Electricity Generation and Cap and Trade CO_2 Programs: What changes can be attributed to RGGI, and who benefits?

Todd Metcalfe*

ABSTRACT

This paper estimates that the Regional Greenhouse Gas Initiative (RGGI) has reduced CO_2 emissions in New York State by nearly 5 million tons yearly on average by changing the fuel mixed used for electric generation. This analysis was performed using a database with fossil fuel generation data from the EPA's Air Markets Data Program (AMPD) supplemented with data from the EIA, NOAA, and U.S. Census. These results are important because RGGI is one type of program that would be permitted under EPA's recently proposed Clean Power Plan (CPP) rule. CPP explicitly encourages states to adopt regional trading programs like RGGI.

INTRODUCTION

Burning fossil fuels for electric generation creates CO_2 as a by-product. The amount of CO_2 emitted while generating a megawatt of electricity will vary depending on the fuel type used: coal will emit roughly twice as much CO_2 as gas will. CO_2 from electric generation cannot economically be captured; when a CO_2 cap is imposed on electricity generation, the only way to reduce CO_2 emissions from fossil fuel generation is to change the mix of fuels being used to produce electricity. Changing the fuel mix will also change the levels of generation of conventional pollutants, such as SO_2 and NO_X, which can negatively affect human health. Since gas is favored over coal when CO_2 is capped and produces lower amounts of conventional pollutants, cap and trade programs for CO_2 create ancillary health benefits. This paper examines the longest running U.S. CO_2 control program's effects by estimating changes in the electric generation mix. This examination is achieved using a unique dataset of observed generation levels at fossil fuel plants from the year 2000 to 2013, in New York and Pennsylvania, to estimate that the Regional Greenhouse Gas Initiative (RGGI) has reduced CO_2 emissions in New York State by approximately 4.9 million tons yearly on average. This paper is part of a larger analysis that estimates the ancillary benefits of RGGI from lowered SO_2 and NO_X production, and the distribution of those benefits.

RGGI is a cap and trade program, implemented in the Northeastern United States, which requires fossil fuel electric power generators over 25 MW to purchase allowances, at auction, for every ton of CO_2 emitted from their operations. Currently, there are 9 states in RGGI: Connecticut, Delaware, Maine, Maryland,

* Social Science PhD Program, Maxwell School of Citizenship and Public Affairs Syracuse University, 413 Maxwell Hall, Syracuse, NY 13244. tmetcalf@syr.edu

Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. Pennsylvania has acted as an "observer" to RGGI, but has not joined. RGGI went into effect on January 1st, 2009.

Understanding the changes in fuel generation mix is important as they help to inform the debate on future programs to curb CO_2 emissions. The electricity sector is the largest source of greenhouse gas emissions in the United States (EPA, 2014b) and has been targeted for reductions by proposed EPA rules. The EPA recently proposed a rule for reducing CO_2 emissions from the electric sector by approximately 30 percent from 2005 levels. The rule calls for these goals to be achieved at the state level, and each state is given a specific emission rate goal to reach these reductions. States are allowed to submit joint plans under this rule, and RGGI is singled out as an example of what such a joint program may look like, provided that the program meets the full level of reductions as required by the rule (EPA, 2014a, p. 34838).

The debate over curbing CO_2 emission makes it important to understand what is gained by these actions, as understanding full benefits are important for informed policy decisions. Reducing CO_2 emissions will have many ancillary benefits to society by reducing costs associated with pollution from burning fossil fuels. Examples of these are environmental damages such as those caused by acid rain, injured human health, and other economic damages or infrastructure deterioration. Risk assessments relating to human health have been used to assign values to changes in environmental quality that result in corresponding gains in human health. Calculating changes in generation are the first step to being able to calculate benefits using risk assessments.

The paper first presents pertinent background about RGGI, CO_2 cap-and-trade programs, and valuing emissions reductions. Next, the dataset constructed and used for the research is described. Then the methods are discussed, followed by the results of the analysis. Finally, conclusions about RGGI's effects on generation are described and future research is detailed.

PRIOR LITERATURE

Previous work on RGGI has focused on the economic impacts of RGGI, consumer demand, and whether or not there has been leakage of CO_2 to states outside of RGGI. Hibbard and Tierney (2011) estimated that RGGI resulted in $1.6 billion of economic value added in to state economies based on the state expenditures from the proceeds of RGGI allowance auctions. Paul et al. (2010) modeled the electricity market in Maryland to determine what the impacts of revenue from RGGI auctions spent on efficiency programs would be on levels of electricity consumption. They found that Maryland's economy would benefit from lower electricity demand and hence lowered electricity bills. Burtraw, Kahn, and Palmer (2006) analyzed the economic impacts of RGGI on power generators, to better understand how the distribution of allowances would impact generators. They found that there would likely be plants that gained value and some that declined in value, and that plants that were outside of the RGGI region would increase in value, but those that were inside of RGGI would in general decrease in value. The impact on the value of non-emitting plants was not clear (Burtraw, Kahn, and Palmer, 2006).

