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Pennsylvania and the Clean Power Plan: Towards a 111(d) Compliance Strategy

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Keywords
Clean Power Plan, RGGI, PJM, Pennsylvania, Climate Change, Cap-and-Trade

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Pennsylvania and the Clean Power Plan: Towards a 111(d) Compliance Strategy

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Abstract

The Environmental Protection Agency released its proposed Clean Power Regulation in June 2014, and in mid-summer 2015, the finalized rule will be the first comprehensive regulation of carbon dioxide emissions from existing power plants in American history. Compliance strategies will be expensive and complex decisions for states to make. Each state faces the choice of whether to comply individually or as a region, but posses the freedom to comply in whatever way they choose. Pennsylvania is unique. The commonwealth has an entrenched coal industry, a nascent natural gas industry, and is a net exporter of electricity. Joining the Regional Greenhouse Gas Initiative (RGGI), a group of northeast states that borders Pennsylvania to the north, may be one compliance option, but joining a different region may be a more desirable lower cost solution. This analysis seeks to show that the cost of compliance would be lower if Pennsylvania joined a select group of states within the PJM Interconnection. One result of the analysis suggests that by joining with complementary states within PJM, relatively minor changes in Pennsylvania coal-fired generation would be required to meet Clean Power Plan compliance 2030 goals.

The Intergovernmental Panel on Climate Change, an organization set up by the United Nations to synthesize all research available around the world regarding climate change and present that data to policymakers reports, "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia."[1] The body begins its summary report for policymakers by saying,

> The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification.[2]

Numerous compounds comprise greenhouse gases, but a key gas is carbon dioxide.[3] Additionally, one of the key sources of emissions of carbon dioxide worldwide are electrical power plants, as the electricity sector accounted for 32% of U.S. greenhouse gas emissions in 2012.[4] Accordingly, the need for reductions in the carbon dioxide emissions of power plants is clear. In the United States, however, there are no regulations surrounding the emission of CO2 by power plants, as there are for other pollutants.[5] This situation comes about as a result of the failure of multiple pieces of legislation

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[1] IPCC, 2013: *Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 2.
[2] Ibid. 9.
[3] IPCC, *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 132.
[4] Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012*, 2-21.
[5] The Clean Air Act was initially passed in 1963, with major amendments in 1970, 1977, and 1990. It maintains National Ambient Air Quality Standards (NAAQS), created a market-based system for acid rain management; required Title V permits for major emissions sources, among other provisions (See Belden, Roy). A related rule is the new Cross-State Air Pollution Rule, which limits nitrous oxide (NO_x) and sulfur dioxide (SO_2) emissions from upwind states in order to help downwind states meet NAAQS. The EPA has not previously regulated the carbon dioxide (CO_2) emissions of major sources like electrical power plants.

that sought to regulate CO_2 emissions in the United States, most prominently with a national cap-and-trade program that stalled in Congress.[6]

In order to bring about regulation of power plant carbon dioxide emissions without the passage of a law in Congress, President Obama ordered the EPA to use its authority under Section 111(b) and Section 111(d) of the Clean Air Act to regulate carbon pollution from new and existing power plants, respectively.[7] This report focuses on the EPA's regulation under Section 111(d), regulation of existing power plants. The EPA released its proposed Clean Power Plan in June 2014, along with troves of data from modeling work, and received public comments on the Plan through December 2014. In June 2015, the EPA will issue final rules on existing power plant carbon pollution, and under the proposed rule, states will need to submit either an individual state compliance plan or a request for an extension (if it intends to comply as part of a regional effort) of one or two years.[8] Pennsylvania emitted 105,184,000 metric tons of carbon dioxide from its electrical power generation sector in 2012, and has been one of the more polluting states in the country in recent years.[9]

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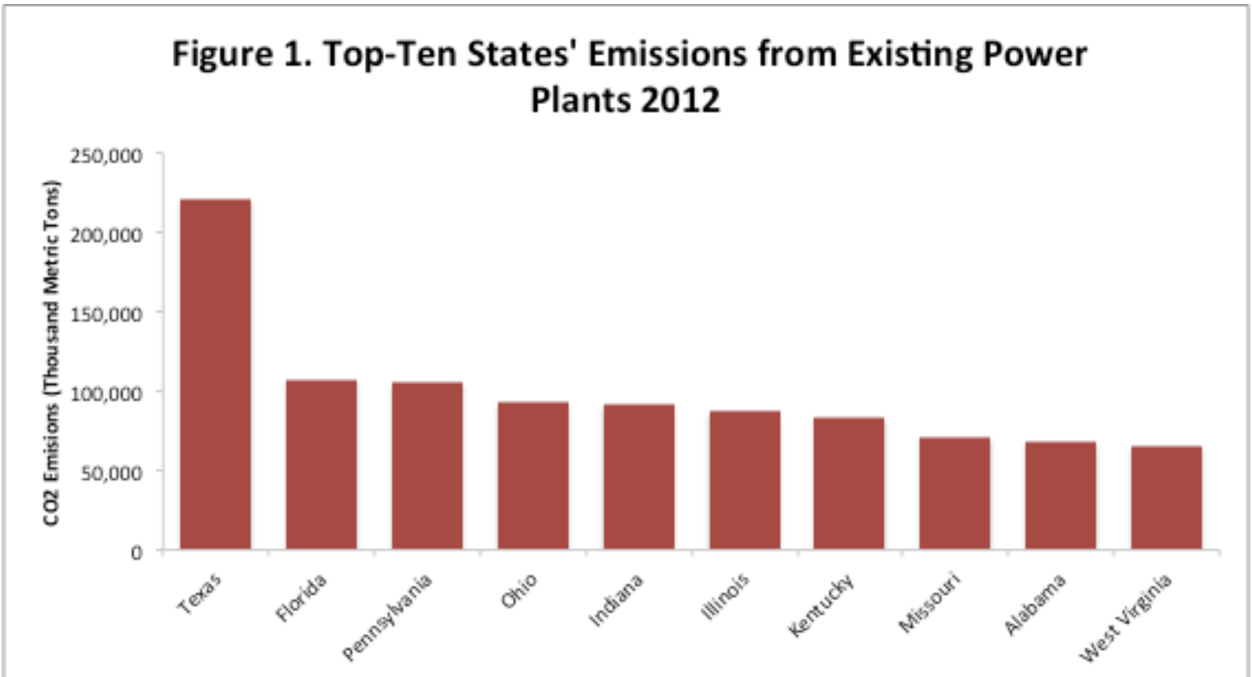
[6] The American Clean Energy and Security Act of 2009 (Waxman-Markey Bill) (H.R. 2454) would have created a national cap-and-trade program, along with other provisions. The Congressional Budget Office (CBO) determined that the bill would have reduced the federal budget deficit by $24 billion between 2010-2019 (See Congressional Budget Office). The Act passed the House of Representatives on a 219-212 vote in 2009 (Open Congress), but was not voted on by the Senate.
[7] Obama, *Presidential Memorandum: Power Sector Carbon Pollution Standards*. Section 1(b).
[8] Environmental Protection Agency. *Clean Power Plan Proposed Rule*.
[9] Environmental Protection Agency. *Clean Power Plan Proposed Rule*. Data File: Rate to Mass Translation.



Source: EPA Clean Power Plan Proposed Rule, Data File: Rate to Mass Translation.

As Figure 1 makes clear, any regulation of carbon dioxide will have a significant impact upon Pennsylvania. The commonwealth faces a major challenge in responding to this regulation, as there are many factors involved and the way forward is not clear. The aim of this paper is to evaluate multiple options for compliance in Pennsylvania, among them joining the Regional Greenhouse Gas Initiative (RGGI), forming a comparable cap-and-trade program with other states, and complying as an individual state. Uncertainty abounds, and the decision is major, with billions of dollars at stake.[10]

[10] The EPA Clean Power Plan has a compliance period of 2017-2029, giving it a reach over a decade in length. The reserve price of an allowance for one ton of CO_2 in the RGGI program is $2.00, with one allowance being equal to one ton of carbon, and over one hundred million tons of CO_2 currently being emitted per year in Pennsylvania, that price could very well increase, and even were it to not, compliance will involve billions of dollars of value at stake.

Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) is a regional cap-and-trade program set up by a group of northeastern states' governors in 2005. The original member states were Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont; the states' governors signed the Memorandum of Understanding (MOU), which set out a model rule for state legislatures to pass.[11] In 2006, Massachusetts and Rhode Island signed the MOU and joined RGGI. In 2011 New Jersey left the organization, bringing current membership to eight northeastern states.[12] RGGI is a voluntary organization, in the sense that the states involved created and joined the program of their own volition in the absence of any federal requirement. While membership is voluntary, when a state joins RGGI, compliance with the cap via the lowering of emissions or purchasing of allowances is mandatory for all qualifying generators in the state.

RGGI is a cap-and-trade program. This form of emissions regulation is nothing new to environmental regulation, with emissions trading being modeled for economic efficiency at least as far back as 1967.[13] In essence, a cap-and-trade program works by setting a "cap," meaning a maximum amount of allowable emissions of a certain type, in this case the maximum number of tons of carbon dioxide, which can be permissibly emitted in the regulated area. The "trade" aspect is that allowances are then created equal to the cap amount of emissions, and these allowances can be traded among qualifying actors in the marketplace. At the end of a compliance period, every

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[11] The Memorandum of Understanding, subsequent amendments, and the Model Rule are available on RGGI.org. The MOU established the program, as originally Connecticut, Delaware, Main, New Hampshire, New Jersey, New York, and Vermont formed the program. Massachusetts, Rhode Island, and Maryland would later join, and New Jersey later exit. The MOU specifies the total cap as a summary of individual state caps. There is a single regional auction for allowances, and revenues are distributed according to state caps.

[12] Massachusetts and Rhode Island had caps determined in the original MOU, and there was an Amendment to the MOU for Maryland's entrance to RGGI, specifying its cap. For entrance into RGGI, a state's governor supports it, and the state legislature will pass a rule, based on the Model Rule, which has sufficient flexibility for states to make such changes as the percentage of allowances that will be sold at auction.

