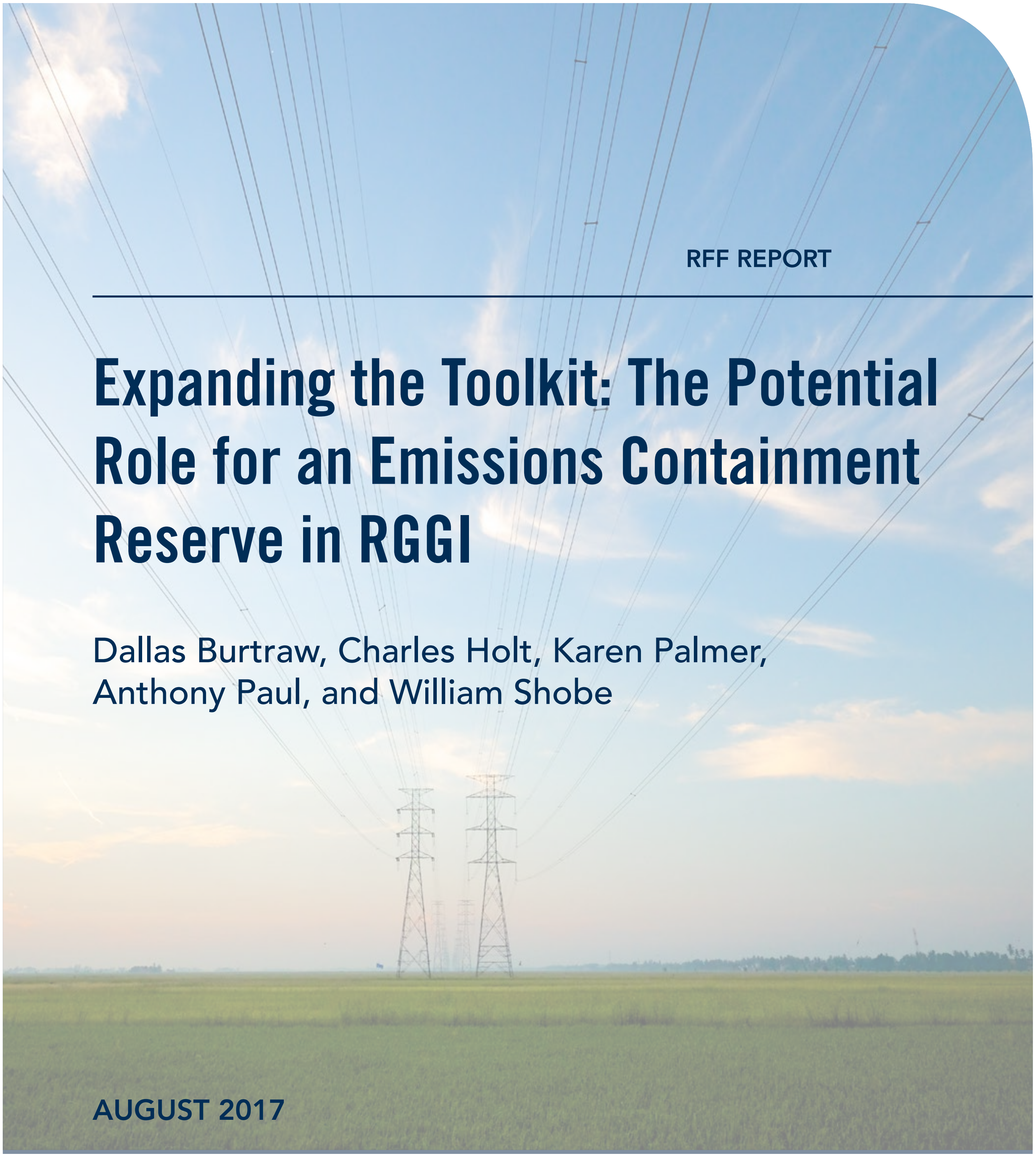

RFF REPORT

Expanding the Toolkit: The Potential Role for an Emissions Containment Reserve in RGGI

