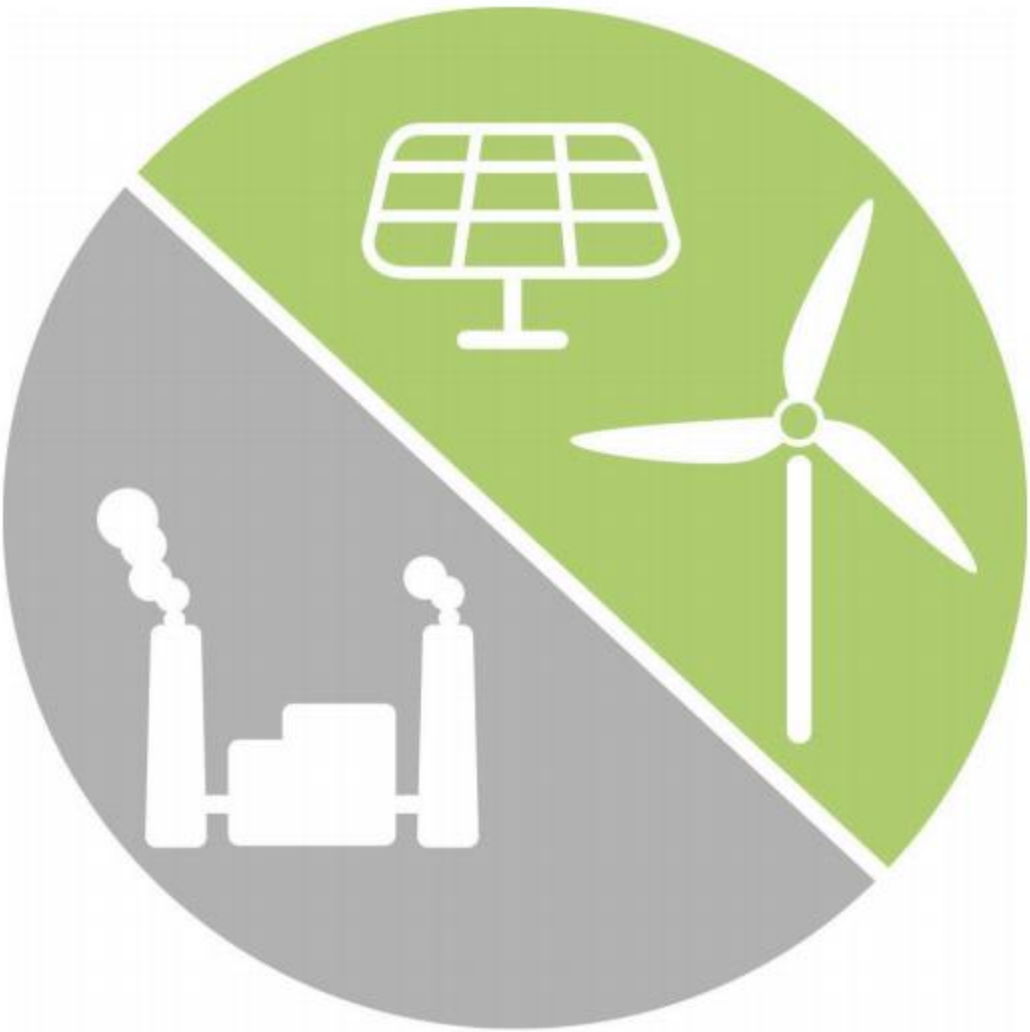
The Regional Greenhouse Gas Initiative:

A Model Program for the Power Sector



July 2015

Acadia Center
Advancing the Clean Energy Future

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Acadia Center is a non-profit, research and advocacy organization committed to advancing the clean energy future.

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This document can be found online at: http://acadiacenter.org/document/rggi-a-model-program-for-the-power-sector-2015-update

1. Introduction – An Effective Program

During six and a half years of operations, RGGI has helped Northeast and Mid-Atlantic States[1] achieve significant reductions in emissions of carbon dioxide (CO_2) and other dangerous pollutants from the electric power sector. At the same time the program has generated significant economic benefits in the region. As states prepare to meet the Environmental Protection Agency's (EPA) forthcoming Clean Power Plan requirements, RGGI offers a proven, cost-effective pathway to achieve emissions reduction targets.

RGGI demonstrates that emissions can be reduced faster and at lower cost than typically assumed. Fuel-switching, improved energy efficiency, and growing renewable energy output have caused emissions to drop by 35% since RGGI launched,[i] with electricity prices falling over that same time period. In addition, the rate of pollution reductions continues to outpace expectations, with 2014 emissions falling 5% below the emissions cap.[i] The fact that CO_2 pollution is already dropping below the new cap reinforces a historic trend of underestimating the capacity of flexible markets to meet environmental goals. Against this backdrop of declining emissions, RGGI state economies have outpaced the rest of the country, demonstrating that the link between economic growth and emissions has broken in the region and that we can address the threat of climate change while promoting continuing prosperity.

Key Facts:

- 2014 emissions of 86,307,909 tons of CO_2 fell 5.2% below the RGGI cap
- Hazardous criteria emissions (SO_x, NO_x, and Hg) from power plants in the RGGI program have dropped even more than CO_2 emissions, and will continue to fall through 2020.
- Electricity prices across the region have decreased by 2% on average since RGGI took effect.
- Electric sector trends responsible for low emissions – including increasing natural gas and renewable generation, growing investments in energy efficiency, and decoupling of economic growth and emissions – show no signs of reversing.
- Similar trends are likely to cause emissions to decline across the country.
- RGGI is a cost-effective mechanism for states to comply with EPA's Clean Power Plan, though minor program modifications will be required.

While RGGI states are at the forefront of reducing emissions, other states are seeing emissions reductions due to similar trends. Outdated and inefficient power plants are shuttering across the country, while improvements in energy efficiency accelerate and renewable energy output continues to grow. As states develop plans to comply with federal carbon pollution standards, RGGI provides both a proven template for state action and an example of the capacity to clean up the power sector while benefitting consumers.