[13] A major analysis using the concept was: Burton and Sanjour, *An Economic Analysis of the Control of Sulphur Oxides Air Pollution*, 1967.

emissions source covered by the regulation must demonstrate possession of allowances equal to their emissions during the period. In other words, one allowance allows the holder to emit one ton of carbon dioxide. At the end of the year, if a power plant has emitted one thousand tons of carbon dioxide, it must have one thousand allowances in its account, or face severe penalty.[14] Each year, the cap declines by a set amount, so that over time there are fewer and fewer allowances available, and emissions in the covered area must correspondingly decline.[15] The trade aspect of these programs allows for significantly improved efficiency relative to "command-and-control" type regulations, because trading leads to emissions being reduced in order of cost, as the cheapest reductions are achieved first, then the next cheapest, and so on. The cost of reducing emissions sets the market price of allowances, and the declining level of the cap ensures that the rising cost of allowances gradually incentivizes increasingly expensive emissions reductions.[16]

Cap-and-trade programs have numerous differences in the specifics of their operation.[17] One important difference is the manner in which the allowances are distributed to power plants (or any regulated body) within a program. The European Union has a carbon dioxide cap-and-trade program, for example, and operates it by distributing allowances to plants based upon historical emissions, and then allowing trade among these actors.[18] Research suggests that this choice was

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[14] An example of a penalty is that RGGI requires non-compliant units to have three times allowances for emissions for a period of years after the infraction.

[15] In RGGI, the MOU sets out an original cap, set to remain unchanged 2009-2014, with 2.5% decline in the cap in each year 2015-2020. The 2012 Program Review concluded that the original cap was too high, and modified it downward by approximately 45% for 2014, keeping the same 2.5% decline per year for 2015-2020.

[16] A cap-and-trade program, like other market-based emissions reductions schemes, gains efficiency over command-and-control type regulation because its price signal sets the price for emissions by the marginal reduction (thereby removing problems of over- or underpriced emissions) and that price signal allows the least expensive emissions reductions to be made until the necessary overall reduction is achieved. A review of various types of market-based emissions reductions programs, and evidence for their success particularly in combating air pollution, is found in: Stavins, *Experience with Market-Based Environmental Policy* Instruments, 2003.

[17] There can be many different specific differences. Some key differences are in the process of allowance allocation, specifically whether all or part of those allocations will be auctioned off. Other points include who is allowed to participate in the auction, which economic actors are required to comply, how long the cap will decline for, and at what rate the decline will take place.

[18] Huber, *How Did RGGI Do It? Political Economy and Emissions Auctions*, 73.

primarily driven by political factors.[19] The example of RGGI is important here. An important feature of RGGI is that nearly all allowances are sold at an auction by the states. Each member state has a portion of the cap allocated to them, and that state's legislature can decide how to allocate that portion of the cap. In RGGI, all states decided to auction nearly all the allowances off. Allocation of allowances based on historical emissions, called "grandfathering," can cause issues such as market bias for incumbents relative to new entrants, windfall profits for existing emitters, slowed emissions reductions due to barriers to market entry, and political manipulation of the market in the allocation system.[20] An auction can help ameliorate all of these issues, raising market efficiency and program efficacy. RGGI has been a success since its inception, raising nearly $2 billion in auction revenue for states' use through 2014 and helping to significantly reduce carbon dioxide emissions in the area.[21] RGGI faces challenges to become a compliance mechanism for the Environmental Protection Agency (EPA)'s Clean Power Plan, as certain modifications will be required to become a qualifying regional implementation plan for its participating states. [22] [23]

Pennsylvania has held non-participant observer status in RGGI since its inception.[24] RGGI has previously been examined as a possible mechanism by which the commonwealth could comply with the upcoming EPA Clean Power Plan regulations.[25] Studies to date have cited potential issues, such as the difference between Pennsylvania, a net-exporter of electricity, a major coal-fired power plant state with a significant coal mining industry, and the RGGI states, which tend to be net importers of electricity without large amounts of either coal mining or coal-fired generation.[26] This

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[19] *Ibid*., 80-83.
[20] *Ibid*., 71-77.
[21] Regional Greenhouse Gas Initiative, *About the Regional Greenhouse Gas Initiative*, 1.
[22] Ramseur, *Regional Greenhouse Gas Initiative: Lessons Learned and Issues for Policy Makers*, 2. This report mentions that the RGGI program's covered entities only emit about 20% of all GHG emissions in the states.
[23] *Ibid*., 16. This would include the cost containment measures as well as the program timeframe.
[24] Bernstein, Montgomery, and Tuladhar, *Economic Consequences of Northeastern States Proposals to Limit Greenhouse Gas Emissions from the Electricity Sector*, 2.
[25] Smokelin and Demase, *Is RGGI in Pennsylvania's Future?*
[26] Silverman, McCarthy, and Day, *EPA Power Plan Rule Raises Questions About Expansion of RGGI Participant States*, 2.

paper will attempt a more in-depth analysis of how Pennsylvania's joining RGGI might look and the effects thereof.

Imagining how Pennsylvania might join RGGI and the costs of doing so is complicated by the difficulties in knowing exactly how joining the group would look. For example, it is hard to determine Pennsylvania's cap for its first year. RGGI calculated its original cap by choosing the base year of 1990, though they had to calculate estimate emissions from the year, since emissions data is not available for carbon dioxide prior to 1995.[27] The state allocations of that cap were determined in a yet more complex process.[28] In addition, RGGI conducted a review in 2012 and decided to reduce the size of its cap significantly for 2014.[29] All of these factors make deciding on a cap for Pennsylvania, should it join RGGI, quite difficult. Studies on Pennsylvania joining RGGI for the Clean Power Plan do not exist, most likely because the final form of the EPA's Clean Power Plan regulation will not be released until summer 2015.[30] Challenges will continue after a cap has been calculated, as it will be difficult to predict how even the electrical power industry will be affected by such broad regulation, let alone numerous other, related industries. RGGI and the EPA use extremely complex, and correspondingly expensive, linear programming models, refined over years, in order to model just the electric power industry under various scenarios.[31] Absent the resources to build a linear programming model from scratch to model broader costs in addition to electric power industry, and absent the resources to purchase results from a firm's model, this paper will attempt to use released model outputs and various techniques with that data to make a best analysis of

[27] Regional Greenhouse Gas Initiative, *Recommendation on Setting a Base Year*, 1.
[28] *Ibid*., 2.
[29] Regional Greenhouse Gas Initiative, *Summary of RGGI Model Rule Changes*, 1.
[30] Environmental Protection Agency, *Clean Power Plan Proposed Rule*.
[31] The EPA and many other organizations contract the modeling work to ICF International, a consulting and technology firm that operates the Integrated Planning Model (IPM) to model the nation-wide power market subject to various constraints and solve for the least-cost means of meeting electrical generation and capacity requirements.

Pennsylvania's choices: joining RGGI, becoming a founding member of a comparable program with different states, or complying as an individual state.

Comparing Compliance Options

Pennsylvania's compliance options for the Clean Power Plan are limitless, as the proposed legislation allows states to meet their prescribed goals in virtually any way. Possible economies of scale suggest the commonwealth would benefit significantly from complying as a member of a group of states, as opposed to doing so alone, as the group of states can achieve savings by reducing emissions in the least expensive way across multiple states. The group of states however, can vary. Two potential groups are an expanded RGGI group, now including Pennsylvania, and the group of states that the EPA used in its calculations associated with the Clean Power Plan. This latter group is called the East Central Region, and it comprises Pennsylvania, Ohio, Maryland, Virginia, West Virginia, Delaware, New Jersey, and the District of Columbia.[32] For the purposes of this analysis, I have considered a scenario in which Pennsylvania joins RGGI, and in so doing creates a "RGGI + PA" group that has no additions other than Pennsylvania, as well as one in which Pennsylvania forms a compliance group with the East Central region, excepting Delaware and Maryland, both of which are party to RGGI. Thus, the two regions are as follows.

- **RGGI + PA –** Pennsylvania, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont
- **East Central –** Ohio, Pennsylvania, West Virginia, New Jersey, and Virginia

The draft proposal of the Clean Power Plan is a rate-based program, meaning that states are assigned an emission intensity that must be met by their existing fleet of generators, in terms of pounds of carbon dioxide emitted per megawatt-hour electricity generated. The rule allows a

[32] The EPA chose groups for regional compliance scenarios on the basis of North American Electric Reliability Corporation (NERC) regions, as well as Regional Transmission Organizations (RTO). NERC regions and RTOs do not always perfectly align with state borders, and so the EPA put states belonging to more than one organization into a single region for the purposes of regional compliance scenarios and renewable generation target calculation. Please see the EPA Regulatory Impact Analysis, 3-11, for more information on these groups. Pennsylvania's region is based the PJM RTO and the RF NERC region. It includes Ohio, Pennsylvania, West Virginia, Maryland, Delaware, New Jersey, and Virginia.

conversion of this emissions rate into a tonnage-based emissions cap.[33] The EPA has since released a technical support document that calculates the mass-based emissions cap proposed for each state, in terms of tons of carbon dioxide.[34] The tonnage cap is used in this analysis, because a cap-and-trade program functions on a tonnage basis, and this analysis considers the cap of a group of states complying together to be simply the sum of the individual caps of the states involved. The caps for the RGGI + PA and East Central regions are summarized in the table below.

EPA-Calculated Final Emissions Caps		
Group	**State**	**Emissions (Thousand Metric Tons)**
RGGI + PA	Pennsylvania	72,272.00
	Connecticut	4,265.00
	Delaware	2,972.00
	Maine	1,323.00
	Maryland	11,613.00
	Massachusetts	74,141.00
	New Hampshire	2,262.00
	New York	17,649.00
	Rhode Island	2,924.00
	Vermont	-
	Total	**189,421.00**
East Central	Ohio	68,751.00
	Pennsylvania	72,272.00
	New Jersey	6,741.00
	West Virginia	52,636.00
	Virignia	18,923.00
	Total	**219,323.00**

Table 1. State and regional caps for RGGI+PA and East Central regions.

As discussed earlier, it is difficult to arrive at a reasonable proxy for the full costs to a state in choosing a particular compliance strategy to respond to the Clean Power Plan. One that may help policymakers approach the problem most easily, though, is the size of the reduction required of each state. Despite the caps being set by the EPA, the reduction a state will need to make from its 2012

[33] Environmental Protection Agency, *TSD: State Plan Considerations*, 5-12.