Dallas Burtraw, Charles Holt, Karen Palmer, Anthony Paul, and William Shobe

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RESOURCES FOR THE FUTURE

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Abstract

Since the Regional Greenhouse Gas Initiative (RGGI) launched in 2009, low allowance prices have been frequent and precipitated important design adjustments at the first program review. As a part of the ongoing 2016 program review, RGGI is considering a new provision, known as an emissions containment reserve (ECR), that would incorporate a minimum price for specified quantities of allowances under the cap and thereby introduce steps into the allowance supply function. This report uses simulation modeling and economic experiments to explore the implications of introducing an ECR and varying its design parameters. Whenever the ECR is in effect it allows advantageous changes in the demand for emissions allowances to be shared between the economy and the environment. From a behavioral perspective we find the ECR does not hinder price discovery in allowance markets.

Key Words: cap and trade, climate policy, greenhouse gas, climate change, electricity

JEL Codes: Q48, Q54, Q58

Read the executive summary—Expanding the Toolkit: The Potential Role for an Emissions Containment Reserve in RGGI.

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Contents

1. Introduction

The Regional Greenhouse Gas Initiative (RGGI) is a cooperative of nine Northeastern states that sets a cap on carbon dioxide (CO_2) emissions from electricity generation. At its inception on January 1, 2009, it was the only such program in the United States. It was also seminal as the first cap-and-trade program for CO_2 emissions anywhere in the world to auction almost all of its emissions allowances. Since the dawn of RGGI, power sector CO_2 emissions in the region have fallen substantially, and $2.7 billion of auction proceeds have been generated through June of 2017 and spent primarily on “strategic energy and consumer programs.” The program is viewed by its participants as a great success.

Over time, the rules of RGGI have evolved and continue to do so. A 2012 Program Review led to a reduction in the trajectory of the emissions cap and the retirement of all allowances that were not sold at previous auctions. These changes amounted to an increase in the stringency of the program in response to compliance costs that were lower than anticipated during its first three years. Indeed, the allowance prices that cleared the quarterly auctions beginning with the fifth one in September 2009 were at or very near the auction reserve price (also known as the price floor). This outcome persisted until the 2012 Program Review was completed in 2013. The auction clearing price came in substantially above the floor for the first time since 2009 in September of 2013.

The increased stringency introduced by the 2012 Program Review harvested the opportunity to improve the environmental performance of RGGI that was created by lower-than-anticipated compliance costs. Now there is a 2016 Program Review taking place that is intended to adjust the program rules again, and again compliance costs are lower than anticipated. Allowance prices rose after 2013, even clearing the auction at a price above the cost containment reserve (CCR) price six times, but since the December 2015 auction prices have been declining. The last auction, in June 2017, cleared at a price near the price floor again and was the lowest clearing price since December of 2012.

There is a recognition that even after the completion of the 2016 Program Review, compliance costs and allowance prices may again settle in at levels that are lower than expected, which has been the experience across most market-based programs. One of the adjustments under consideration is the introduction of an emissions containment reserve (ECR). An ECR is a mechanism to support the program by reducing the number of allowances that are sold at low prices. It would specify a minimum price for a portion of the allowances offered at auction. Those allowances would not sell at a price below the ECR price. The ECR can be thought of as a “soft” price step because it does not identify the minimum possible price in the auction overall; it identifies the minimum price for only a portion of the allowances. The “hard” price floor that is the auction reserve price applies to all allowances. No allowances sell below the hard price floor and thus it provides a minimum overall auction price. An ECR is an automatic response in allowance auctions that would yield some environmental benefits in the event that compliance costs again fall below the anticipated level.

In this report, we look at how an ECR could work in the RGGI context and what effects it might have on allowance market performance and on electricity market outcomes. We employ a combination of simulation modeling, laboratory market experiments, and analytical investigation. In our simulation modeling, we consider a number of different scenarios that would reduce demand for allowances relative to expectations and how different approaches to implementing an ECR—including single-step and multi-step designs, affect equilibrium outcomes. In our experiments, we analyze the effects of different ECR designs, including a single step and a continuous ramp, on the behavior of market participants and the implications for market performance and price discovery in addition to other outcomes. Analytical study provides additional guidance about the design characteristics of an ECR.