Kindle, Shawhan, and Swider (2011) tested leakage resulting from RGGI between Pennsylvania and New York using historical data on the scheduled flows of electricity between the two states. Their study did not find evidence supporting CO_2 emissions leakage, and stated that the allowance "price is too low to permit the empirical detection of inter-regional emissions leakage" (Kindle, Shawhan, and Swider, p. 19, 2011).

For this work the most important previous work was performed by Murrray, Maniloff, and Murray. Their work utilizes a yearly database from 1991 to 2011 for CO_2 emissions and electricity generation at the state level for the 48 continental states to estimate the effects of RGGI on electricity generation. Their study concludes that emissions have been reduced for RGGI states, but these reductions were due to a "combination of policy, natural gas market, and macroeconomic factors that emerged in the late 2000s" and that at least one third of these reductions can be attributed to natural gas prices and availability (Murray, Maniloff, and Murray, 2014, p. 25 – 26). Further, they find that RGGI is a factor in the reduction of emissions but they are not able to determine if it is due to carbon allowance prices, demand reductions aspects of the policy, or increased imports from generation in other states (Murray, Maniloff, and Murray, 2014).

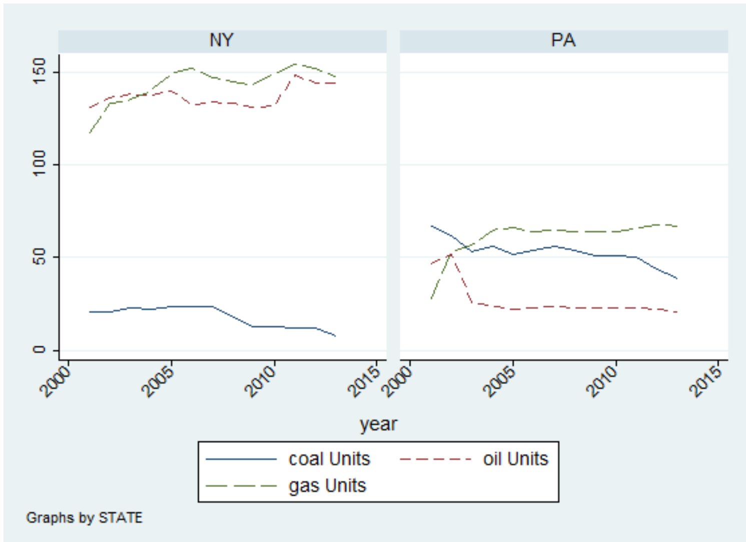
DATA

To determine the effect of RGGI on the generation at the plant level this analysis utilizes panel data, spanning the years 2000 to 2013 for New York and Pennsylvania. New York was a founding member of RGGI, however Pennsylvania has not joined. Data was collected from a variety of sources for the information in the database, including the EPA, NOAA, the U.S. Energy Information Administration (EIA), and U.S. Census.

The most important data for this project comes from the EPA's Air Markets Data Program, which has hourly reports from power plants across the country. In general, power plants burning fossil fuels are required to report to the EPA if they have generating capacity greater than 25 megawatts under the Acid Rain Program (ARP) (USEPA, 2009, p. 2). Plants in the ARP program are required to report year round. Other plants can be required to either report year round or only during specific seasons depending on if the plant is subject to the annual CAIR SO_2 and NO_X or the seasonal CAIR NO_x program (USEPA, 2009, p. 68). Data from the ARP exists dating back to 1995, when it was first collected. However, at that time not all plants were required to report: only 110 facilities, nationwide, were originally affected. Starting in 2000, the current ARP rules for reporting were put into place. In general, these plants report hourly their electricity generation and their SO_2, NO_X, and CO_2 emissions.

AMPD gives very detailed fuel definitions, sometimes including multiple fuel types that a plant may burn. These fuel types are collapsed to three main categories, coal, oil, and gas[1]. For example, some plants have a primary fuel source described as “Diesel Oil, Pipeline Natural Gas” these are mapped to being oil for this analysis. Generation and emissions levels are summed and the data is processed to the monthly level for Pennsylvania and New York.