[34] Environmental Protection Agency, *TSD: Translation of the Clean Power Plan Emission Rate- Based CO2 Goals to Mass-Based Equivalents*.

emissions to its 2029 emissions will not be the same under all compliance strategies. Forming a group for compliance purposes allows states to "subsidize" one another's compliance and allow some states to actually have a lessened reduction. While the particulars of that reduction, in terms of plant closures, fuel switching, demand reductions, renewable generation build-up, and others are unknown and can have different costs; it seems reasonable to suggest that a lower reduction, from 2012 to 2029 emissions, for a state implies a lower cost of compliance. It is assumed that a lesser reduction will be less costly. Thus, the primary methodology will be to compare reduction sizes between compliance strategies.

Comparing compliance strategies by emission reduction amounts involves forming groups of states under certain conditions, modeling a reduction plan, and then determining the reduction in an individual state. An assumption throughout is that states have a set proportion of the regional cap allotted to them, which is the same both before and after the reduction takes place. As an example, if States A, B, and C formed a group, and State B represented forty-five percent of emissions in the base year, when the cap reduced emissions over the course of two decades, State B's reduction could be found by subtracting its base year emissions from forty-five percent of the cap in the final program year. This assumption could of course be incorrect should a program design choose to allocate differing percentages of the ending cap to states than they originally contributed in base year emissions, but the analysis would still be the same in such a case, using given percentages instead. This paper uses all constant cap percentages for simplicity of analysis.

In the East Central region analysis, determining a cap is relatively straightforward. Since the group does not exist, it is simple to choose a cap as the one the states are required to reach under the Clean Power Plan, to use a base year of 2012 as supplied by the Clean Power Plan, and then to consider different paths for reduction in the intervening years. This is somewhat more challenging when considering the RGGI + PA group. RGGI formed its initial cap by considering a dataset of past emissions and using an adjusted figure for each member state, based on the average of the emissions during the three years of highest emissions between 2000-2004.[35][36] In the Program Review undertaken by RGGI in 2012, the organization decided to revise its cap downward, in order to compensate for emissions reductions higher than expected.[37] This adjustment represented approximately a forty-five percent reduction in the RGGI cap. Given the significant reductions in RGGI emissions and the consequent downward adjustment in the regional cap, determining a cap for a carbon-intensive new entrant like Pennsylvania would be difficult.

In this analysis, I consider four different scenarios for Pennsylvania's entry into RGGI, which offer varying amounts of recalculation for the current member states, and therefore have very different beginning cap figures and corresponding paths to reaching the Clean Power Plan's proposed goals. Of course there are nearly infinite possibilities for Pennsylvania's entry into RGGI, and this selection is only meant to consider a brief menu of reasonable options for the purposes of comparison between each other, and between the RGGI + PA, the East Central, and Pennsylvania-alone compliance strategies. Results from modeling four RGGI scenarios and three East Central scenarios for Pennsylvania are summarized in the table below.

[35] Regional Greenhouse Gas Initiative. *Revised Staff Working Group Package Proposal*. 1.
[36] RGGI's *Revised Staff Working Group Package Proposal* also reports, "In developing state emissions budgets, consideration was given to the following factors: 2000-2004 emissions, electricity consumption, population, potential emissions leakage, and provision for new sources." This analysis simplified the process, considering only 2000-2004 emissions. Each calculation was an approximation of RGGI's own calculation, using different data, and so is a source of error. This analysis operated under the assumption that adding additional considerations, without the benefit of a detailed RGGI description of their use, would increase error more than it would improve precision of the analysis' estimate.
[37] Regional Greenhouse Gas Initiative. *RGGI 2012 Program Review: Summary of Recommendations to Accompany Model Rule Amendments*. 1.

111(d) Cap-and-Trade Compliance Scenarios and their Effects Upon Pennsylvania						
		2029 CPP Compliance?	First Year of Reduction	Last Year of Reduction	Reduction/Year	Estimated PA Emissions Change (tons)
Current RGGI + PA	Scenario 1	YES	2015	2022	2.50%	(56,386,242.21)
	Scenario 2	YES	2015	2029	3.50%	(38,238,677.74)
	Scenario 3	YES	2015	2029	3.00%	(42,522,828.42)
	Scenario 4	YES	2015	2029	3.00%	(42,522,828.42)
East Central Region	Scenario 5	NO	2018	2029	2.50%	(30,377,880.05)
	Scenario 6	YES	2017	2029	2.50%	(32,517,067.43)
	Scenario 7	YES	2018	2029	2.60%	(31,425,097.94)

Table 2. Summary of Pennsylvania Emission Changes After Seven Compliance Scenarios.

The results of this suggest that the least expensive compliance options would be Scenarios 5, 6, and 7. All of these scenarios are ones in which Pennsylvania forms its own East Central group, rather than joining RGGI. All of these take the 2012 carbon dioxide emissions of New Jersey, Ohio, Pennsylvania, Virginia, and West Virginia as a baseline and then reduces emissions at a similar rate that RGGI does, at around 2.5% per year. In RGGI, reductions are currently scheduled to happen each year, 2015-2020. Scenarios 6 and 7 illustrate two different East Central options, beginning the reductions immediately in 2017. These suggest that an East Central compliance group may be a lower cost option for Pennsylvania, relative to RGGI. The difference is not insignificant, either, as the least expensive RGGI compliance option, Scenario 2, has about 5.7 million tons more of a reduction in emissions than the most expensive East Central option. This difference is roughly equal to the emissions of one coal-fired unit in Pennsylvania.[38]

Many questions remain regarding RGGI + PA that will need to be addressed by talks between Pennsylvania, RGGI, and the latter group's constituent states. This paper sought to create different scenarios given what is known about how RGGI formed its original caps. RGGI's process can be summed up in three steps: (1) RGGI formed its own data set of emissions from the qualifying sources for many years in the past, then (2) used the average of the annual emissions from

[38] Environmental Protection Agency. *Data File: 2012 Unit-Level Data Using the eGRID Methodology*. Note that this figure looks at coal *units*, not entire plants. Large coal-fired power plants may include three individual units.

the three highest years 2000-2004 for each state's base emissions cap, and finally (3) adjusted the overall cap downwards roughly forty-five percent to account for emissions reductions being greater than expected between RGGI's inception and 2012.[39]

Accordingly, this general framework was used. For example, emissions data is calculated using generation data by source and emissions factors from the Energy Information Agency. From this was calculated an average emissions figure for Pennsylvania's three highest annual emissions from the period 2000-2004. The scenarios are then constructed to test the effects of different choices around this process. Scenario 1 combines Pennsylvania's average emissions figure with the other RGGI states, and then adjusts this cap down by 45% in an attempt to replicate RGGI's process as closely as possible (including the 2012 Program Review adjustment). Scenario 2 recognizes the argument that the 2012 Program Review was based on the RGGI states specifically, and may not be applicable to Pennsylvania, and so adds the adjusted RGGI cap to the unadjusted Pennsylvania average emissions figure. Scenario 3 examines a situation in which RGGI and Pennsylvania agree to re-calculate the cap entirely and use the 2012 emissions that the EPA provides as a beginning cap, in order to streamline compliance with the Clean Power Plan. Finally, scenario 4 is a hybrid approach, taking the current RGGI cap figure and adding Pennsylvania's 2012 EPA-provided emissions to form its initial cap. There is great difference between the caps that result from these differences in calculation, and it is my contention that this calculation ought to be the heart of discussion and negotiation between Pennsylvania and the RGGI states as the former makes its decision about compliance with the Clean Power Plan.

Joining RGGI is an attractive prospect for Pennsylvania's, perhaps most saliently because the program is already running and has been for some years, and therefore it can expected that

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[39] Regional Greenhouse Gas Initiative. *RGGI 2012 Program Review: Summary of Recommendations to Accompany Model Rule Amendments*. 1.

administrative costs of getting the program up-and-running in Pennsylvania may be lower and implementation may be smoother than creating an entirely new group. There are also potential political advantages to joining RGGI for the Pennsylvania governor and legislature, which may seek to publicly join many northeastern states and thereby signal agreement with certain values and approaches to issues. RGGI also stands to gain from the potential union. Its stated goal is to grow the regional organization.[40] Furthermore, Pennsylvania has such a high cap figure, due to its high previous generation, that the state would at least partially "subsidize" compliance in other states by increasing the regional cap that would need to be hit for compliance with the Clean Power Plan and presumably make reductions that would not need to be made in current RGGI states as a result. Furthermore, Pennsylvania's entrance into RGGI could be pivotal to the expansion of the organization. New Jersey is an illustrative example as to why. New Jersey is an original signatory of RGGI, but withdrew almost immediately, citing the issue of electricity imports, specifically from Pennsylvania.[41] These meant that New Jersey paid the costs associated with RGGI without really improving emissions, as generators in the state simply became less competitive relative to those outside. It is true that Pennsylvania is a major electricity exporter, and so its joining RGGI may reduce the "emissions leakage" problem that could grow if RGGI continued to add more states.[42] Thus, it might be in RGGI's interest to persuade Pennsylvania to join as its compliance strategy. While Pennsylvania would likely see streamlined compliance as a result, the lessons of RGGI could be applied to making an East Central compliance group as well, thereby reducing the relative

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40 Regional Greenhouse Gas Initiative, *Memorandum of Understanding*, 8.
41 Christie, *New Jersey's Future is Green*.
42 Emissions leakage refers to a problem specific to regional emissions reductions programs. Electrical transmission grids do not conform to state borders as regional emissions reductions programs like RGGI do. As a market-based program seeks to raise the cost of production for units emitting pollutants, the cost of production for a unit outside the compliance region and not subject to the emissions cost is consequently relatively lower. Therefore, there is potential for "emissions leakage," whereby units inside the compliance region run less, electrical demand is met by generation outside the compliance region, and instead of being reduced, emissions "leak" out the region, and are simply emitted outside the regulatory borders. In the New Jersey example, there is potential for New Jersey power plants to simply run less and New Jersey to import electricity from Pennsylvania, where there was no emissions cost, and so emissions aren't reduced, but simply emitted in Pennsylvania instead of New Jersey.

attractiveness of RGGI somewhat. The important consideration for Pennsylvania must be whether joining RGGI can be handled in such a way as to benefit the commonwealth, relative to spearheading an East Central compliance initiative.