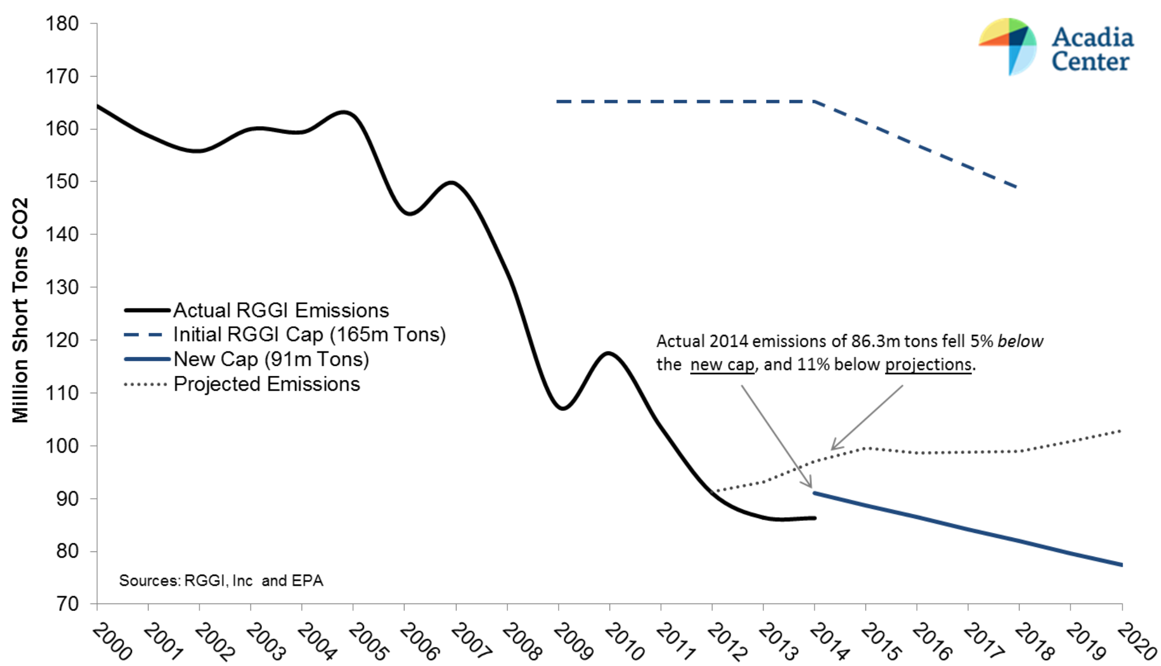
[1] Analysis in this report covers the participating RGGI states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. New Jersey stopped participating in RGGI after 2011, but the withdrawal has been overturned in court and New Jersey may rejoin the program. [*Footnotes elaborate on points within this report, whereas endnotes cite references and provide detailed analytic methodologies where relevant.*]

RGGI has largely achieved its initial goals. Power generators have incorporated RGGI requirements into normal business operations, and the electric sector as a whole has adapted to the shifting economics of different generation sources while continuing to provide a reliable supply of electricity. Requiring electric generators to pay for emitting CO_2 into the atmosphere has led the market to incorporate the cost of pollution into planning decisions, while at the same time raising revenue for states to reinvest in clean energy and consumer programs that drive additional emissions reductions and economic growth.

1.1 Emissions Reductions

Emissions in 2014 continued the downward trend of recent years. CO_2 emissions from the 167 power plants covered by RGGI totaled 86,307,909 short tons of CO_2 in 2014, which was 5.2% below the 2014 emissions cap of 91,000,000 tons.[ii] The fact that RGGI emissions continue to decline indicates how important it was for the states to lower the cap starting in 2014, and to further account for surplus allowances already in circulation.[2]

Figure 1: RGGI Caps and Actual Emissions



[2] As a result of the 2012 Program Review process, the RGGI states reduced the 2014 cap by 45%, from 165 million tons to 91 million tons. This change came as a response to the fact that emissions declined much more quickly than originally projected, creating a surplus of cheap allowances and lessening the incentive for further emissions reductions. By tightening the cap, the RGGI states have demonstrated a commitment to driving additional emissions reductions. In order to ensure that allowances purchased prior to the cap reduction do not inflate the new cap, states have held two 'interim adjustments' to account for banked allowances. For more detail, see: https://www.rggi.org/docs/SCPIABA.pdf

1.2 Electricity Prices

Contrary to projections, electricity prices have declined since RGGI took effect. Comparing average retail electricity prices[iii] from 2008 (before RGGI's launch) to 2014 shows that prices have dropped by 2% on average across the region, with Vermont being the only state to experience a significant price increase.[3] During the same 2008-2014 period electricity prices in non-RGGI states increased by 13%.[iii] While RGGI's precise impact on electricity prices (and other trends described in this report) is difficult to isolate from other factors, it is clear that the program has not caused electricity prices to increase across the region since 2008.

Table 1: RGGI State Electricity Prices, 2008 and 2014 (Cents/kWh)

	CT	DE	MA	MD	ME	NH	NY	RI	VT	RGGI
2008	17.80	12.38	16.23	13.01	13.80	14.63	16.47	16.04	12.33	14.74
2014	16.89	11.36	15.22	12.12	12.63	15.22	16.26	15.54	14.58	14.42
% Change	-5%	-8%	-6%	-7%	-8%	4%	-1%	-3%	18%	**-2%**

1.3 Economic Impacts

RGGI has generated significant economic benefits for states participating in the program. By selling allowances (permits to emit CO_2), RGGI states raise revenue to reinvest in energy efficiency, renewable energy, and other consumer programs that increase economic activity in participating states. The majority of program revenue (59% during the second control period, 2012-2014[iv]) has been invested in energy efficiency programs that reduce consumers' bills and reduce demand for power. Lower power demand means fewer emissions from power plants, and less money leaving the region to pay for imported fossil fuels. Consumers' energy bill savings are spent in part within the local economy, benefiting businesses that offer goods and services in the region. Independent macroeconomic analysis found that programs supported with revenue raised over RGGI's first six years of operation would generate over $1.73 billion in energy bill savings.[v] These savings create over $2.76 billion in net economic gains and 28,500 job-years of employment.[4]

