How Modeling Informed the Design of the US Regional Greenhouse Gas Initiative

October 2010

Abstract

Extensive modeling was undertaken during the design phase from 2004-2005 of the Regional Greenhouse Gas Initiative (RGGI) in the northeast United States. A model commonly used by US federal agencies and utilities, called the Integrated Planning Model or IPM, was selected. The modeling revealed key truths about behavior generally and where the best and most economic opportunities for greenhouse gas (GHG) emissions reductions lay, among them:

- Reducing consumption and improving the performance of energy used—that is, increasing end-use energy efficiency—is the most cost-effective means to reduce GHG emissions.

- A cap-and-trade program alone would not be enough to bring about reductions in GHG emissions. Achieving real reductions in emissions would instead require that the program be converted to a "cap-and-invest" regime, which calls for CO_2 allowances (pollution permits) to be auctioned and the resulting revenues to be invested in reduction and prevention measures, specifically energy efficiency and other clean energy resources.

- Demand reductions resulting from investment in energy efficiency would create a positive feedback loop in the program, consisting of three benefits: (1) reductions in demand will reduce consumer bills and reduce GHG output; (2) reductions in GHG output will reduce demand for emissions allowances; and (3) the reduction in demand for allowances will put downward pressure on their prices, thereby further reducing consumer bills. In this way, RGGI achieves its targets without relying on significant increases in carbon prices to effect changes in behavior.

Overview of RGGI

The Regional Greenhouse Gas Initiative is the first program to set a mandatory cap and a schedule for reductions of power sector emissions of greenhouse gases in the United States. The ten northeastern states participating in RGGI[1] represent 20% of the US GDP (2007). RGGI applies to electric generating units that are larger than 25 MW, of which there of more than 600 in the RGGI region. Their annual GHG emissions amount to approximately 188 million tons. From 2009-2014, GHG emissions from these units will be stabilized at 2002-2004 baseline levels, after which they will be reduced 2.5% per year through 2018. Total emissions in the RGGI region will be reduced 10% below the established baseline, or by about 19 million tons per year, by 31 December 2018.

[1] Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont.

Driving Forces behind the Modeling for RGGI

Determining the quantity of GHG emissions to be reduced and evaluating the potential economic impacts of mandatory reductions required extensive modeling. Of the numerous questions that the analytic work would examine, three were of chief concern to the governors of the RGGI states.

First, the RGGI governors were deeply concerned about potential economic impacts of imposing mandatory GHG reductions. Electricity rates in the RGGI states are among the highest in the United States—even small increases to rates could create public opposition and political difficulties for these governors. As a result, the governors directed their staffs to evaluate the potential costs of RGGI on electricity rates.

Second, although the RGGI states have forty years of experience collaborating on environmental and energy issues,[2] in the past these efforts had been facilitated by federal support and oversight. In the case of RGGI, the states were on their own. In this respect, RGGI represented an unprecedented degree of state leadership. While states also drove the creation of the acid rain and NO_X budget programs in the 1990s, both of these programs were eventually adopted by the federal government. In those instances, the US Environmental Protection Agency (EPA) took responsibility for technical analyses and program implementation. For RGGI, not only was there no federal support, but the EPA was actually prohibited from working on greenhouse gas regulations. Without federal involvement to guide policy development and influence stakeholders, building consensus among the states was significantly more difficult than it had been in the past. Modeling collective impacts across the region was considered to be an important way to foster solidarity among the states.

And, third, RGGI designers hoped that, even without federal support, the program would lay the groundwork for a future national GHG program. RGGI was therefore designed to have the potential to integrate with such a program. With this in mind, designers from all states agreed to use a single modeling platform to calculate impact scenarios.

They selected a model known as the Integrated Planning Model (IPM), a model developed by a Washington, DC consulting firm, ICF Consulting. IPM is the platform used by the EPA and utilities to assess impacts of environmental regulations on electric system planning and dispatch and on economic output. The governors and their staffs agreed that, by using this model, RGGI would create a body of defensible information for subsequent regulatory proceedings at the state, regional, and national levels. Because the model is generally well-known and understood by a majority of affected parties, designers also hoped that using IPM would help to overcome some of the obstacles posed by the lack of federal support for the program.

