Analysis of the Public Health Impacts of the Regional Greenhouse Gas Initiative, 2009–2014

Prepared by:
Abt Associates
55 Wheeler Street
Cambridge, MA 02138

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Executive Summary

Purpose of this Study

This independent study provides an analysis of the public health impacts of the Regional Greenhouse Gas Initiative (RGGI) over its first six years of implementation (2009 to 2014). RGGI is the nation's first regional regulatory program designed to reduce greenhouse gas (GHG) emissions from large electric power plants, and builds from a long and successful tradition in the Northeast states of using market-based programs to cost-effectively reduce air pollution. Since RGGI started in 2009, the program has raised nearly $3 billion to support the RGGI states' investments in energy efficiency, renewable generation, and other public benefit programs, and these states are on track to achieve reductions of GHG emissions of 45 percent below 2005 levels by 2020.

Because "criteria" air pollutants[1] are co-produced along with GHG emissions from fossil-fuel power plants, RGGI is also expected to drive reductions in these air pollutants and their adverse effects on human health. The objective of this independent study is to provide a *retrospective* analysis of the impacts of an existing GHG reduction program—RGGI—on air quality and public health.

Using publicly available, peer-reviewed air quality and public health models and historical data characterizing RGGI's actual performance during the program's first two compliance periods (covering 2009 to 2014), we addressed the following questions in this analysis:

- Did RGGI result in measurable changes in emissions of criteria air pollutants and air quality?
- If so, how did changes in air quality resulting from RGGI affect public health and to what degree?
- What were the spatial and temporal patterns to changes in air quality and public health due to RGGI implementation?
- Will health benefits from RGGI's first two compliance periods be replicated in the future?

Key Results and Findings

The RGGI program improved air quality throughout the Northeast states and created major benefits to public health and productivity, including avoiding hundreds of premature deaths and tens of thousands of lost work days. RGGI's impact on electricity markets resulted in significant reductions in key air pollutants with adverse effects on human health. Over the first six years of the program, RGGI avoided hundreds of cases of premature deaths, heart attacks, hospitalizations, and emergency room (ER) visits; tens of thousands of lost work days, and hundreds of thousands of cases of restricted activity days due to poor air quality. Table 1 summarizes cumulative avoided health and productivity effects associated with RGGI's first two compliance periods.

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1 "Criteria air pollutants" refer to the six most common air pollutants in the United States: carbon monoxide (CO), lead, ground-level ozone (O_3), nitrogen oxides (NOx), particulate matter (PM), and sulfur dioxide (SO_2). The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS), which are maximum allowable concentrations for these pollutants that are protective of public health.

Table 1. Summary of Cumulative RGGI Health Benefits, 2009 to 2014

<table>
<tr><th rowspan="11">Avoided Health Effects</th><th colspan="3">Avoided Mortality</th></tr>
<tr><td colspan="3">• 300–830 premature adult deaths</td></tr>
<tr><th colspan="3">Avoided Morbidity</th></tr>
<tr><td colspan="3">• 35–390 non-fatal heart attacks
• 420–510 cases of acute bronchitis
• 8,200–9,900 asthma exacerbations
• 13,000–16,000 respiratory symptoms</td></tr>
<tr><th colspan="3">Other</th></tr>
<tr><td colspan="3">• 180–220 hospital admissions
• 200–230 asthma ER visits
• 39,000–47,000 lost work days
• 240,000–280,000 days of minor restricted activity</td></tr>
<tr><th rowspan="2">Value of Avoided Health Effects</th><th>Low</th><th>Central</th><th>High</th></tr>
<tr><td>$3.0 billion</td><td>$5.7 billion</td><td>$8.3 billion</td></tr>
</table>

Source: Abt Associates analysis (2017).