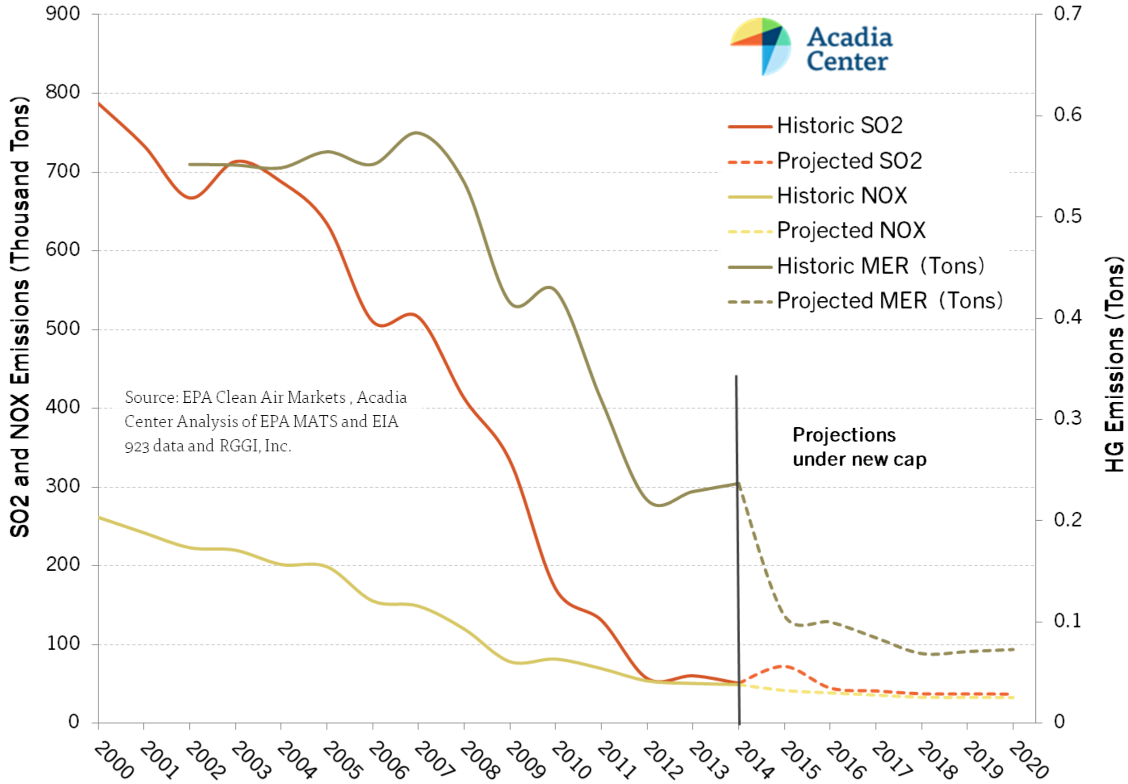
[3] VT buys more power through long term contracts than other states in the region. This approach has stabilized prices, but means that VT is insulated from wholesale price trends, which have recently decreased power prices in other states in the region. It is worth noting that Vermont's RGGI revenue supports thermal efficiency programs for customers using propane, fuel oil, and natural gas. While thermal efficiency programs generate greater cost and GHG savings than electricity programs in Vermont, electric price suppression is not as significant as in other states that direct RGGI revenue to electric efficiency programs. NH is also more dependent on long term contracts, though not to the same extent as VT, and NH directs the majority of auction revenue to rebates, which do not suppress electric prices.

[4] These figures are based on the combined findings from two separate reports from the Analysis Group, the first of which covered impacts from 2009 through the first half of 2011 (New Jersey impacts have been excluded from this analysis), the second report covering 2012-2014. As a result, the combined benefits included above only account for five and a half years of revenue reinvestment, rather than the full six years from 2009-2014.

1.4 Health Impacts

The decline in carbon dioxide emissions from power plants in the RGGI region has been accompanied by an even more significant decline in hazardous pollutants that threaten public health. Emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury (Hg) are all down significantly, and are projected to drop even more under the new RGGI cap. Both SO_2 and NO_x can trigger asthma attacks and difficulty breathing, and NO_x can increase the risk of developing infectious disease.[vi] SO_2 and NO_x also react in the air to form more dangerous pollutants, including ground level ozone – which increases susceptibility to respiratory illnesses like pneumonia and bronchitis – as well as particulate matter – which is breathed deep into the lungs and can cause or contribute to heart attacks, stroke, and increases the risk of premature death in infants and young children as well as adults.[vii] Mercury deposited in waterways and accumulated in seafood has adverse neurological and reproductive impacts.[viii]

Figure 2: Reduction of Hazardous Pollution



Reducing emissions of hazardous pollutants leads to health savings by avoiding illness, hospital visits, lost work days, and premature deaths. In monetary terms, the reduction in hazardous emissions from RGGI's launch (January 1, 2009) through 2014 translates into nearly $11 billion for SO_2 and NO_x alone, and additional reductions in hazardous emissions under the new RGGI cap will lead to an additional $1.4 billion in health savings through 2020.[ix]

Table 2: To-Date and Projected Reductions in Hazardous Emissions

	SO_2	NO_X	Mercury
2009-2014			
Avoided Emissions (tons)	282,786	29,107	0.1789
% Reduction (annual emissions)	85%	37%	43%
Health Savings (million $)	**$10,832**	**$166**	--
2015-2020			
Avoided Emissions (tons)	35,236	8,996	0.0334
% Reduction (annual emissions)	69%	18%	14%
Health Savings (million $)	**$1,350**	**$51**	--

While these emissions reductions and health savings were largely driven by the broader electric trends described in this report and regulations specific to hazardous pollutants, RGGI did contribute to reducing hazardous emissions. Power plants that emit large quantities of pollutants like SO_2, NO_x and mercury also emit large quantities of CO_2. Requiring these plants to pay for CO_2 emissions makes it less economical to operate dirtier plants in comparison to cleaner generating sources. Thus, while market-based programs like RGGI allow for flexibility in achieving emission-reduction targets for CO_2, they also support existing controls for hazardous pollutants. Since the impact of CO_2 is global rather than local, providing flexibility to achieve CO_2 targets most cost-effectively facilitates greater CO_2 emissions reductions at lower cost.