Chart 1. Units Reporting by Fuel Type for NY and PA 2001 to 2013

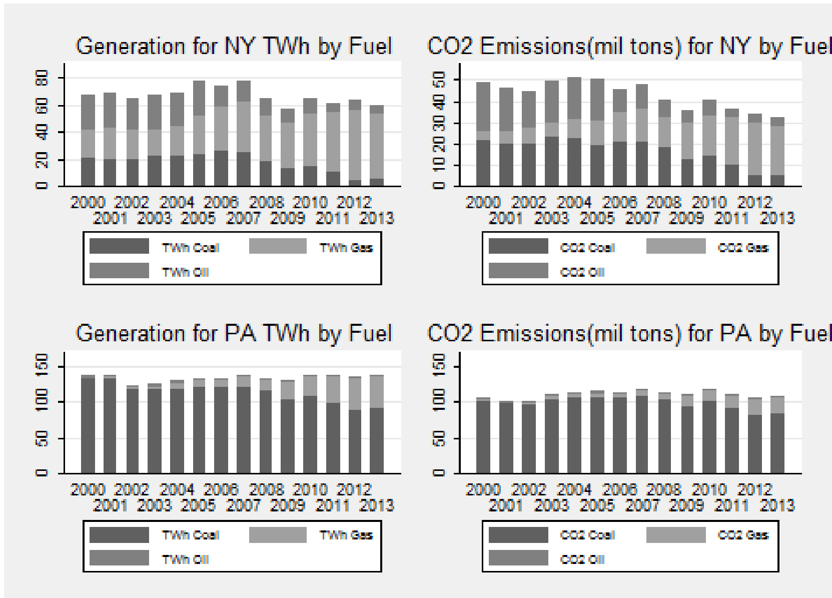


There has been a reduction in the number of coal units[2] reporting in both NY and PA, from 2008 (pre-RGGI) to 2013 (post RGGI). In New York, coal units have gone from 18 to 8, and in Pennsylvania, from 54 to 39. Chart 1 illustrates the change in the number of units by generation. As can be seen in Chart 1 NY has far more generation units in oil and gas than in coal. Also, there has been a drop in the number of coal units over time, and an increase in the number of oil and gas units. In Pennsylvania there as been a downward trend in coal plants, especially after 2010. There has also been a slight increase since about 2010 in the number of gas units.

In NY, the CO2 emissions have had a downward trend, however, this trend is not evident in PA (Chart 2). However, there is has been a significant shift away from generation with coal in NY compared to PA as seen in (see Chart 1). These trends indicate two possible sources of effects from RGGI. First, a unit could elected to not generate electricity in a given time period. The plant could also, produce less generation during a specific time period than it would otherwise. Both demand and generation for electricity are not homogenously distributed, which will impact the program be generation at two points are not perfect substitutes for each other. See Map 1 for fossil fuel generation in 2007.

Average fuel price was obtained from EIA’s Monthly Energy Review, Table 9.9 “Cost of fossil-fuel receipts at electric generating plants.” This provides prices in dollars per million BTU, including taxes for coal, oil, gas, and other fossil fuels. For oil, the variable “Total Petroleum Receipts” was used to approximate the cost to plants. Fuel prices have behaved differently for each fuel per million BTU in the data set from 2000 to 2013. As can be seen in Chart 3, below, coal prices have remained relatively stable over time, with a slight increase. The cost of gas and oil roughly followed each other until approximately 2009, when the cost of gas fell and the cost of oil increased. Even with the falling price of gas, it is still relatively more expensive per mmbtu than coal.

Chart 2. NY and PA Generation and CO_2 by Year by Fuel Source.



The final step for creating the dataset for this analysis was to fill in the unobserved "observations" where a plant did not run. The data set contains 86,613 observations in total, of these 46,357 were censored, and 40,256 uncensored observations.