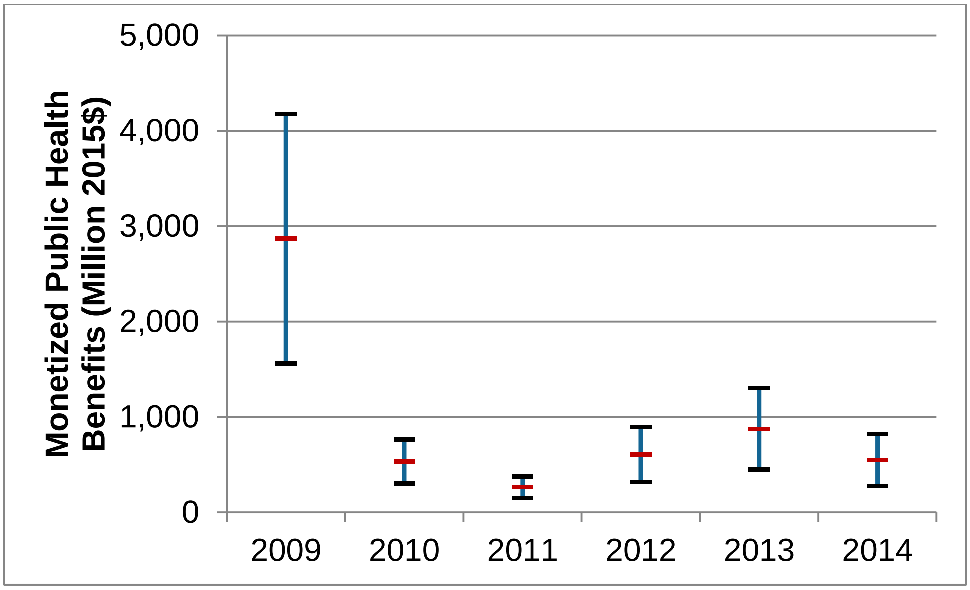
Notes: The total value of avoided health effects is the sum of health benefits in states participating in RGGI and in neighboring northeastern states, based on a 3 percent rate of discount. Values are in 2015 dollars.

The economic value of RGGI's health and productivity benefits is estimated at a cumulative $5.7 billion ($3.0 billion low-end, $8.3 billion high-end). Avoided cases of premature deaths due to reduced levels of fine particulate matter $PM_{2.5}$ account for the majority of RGGI's monetized health benefits. However, other important benefits to the region's economic productivity and quality-of-life include more than 39,000 avoided lost work days and at least 240,000 avoided days with restricted activities (e.g., exercising outdoors) due to poor air quality.

Estimated benefits to health are positive in every state in the Northeast region (including RGGI and certain neighboring states)), and in almost every year of the study period. States with the highest total monetized health benefits over RGGI's first six years include: Delaware, Maryland, New Jersey, New York, and Pennsylvania. Sizeable benefits also occur in Massachusetts, Connecticut, and New Hampshire. Benefits in Rhode Island, Vermont, and Maine are smaller in magnitude compared to those in states with larger populations, but are relatively consistent over the study period. Overall, health benefits estimated for the first compliance period are higher than for the second period.

The largest annual improvements in air quality and health benefits from RGGI are in 2009 and 2013. The largest single-year benefits in health due to RGGI occur in 2009 (shown in Figure 1). This result is consistent with RGGI's two observed effects on wholesale power markets: 1) changes in power prices to absorb CO_2 allowance costs, which results in shifting electricity dispatch from higher- to lower-carbon sources, and 2) investments in energy efficiency that reduce electricity demand, fossil fuel-based generation, and emissions. There is also some evidence that power plant owners, anticipating the requirements of the program, may have taken early action to reduce CO_2 emissions immediately before and after the start of the program in 2009. Energy efficiency investments were comparatively high in this year as well. The combination of higher prices and energy efficiency investments, together with early action, likely account for the largest single-year emission reductions and health benefits across the six year period. Similarly, higher benefits in 2013 most likely correspond to higher relative investments in energy efficiency and renewable energy in that year, and also reflect energy savings accruing from efficiency investments made in prior years.