As has been shown, the negotiation over the cap calculation for Pennsylvania is not simple. Upon a first glance, it seems that RGGI would mean more of a reduction, and thus costlier compliance, for Pennsylvania, relative to forming a different compliance group. Also vital to these discussions is the fact that Pennsylvania's reduction alone is just over thirty-six million tons in the proposed regulation.[43][44] No RGGI+PA compliance scenario examined in this paper was less expensive than this figure, which means that Pennsylvania would be subsidizing the RGGI states, taking on a higher compliance burden in order to reduce theirs. Pennsylvania joining RGGI makes sense, then, only on the assumption that some "grand bargain" is reached between the two parties, such that the calculation of the RGGI + PA cap does not impose too arduous a burden upon Pennsylvania,[45] and the new entrant received some other benefit.

[43] Environmental Protection Agency. *Rate to Mass Translation Data File.*

[44] Ibid. PA 2012 Emissions: 105,184 thousand metric tons = 115,945,375.04 tons; PA Emissions Goal: 72,272.31 thousand metric tons = 79,666,489.85; Difference: 28,181,657.46 metric tons. Thousand Metric tons = 1,102.31 short tons. PA Reduction = 36,278,885.19 tons.

[45] It is likely that any calculation would result in some burden being placed on Pennsylvania, meaning that joining RGGI would entail a larger reduction, and thus cost, than would compliance as an individual state.

East Central Regional Compliance Modeled Outcomes

In considering the impact of a potential East Central compliance region, the EPA does provide some advantages. In its modeling work, the EPA considers both a state and a regional approach.[46] The regional approach uses what the EPA considers to be the East Central region, with is the same as this analysis' assumption, with the exception of the states in the RGGI compliance group already.[47] The modeling outputs are certainly inclusive of a degree of error because of the inclusion of states already in RGGI: Delaware and Maryland, as well as Washington, D.C., which was not included in this analysis.[48] However, the study of these modeling outputs are nonetheless an important consideration, as the Integrated Planning Model linear programming model is powerful tool for modeling an entire power market, and thus can provide unique insight that cannot be otherwise attained. Most usefully, the model takes into account the constraints of the Clean Power Plan regulation as well as other regulation, and then solves for regional compliance allowing for changes in existing assets' generation, new assets to be built and run, energy efficiency measures, and so on to provide a detailed compliance scenario.[49] Figures 2 and 3 below show the changes over time of modeled generation by fuel type in the East Central region and in Pennsylvania. The East Central region shown here is that of this analysis, and removes Delaware, Maryland, and the District of Columbia.

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[46] Environmental Protection Agency, *EPA Analysis of the Proposed Clean Power Plan: IPM Run Files*.
[47] Environmental Protection Agency, *Technical Support Document: GHG Abatement Measures,* 4-15.
[48] *Ibid.*
[49] Environmental Protection Agency, *Documentation for v.5.13*, 2-1 – 2-13.

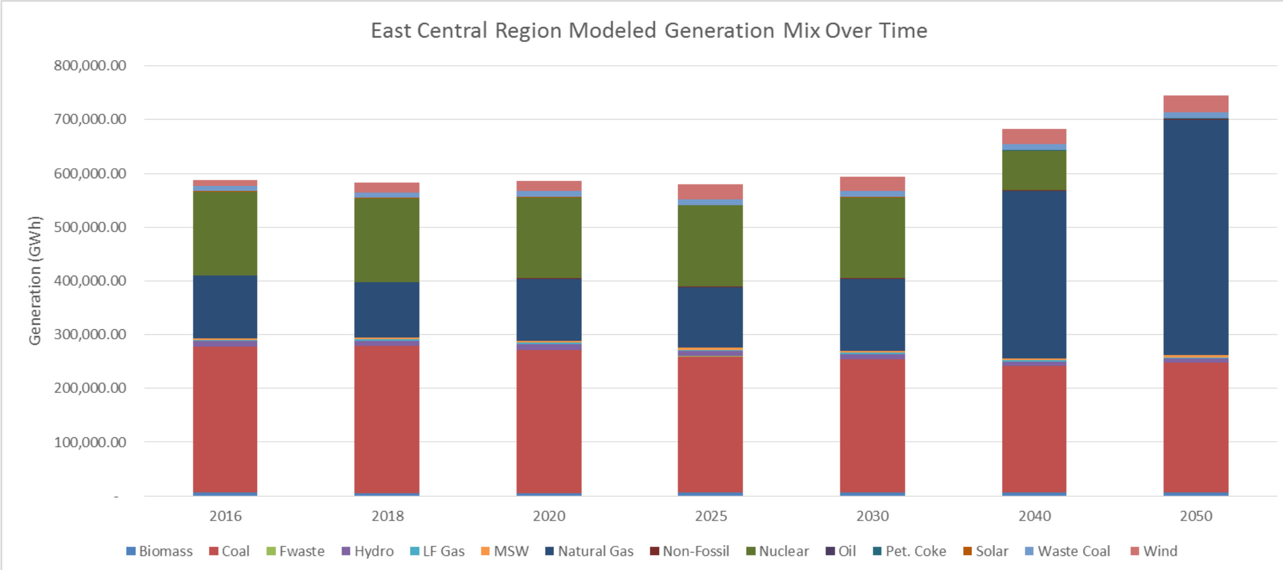

Figure 2. East Central region modeled generation mix by fuel type.[50]

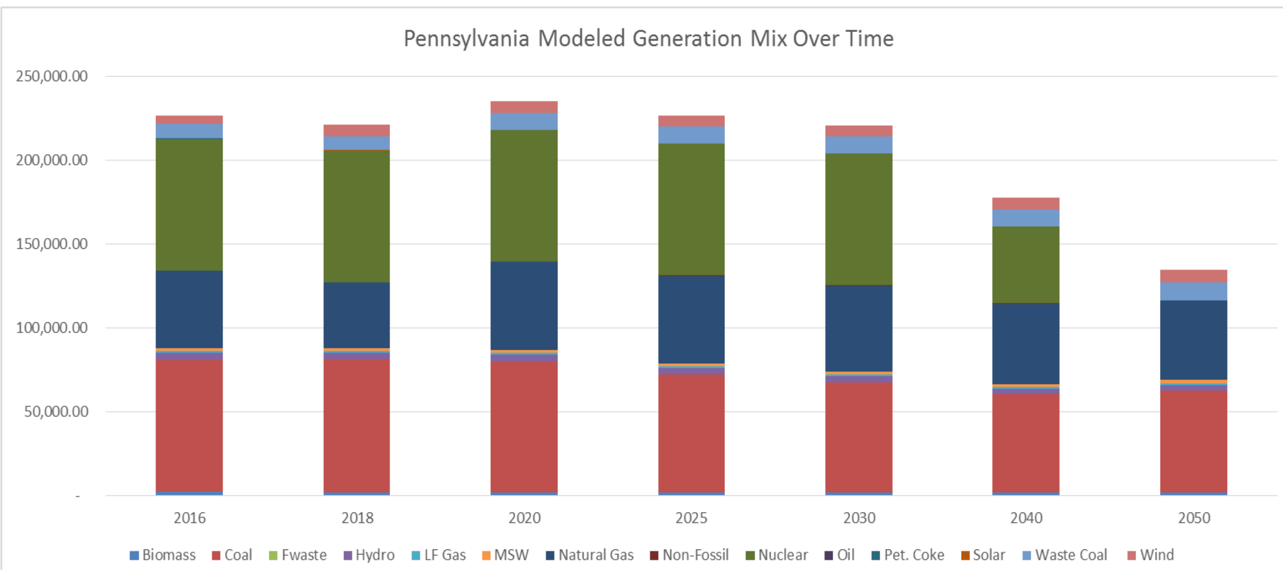

Figure 3. Pennsylvania modeled generation mix by fuel type.[51]

The above figures have several salient features. First, nuclear power is completely phased out of the generation mix for the 2050 model year, both in the region and in Pennsylvania, after

50 Data source: Environmental Protection Agency, *EPA Analysis of the Proposed Clean Power Plan: IPM Run Files*, Option 1 – Regional, RPE file.
51 *Ibid.*

experiencing a significant decline in the 2040 model year. Note that both 2040 and 2050 model years are intended to represent a ten-year period. This is unsurprising in the sense that current nuclear plants would likely age and retire by that timeframe, but it is illuminating to see that the model does not have new nuclear generation built. Secondly, coal generation does not decline as precipitously as might be expected. In Pennsylvania, 2050 generation is just under sixty-one thousand Gigawatt-hours (GWh), which is only a 22.5% decline from seventy thousand five hundred GWh generated in 2016 in this scenario. Similarly, in the region as a whole, coal generation only dips 11% between 2016 and 2050. Finally, it is insightful to see a major difference between Pennsylvania and the region as a whole. While the built-up of natural gas generation in Pennsylvania is modest, peaking in 2020 at 13.9% above 2016, it is enormous in the overall region, with a 2050 peak 278% higher than 2016. This is the manifestation of the fact that Pennsylvania's generation overall declines over time, at a compound annual growth rate (CAGR)[52] of -1.51%, whereas the region over experiences generation growing at a CAGR of 0.70%. The takeaway is that Pennsylvania generation declines significantly in order to comply with the Clean Power Plan and the vast majority of that decline can be attributed to the decline in nuclear generation, whereas regional generation grows and growth in natural gas-fired generation accounts for even more than this increase (as it replaces the lost nuclear generation as well).

This modeling result does have some error. Most prominently, the above figures are based on the exclusion of Delaware, Maryland, and the District of Columbia (DC), which were used by the model in calculating the result above. However, when considering the modeled generation mix of the region including Maryland, Delaware, and DC, the results do not differ significantly. Overall generation increases with a CAGR of 0.57%, nuclear generation is nearly zero by 2050, and natural

[52] Compound annual growth rate (CAGR) is calculated as: CAGR = $\left(\frac{Ending\ Value}{Beginning\ Value}\right)^{\frac{1}{\#\ of\ Years}} - 1$.

gas-fired generation increases 236% between 2016 and 2050, replacing the nuclear generation as well as fueling growth in generation. Since the profile is so similar to the scenario without the two RGGI states and DC, it seems reasonable to use the data to consider just this analysis' proposed East Central region. The generation mix by fuel type is summarized in Figure 4 below.

