.7	5.6	40.3	2.2	3.5	103.1

2030	CT	DE	MA	MD	ME	NH	NY	RI	VT	Total
Coal	0.0	0.3	0.0	3.0	0.0	0.0	0.3	0.0	0.0	3.6
Natural Gas	4.4	1.8	6.3	5.5	1.4	1.2	11.2	1.7	0.2	33.7
Nuclear	2.1	0.0	0.0	1.7	0.0	1.2	3.1	0.0	0.0	8.1
Other	1.0	0.2	3.7	2.5	1.9	0.9	10.8	0.2	0.5	21.6
Solar	1.1	1.2	1.7	3.0	2.4	0.8	3.1	0.5	0.5	14.2
Wind	0.2	0.0	1.3	0.9	5.2	1.9	8.9	0.0	3.6	21.9
Total	8.8	3.5	12.9	16.6	10.8	6.0	37.3	2.5	4.8	103.2

Source: Synapse Energy Economics.