Figure 1. Annual Health Benefits due to RGGI, 2009 to 2014

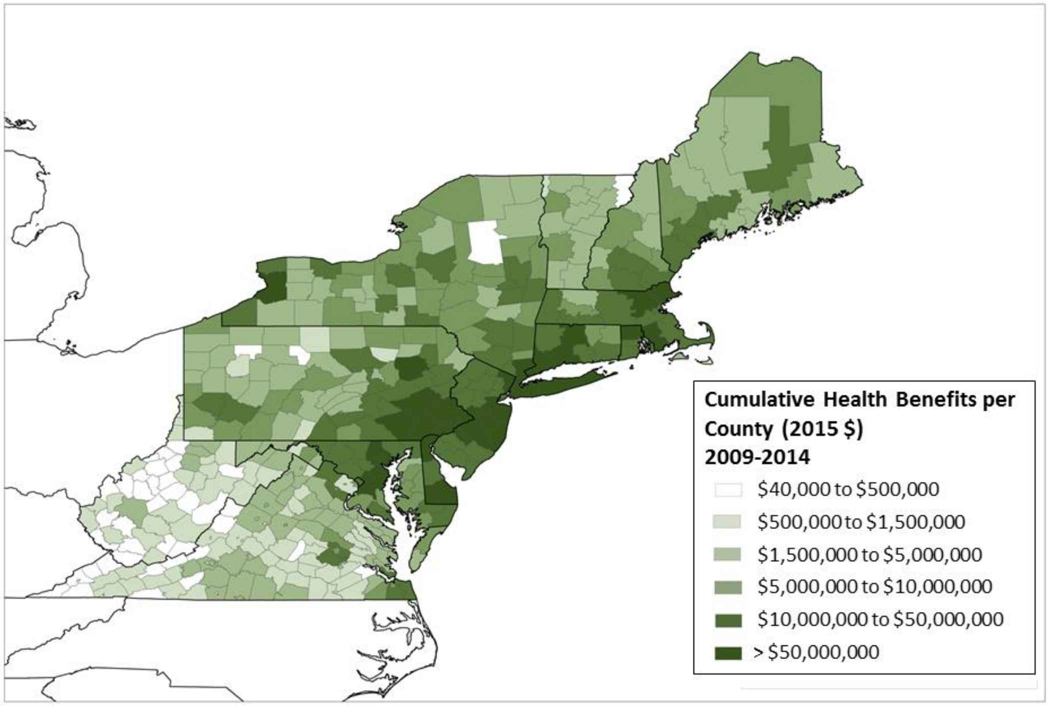


Source: Abt Associates analysis (2017).

Note: Value of annual health benefits is the sum of health benefits to RGGI states and neighboring northeastern states, based on a 3 percent rate of discount.

Multiple states in the mid-Atlantic and New England regions experienced significant health benefits from RGGI-induced changes to air quality which originate in the RGGI states. Due to regional transport of air pollutants, our modeling shows that states with densely populated areas located directly downwind of key coal-fired power plants experienced substantial health benefits, regardless of whether they participate in RGGI. As shown in Figure 2, Pennsylvania experienced the most significant benefits overall from RGGI due to reductions in emissions from Maryland's (and to a lesser extent Delaware's) large coal plants. The District of Columbia, Virginia and West Virginia also experienced modest health benefits from emissions reductions occurring in RGGI states. Similarly, emissions reductions due to RGGI from coal plants in western New York, Massachusetts, and New Hampshire create health benefits not only in those states, but also in Rhode Island, Vermont, and Maine.

Figure 2. Cumulative Health Effects of RGGI, 2009 to 2014



Source: Abt Associates analysis (2017).

A small number of legacy coal plants, particularly in the mid-Atlantic RGGI states, account for the majority of RGGI's health benefits. Coal-fired power plants have the highest emission rates of SO_2, which is the primary contributor to ambient $PM_{2.5}$ levels and risks to health. So, reductions in SO_2 emissions by coal plants account for the majority of health benefits. Of the RGGI states, Maryland has the most significant footprint of older coal-fired power plants and the largest inventory of SO_2 emissions. RGGI-induced changes in generation and emissions from five of Maryland's coal plants alone account for roughly 62 percent of SO_2 reductions in 2009, and 55 percent of cumulative SO_2 reductions from RGGI's first two compliance periods (2009 to 2014).