Map 1. Generation by County Log of Total Generation for 2007, by Fossil Fuel

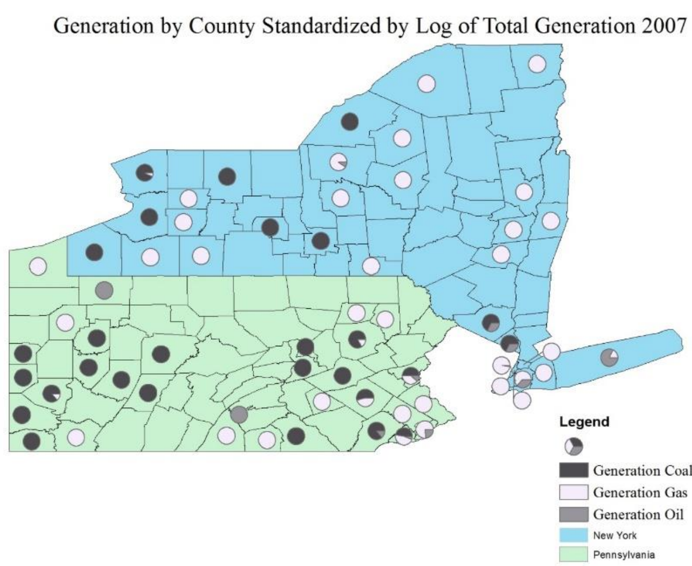
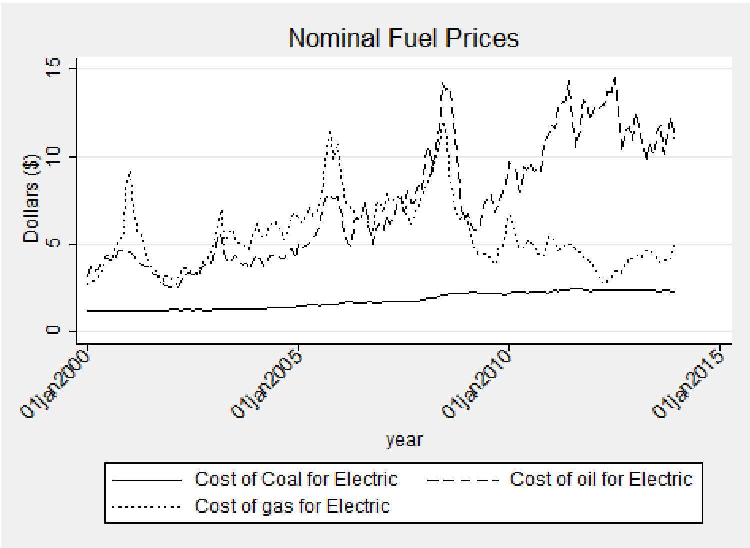


Chart 3. Fuel Prices mmbtu for Coal, Gas, and Oil



METHODS

The decision to run a power plant on a given day or not is complex, depending on the fuel used, time of year, anticipated demand, and characteristics of the individual plants such as age and technology used. The decision that plants face about running in a given time period can lead to biased coefficient estimates due to censoring. Heckman (1976, 1979) corrects for selection bias by first creating a term, the inverse Mills ratio (λ_i) to estimate the likelihood that an observation occurs in the sample. There are two ways that RGGI could affect the operation of power plants. First, it could cause plants to close and go offline entirely. Second, it could cause plants to change their level of generation. A two-step Heckman model is used for this study.

The selection model on whether the plant[3] generates during a given time period is given by the probit model:

$$\Pr(z_{i,t}) = \Phi(\alpha' w_{i,t} + \gamma' R_t)$$

$$z_{i,t} = \begin{cases} 1 \; if \; z^*_{i,t} > 0 \\ 0 \; if \; z^*_{i,t} = 0 \end{cases}$$

Where $z_{i,t}$ is 1 when the plant runs and generates electricity, and $z_{i,t}$ is 0 when the plant is not observed producing electricity. Whether a plant will run during a giving period is based on cost schedules at the plant. As such the selection model of whether a plant will run is predicted based on the $w_{i,t}$ matrix, which consists of the variables that determine the costs of a running a plant, i.e. the size of the plant, age of the plant, and relative monthly price of each fuel. Plants were determined to be running based on the amount of electricity they produced in the previous month. Plants that did not report, or produced less than 300 MWh of electricity during a given month were considered to not run for the selection model.

The generation effects equation is in the form of:

$$y_{i,t} = X_{i,t}\beta + D_i\gamma + D_t\Delta + u_{i,t}$$

Where $y_{i,t}$ is the log of the generation of each plant *i* during each month (*t*). The *X* matrix consists of plant specific data such as fuel type, age of the plant, a categorical value for the size of the generation capacity, monthly temperature minimum's and maximum's (which vary at the county level), and population for each county, and dummy variables for fuel type (which for some plants do vary over time), and an interaction of fuel type and being in RGGI, month and years present in the data set, and the inverse Mills Ratio from the selection equation above. The D_i vector contains dummy variables for the state, the size of the generation capacity by plant. Lastly, the D_t vector contains dummy variables for being in RGGI (any plant in New York after 1/1/2009, note that this is a bit of an oversimplification only having it vary by time, which is acknowledged but helps with illustration), and for fuel price which only varies by time and not plant in this data set.