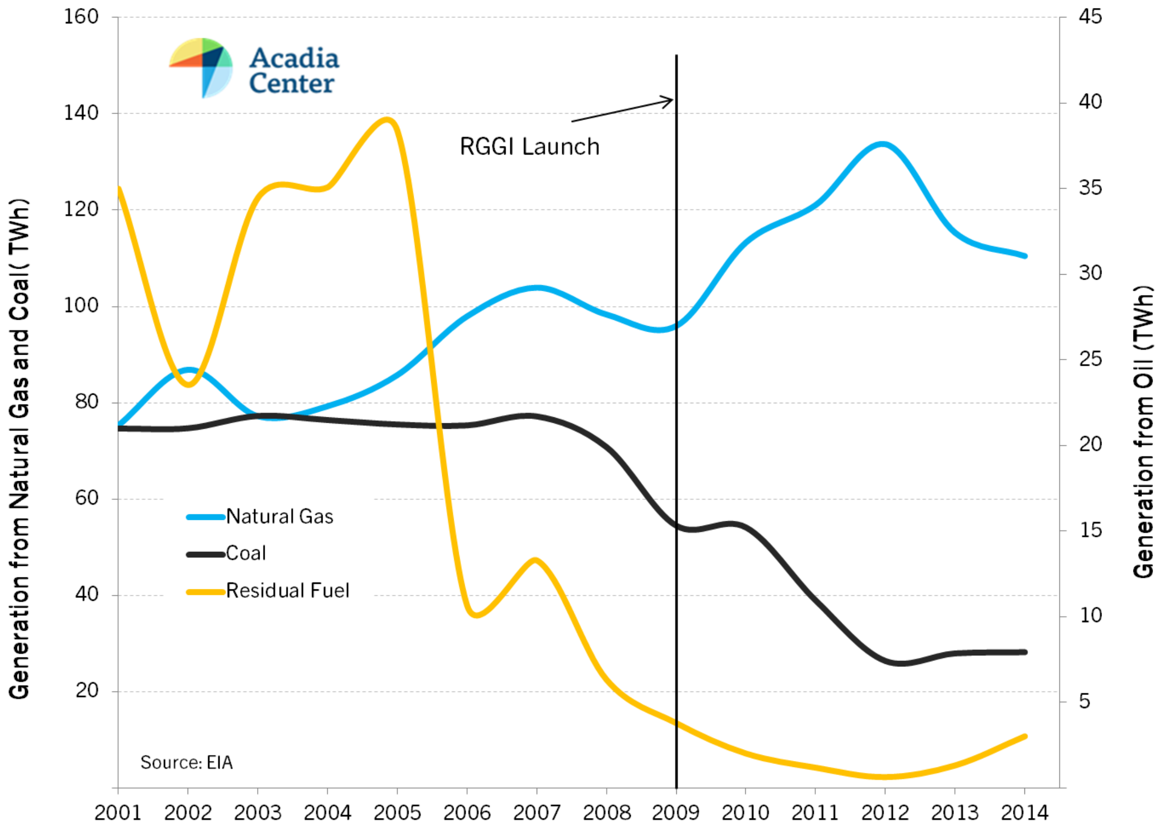
2. Electric Sector

Electric sector carbon dioxide emissions are determined by two main factors: 1) what source the electricity comes from; and 2) how much electricity is consumed.

2.1 Fossil Generation

Electric generation from fossil fuels is increasingly shifting to lower-priced natural gas. The relative prices of natural gas, residual fuel (oil), and coal in the RGGI region determine which fuels are used to generate power. Since 2008, when RGGI took effect, generation has decreased from residual fuel (-52%) and coal (-60%), while natural gas generation increased (+12%). This fuel switching from coal and oil to natural gas has had a significant impact on emissions, as natural gas emits 44% less carbon than coal and 33% less carbon than fuel oil when burned to produce heat[x] and natural gas plants are more efficient.[5]

Figure 3: Fuel Switching from Coal and Oil to Natural Gas



During recent cold winters some RGGI states – particularly in New England – have increased utilization of coal and oil, when building heating consumes the majority of the natural gas supply. However, with

[5] Note that direct stack emissions from natural gas are much lower than stack emissions from coal and oil, but there is increasing concern about upstream GHG and other pollution from natural gas, which needs to be more thoroughly investigated and quantified.

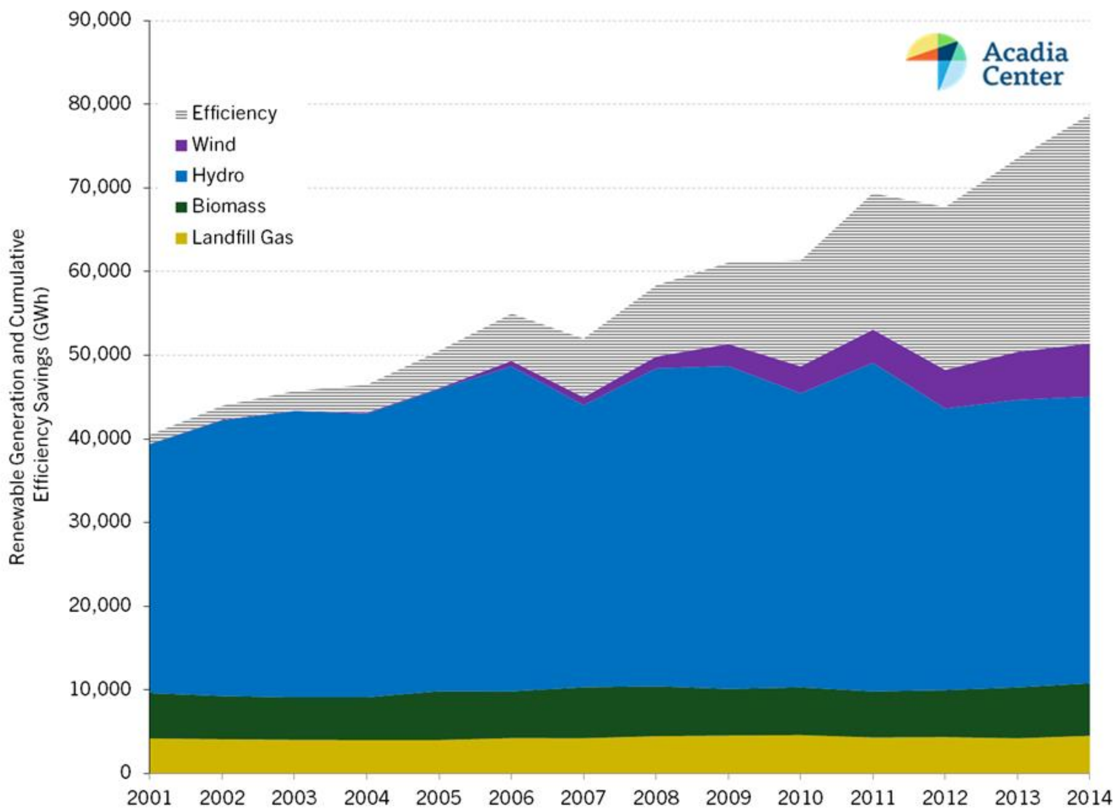
2014 emissions falling below the new cap, it appears that this temporary[6] uptick in oil and coal generation is not increasing emissions significantly.