Description of the IPM model

IPM is an electric system dispatch model routinely used by many federal agencies, including EPA and Department of Energy (DOE), and electric utilities to evaluate the economic and system impacts of various policies. It is also used for long-term planning purposes. For example, EPA

[2] Such issues include acid rain, technology requirements for new generating units, and advanced energy efficiency programs.

used IPM to evaluate the effects of more stringent NO_X and SO_X regulations on US electricity markets and emissions.[3] IPM assumes economic dispatch; that is, that generating units are run according to their operating costs—from lowest cost to highest. It also assumes that new generation is acquired according to the same general principle: units with the lowest total costs (both capital and operating) over their expected lifetimes will be chosen first.[4]

It is important to acknowledge that, like any model, IPM has limitations. For one, it is best applied at a regional scale, such as to a geographic area corresponding to a regional transmission operator (RTO). Multiple regions can also be analyzed. But the precision of IPM is reduced for analysis of areas smaller than RTO regions and for analysis of single states. IPM does not account for the several units in New England that operate outside the economic dispatch order to provide for voltage support and load following. IPM also makes no assumptions with regard to siting new coal or nuclear plants. Distributed resources, such as renewables and combined-heat-and-power (CHP) can be evaluated, but only as a block (i.e., so many MW of capacity or MWh of energy) rather than as distributed throughout the electricity grid. Energy efficiency resources are also added as a block. Projections of fuel prices and construction costs are developed with linear assumptions of increases or decreases. IPM results include the capacity of new generation that will be built or retired within the region analyzed by the model. IPM does not provide specific locations for these generation additions or retirements.

IPM is capable of analyzing literally dozens of different variables to show their potential effects. However, for modeling results to be useful to policy makers, it is important to constrain the analysis to the few key variables that are expected to have the highest degree of influence on outcomes. An important objective of the modeling was *not* to predict that electricity rates *would* increase a certain percentage over a certain number of years. But instead the objective was to determine *if* electricity rates increase and their relative changes are forecast to occur based on the assumptions made, the degree of variability evaluated for these assumptions, and the degree to which the chosen policy and its variability influence the rate of change in electricity rates. For this reason, the variables analyzed were chosen to forecast boundary effects, maxima and minima. The actual impact of program implementation was expected to fall somewhere between the two extremes.

Modeling Results

Several dozen individual modeling runs were completed to analyze the potential effects of implementing RGGI. The few key modeling runs and their results will be discussed here.[5]

---

[3] Sam Napolitano's (EPA) presentation to the RAQM in Beijing on 6 November 2008 referred to IPM on several occasions.

[4] This should be qualified in two ways. The first is that the model recognizes that different needs are served by different kinds of generation—baseload, intermediate, and peaking—and that these needs are driven by the expected shape of demand across days, seasons, and years. The average cost per kilowatt-hour of a baseload plant might be significantly less than that of a peaking plant, but this would not be the case if the baseload plant were to be used only for peaking needs. In other words, the model chooses the lowest total cost resource *for the particular service it will provide*. And, second, the model does not account for the environmental damage costs of the various kinds of resources. These costs are real and should, as a general principle, be recognized in planning and operational decisions. A cap-and-trade program is one means of "internalizing" those costs in the system.

[5] For further detail, see www.rggi.org/about/history/modeling.

Reference Case

The reference, or business-as-usual, case establishes a basis against which other modeling results can be compared. The reference case assumes that current environmental conditions do not change, and that new power plants will be constructed and operated according to the narrow economics described earlier. IPM therefore assumed that the multi-pollutant EPA regulatory package would be implemented.[6] These rules included CAIR (Clean Air Interstate Rule for NO_X, SO_X and fine particulate), CAMR (Clean Air Mercury Rule) and CAVR (Clean Air Visibility Rule). At the state level, IPM assumed that more stringent requirements for NO_X, SO_X and mercury emissions (enacted in several states) would remain in effect. Inputs to IPM also included state RPS requirements, and assumed that the required percentage of renewable resources would remain constant after the latest year included in a particular state statute.[7] Costs associated with fuels and power plant construction are based on current EIA (Energy Information Administration) data and forecasts.