We find that the introduction and triggering of an ECR has virtually no impact on electricity prices and small and predictable impacts on the mix of resources used to generate electricity. The ECR tends to result in an increase in allowance revenues and thus program-related spending as the price-supporting effect tends to outweigh the reduction in allowance quantities sold. We find evidence of incremental leakage as a consequence of introducing an ECR on the order of 30 percent of the additional emissions reductions that are achieved in the region, which is a familiar value that has been identified for RGGI previously. Results are mixed and somewhat unpredictable with respect to the effect on the size on the allowance bank under an ECR. Under the assumptions we used in the simulation modeling coupled with the model's constraints, we find that the volume of the bank could increase—but our laboratory experiments suggest that the volume of allowance banking could diminish with an ECR.

An important result is that the ECR allows a decline in the demand for emissions allowances to be shared between the economy and the environment. In the absence of an ECR, if the demand for emissions allowances falls the price of allowances will fall, but there is no environmental effect until the price falls all the way to the price floor. The ECR introduces a rule-based mechanism to share the benefits of low allowance demand through both lower prices and fewer emissions.

The remainder of this report is organized as follows. We begin with a review of the role of cost and price containment in the RGGI program currently and how allowance prices have evolved over the life of the program to date. We then explain the ECR, how it would affect market outcomes, and how it might be implemented generally. Then, we discuss the application of the ECR to RGGI and the assumptions used in our modeling, followed by a presentation of scenarios, simulation model results, and findings. After reviewing the model results, we discuss the findings to date of our laboratory experiments, further analytical insights on implementation issues, and our conclusions.

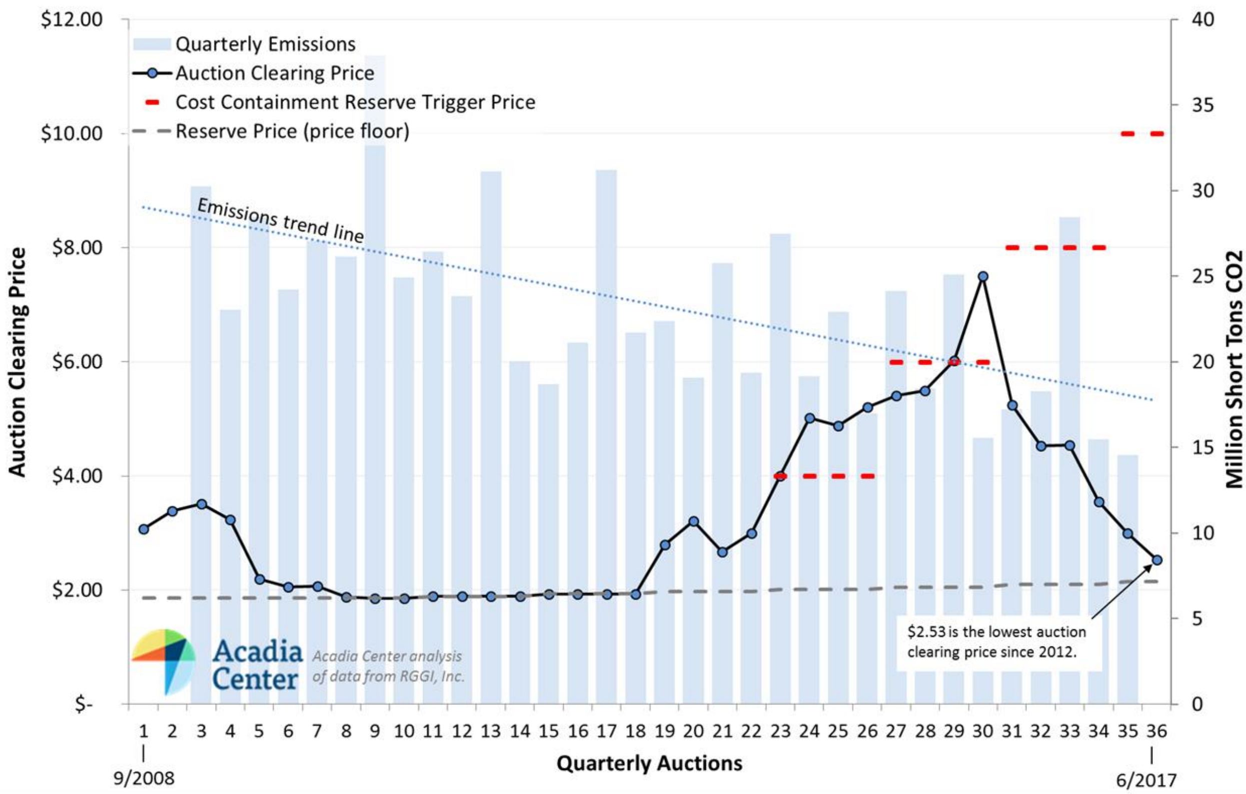
2. Cost and Price Containment Currently in RGGI