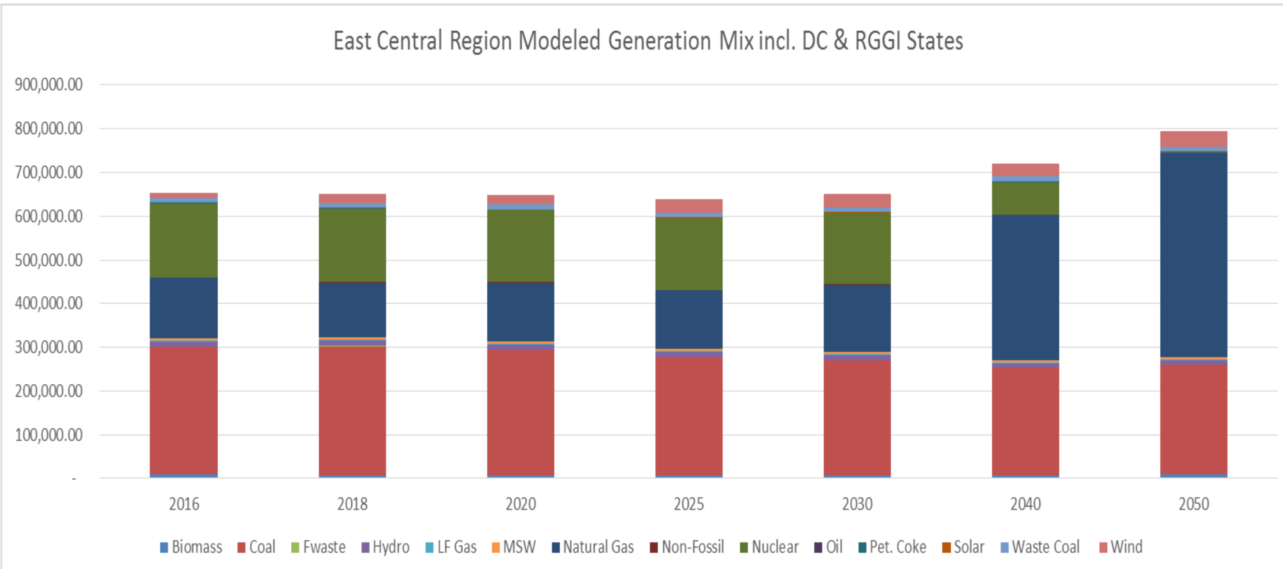

Figure 4. East Central region generation mix by fuel type including Delaware, Maryland, and DC.[53]

Overall, EPA's IPM modeling outputs allow for an instructive examination of how generation types would change under a regional compliance scenario of an East Central region. In short, the region would continue to see generation growth through 2050, and it would be fueled by a sustained and massive increase in natural gas-fired generation. Pennsylvania, however, would see its overall generation rapidly fall with a CAGR of -1.51%, as nuclear generation would cease over time coal generation would decrease by 22% and natural gas generation would increase by 13.9%, both between 2016 and 2050. With respect to the Clean Power Plan, compliance for Pennsylvania seems to be driven primarily by energy efficiency and demand reduction measures, along with modest fuel-

[53] Data source: Environmental Protection Agency, *EPA Analysis of the Proposed Clean Power Plan: IPM Run Files*, Option 1 – Regional, RPE file.

switching measures. In the East Central region more broadly, fuel shifting seems to play a much larger role. New-built renewable sources of energy are a significant means of compliance in neither Pennsylvania nor the broader region.

Additional Considerations

One important consideration when evaluating a regional compliance program is the "revenue circle," meaning the way in which money leaves generators in the state, goes into a regional auction pool, is distributed back to states, and then reinvested in those states. A critical question is how the revenues are allocated back to states following a regional auction. In the RGGI marketplace, states are allocated a state cap of allowances, and can then decide to sell a portion of those allowances at the regional auction, to sell a portion at a fixed price, or distribute some in a different manner. Table 3 shows the distribution of allowances by the original RGGI states, and Table 4 shows their respective auction revenues.

State	Initial Annual CO2 Allowance Budget	Percent Offered Through Auctions	Percent Offered for Sale at a Fixed Price
Connecticut	10,695,036	77%	13%
Delaware	7,559,787	60%	0%
Maine	5,948,902	80%	0%
Maryland	37,503,983	80%	0%
Massachusetts	26,660,204	98%	0%
New Hampshire	8,620,460	69%	0%
New Jersey	22,892,730	74%	25%
New York	64,310,805	94%	0%
Rhode Island	2,659,239	99%	0%
Vermont	1,225,830	99%	0%
Total	**188,076,976**	**86%**	**4%**

Table 3. Original RGGI states' allowance budgets and distribution decisions.[54]

[54] Data source: Regional Greenhouse Gas Initiative, *Investment of Proceeds from RGGI CO_2 Allowances*, 3.

State	Proceeds - Auctions 1-10	Proceeds - Direct Sale ('09-'10)	Total Allowance Proceeds
Connecticut	$ 44,900,580.00	$ 441,094.00	$ 45,341,674.00
Delaware	$ 18,858,578.00	$ -	$ 18,858,578.00
Maine	$ 23,544,204.00	$ -	$ 23,544,204.00
Maryland	$ 147,530,363.00	$ -	$ 147,530,363.00
Massachusetts	$ 123,229,478.00	$ -	$ 123,229,478.00
New Hampshire	$ 28,215,274.00	$ -	$ 28,215,274.00
New Jersey	$ 90,913,275.00	$ 11,310,356.00	$ 102,223,631.00
New York	$ 282,272,683.00	$ -	$ 282,272,683.00
Rhode Island	$ 12,340,209.00	$ -	$ 12,340,209.00
Vermont	$ 5,701,535.00	$ -	$ 5,701,535.00
Total	**$ 777,506,180.00**	**$ 11,751,450.00**	**$ 789,257,630.00**

Table 4. Original RGGI states' allowance auction proceeds.[55]

These represent only the revenues from RGGI auctions through 2010, and are in excess of three-quarters of a billion dollars, thus the importance of revenue distribution. As is shown in these charts, RGGI auction revenues are distributed simply, as the auction price is multiplied by the by the number of allowances in that state's allowance budget, or in other words, each state gets to sell their allowance budget and receive the revenues of that sale. It should be noted that this means that auction revenues, being distributed on the basis of the budget, are not allocated the basis of where the emissions were actually emitted. This seems relatively reasonable, given the nature of CO_2 emissions' global impact – the program revenues are for furthering the program of reducing these emissions, not for direct cleanup.

The revenues, then, can be reinvested into the state itself, such that the "revenue circle" is closed inside of Pennsylvania – money is not significantly flowing out of the state as a result. It could be plausibly argued that it is still possible for money to flow out of the state if Pennsylvania generators purchase the allowances disproportionately, such that the state's generators ended up buying other states' allowances in large amounts. This would have to be quite a significant effect in

[55] *Ibid.*, 4.

order to genuinely flip the balance of economic effect, however. Studies have already analyzed the effects of RGGI on the states currently in the program, and have found them to be positive, meaning that more economic benefits were attained than the value of the allowances themselves, or that the money taken from generators when they purchased allowances earned more when reinvested by the states.[56] Thus even if there were to be some outflow of revenue proceeds, that outflow would need to outweigh the economic benefits of the reinvested proceeds of auctioning the state's allowance budget, which does not seem likely.

States achieve these economic benefits by investing auction proceeds in a variety of programs aimed at curbing greenhouse emissions and improving local economies. Overall, the proceeds of the early RGGI program (for which good data exists) were split up such that about half were invested in energy efficiency (52%), a quarter in renewable energy generation and direct energy bill payment assistance (25%), with the remainder being put towards budget deficit repayment in New Hampshire, New Jersey, and New York, and all states proportionately contributing to program administration.[57] Energy efficiency comprises numerous different types of programs by different states, such as home and small business weatherization and retrofits, energy efficient appliance programs, educational programs, large-scale commercial and industrial projects including combined heat and power projects, municipal clean energy programs, and energy efficiency job training programs.[58] These different programs ensure that revenues within a state are going to numerous constituencies, from large companies in utility-administered projects to small businesses and individual consumers. RGGI auction proceeds within a state do provide positive economic benefits, and those benefits are broadly distributed throughout the economy.

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56 Hibbard and Tierney, *Carbon Control and the Economy: Economic Impacts of RGGI's First Three Years*, Figure 1.
57 Regional Greenhouse Gas Initiative, *Investment of Proceeds from RGGI CO_2 Allowances*, 12.
58 *Ibid*., 14-22.

A final point of additional consideration is just how Pennsylvania, or any state, could comply with the Clean Power Plan alone. For the purposes of comparing compliance options, this analysis assumed a simple cap-and-trade within the state, but that is not the only option. A state could also return to an integrated resource planning approach. This would entail the state requiring all actors involved to submit plans for various emissions improvements, likely following the broad outlines of the EPA building blocks of the Clean Power Plan, and the state would then build a supply curve of actors' plans, and implement the least expensive ones in order until the requirements were met. In effect, this would mean distribution companies would need to build supply curves of energy efficiency and demand reduction measures they could provide at different price points, coal plant operators creating a curve for heat rate improvements, a commissioned study into the curve for incentivizing renewables construction, and so on. This would be complicated by Pennsylvania's position within PJM, a competitive power market, that would make it difficult to find a way to re-dispatch generation from coal plants to natural gas combined-cycle plants, in accordance with the EPA's Clean Power Plan building block 2. Nonetheless, such a program would likely be able to work out the difficulties associated with it. The importance of understanding such an approach's complexity, though, is to make it clear that while joining a regional program would have administrative difficulties associated with it as a result of the program and the marshaling of different states, individual compliance would also be fraught with complexity.

The additional considerations discussed above serve to reinforce the conclusions from earlier in the analysis. There are additional costs and difficulties that help to make regional compliance attractive for Pennsylvania. The closed "revenue circle" should assuage fears over a capital outflow to other states in such a scenario. However, these thoughts, in particular the notion of economic benefits exceeding the value of allowances auctioned off, ought also to question the means by which different options are considered. It is possible that a larger reduction, the proxy for cost in this analysis, to be preferable to Pennsylvania, as that reduction could be equal to funds reinvested and creating additional economic value for the state. It is beyond the scope of this analysis to determine whether the economic impact of reinvested auction proceeds outweighs the cost of having to reduce emissions further and administer a larger change in the state's electrical power markets, but it appear a fruitful avenue for further research. For the present, it seems clear that Pennsylvania ought to seriously attempt regional compliance with the Clean Power Plan regulation, and that an "East Central" compliance region is worth consideration as a compliance strategy.