2.2 Energy Efficiency and Non-Emitting Generation

Energy efficiency programs are reducing demand for electricity across the region, while electricity is increasingly being supplied by non-emitting energy sources. State data shows that energy efficiency programs in RGGI states have saved a cumulative total of 18,934 GWh of electricity since RGGI launched.[xi] During the same period renewable energy generation – led by hydroelectricity, as well as landfill gas, biomass, and wind – has increased by 2,297 GWh in RGGI states, according to EIA.

In 2014 energy efficiency savings and increasing renewable energy output also helped offset a modest increase in generation from oil and coal, keeping emissions similar to 2013 levels, despite the uptick in generation from more carbon-intensive fuels.[7]

Figure 4: Increasing Role of Energy Efficiency and Renewable Generation



[6] Additional natural gas pipeline capacity (the Algonquin Incremental Market expansion) will deliver 345 million cubic feet of natural gas into New England in 2016, and increasing investment in demand side solutions (natural gas and electric energy efficiency, demand-response, combined heat and power) and additional electric imports are likely to alleviate problems caused by overreliance on natural gas.

[7] Emissions of CO_2 in the RGGI region fell slightly from 2013 (86.4 million tons) to 2014 (86.3 million tons).

Reliance on Natural Gas

Concerns about overreliance on natural gas and about the environmental impacts of extracting, processing, and transporting it have raised important questions about how RGGI interacts with other energy and environmental priorities. Due to their higher carbon-intensity, coal- and oil-fired power plants have to purchase more RGGI allowances than natural-gas-fired generators. However, it is important to note that gas generators still have to purchase allowances, making natural gas less competitive than non-emitting sources of power.
Furthermore, reinvesting revenue from the sale of emissions allowances in energy efficiency reduces direct consumption of natural gas in buildings and reduces power plant consumption of natural gas to generate electricity. Thermal efficiency programs funded by RGGI through 2013 saved 2.9 trillion BTU, and are projected to save 49 trillion BTU over their (typically 10-year) measure lifetimes[vi]. If only half of these savings are from natural gas,[8] this would translate into approximately 1.45 million cubic feet (MMcf) of avoided natural gas in demand through 2012, and 24.4 MMcf in lifetime savings. Electric efficiency programs avoid demand for electricity and the need to burn natural gas at power plants. With natural gas used to generate 44% of electricity in the RGGI region in 2012 (EIA), electricity savings of 928,000 MWhs[vi] avoided the combustion of an additional 409 MMcf of natural gas at power plants. Over their lifetimes these electric efficiency investments will avoid the consumption of an additional 3,750 MMcf of natural gas.[xii]

Both energy efficiency and non-emitting generation are projected to continue increasing in the years ahead. In the nine RGGI states, budgets for electric efficiency programs grew from $575 million in 2008 to $1.745 billion in 2014, an increase of 203% (during the same 2008-2014 period electric efficiency budgets in non-RGGI states increased from $1.954 billion to $4.277 billion, a 119% increase).[xiii] Escalating annual electricity savings requirements in eight of the nine RGGI states will require increasing investments in future years.[xiv] Renewable generation is also projected to continue increasing nationwide according to EIA,[xv] and all nine RGGI states have Renewable Portfolio Standards that require electric utilities to procure increasing quantities of renewable electricity.[xvi]

It is worth noting that with the exception of steady, incremental growth in wind capacity and modest natural gas additions, the decline in electric sector emissions has occurred without the addition of significant new capacity or capital expenditures. This low-cost transition to lower regional emissions indicates that reducing emissions can be far more cost-effective than commonly assumed.

[8] Division of thermal savings between natural gas and other fuels not available, but efficiency programs in a number of RGGI states are fuel-blind, or mingle use of revenue.

2.3 Decoupling of Economic Expansion and Emissions Growth

As the regional economy has become less energy-intensive and efficiency investments have increased, the relationship between economic growth and emissions has broken. This is demonstrated by comparing emissions and economic growth of RGGI states to states that do not regulate or put a price on carbon emissions. (This group of 40 "other states" does not include California, which has outpaced national growth in 2011, 2012 and 2013 since capping GHG emissions.[9]) From 2009 (the year RGGI began) to 2014, emissions in the RGGI region dropped by 35% versus 12% other states. Over the same period, RGGI states' economies grew by 21.2% versus 18.2% in other states.

Figure 5: Emissions in RGGI States versus Other States

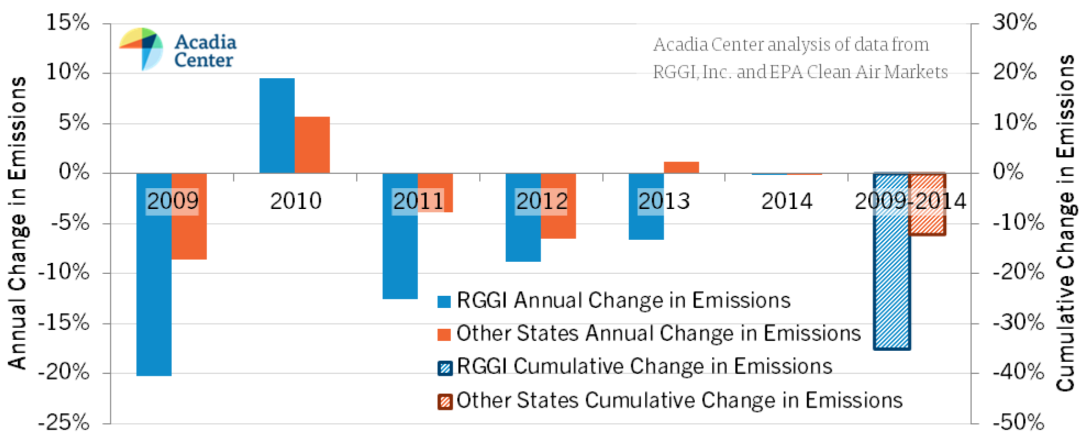
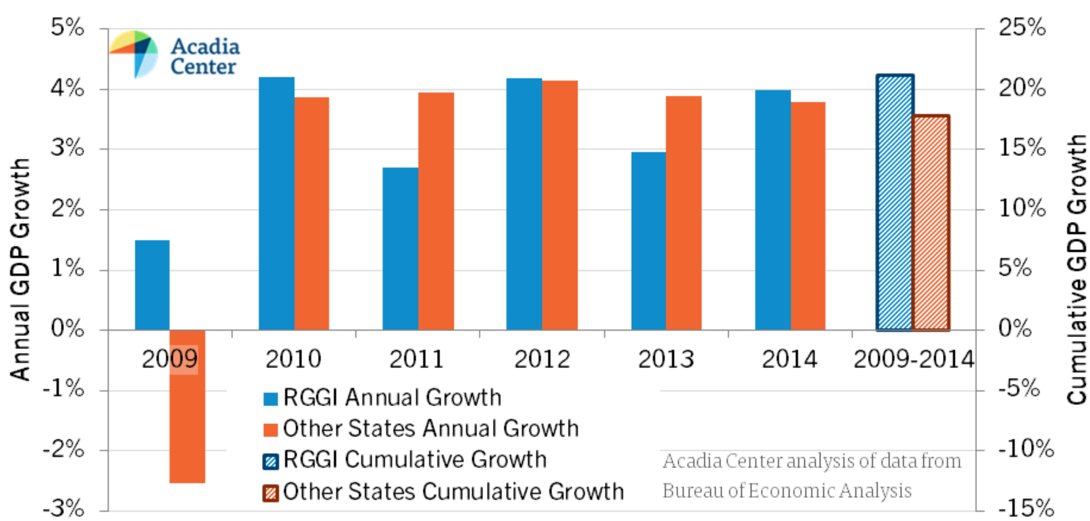