The reference case results concluded that, for the RGGI region as a whole:

- Electricity prices (expressed in $/MWh) would rise continuously, to about a 1% annual increase in 2012, 1.5% annual increase in 2015 and 1.7% annual increase in 2018.
- CO_2 allowance prices begin at about $2 each in 2009, rise to $2.50 in 2012, increase to $3 in 2015, and hit about $3.75 in 2018.
- Price triggers and safety valves do not go into effect. The percentage of offsets permitted to meet compliance obligations remains constant at 3.3% (as compared to the obligation to reduce emissions 10% by December 31, 2018).[8]

The modeling results for the reference case reflect the modest initial design of RGGI— that emissions are capped at current levels for the first two compliance periods (six years), and decline by 2.5% each year thereafter.

Non-Reference Cases

Due to the ground-breaking nature of RGGI and a need to reassure the governors of the RGGI states that implementing the program as designed would reduce greenhouse gases without damaging states' economies, extensive additional modeling runs were completed. These runs analyzed many potential effects and sensitivities. The most influential factors evaluated were:

- *Differences in emissions reduction trajectories*. Modeling evaluated capping emissions at current levels (which is a reduction of emissions from the reference case, since without any constraints, GHG emissions from the power sector would continue to increase by

[6] Ultimately, the legality of the Clean Air Mercury Rule was called into question. In 2008, a federal court ruled it invalid and sent it back to EPA to be amended. To date, it has not been implemented.

[7] For example, if a state statute required an increase in renewable energy resources to 20% by 2020, IPM assumed that in 2021 and beyond that at least 20% of the resources would continue to be renewable for this state.

[8] RGGI rule includes stipulations to allow for compliance flexibility through allowance price triggers in the event that the price gets too high. There are two phases of price triggers. In the first, if the rolling 12 month average price of the allowances meets or exceeds $7.00 (2005 dollars), then units are permitted to meet a greater portion of their obligation through offsets, from 3.3% to 5% of their obligation. A second phase price trigger occurs when the allowance price reaches a rolling 12 month average of $10.00 (2005 dollars), allowing greater compliance flexibility through the use of offsets for up to 10% of compliance obligation and a through the extension of the compliance duration period.

1-1.5% each year) and reducing levels by various percentages up to a maximum of 35% compared to the reference case.

- *Energy efficiency (EE) programs*. RGGI states operate successful energy efficiency programs today.[9] Modeling evaluated the effects of those programs on GHG emissions, and then analyzed the effects on emissions from the doubling and tripling of current EE investment.
- *Electricity sales between RGGI states and non-RGGI regions*. Differences in the stringency of environmental requirements across regions can create incentives to export electricity generated from areas with lax regulations to areas with more strict requirements. This is referred to as "leakage," and it can affect the degree to which the capped region achieves its environmental goals.
- *The allowance price for carbon*. The RGGI program currently applies only to electric generating units and only the emissions of carbon dioxide. The other five Kyoto Protocol gasses are not currently part of RGGI.

Other factors evaluated included: high and low natural gas prices, increasing state Renewable Portfolio Standards (RPS), and the economic effects of auctions on consumer benefits.[10] These factors will be described in greater detail in the following section.

Emissions Reduction Trajectories

Modeling evaluated emissions from the RGGI region under five scenarios: the reference or business-as-usual (BAU) case, and reductions of 10%, 15%, 25% and 35% below the business-as-usual level by 2024. All emissions reductions discussed here were compared to those that were forecast to occur under a BAU scenario. Electricity load growth was assumed to continue at current rates of 1.2-1.9% annually for the period from 2006 through 2024.

Under the reference case, emissions in the RGGI region increase by 25 million tons (or about 20%) from 2006 to 2024. The 35% reduction from BAU produced the only scenario where GHG emissions declined, as compared to a 2006 baseline. In the 35% reduction scenario, emissions decline by 15 million tons, or about 10%. For the remaining three scenarios evaluated, emissions increase by about 17% in the 10% reduction from BAU scenario, increase by 10% in the 15% reduction from BAU scenario, and stay constant under the 25% reduction from BAU scenario.[11] See Table 1.

---

[9] According to the American Council for an Energy-Efficient Economy (ACEEE), the RGGI states are consistently ranked in the top ten states nationally for energy efficiency.