Conclusion

Pennsylvania's choice of compliance method for the Clean Power Plan could have enormous repercussions for the state and its economy, not only through the program's end date of 2030, but into the future. By taking size of required reduction in emissions as a proxy for the burden of the regulation, the relatively simple modeling in this analysis shows that Pennsylvania stands to gain from forming an East Central compliance region, and stands to lose from joining RGGI. The comparison of the two is done relative to simply complying as an individual state. This may not be the ideal baseline, however, as it assumes the state will put in place a cap-and-trade program of its own. As an electricity exporter, this might not be in Pennsylvania's interest, as it could lead to Pennsylvania electricity being disadvantaged in the regional PJM marketplace, relative to generators in states without such a program. Instead, Pennsylvania might choose an integrated resource planning approach, or another approach entirely, but the burden of such a compliance method is unknown, especially without the benefit of an advanced linear programming model to test additional hypothesized compliance schemes. The results of the IPM model runs, an example of an advanced linear programming model, released by the EPA showed that the burden of regulation for Pennsylvania in an East Central compliance region was less than feared.

Even if the state complying as an individual cap-and-trade program is an unrealistic baseline, the cap-and-trade programs of the East Central region and RGGI are entirely reasonable to compare directly, and in all scenarios modeled in this analysis, the East Central region imposes a lessened burden upon Pennsylvania than joining RGGI. It seems likely that this is due to the composition of generation in the two regions. RGGI has less generation overall, and less coal-fired generation, thus Pennsylvania's generators work out to be the marginal emitters in such a union.[59] In contrast, the

[59] The concept of marginal emitters is relevant in a cap-and-trade compliance scenario. In such a scenario, the price of allowances is set by the cost of the marginal reduction in emissions at a source. If all such marginal sources are in

East Central region comprises states more akin to Pennsylvania from a generation mix standpoint. For this reason, the marginal emitters are not as likely to be exclusively in Pennsylvania, and thus the burden of compliance is shared more equitably amongst the states therein. From this point, this analysis concludes that it is in the interest of Pennsylvania to pursue the East Central region, or a similar region, for compliance with the Clean Power Plan, in order to meet the regulation with the least burden upon Pennsylvania's economy. The analysis stops short of specifically modeling a unit-by-unit effect of the two regions, as well as short of an economy-wide, and not just electrical power market, standpoint. These are likely to be fruitful avenues for future research, not least because of the closed "revenue circle" mentioned above, as concerns the possible positive return to investment of cap-and-trade auction revenues. In short, this analysis began at there being no coherent basis in the debate as to whether Pennsylvania should join RGGI. It ends not with a hypothesized answer, but more importantly with a reasonable basis of comparison somewhat explored. The door is very open for the fine-tuning of the analysis and expensive modeling, as this debate is not one that ought to be answered lightly.

Pennsylvania, then reductions will occur in Pennsylvania (and not other states), thereby increasing its burden under the regulation.

Appendix I – Compliance Scenarios

Scenario 1. Cap Basis: Average of 3 Highest Years 2000-'04 with a 45% Adjustment

RGGI+PA				
Year	Reduction	Cap (tons)	Low Cap	High Cap
2014	0.0%	163,782,213.01	157,152,133.22	196,932,611.97
2015	2.5%	159,687,657.69	153,223,329.89	192,009,296.67
2016	2.5%	155,695,466.24	149,392,746.64	187,209,064.26
2017	2.5%	151,803,079.59	145,657,927.98	182,528,837.65
2018	2.5%	148,008,002.60	142,016,479.78	177,965,616.71
2019	2.5%	144,307,802.53	138,466,067.78	173,516,476.29
2020	2.5%	140,700,107.47	135,004,416.09	169,178,564.38
2021	2.5%	137,182,604.78	131,629,305.69	164,949,100.27
2022	2.5%	133,753,039.66	131,629,305.69	160,825,372.77
2023	0.0%	133,753,039.66	131,629,305.69	156,804,738.45
2024	0.0%	133,753,039.66	131,629,305.69	152,884,619.99
2025	0.0%	133,753,039.66	131,629,305.69	149,062,504.49
2026	0.0%	133,753,039.66	131,629,305.69	145,335,941.87
2027	0.0%	133,753,039.66	131,629,305.69	141,702,543.33
2028	0.0%	133,753,039.66	131,629,305.69	138,159,979.74
2029	0.0%	133,753,039.66	131,629,305.69	134,705,980.25

Meet 2029 Rule?	YES
Tonnage Change:	(30,029,173.35)
% Change:	-18%
Est. PA Change:	(13,371,744.89)
PA in Original Cap:	72,930,877.71
PA % of Original Cap:	45%
PA 2012 Emissions:	115,945,375.04
PA Total Change:	(56,386,242.21)

This scenario uses the RGGI states as well as Pennsylvania. It attempts to calculate Pennsylvania's cap using the same calculation as was used to calculate the other RGGI states' originally, i.e. the average of the emissions in the three years with highest emissions between 2000 and 2004. This calculation also adjusts Pennsylvania's calculated cap downwards by 45%, in keeping with the 45% reduction to the RGGI cap after the 2012 Program Review. This scenario calculation includes a lower version (Pennsylvania has a 50% reduction from base average 2000-2004 emissions, other states have 45%) and a higher version (Pennsylvania has a 20% reduction from base emissions, other states have 45%) for illustrative purposes of the options facing negotiators. The calculation of Pennsylvania's total change is based upon the base cap. Note that in compliance scenarios 1-4, reductions begin in 2015, adding to the total compliance period before 2029, and are based on the idea that joining RGGI would allow a streamlined adoption of emissions reductions in Pennsylvania, and therefore Pennsylvania would begin reducing emissions in 2015, when RGGI is already scheduled to do so.[60] This is a conservative estimate, as PA would likely need more time to begin.

[60] Regional Greenhouse Gas Initiative, *RGGI 2012 Program Review: Summary of Recommendations to Accompany Model Rule Amendments*, 2.

Scenario 2. Cap Basis: PR2012 + PA Average of 3 Highest Years 2000-'04 (no PA adjustment)

RGGI+PA		
Year	Reduction	Reference Cap (tons)
2014	0.0%	223,601,595.84
2015	3.5%	215,775,539.99
2016	3.5%	208,223,396.09
2017	3.5%	200,935,577.22
2018	3.5%	193,902,832.02
2019	3.5%	187,116,232.90
2020	3.5%	180,567,164.75
2021	3.5%	174,247,313.98
2022	3.5%	168,148,657.99
2023	3.5%	162,263,454.96
2024	3.5%	156,584,234.04
2025	3.5%	151,103,785.85
2026	3.5%	145,815,153.34
2027	3.5%	140,711,622.98
2028	3.5%	135,786,716.17
2029	3.5%	131,034,181.11

Meet 2029 Rule?	YES
Tonnage Change:	(92,567,414.73)
% Change:	-41%
PA % Contrib. Cap:	59%
PA Cap 2029:	77,706,697.30
Est. PA Change:	(38,238,677.74)

This scenario uses the RGGI-determined cap following its 2012 Program Review: 91 million short tons.[61] It adds to that Pennsylvania's average annual emissions for the three highest years 2000-2004, attempting to replicate Pennsylvania joining RGGI with an original cap similar to how the RGGI original caps were calculated, and without the Program Review 2012 reduction, which Pennsylvania's emissions were not included in. It then makes 3.5% per year reductions, 2015-2029.

[61] Regional Greenhouse Gas Initiative, *RGGI 2012 Program Review: Summary of Recommendations to Accompany Model Rule Amendments*, 2.

Scenario 3. Cap Basis: RGGI + PA 2012 Emissions

RGGI+PA				
Year	Reduction	Reference Cap (tons)	Low Cap	High Cap
2014	0.0%	205,543,336.46	174,711,835.99	213,765,069.92
2015	3.0%	199,377,036.37	169,470,480.91	207,352,117.82
2016	3.0%	193,395,725.28	164,386,366.48	201,131,554.29
2017	3.0%	187,593,853.52	159,454,775.49	195,097,607.66
2018	3.0%	181,966,037.91	154,671,132.22	189,244,679.43
2019	3.0%	176,507,056.77	150,030,998.26	183,567,339.05
2020	3.0%	171,211,845.07	145,530,068.31	178,060,318.87
2021	3.0%	166,075,489.72	141,164,166.26	172,718,509.31
2022	3.0%	161,093,225.03	136,929,241.27	167,536,954.03
2023	3.0%	156,260,428.28	132,821,364.03	162,510,845.41
2024	3.0%	151,572,615.43	132,821,364.03	157,635,520.05
2025	3.0%	147,025,436.97	132,821,364.03	152,906,454.44
2026	3.0%	142,614,673.86	132,821,364.03	148,319,260.81
2027	3.0%	138,336,233.64	132,821,364.03	143,869,682.99
2028	3.0%	134,186,146.63	132,821,364.03	139,553,592.50
2029	3.0%	130,160,562.23	132,821,364.03	135,366,984.72

Meet 2029 Rule?	YES
Tonnage Change:	(75,382,774.23)
% Change:	-37%
Est. PA Change:	(42,522,828.42)

This scenario assumes that RGGI and Pennsylvania decide to revamp the calculation of their cap in order to more easily comply with the 111(d) regulations. The cap uses the 2012 emissions given by the EPA as the original cap.[62] It then makes reductions of 3% per year, 2015-2029.

[62] Environmental Protection Agency, *Rate to Mass Translation Data File*.