Figure 6: GDP Growth Rates in RGGI States versus Other States



[9] As detailed in the Environmental Defense Fund's recent report, *Carbon Market California: A Comprehensive Analysis of the Golden State's Cap-and-Trade Program*, California has experienced significant economic benefits resulting from AB 32, and GDP growth in the state outpaced the national average in 2011, 2012 and 2013: http://www.edf.org/sites/default/files/content/carbon-market-california-year_two.pdf

Electricity demand has historically been tied to economic growth, with electricity consumption and related emissions increasing during periods of economic expansion and decreasing in economic downturns. This correlation has broken in the RGGI region, and appears to be mirrored at the national level, suggesting that emissions reductions are not incompatible with economic growth.

3. EPA Regulations

EPA's Clean Power Plan, the first federal limit on CO_2 emissions from existing power plants, will require each state to submit plans for reducing GHG pollution. In developing the Clean Power Plan, EPA has encouraged the use of multi-state plans and facilitated the implementation of mass-based trading programs, leaving RGGI well positioned to serve as a compliance pathway. The final version of the rule will likely require modest revisions to RGGI, but – more importantly – it will create an environment for other states to build on RGGI's successful model by establishing their own regional carbon markets or by participating in the RGGI program.

3.1 Potential Revisions

Modest revisions to RGGI's structure may be required in order for EPA to determine that the program will deliver intended emissions reductions in the near and long term. Specifically, RGGI's allowance reserve and cap decline mechanisms may require revisions, and the viability of offsets is not yet clear.

3.1.1 RGGI Cap Extension

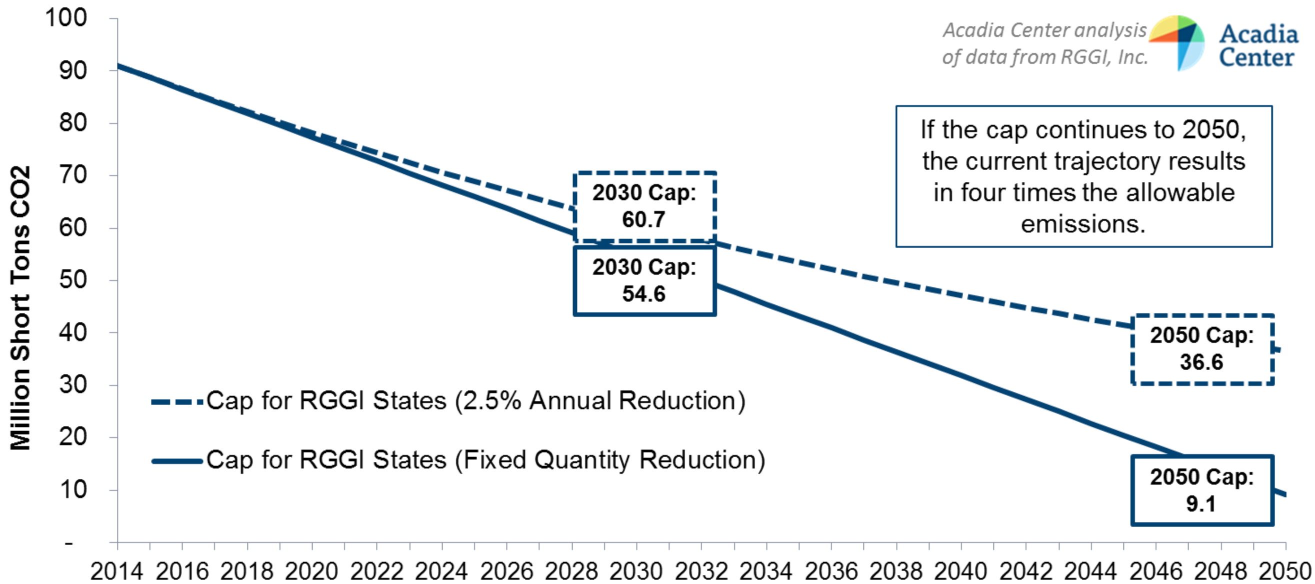
The RGGI cap only extends to 2020, and the RGGI states must extend the cap to 2030 to be consistent with EPA's final targets. The RGGI cap was restructured in 2013 to reflect actual regional $CO2$ emissions, with allowances apportioned to each participating state, consistent with the proportion of allowances that each state received at the start of the program. We assume that the states will agree to preserve these proportions of the total RGGI budget, but apportionment of the RGGI cap among states could be modified so long as the total cap does not increase.

3.1.2 Trajectory of the Cap Decline

The manner in which RGGI's cap declines will require revision to ensure achievement of long-term emissions reduction objectives. RGGI's new cap declines by 2.5% annually, but instead of declining by a fixed quantity of allowances, the yearly step-down is based on a percentage of the prior year's cap. By 2030 the difference between a fixed quantity reduction and percentage reduction is significant. The proper, fixed quantity approach leads to a regional cap of 54.6 million tons while the current, percentage-based approach leads to a regional cap of 60.7 million tons. By 2050, the current approach would allow four times the emissions of the fixed quantity approach. RGGI's initial cap required a fixed quantity reduction from the baseline year, so returning to this approach would be consistent with RGGI's intent, and would support states' efforts to achieve deep emissions reduction targets by

2050.[10] For these reasons, our "2030 Projected RGGI Cap" is based on the annual fixed quantity reduction approach.