[10] Note that modeling evaluated an auction level of 25% of allowances, the minimum level which was agreed to by the RGGI states in the December 2005 MOU. No modeling runs were completed for today's RGGI program, where nearly 100% of allowances are auctioned in many states.

[11] Note that differences exist between the emissions reflected in the IPM modeling results and those included in the final RGGI state budgets. State budgets reflect the results of negotiations that occurred over the course of the design of RGGI.

Table 1. Projected Emissions in 2024 under Modeled Scenarios

Scenarios (relative to BAU in 2024)	**Modeling Results (for 2024 over a 2006 baseline)**
Business as Usual	Increase 20%
10% Reduction	Increase 17%
15% Reduction	Increase 10%
25% Reduction	Constant at 2006 levels
35% Reduction	Decrease by 10%

Energy Efficiency Programs

The reference case results included the existing energy efficiency programs that were being run by each of the RGGI states. In the reference case, these programs were assumed to continue at their current funding levels. Additional modeling was done to evaluate the effects of increased funding for energy efficiency at two levels: 1) at twice the levels being achieved by existing state programs; and 2) all cost-effective energy efficiency (namely all energy efficiency that could be economically justified when compared to the alternatives and therefore unconstrained by arbitrary budget limits).

Modeling of double investment levels reflected that: CO_2 emissions remained constant for the period from 2006 to 2024. Emissions for other pollutants, although not the target of RGGI, were also significantly reduced by increased investment in energy efficiency. Over the same period, NO_X emissions declined by 35%, SO_X emissions declined by 65%, and mercury emissions declined by 50%.

Modeling the effects of funding all cost-effective energy efficiency reflected that: CO_2 emissions decreased by 10% over the period from 2006 to 2024. Emissions for other pollutants declined by 35% for NO_X, 65% for SO_X, and 50% for mercury, or at about the same levels as for the previous run. This may be explained by a fact described earlier: IPM includes the inputs of the national acid rain and CAIR (Clean Air Interstate Rule) programs that required significant NO_X and SO_X reductions to be achieved in 2009 and 2013.[12]

Effects on Electricity Sales (Leakage)

Leakage is a problem that can reduce the degree to which environmental programs achieve their design objectives. The cost of controlling GHG emissions may put power plants within the RGGI region at an economic disadvantage to plants outside the region and promote the purchase and investment in electricity from polluting sources outside the RGGI region, thereby diluting the overall efforts to reduce GHG emissions. From an economic perspective, leakage disadvantages generators located inside of RGGI several ways:

- The units outside RGGI have lower operating costs (hourly electricity prices outside of RGGI are $4-8 per MWh less than those of the RGGI states).[13]

---

[12] CAIR was remanded to the EPA in July 2008 to address concerns raised by the US District Court in DC, but this outcome could not have been foreseen in 2005 when the IPM model was run. EPA announced in December 2008 that it had addressed the concerns of the District Court and was intending to move forward with the program, with the same emissions reductions objectives as in the earlier rule.

[13] Union of Concerned Scientists, "Importing Pollution, Coal's Threat to Climate Policy in US Northeast," December 2008, available online at

- Whereas most RGGI states have restructured electricity markets, most states adjacent to the RGGI region do not. Restructured electricity markets mean that the hourly clearing price is set by the highest-priced generating unit to operate in that hour. All generators that operate during that hour are paid the same price. Within RGGI, natural gas-fired units set the price most of the time. Cheaper and older coal plants that sell into RGGI therefore receive the higher price. Because the cost of controlling GHG emissions would raise the clearing price, under RGGI, these polluting generators make more money.
- There is the potential for less-expensive, coal-generated electricity to be transmitted into RGGI region, displacing many of the region's cleaner units and causing them to run fewer hours.

Note that even before RGGI, electricity was imported into the RGGI region. Many states outside of RGGI were net exporters for years before RGGI was even considered as a concept. But, the effect of RGGI, which set a carbon price for the first time, highlighted the differences in generating costs between RGGI and non-RGGI states. Adding an effective price of $1.50-$3.00 per MWh increased the profit potential for units located outside of RGGI, but which had no carbon abatement costs or control responsibilities themselves. These generating units then bid into the RGGI market. While they bid only their marginal operating costs, they receive the higher market price of the marginal units (the additional $1.50-$3.00/MWh), thus further increasing their profits.