If coal plants in RGGI states retire as planned in the near future, reductions of air pollutants and annual health benefits resulting from the RGGI program will likely level off. However, additional health benefits will occur as energy demand from other sectors—transportation and buildings—shifts onto a cleaner grid in RGGI and neighboring states. As noted above, RGGI-induced changes at a relatively small number of coal plants drive a high proportion of RGGI's total reductions in key air pollutants and health benefits. However, a number of older coal-fired power plants in RGGI states driving many of the health benefits presented in this analysis are scheduled to retire within the next five years (e.g., Chalk Point in Maryland, Brayton Point in Massachusetts). As such, the fleet of power plants in RGGI states will on average be cleaner in the near future than the current fleet, so that future RGGI-induced reductions in generation are likely to result in less average annual health benefits going forward. However, states will be able to move energy use from other sectors, such as transportation and heating, to this cleaner grid. This process, known as "electrification," can further reduce air pollutants resulting in significant health benefits. For example, transitioning the light-duty vehicle fleet to about 65 percent zero-emission vehicles (ZEVs) by 2050 in eight northeastern states could result in emission reductions that generate nearly $12 billion in health benefits (American Lung Association of California 2016).

RGGI-funded investments in energy efficiency strategically targeted to address daily air quality goals during high-electricity demand periods can generate additional health benefits. The scope of this analysis addressed only annual changes in average $PM_{2.5}$ concentrations. However, air quality in a given location can be highly variable over the course of a year, and a single short-term exposure to high $PM_{2.5}$ concentrations can lead to more severe health outcomes than multiple exposures to low $PM_{2.5}$ concentrations. To the extent that RGGI states' future investments in energy efficiency programs can effectively target peak load on days with high electricity demand, RGGI can further reduce the number of low air quality days and thereby generate additional health benefits in the future.

Estimates of RGGI's health benefits presented in this study are likely conservative, and also do not include the value of other co-benefits associated with reductions in air pollution, such as improved ecosystem services. Health benefits resulting from energy savings associated with RGGI states' efficiency investments that persist beyond 2014 and from reductions in ozone were beyond the scope of this study, but could be significant. In addition, additional benefits to terrestrial and aquatic ecosystems resulting from reductions in sulfur and nitrogen deposition are not included in this analysis.

Approach

The analytic approach used in this study for estimating RGGI's impact on emissions, air quality, and public health consisted of three sequential steps described below:

1. **Estimate annual changes in electric generation and emissions of air pollutants at power plants as a result of RGGI implementation from 2009 to 2014.**

   The RGGI program created changes to annual electricity generation, the mix of power plants (and fuels) dispatched to meet electric demand, and associated changes in emission profiles through its two direct effects on the electricity market: 1) Owners of large fossil-fuel power plants purchase CO_2 allowances to meet RGGI's emissions cap, and then build the costs of these purchases into wholesale power prices. In this way, purchases of CO_2 allowances result in shifts in power production from higher- to lower-carbon generation sources; and 2) Participating RGGI states' investments of proceeds from allowance auctions into energy efficiency measures and renewable generation result in reductions in overall electricity demand and increase the capacity for low- or zero-carbon electricity, respectively.

   We used results from electricity dispatch modeling to determine annual changes in generation (in megawatt-hours (MWh), at the plant level) due to the RGGI program and also for a counterfactual scenario representing the world without RGGI. Using EPA historical data on actual power plant-level emissions (and emissions rates), we then used the incremental difference in plant-level output due to RGGI, calculated associated changes in SO_2 and NOx emissions, and aggregated these emission changes at the county level. These results became the inputs to the air quality modeling conducted in the second step of this analysis.

2. **Estimate annual changes in air quality at the county level associated with changes in sulfur dioxide (SO_2) and NO_x emissions from power plants, by year.**

   To estimate the air quality impacts of RGGI using annual county-level emission changes calculated under the first analytic step, we used EPA's Co-Benefits Risk Assessment (COBRA) model. COBRA is a free, screening-level tool that assists government agencies and others in assessing the benefits of clean energy and climate mitigation policies by estimating the effects of changes in air pollutant emissions on ambient air concentrations of fine particulate matter ($PM_{2.5}$). Using the estimated incremental change in county-level emissions of NO_x and SO_2 due to RGGI that we calculated under Step 1, we performed a COBRA modeling run for each individual year from 2009 to 2014. Outputs from the COBRA modeling step consist of annual changes in ambient $PM_{2.5}$ levels in each county in RGGI and adjacent non-RGGI states, and become the inputs to the modeling of associated health impacts under Step 3.