Figure 7: RGGI Cap Trajectory



3.1.3 Cost Containment Reserve

In order to mitigate price volatility, RGGI states established a Cost Containment Reserve (CCR) that mints additional allowances when price thresholds are reached. That price threshold was reached in the first RGGI allowance auction of 2014, and all five million available CCR allowances were purchased, thus increasing the effective 2014 cap by five million tons of CO2. In each year from 2015 to 2020, ten million additional CCR allowances will be available if price thresholds are met, thereby increasing the potential cap by ten million tons of CO2 each year. From 2014-2020, the CCR allowances could permit 65 million tons of CO2 emissions in addition to the nominal cap—almost equivalent to a whole year's worth of emissions.

As the following figure illustrates, these CCR allowances could increase the cap to the point that the RGGI program would not be as stringent as EPA's proposed mass-based targets in 2030. Adopting the cost containment approach currently being used by the California emissions trading program would solve this problem. Like the RGGI CCR, in California's program additional allowances become available for purchase when price thresholds are met. Unlike the RGGI CCR, about 4% of California's original number of allowances from the capped budget is held back in the allowance price containment reserve. If this reserve of allowances is exhausted, there is limited "borrowing" allowed from the latest program years, and therefore the cumulative supply of allowances – and permissible emissions – is not increased.[11]

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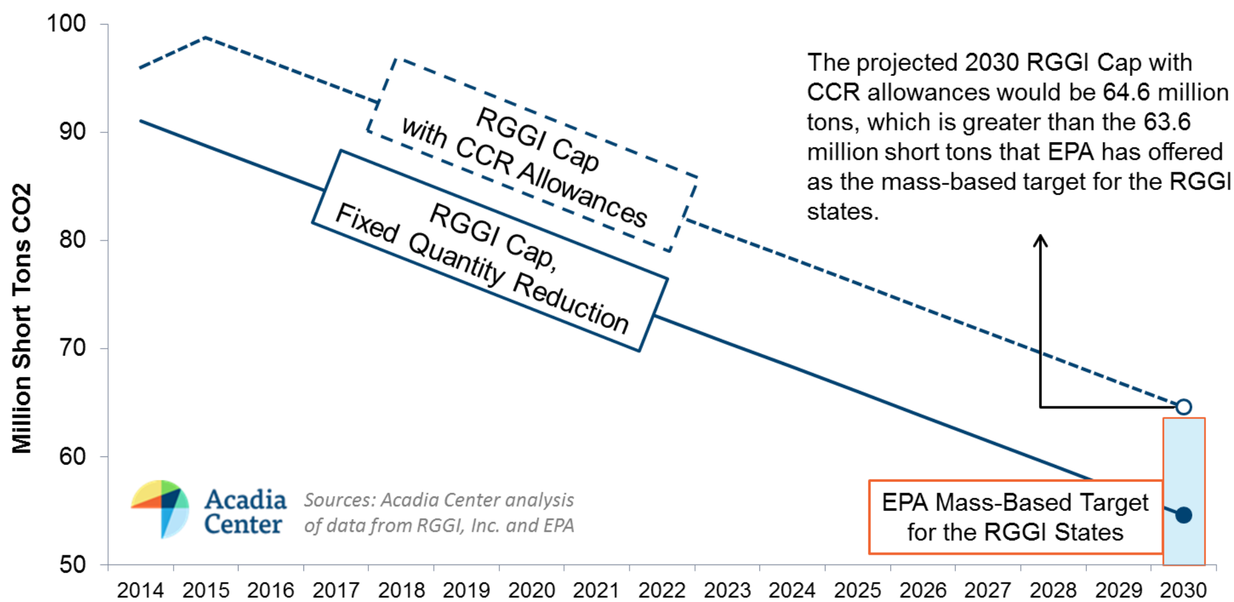
[10] All RGGI states, with the exception of Delaware, have mandated GHG emissions reduction targets. For additional details on state emissions reduction targets see: http://www.c2es.org/what_s_being_done/targets

[11] Explanation of California's Allowance Price Containment Reserve: http://www.arb.ca.gov/regact/2010/capandtrade10/capv3appg.pdf

Figure 8: Cost Containment Reserve



3.2 Broader Appeal

New states may find the RGGI approach an attractive option for complying with federal requirements. RGGI's flexible, market-based system reduces emissions at lower cost than alternative approaches (see text box). Additionally, states' control over key decisions related to allocation of allowances and auction proceeds provides the flexibility to achieve distinct local objectives. RGGI is also simple to administer and familiar to regulators and emitters alike. Power plant owners in the majority of the country are already accustomed to market-based environmental programs that regulate emissions responsible for acid rain, smog, and other

Cap & Trade – The Cheapest Solution
RGGI's market-based approach requires emitters to purchase pollution permits (called 'allowances') from a supply that declines over time. Power companies that reduce emissions purchase fewer allowances, thus reducing allowance prices and consumer costs. This approach rewards innovative and flexible power companies that take advantage of new market opportunities, and reduces emissions at lower cost than more prescriptive approaches that rely on specific technologies or administratively-determined measures.

hazardous pollutants.[12] This familiarity with market-based programs is one reason that the power sector appears more receptive to carbon standards than political discourse would suggest.[13]

Market-based programs also have a history of achieving objectives at lower costs than anticipated, as the capacity to realize profits drives innovation in business operations and technological advancement. The landmark Acid Rain Program, which utilizes an allowance trading approach to reduce emissions of acid rain-causing sulfur dioxide (SO_2), was projected to have allowance costs of $250-$500/ton. However, in order to realize cost savings, power plant operators were able to reduce emissions far faster than expected by switching to cleaner sources of coal and driving advances in technology to remove SO_2 pollution from smokestacks using "scrubbers." These market-driven innovations meant that actual allowance prices were only $100-$200/ton, or less than half the anticipated cost.[xvii] RGGI itself follows this pattern. Before RGGI launched, states projected that the program would cause the price of electricity to *increase* by approximately 1.25% by 2012.[xviii] In practice, electricity prices have actually *decreased*, falling by 2% across the region since RGGI launched (see page 5 of this report).

The tendency to overestimate the costs of market-based programs helps to illustrate the inherent effectiveness of market-based programs. Before RGGI or the Acid Rain Program launched, no one could predict how emissions would be reduced. By design, market-based programs drive innovations that are difficult to predict, but are natural in response to new profit opportunities.