Effects on Electricity Imports into the RGGI Region

Several factors affect the quantity of electricity imported into the RGGI region:[14]

- *Stringency of the emissions cap*. The deeper the reduction, the more electricity that would be expected to be imported into RGGI.
- *Differential electricity prices*. The higher the carbon allowance price, the greater the quantity of electricity that would be expected to be imported into RGGI region.
- *Energy efficiency*. Reducing consumption within RGGI has two important benefits: (1) energy efficiency reduces the need to import electricity at all, and (2) it reduces electricity prices, therefore narrowing the differences between RGGI and non-RGGI regions, and reducing the demand that creates incentives to export electricity from non-RGGI regions into RGGI.

In the reference case, electricity imports were forecast to decline by two-thirds (from 90 to 35 TWh) for the period from 2006 to 2024.[15] In the 35% reduction from BAU case (representing an actual emissions reduction of 10% from the 2006 baseline), imports decline slightly from 90 TWh to 80 TWh in 2012, then increase again, reaching 100 TWh by 2024. This level of imports is driven by differences in electricity prices, which are influenced by carbon allowance prices. For the 10% reduction from BAU case (in which RGGI region emissions increase 17% from 2006 to 2024), the carbon allowance price was effectively zero (less than $1), since that level of reduction is modest and non-binding. Power imports under the 10% reduction from BAU scenario are approximately

---

http://www.synapse-energy.com/Downloads/SynapseReport.2008-12.UCS.Importing-Pollution.08-063.pdf. Figure 13, based on carbon prices of $0 and $3 per ton. See also PJM, 2005 State of the Market Report, pg 299.

[14] This analysis assumes that regions outside RGGI have not imposed any restrictions on GHGs, no national program to reduce GHGs exists, and no new transmission construction or upgrades occurs.

[15] Data from IPM modeling results was presented by ICF to RGGI Stakeholder Group on April 6, 2005, available online at http://www.rggi.org/design/history/stakeholder_meetings.

the same as those for the reference case. For the 35% reduction from BAU scenario, allowance prices begin at about $4.25 in 2006 and rise to $12 in 2024.

Energy efficiency, both the double funding level scenario and for all cost-effective measures, was forecast to decrease the level of electricity imported into RGGI by about 30%.[16]

Table 2. Modeling Results for Emissions Reduction and Electricity Imports

Scenarios (from BAU in 2024)	Emissions (for 2024 over a 2006 baseline)	Change in Electricity Imports (2024)	Carbon Allowance Price
Business as Usual	Increase 20%	Decrease 55 TWh	n/a
10% Reduction	Increase 17%	Decrease 55 TWh	< $1 (2009 through 2024)
15% Reduction	Increase 10%	Decrease 30 TWh	$1 (2009) - $3 (2024)
25% Reduction	Constant at 2006 levels	Decrease 10 TWh	$3 (2009) - $6.50 (2024)
35% Reduction	Decrease by 10%	Increase 10 TWh	$4.25(2006) - $12 (2024)

How Modeling Results Were Incorporated into the RGGI Design

The IPM results significantly influenced decisions made by the RGGI states on program design and implementation.

Implementation of RGGI should result in real reductions of GHG emissions in the region. The RGGI governors agreed that any program implemented should produce actual reductions in real terms, not just be a decrease from the reference, or business-as–usual case. The 35% reduction from BAU was adopted. This level of emissions reduction was forecast to be 10% below actual GHG emissions from a 2006 baseline. The RGGI designers were also influenced by a 2004 report produced by the National Commission on Energy Policy (NCEP) that urged utility sector policies to focus on "slowing, stopping, and reducing" GHG emissions. Both the modeling and the NCEP report factored into the decision to cap GHG emissions at current levels for six years (2009-2014), and then to decrease them 2.5% each year through 2015, for a cumulative reduction of 10% below the 2006 baseline.