Scenario 4. RGGI 2014 Cap + PA 2012 Emissions

RGGI+PA				
Year	Reduction	Reference Cap (tons)	Low Cap	High Cap
2014	0.0%	206,945,375.04	189,553,568.78	212,742,643.79
2015	3.0%	200,737,013.79	183,866,961.72	206,360,364.48
2016	3.0%	194,714,903.38	178,350,952.87	200,169,553.54
2017	3.0%	188,873,456.27	173,000,424.28	194,164,466.94
2018	3.0%	183,207,252.59	167,810,411.55	188,339,532.93
2019	3.0%	177,711,035.01	162,776,099.21	182,689,346.94
2020	3.0%	172,379,703.96	157,892,816.23	177,208,666.53
2021	3.0%	167,208,312.84	153,156,031.74	171,892,406.54
2022	3.0%	162,192,063.45	148,561,350.79	166,735,634.34
2023	3.0%	157,326,301.55	144,104,510.27	161,733,565.31
2024	3.0%	152,606,512.50	139,781,374.96	156,881,558.35
2025	3.0%	148,028,317.13	135,587,933.71	152,175,111.60
2026	3.0%	143,587,467.61	131,520,295.70	147,609,858.25
2027	3.0%	139,279,843.59	131,520,295.70	143,181,562.51
2028	3.0%	135,101,448.28	131,520,295.70	138,886,115.63
2029	3.0%	131,048,404.83	131,520,295.70	134,719,532.16

Meet 2029 Rule?	YES
Tonnage Change:	(74,494,931.63)
% Change:	-36%
PA Contib. Cap:	56%
PA Cap 2029:	73,422,546.62
Est. PA Change:	(42,522,828.42)

Scenario 4 assumes that RGGI and Pennsylvania decide to use the Program Review 2012 determined 2014 RGGI cap of 91 million tons,[63] and add Pennsylvania's 2012 emissions, as reported by the EPA in the Clean Power Plan technical support documents.[64] It adds the two for an original cap, and then reduces the cap by 3% per year, 2015-2029.

[63] Regional Greenhouse Gas Initiative, RGGI 2012 Program Review: Summary of Recommendations to Accompany Model Rule Amendments, 2.
[64] Environmental Protection Agency, *Rate to Mass Translation Data File.*

Scenario 5. Cap Basis: 2012 Emissions, 2.5% Reduction Per Year Beginning 2018.

Year	Reduction	Cap
2017	0.0%	331,075,501.57
2018	2.5%	322,798,614.03
2019	2.5%	314,728,648.68
2020	2.5%	306,860,432.46
2021	2.5%	299,188,921.65
2022	2.5%	291,709,198.61
2023	2.5%	284,416,468.64
2024	2.5%	277,306,056.93
2025	2.5%	270,373,405.51
2026	2.5%	263,614,070.37
2027	2.5%	257,023,718.61
2028	2.5%	250,598,125.64
2029	2.5%	244,333,172.50

Meet 2029 Rule?	NO
Tonnage Change:	(86,742,329.07)
% Change:	-26%
Est. PA Change:	(30,377,880.05)

This cap scenario is the first of the East Central region calculations. It uses the region the EPA used to calculate renewable generation targets for Pennsylvania: Pennsylvania, New Jersey, Maryland, Ohio, Washington, D.C., Delaware, Virginia, and West Virginia. It removes those states that belong to RGGI, as well as Washington, D.C., and so comprises Pennsylvania, New Jersey, Ohio, Virginia, and West Virginia. This scenario uses the 2012 EPA-calculated mass emissions, with a 2.5% reduction per year beginning in 2018.

Scenario 6. Cap Basis: 2012 Emissions, 2.5% Reduction Per Year Beginning 2017.

Year	Reduction	Cap
2017	2.5%	322,798,614.03
2018	2.5%	314,728,648.68
2019	2.5%	306,860,432.46
2020	2.5%	299,188,921.65
2021	2.5%	291,709,198.61
2022	2.5%	284,416,468.64
2023	2.5%	277,306,056.93
2024	2.5%	270,373,405.51
2025	2.5%	263,614,070.37
2026	2.5%	257,023,718.61
2027	2.5%	250,598,125.64
2028	2.5%	244,333,172.50
2029	2.5%	238,224,843.19

Meet 2029 Rule?	YES
Tonnage Change:	(92,850,658.38)
% Change:	-28%
Est. PA Change:	(32,517,067.43)

This cap calculation uses the EPA-calculated 2012 mass emissions of the East Central states as the basis for the cap. This is accompanied with a 2.5% reduction per year, which is the same as the RGGI annual reduction.

Scenario 7. Cap Basis: 2012 Emissions, 2.6% Reduction Per Year Beginning 2018.

Year	Reduction	Cap
2017	0.0%	331,075,501.57
2018	2.6%	322,467,538.53
2019	2.6%	314,083,382.53
2020	2.6%	305,917,214.58
2021	2.6%	297,963,367.00
2022	2.6%	290,216,319.46
2023	2.6%	282,670,695.15
2024	2.6%	275,321,257.08
2025	2.6%	268,162,904.40
2026	2.6%	261,190,668.88
2027	2.6%	254,399,711.49
2028	2.6%	247,785,318.99
2029	2.6%	241,342,900.70

Meet 2029 Rule?	YES
Tonnage Change:	(89,732,600.87)
% Change:	-27%
Est. PA Change:	(31,425,097.94)

This cap calculation uses the EPA-calculated 2012 mass emissions of the East Central states as the basis for the cap, along with a 2.6% reduction per year, 0.1% above the RGGI annual reduction, beginning in 2018.

Appendix II – Calculation of Pennsylvania Average Emissions Figure

Calculation of Pennsylvania's average emissions figure to use in RGGI+PA scenarios was based upon the methodology of RGGI's initial calculation of state caps. Information regarding the specifics of the calculation used by RGGI is relatively difficult to come by. For example, the actual data on emissions is not available. EPA released a large amount of data on emissions in its eGRID database, but eGRID data is only available for 2000 and 2004, and so is not helpful for a calculation of the average of the three highest annual emissions, 2000-2004. Absent a reliable source of state-by-state emissions by generation type, this analysis used Energy Information Agency state-by-state generation data by generation type along with standard emissions figures for various generation types in order to form emissions data for the years 2000-20004.[65]

The Energy Information Agency provides carbon dioxide emissions factors for electric utility coal in 1980 and 1992.[66] These emission factors are in lbs/mmBTU, thus emissions from plants require heat rates as well. Table 4 summarizes the average heat rates used in this analysis.

Year	Coal (BTU/kWh)	Coal (MMBtu/MWh)	Petroleum (BTU/kWh)	Petroleum (MMBtu/MWh)	Natural Gas (BTU/kWh)	Natural Gas (MMBtu/MWh)
2002	10,314.0000	10.3140	10,641.0000	10.6410	9,533.0000	9.5330
2003	10,297.0000	10.2970	10,610.0000	10.6100	9,207.0000	9.2070
2004	10,331.0000	10.3310	10,571.0000	10.5710	8,647.0000	8.6470
2005	10,373.0000	10.3730	10,631.0000	10.6310	8,551.0000	8.5510
2006	10,351.0000	10.3510	10,809.0000	10.8090	8,471.0000	8.4710
2007	10,375.0000	10.3750	10,794.0000	10.7940	8,403.0000	8.4030
2008	10,378.0000	10.3780	11,015.0000	11.0150	8,305.0000	8.3050
2009	10,414.0000	10.4140	10,923.0000	10.9230	8,159.0000	8.1590
2010	10,415.0000	10.4150	10,984.0000	10.9840	8,185.0000	8.1850
2011	10,444.0000	10.4440	10,829.0000	10.8290	8,152.0000	8.1520
2012	10,498.0000	10.4980	10,991.0000	10.9910	8,039.0000	8.0390
Average:	10,380.9091	10.3809	10,799.8182	10.7998	8,513.8182	8.5138

Table 5. Average heat rates by generation type, 2002-2012.[67]

[65] Generation dataset generated with the Energy Information Agency (EIA)'s Electricity Data Browser. Data is generated by using the pre-generated report 1.2: Net generation by energy source: electric utility, and sorting by annual figures with Filter/Order commands used to add a geography split, specifically New England and the Middle Atlantic.
[66] Hong and Slatick, *Carbon Dioxide Emission Factors for Coal.*
[67] Energy Information Agency, *Electric Power Annual 2013*, Table 8.1.

This analysis used the average of the average heat rates 2002-2012, as shown in Table 4. These heat rates are then used to convert the lbs/mmBTU heat content-based emission factor to lbs/MWh generation-based emissions factor. The results for three major fossil-fuel categories are shown in Table 5.

Emission Rates (lbs/MWh)	
Coal	2,156.11
Petroleum	1,955.15
Natural Gas	996.80

Table 6. Emission rates by fuel type.[68]

These emission rates were combined with the EIA net generation by energy source in the electric utility sector data to form annual emission amounts for Connecticut, Maryland, Massachusetts, Maine, New Hampshire, and Pennsylvania. The purpose of calculating emissions for more than just Pennsylvania in this way was to compare the calculated results of the other states to the calculated figures from RGGI in order to provide some degree of validation to the estimate. Results are provided in Table 6.

[68] Combines figures from Hong and Slatick, *Carbon Dioxide Emission Factors for Coal* and Energy Information Agency, *Electric Power Annual 2013*, from the latter both Table 8.1 "Average operating heat rate for selected energy sources" and Table A.3 "Carbon dioxide uncontrolled emission factors."

CT			
	Generation (MWh)	Emissions (lbs)	Emissions (tons)
2000	32,967,570.00	23,977,147,196.02	11,988,573.60
2001	30,490,646.00	22,243,796,731.35	11,121,898.37
2002	31,311,219.00	20,369,215,135.67	10,184,607.57
2003	29,545,050.00	18,134,563,191.07	9,067,281.60
2004	32,633,408.00	20,658,454,324.71	10,329,227.16
MA			
	Generation (MWh)	Emissions (lbs)	Emissions (tons)
2000	38,697,881.00	51,855,045,395.23	25,927,522.70
2001	38,478,434.00	52,128,925,838.98	26,064,462.92
2002	42,027,818.00	53,915,273,485.52	26,957,636.74
2003	48,385,024.00	60,429,777,988.55	30,214,888.99
2004	47,500,483.00	58,329,095,763.19	29,164,547.88
MD			
	Generation (MWh)	Emissions (lbs)	Emissions (tons)
2000	51,145,380.00	71,013,689,541.79	35,506,844.77
2001	49,062,340.00	68,852,207,694.00	34,426,103.85
2002	48,279,088.00	68,576,329,202.40	34,288,164.60
2003	52,244,237.00	72,728,088,504.39	36,364,044.25
2004	52,052,770.00	70,574,105,591.57	35,287,052.80
ME			
	Generation (MWh)	Emissions (lbs)	Emissions (tons)
2000	14,047,947.00	9,904,831,704.50	4,952,415.85
2001	19,564,821.00	15,268,874,040.77	7,634,437.02
2002	22,535,033.00	17,166,713,342.14	8,583,356.67
2003	18,971,635.00	13,973,339,983.22	6,986,669.99
2004	19,098,885.00	13,140,623,979.69	6,570,311.99
NH			
	Generation (MWh)	Emissions (lbs)	Emissions (tons)
2000	15,031,499.00	9,610,038,510.31	4,805,019.26
2001	15,074,624.00	9,051,321,019.82	4,525,660.51
2002	15,953,078.00	9,515,836,160.21	4,757,918.08
2003	21,597,107.00	16,608,583,533.52	8,304,291.77
2004	23,875,787.00	18,003,945,491.82	9,001,972.75
PA			
	Generation (MWh)	Emissions (lbs)	Emissions (tons)
2000	201,687,980.00	260,586,274,508.13	130,293,137.25
2001	196,576,591.00	251,262,194,887.16	125,631,097.44
2002	204,322,878.00	257,632,724,476.71	128,816,362.24
2003	206,349,513.00	264,498,753,815.93	132,249,376.91
2004	214,658,501.00	270,524,546,722.85	135,262,273.36

Table 7. Calculated emissions based on generation.