4. Conclusion

RGGI has successfully demonstrated the viability of a market-based program to reduce CO_2 emissions from the power sector while generating significant benefits for participating states. Trends that have contributed to emissions reductions – fuel-switching, improved energy efficiency, and increases in renewables – show no sign of reversing in the RGGI region, and are paralleled nationwide. These trends suggest that emissions can be reduced at lower costs than anticipated. As states develop plans to comply with new EPA carbon regulations, RGGI presents an attractive model that is flexible, administratively-straightforward, and capable of reducing emissions at lowest cost.

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[12] 27 states comprising the majority of the Midwest, South, Mid-Atlantic, and Northeast are currently included in the 3 market-based Clean Air Interstate Rules, see http://www.epa.gov/airmarkets/progress/ARPCAIR12.html

[13] Some of the largest power companies in the country – including Calpine, Consolidated Edison, Exelon, National Grid, New York Power Authority, and NextEra – submitted joint comments to with the environmental community calling for EPA to recognize RGGI as a compliance mechanism for current states and any other states wishing to join. See: http://energy.pace.edu/sites/default/files/publications/RGGI%20EPA%20Collaborative%20Dec%205%20with%20Signatories.pdf

Endnotes

[i] Acadia Center analysis of emissions data from RGGI, Inc., at: https://rggi-coats.org/eats/rggi/index.cfm?fuseaction=search.rggi_summary_report_input&clearfuseattribs=true
[ii] 2013 cap level and emissions from RGGI, Inc., at: http://rggi.org/
[iii] Energy Information Administration (EIA) 826 Dataset, http://www.eia.gov/electricity/data/eia826/
[iv] Analysis Group, 2015, *The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States*, available at: http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/analysis_group_rggi_report_july_2015.pdf
[v] Id.
[vi] *American Lung Association Energy Policy Development: Electricity Generation Background Document*, 2011, http://www.lung.org/healthy-air/outdoor/resources/electricity-generation.pdf
[vii] Id.
[viii] EPA, 1997, *Characterization of Human Health and Wildlife Risks from Mercury Exposure in the United States*, http://www.epa.gov/ttn/oarpg/t3/reports/volume7.pdf
[ix] The monetized health benefits of avoided SO_2 and NO_x emissions were approximated using EPA's sector-based benefit per ton estimates of $PM_{2.5}$ precursors. SO_2 and NO_x emissions reductions data to-date (2009-2014) are from EPA's Clean Air Markets Division (http://www.epa.gov/airmarket/emissions/). Projected emissions reductions (2015-2020) are from *IPM Electricity Sector Modeling Results* prepared by ICF International for RGGI, Inc. (http://rggi.org/docs/ProgramReview/February11/Results_91_Cap_Alt_Bank_MR.xls). Emissions data covers RGGI regulated units for the nine states currently in RGGI. Approximate monetized health benefits were calculated by multiplying the to-date and projected emissions reductions by sector-based $PM_{2.5}$-related benefit per ton (BPT) estimates. The EPA provides several reduced-form tools for calculating $PM_{2.5}$-related health benefits, including updated versions of the BPT tables (http://www.epa.gov/airquality/benmap/sabpt.html) published in *Characterizing the $PM_{2.5}$-related health benefits of emission reductions for 17 industrial, area and mobile emission sectors across the U.S.* (Fann, Baker and Fulcher, 2012) (http://www.sciencedirect.com/science/article/pii/S0160412012001985). The methodology is detailed in the Technical Support Document, *Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors* (http://www.epa.gov/airquality/benmap/models/Source_Apportionment_BPT_TSD_1_31_13.pdf). Fann, Baker and Fulcher (2012) assess the incidence of $PM_{2.5}$-related deaths and illnesses, including non-fatal heart attacks, hospital admissions, emergency department visits, respiratory symptoms, cases of acute bronchitis, cases of aggravated asthma, and lost work days. For this analysis, we used the 2016 BPT estimates for SO_2 and NO_x for Electricity Generating Units. These values are national estimates in 2010 dollars, which were adjusted to 2015 dollars. The sector-based BPT estimates are based on the Krewski et al. (2009) $PM_{2.5}$ mortality risk estimate and reflect a 3% discount rate. The 2016 estimates use emissions, population and income growth projections for 2016, and use baseline mortality incidence rate projections for 2015 (best available data). The resulting health benefits (shown in Table 2 of this report) offer a simplified quantification of the avoided health impacts of SO_2 and NO_x emissions, but should not be interpreted as a substitute for more detailed, comprehensive analyses of the per-ton benefits of reducing SO_2 and NO_x emissions in the RGGI region. For more on the limitations of this simplified approach, see *Economic value of U.S. fossil fuel electricity health impacts* (Machol and Rizk, 2013) (http://www.sciencedirect.com/science/article/pii/S0160412012000542).

Hg data from 2002-2010 is from EPA's MATS portal (http://www.epa.gov/ttn/atw/utility/utilitypg.html). 2011-2014 Hg data is based on EPA MATS HG Emission Factors and EIA 923 Boiler Fuel Consumption Data. The EPA has not developed reduced-form tools for calculating Hg health benefits, and our research did not uncover suitable health benefit multipliers from other sources.
[x] Carbon emissions factors for natural gas (117.0 lbs CO_2/MMBtu), residual fuel oil (173.7 lbs CO_2/MMBtu) and coal (210.0 lbs CO_2/MMBtu) from EIA: www.eia.doe.gov/oiaf/1605/excel/Fuel%20Emission%20Factors.xls
[xi] Data for 2014 energy efficiency savings in Maryland and New York was not available at the time of writing this report, so 2014 savings were assumed to be equal to 2013 savings in those two states.
[xii] Gas savings from electric efficiency programs assumes EIA average natural gas power plant efficiency of 1mcf/MWh (http://www.eia.gov/tools/faqs/faq.cfm?id=667&t=2).
[xiii] Electric efficiency program budgets from the Consortium for Energy Efficiency, from *2014 State of the Efficiency Program Industry*, available at: http://library.cee1.org/content/2014-state-efficiency-program-industry
[xiv] See American Council for an Energy Efficient Economy (ACEEE) for information on state efficiency programs: http://aceee.org/sector/state-policy
[xv] EIA, 2014, *Annual Energy Outlook 2014: Early Release Overview*, Available at: http://www.eia.gov/forecasts/aeo/

[xvi] For additional information on State Renewable Energy Portfolios see the Department of Energy's EERE State Activities & Partnerships, Available at: http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm

[xvii] See: http://ny.water.usgs.gov/projects/NAPAP/NAPAP_2011_Report_508_Compliant.pdf

[xviii] See "Updated Reference, RGGI Package – 10/11/06" available at: http://rggi.org/design/history/modeling