3. **Assess public health impacts associated with changes in air quality due to RGGI implementation from 2009 to 2014.**

   To quantify and value the public health impacts associated with RGGI's first six years, we used EPA's BenMAP. The BenMAP model uses data describing population, background levels of health outcomes in populations, and economic values for health effects from literature to estimate the number and economic value of health impacts resulting from changes in air quality. We used the county-level changes in ambient $PM_{2.5}$ levels generated by COBRA as inputs to BenMAP. BenMAP then calculated annual health benefits from RGGI's relative effect on ambient $PM_{2.5}$ for 2009 to 2014.

In addition, we conducted sensitivity analysis to address uncertainties surrounding data, assumptions, and key modeling relationships. Specifically, we applied a sensitivity factor of 50 percent to discount estimates of health benefits for states not participating in the RGGI program, to account for a gap in information about changes in air emissions that may have occurred in these states as a result of RGGI. In addition, outputs from the BenMAP model also reflect uncertainties in the assumed relationship between reductions in exposures of human populations to key air pollutants and health outcomes, especially premature mortality. Finally, we did not quantify other benefits outside the scope of this analysis, such as health benefits associated with reductions in ozone and RGGI-induced energy savings occurring after 2014, or improved ecosystem health. As such, the benefits presented here can be considered a conservative representation of the co-benefits of the RGGI program to human health and ecosystems.

Acknowledgements

This report is an independent, retrospective study of the public health impacts of the Regional Greenhouse Gas Initiative (RGGI) over its first six years of implementation (2009-2014). Abt Associates relied on modeling results from two Analysis Group reports, *The Economic Impacts of the Regional Greenhouse Gas Initiative on Northeast and Mid-Atlantic States*, covering the 2009-2011 and 2012-2014 periods. Abt is grateful to Analysis Group for providing access to results of their dispatch modeling, which served as a foundation of our analysis of the impacts of RGGI on air emissions, air quality, and public health.

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In addition, Abt formed a Technical Advisory Group (TAG) to obtain feedback on our approach, methods, and interpretation of analytic results. We would like to thank the TAG members for sharing their time and expertise:

- **George (Tad) Aburn,** Air Director, Maryland Department of the Environment
- **Paul Hibbard,** Principal, Analysis Group
- **Dr. Patrick Kinney,** Professor of Environmental Health, Boston University
- **Dr. Paul Miller,** Deputy Director, Northeast States for Coordinated Air Use Management (NESCAUM)
- Additional anonymous contributors also provided informal input and review.

Michelle Manion of Abt Associates was the lead author of this report. Claire Zarakas, Stefanie Wnuck, Jacqueline Haskell, Anna Belova, David Cooley, Jonathan Dorn, Marissa Hoer, and Lisa Mayo of Abt Associates all made important contributions to this report.

The findings of this independent study are based solely on the analysis and judgment of Abt Associates and do not necessarily reflect the views of the TAG members, Laurie Burt, or our funders.

About Abt Associates

Abt Associates is a mission-driven, global leader in research, evaluation, and program implementation in the fields of health, social and environmental policy, and international development. Known for its rigorous approach to solving complex challenges, Abt is regularly ranked as one of the top 20 global research firms and one of the top 40 international development innovators. The company has multiple offices in the United States and program offices in more than 40 countries.

Abt's experts in climate change, clean energy, and public health include economists, public health experts, epidemiologists, natural scientists, data scientists, attorneys, and others. In addition, Abt economists and public health experts support the U.S. Environmental Protection Agency's (EPA's) efforts to develop, maintain, and update the Benefits Mapping and Analysis Program (BenMAP) and the Co-Benefits Risk Assessment (COBRA) tools, both of which are utilized in this analysis.

For questions and comments on this report, please contact:

Michelle Manion, Senior Associate

Abt Associates

Ph: 617.520.2379

Email: Michelle_Manion@abtassoc.com