Average values from the three highest annual emissions for these states are summarized in Table 7, along with the percent different of that estimate from the RGGI figure where appropriate, Pennsylvania does not have such a figure as RGGI has not calculated a figure for that state's cap.

	Tons	% Difference	Absolute Value %
CT	11,146,566.38	-70%	70%
MA	28,779,024.54	8%	8%
MD	35,719,313.94	-5%	5%
ME	7,734,821.23	30%	30%
NH	7,370,427.92	-15%	15%
RI	3,288,513.32	24%	24%
VT	54,795.52	-96%	96%

Table 8. Calculated caps with differences from RGGI calculations.

As Table 7 showed, differences were often significant from RGGI calculations. These differences come from a variety of sources, such as different data sets, emissions factors, and adjustments to cap figures made by RGGI after calculating one from the average emissions. There is a correlation of -0.61 between the size of the calculated cap and the absolute value of the percent difference from the RGGI cap, meaning that larger calculated caps tend to be somewhat more like RGGI's calculations. This adds to the theory that larger caps, like Pennsylvania, would be less adjusted by RGGI, and therefore Pennsylvania's calculated cap is reasonable for the purposes of this analysis. This Pennsylvania figure, the average of calculated emissions for the three highest years 2000-2004, is used in scenarios 1 and 2.

Appendix III – Output and Methodology of EPA IPM Modeling Results

The EPA's results from modeling the proposed Clean Power Plan in IPM were released alongside the proposed regulation in June 2014.[69] There are output files for numerous scenarios, both regional and state-by-state, and within each scenario are numerous output files with extensive data.[70] The analysis of outputs used in this analysis centered on the Option 1 – Regional scenario, in which option 1 refers to the EPA's expected version of the regulation, and regional meaning compliance by states in groups, as opposed to individually. In particular, data was taken from the RPE file, which is the file of plant-by-plant outputs including generation, emissions, capacity, fuel type, and so on.[71]

In order to hone in on the region in question, this analysis sorted the data by model region and then on a plant-by-plant basis for states, since the regions cross state borders. The model regions are shown on the cover of the documentation, and by filtering based on the regions that at least partially overlap a state in the region in question, all plants in the region in question will be included in the sorted data. The "Unit Long Name" column of the data is used to make the search finer, as units' long names include the abbreviation of the name of the state in which they are located.[72] To locate all plants in Pennsylvania, for example, the regions PJM_AP, PJM_ATSI, PJM_EMAC, PJM_PENE, and PJM_WMAC are further sorted by all unit long names including 'PA' somewhere in their name. By sorting by fuel type and adding generation figures, the following charts were made summarizing data on generation amounts by fuel type over the time period covered by the IPM runs, 2016-2050. The three charts cover this data for Pennsylvania, the East Central region as proposed by this analysis (with RGGI states and the District of Columbia

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69
70 Guide to outputs
71 *Ibid.*, 1.
72 Cite data directly

removed), as well as the EPA's proposed East Central region, which includes Delaware, Maryland, and Washington, D.C. The two former states are already a part of RGGI, and the latter much smaller than the remaining states, and so this analysis did not consider them a part of a viable compliance group.

As mentioned in the section interpreting this data, the model solves for compliance over the entire region including Delaware, Maryland, and D.C., and so the results discounting them have to be read with the understanding that there is error inherent in that they were included in the calculation of the outputs, but are not presented as part of the outputs in this analysis, except where noted. However, and as mentioned in the section interpreting the results, there is not a significant difference in the region with and without these three areas, in terms of broad trends. Thus, the modeled outputs, though not modeled on the exact basis of this paper's proposed East Central region, are still quite useful in showing the possible least-cost means of compliance for the group and state, and serve as a strong basis for understanding the options facing policymakers as they consider this and other regional compliance scenarios.

Pennsylvania Generation Modeled Output (GWh)														
	Biomass	Coal	Fwaste	Hydro	LF Gas	MSW	Natural Gas	Non-Fossil	Nuclear	Oil	Pet. Coke	Solar	Waste Coal	Wind	**Total**
2016	2,721.85	78,646.63	-	3,893.41	1,052.62	1,716.57	46,185.34	178.59	78,462.93	-	331.65	102.13	8,477.50	4,961.46	226,730.68
2018	1,973.19	79,725.51	-	3,893.41	1,052.62	1,716.57	38,728.19	178.59	78,462.93	-	331.65	102.13	8,477.50	6,621.93	221,264.21
2020	1,930.15	78,307.41	-	3,893.41	1,052.62	1,716.57	52,603.93	178.59	78,462.93	0.31	-	102.13	10,297.90	6,621.93	235,167.88
2025	2,338.12	70,011.81	-	3,893.41	1,052.62	1,716.57	52,225.68	178.59	78,462.93	0.31	-	102.13	10,297.90	6,768.50	227,048.56
2030	2,181.61	65,258.38	-	3,893.41	1,052.62	1,716.57	51,219.55	178.59	78,462.93	0.31	-	102.13	10,297.90	6,768.50	221,132.49
2040	2,015.11	58,406.54	-	3,391.64	1,052.62	1,716.57	48,054.61	178.59	45,647.94	-	-	102.13	10,297.90	6,768.50	177,632.14
2050	2,045.58	60,887.43	-	3,391.64	1,052.62	1,716.57	47,460.65	178.59	-	-	-	102.13	10,297.90	7,863.44	134,996.54

Table 9. Summary of Pennsylvania modeled generation by fuel type.

Modified East Central Region Generation Modeled Output (GWh)														
	Biomass	Coal	Fwaste	Hydro	LF Gas	MSW	Natural Gas	Non-Fossil	Nuclear	Oil	Pet. Coke	Solar	Waste Coal	Wind	**Total**
2016	7,150.79	270,467.35	203.59	10,046.36	2,118.80	3,574.64	115,929.35	1,161.58	155,324.22	118.26	331.65	766.81	8,845.57	11,127.67	587,166.65
2018	4,593.89	274,236.77	203.59	9,754.31	2,118.80	3,574.64	102,537.77	1,161.58	155,401.24	-	331.65	766.81	8,845.57	18,629.00	582,155.62
2020	5,457.82	266,374.22	203.59	10,442.36	2,118.80	3,574.64	115,509.94	1,161.58	150,616.67	11.35	-	766.81	10,665.97	19,401.10	586,304.87
2025	6,640.54	252,934.59	203.59	10,180.65	2,118.80	3,574.64	113,166.32	1,161.58	150,616.67	10.86	-	766.81	10,665.97	27,380.85	579,421.87
2030	5,895.95	247,717.00	203.59	10,156.14	2,118.80	3,574.64	134,039.69	1,161.58	150,616.67	4.35	-	766.81	10,665.97	27,380.85	594,302.05
2040	6,619.01	235,053.29	203.59	8,096.80	2,118.80	3,574.64	311,321.17	1,161.58	74,514.97	-	675.79	766.81	10,665.97	27,380.85	682,153.28
2050	7,124.08	240,298.39	203.59	8,096.80	2,118.80	3,574.64	438,718.95	1,161.58	7.81	-	884.41	766.81	10,665.97	31,712.41	745,334.23

Table 10. Summary of East Central regional generation excluding RGGI states and D.C.

Modified East Central Region Generation Modeled Output (GWh)															
	Biomass	Coal	Fwaste	Hydro	LF Gas	MSW	Natural Gas	Non-Fossil	Nuclear	Oil	Pet. Coke	Solar	Waste Coal	Wind	**Total**
2016	8,637.37	292,541.19	924.67	11,992.28	2,262.55	4,319.84	138,691.54	1,161.58	169,528.25	364.15	331.65	1,544.19	8,845.60	13,098.23	654,243.09
2018	6,012.72	296,511.04	924.67	11,700.22	2,262.55	4,319.84	125,729.72	1,161.58	169,605.27	11.73	331.65	1,544.19	8,845.60	21,551.01	650,511.79
2020	6,799.51	286,868.62	924.67	12,388.28	2,262.55	4,319.84	134,861.20	1,161.58	164,820.71	10.86	-	1,544.19	10,665.97	22,323.11	648,951.10
2025	7,800.57	269,374.99	924.67	12,126.56	2,262.55	4,319.84	133,627.13	1,161.58	164,820.71	4.35	-	1,544.19	10,665.97	30,302.86	638,935.98
2030	6,966.44	262,577.50	924.67	12,102.05	2,262.55	4,319.84	153,592.74	1,161.58	164,820.71	-	-	1,544.19	10,665.97	30,302.86	651,241.10
2040	7,449.72	245,438.33	924.67	10,042.71	2,262.55	4,319.84	331,674.06	1,161.58	74,514.97	-	675.79	1,544.19	10,665.97	30,302.86	720,977.25
2050	8,202.33	252,233.24	924.67	10,042.71	2,262.55	4,319.84	465,561.79	1,161.58	7.81	-	884.41	2,692.47	10,665.97	34,639.53	793,598.91

Table 11. Summary of East Central regional generation including RGGI states and D.C.

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