Reducing consumption and improving the performance of energy used is the most cost-effective means to reduce GHG emissions. Many RGGI states operate effective energy efficiency programs. Most of the RGGI states also completed climate change action plans in which energy

[16] The above paragraphs review the main variables that were evaluated for RGGI by the IPM model. Many other variables were also evaluated, and details for these can be found in the RGGI modeling results (www.rggi.org). The price of carbon is important, but it was not analyzed as a discrete variable. In other words, the modeling questions focused on what the allowance price was forecast to be based upon assumed levels of reduction, not what would the reductions be if the carbon allowance price was X? Also, sensitivity runs were performed to develop a supply curve for offsets. The curve was developed off a 25% reduction from BAU (equivalent to keeping RGGI region emissions constant for 2006 to 2024). The model assumed that CDM quality offsets would be permitted, the 2009 allowance price would be $6.50 each, Canada's GHG emissions would stabilize in 2008, and US GHG emissions would stabilize in 2015. Based on these assumptions, the modeling results for 2015 forecast that about seven million tons of offsets would be available for $1 each, rising to 7.5 million tons of offsets being available for less than $10 per.

efficiency was consistently ranked among the top ten measures to reduce GHG emissions. The modeling results helped to confirm the significance of energy efficiency to reduce GHG emissions. Not only was energy efficiency forecast to be effective in meeting the RGGI emissions reduction goals, the modeling showed that energy efficiency also helped to maintain the integrity of those reductions by reducing the amount of electricity imported into RGGI from uncapped areas just outside RGGI. Energy efficiency also was shown to reduce peak electricity prices, which further help in decreasing the incentive for power plants outside of RGGI to export their generation.

Cost-containment mechanisms matter. Modeling results forecast electricity prices to rise modestly (1-2%) from 2009-2015. This increase is small compared to the double-digit fuel price- and construction cost-driven increases that many jurisdictions are experiencing currently. However, the RGGI governors were quite concerned about any increases in electricity rates that would be the result of a state program to reduce GHG emissions. The governors therefore insisted that the RGGI program include two mechanisms that would help minimize any increases in electricity rates:

- A change in the number of offsets that can be claimed by participants, triggered by an allowance price of $7 (2005$); if allowance prices equal or exceed this price, the amount of offsets allowed will double; and
- A “safety valve” that freezes the level of the cap for up to three years. The price of the safety valve is set equal to $10 (2005$), adjusted by the consumer price index plus 2% each year.

Neither mechanism is triggered on the basis of spot market prices for allowances or the results of a single RGGI auction. Instead, the allowance prices must remain at or above the trigger levels for an extended duration—i.e., 14 months—referred to as the “settling” period.

Conclusion

Development of RGGI required a willingness to accept a higher degree of political risk by the RGGI governors than federal policymakers were, and still now are, prepared to shoulder. The governors and their staffs acknowledged that the certainty of the science demanded actions to reduce emissions, and that such actions should be completed regardless of federal inaction. However, the potential economic effects from implementing a state-driven program could have undermined the political support that was necessary in order for it to be successful and for it to serve, as intended, as a model that would influence the design of a national program to reduce GHG emissions.

The decision to complete modeling had many important ramifications for RGGI and established a precedent that subsequent state-driven programs, such as the Western Climate Initiative and the Midwestern Governor’s Association have also adopted. Using credible analytical tools, the same tools used by EPA and utilities, to forecast economic and energy impacts from RGGI had the following impacts:

- Helped to establish the level of emissions reductions, their timing, and annual reduction percentages;
- Led to the decision to auction allowances and direct the resulting revenues to energy efficiency and renewable energy programs; and

- Formed a strong analytical basis that the RGGI states needed in their subsequent regulatory proceedings to defend the program and its architecture.

The success of RGGI also persuaded the states that they could continue to expand their efforts to address climate change, even while Washington and Congress continued to ignore the issue. The RGGI states and California were influential in transforming the California Climate Action Registry to The Climate Registry (TCR) during 2007. TCR now includes 40 US states, several Mexican states, and most of the Canadian Provinces. RGGI's success has also influenced Congress. The Lieberman-Warner bill (S 2191, 2007) contained provisions to auction a substantial portion of allowances for energy efficiency and renewable energy development. Such a provision would not have been included without the leadership of the RGGI states, and the modeling completed for the states that showed that such investments would be most effective in reducing GHG emissions.