The selection equation shows how the variables effect whether a plant runs or not (Chart 4). In general plants in New York are more likely to run. Plants are less likely to run the older they are, and as fuel prices go up. The plant size also effects its likelihood to run. All things equal, at the means, the largest plants are most likely to run in the sample, with the smallest plants least likely. We can see that coal plants and gas plants are more likely to run in the sample, and that the RGGI significantly effects gas and oil, which are both less likely to run under RGGI. Coal plants under RGGI (RGGI Coal) is the only variable in the selection model that is not significant. For Any given month, RGGI has not had much of an effect on whether a coal unit runs.

Chart 4. Heckman Selection Equation Coefficients

Variable	Model Coefficient	Z Score	Plant Size Variables	Model Coefficient	Z Score
Coal	0.905***	38.44	10 to 25	1.088***	29.50
Gas	0.445***	28.27	25 to 50	1.332***	37.32
RGGI Coal	0.077	1.32	50 to 75	1.608***	45.45
RGGI Gas	-0.188***	-7.51	75 to 90	2.348***	62.17
RGGI Oil	-0.153***	-4.87	90 to 95	2.318***	57.79
NY	0.323***	20.32	95+	2.443***	59.92
Age	-0.028***	-66.12			
Fuel Price	-0.053***	-18.71			

*** Significant at .01% level, coefficients not listed – temperature (maximum and minimum), population, and control variables for years.

The parameter estimates for the generation equation are shown in Chart 5. RGGI effects equation shows a number important and significant factors effecting energy generation (the log of the generation is the dependent variable). If a plant is in New York, everything else being equal it produces 31.9 percent more electricity, this is likely due to differences in the distribution in plant capacity in the two states. New

York is more heavily weighted to smaller plants, while Pennsylvania's generation is more heavily weighted to larger plants. Coal will generate 146 percent more than oil, while gas will produce 39.1 percent more electricity generation relative to oil. However, when RGGI is introduced the picture changes slightly. Oil interacted with RGGI produces 11.2 percent less electricity, coal interacted with RGGI produces 79.5 percent less electricity, and gas interacted with RGGI produces 30.9 percent less. All of these values are statistically significant.

Chart 5. Heckman Second Stage Equation Coefficients

Variable	Model Coefficient	Z Score	Plant Size Variables	Model Coefficient	Z Score
Coal	1.46***	50.02	10 to 25	-1.594***	-26.03
Gas	0.391***	18.54	25 to 50	-0.971***	-15.81
RGGI Coal	-0.795***	-12.80	50 to 75	0.154**	2.56
RGGI Gas	-0.309***	-10.45	75 to 90	1.077***	17.17
RGGI Oil	-0.112*	-2.51	90 to 95	2.201***	34.15
NY	0.319***	16.65	95+	2.306***	35.34
Fuel Price	-0.033***	-7.42			

*** Significant at .01% level, ** Significant at 1% level, * Significant at 5% level. coefficients not listed – temperature (maximum and minimum), population, and control variables for years. Age excluded from second stage.

CONCLUSIONS

This study uses a unique data set of observed electric generation for fossil fuel plants in New York and Pennsylvania to estimate how RGGI has changed the behavior of these plants. The results from this study indicate that the distribution of pollution resulting from fossil fuel generation will shift in terms of location due to the non-homogenous distribution of generation by fuel type. This shift in location means that different areas will benefit differently from ancillary benefits. This study is part of a larger study, which has used these results to estimate that RGGI has produced nearly $70 million in ancillary benefits through reductions in NOX, SO2, and particulate matter emissions. These benefits are not uniformly distributed, and those in the Western most part of the state and South Eastern area benefit the most from RGGI.

There is still much future research to be done that can be supported with this data, including a more thorough accounting of the health benefits mentioned above. Future work will also increase the frequency of observations to better understand the behavior and response of power plants to cap and trade programs, and to understand dynamics between generation and demand at different times of day when a cap is present. Lastly, it would be interesting in exploring how has RGGI effected the mixture of electricity generation in all of the States belong to RGGI. How has RGGI redistributed electricity generation, and allowances among states.

ACKNOWLEDGEMENTS

I would like to thank Pete Wilcoxen for his comments on this work. This work is part of a larger analysis done to estimate the benefits of RGGI. Please contact the author for the full work.

ENDNOTES

1. Note that there are some plants that burn wood and biomass, however these are not considered for this analysis.
2. Units are used here instead of plants, because units inside of a single plant can be operating on different fuel sources.
3. Plant is used here, however "unit" is a better term. The data is processed at the unit level. However, this is an awkward term due to the EPA's definition for AMPD of unit as "A fossil fuel-fired combustion device" (EPA, 2014b) does not consistently match up definitions of boilers or generators in EIA data.

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