As currently implemented, the RGGI program includes two cost containment measures that affect the quantity of allowances in the market. On the low-cost side, the RGGI program includes a reserve price that constitutes a price floor in the allowance auction, which is set at $2.15 per ton in 2017 and is scheduled to rise at 2.5 percent per year going forward. On the high-cost side, RGGI includes a cost containment reserve (CCR) that introduces up to 10 million additional allowances per year at prices above the CCR trigger price. The CCR price step price started at $4.00 per ton in 2014, rising to $6.00 in 2015 and $8.00 in 2016. It is set at $10 per ton in 2017 and is scheduled to rise by 2.5 percent per year hereafter.

Figure 1 shows the clearing price results of all 36 allowance auctions beginning with the first two auctions that occurred just prior to the cap coming into effect in 2009 plotted on top of the quarterly CO_2 emissions outcomes in the RGGI states. The graph reveals that after 7 initial auctions where prices cleared above the floor, auctions cleared at the floor price for eleven quarterly auctions. Then, prices started to head upward beginning in 2013, after the 2012 Program Review had reduced the number of allowances that would enter the market beginning in 2014. This was also the beginning of the second term of the Obama Administration when EPA started to formulate the Clean Power Plan to regulate CO_2 emissions from the electricity sector under the Clean Air Act. Anticipation of these regulations and the role that RGGI allowances could play in Clean Power Plan compliance likely contributed to increased allowance demand and clearing prices rose high enough to trigger the cost containment reserve in both 2014 and 2015 before falling again, starting in 2016. Thus, both the price floor and the price ceiling have been called into action during the first 9 years of the program.

Prices in a market-based emissions cap-and-trade program are uncertain and depend on a number of factors that affect the demand for the fixed quantity of emission allowances created by the program. In the case of RGGI, the factors that contribute to uncertainty in allowance demand are several and most have tended to lower demand for allowances below what was expected when the program was created, and subsequently what was expected at the time of the 2012 Program Review.

FIGURE 1. AUCTION PRICES IN RGGI



Substantial declines in the price of natural gas over the past decade as a consequence of the introduction of fracking technology and the resulting abundance of supply have reduced reliance on coal-fired generation and thus lowered demand for CO_2 emissions allowances. There is also uncertainty about how much electricity demand will grow over time and demand growth has been slowing relative to past trends and to expectations for several years. The economic recession reduced demand for electricity and emissions fell accordingly, but electricity demand has remained low as the economy has recovered. Operation of the existing nuclear fleet is also subject to uncertainty as low prices for wholesale electricity reduce nuclear profitability. Uncertainty about closure dates of certain large nuclear plants in the region affect the anticipated contribution of this non-emitting source to the generation mix. State and federal policies and programs to support renewable technologies also put downward pressure on emissions allowance prices, as do programs to promote energy efficiency in buildings. Uncertainty about future regulatory changes directed at CO_2 emissions, particularly at the federal level, may also reduce demand for allowances. All of these factors taken together suggest that the possibility for a slack emissions cap in RGGI is real

3. What is the Emissions Containment Reserve?

Figure 2 illustrates how lower-than-expected allowance demand affects allowance market clearing prices and sales volume in the context of RGGI's current market design. As illustrated, low demand reduces allowance prices without having any effect on the number of allowance sold at auction, and therefore, no effect on emissions.

The figure illustrates a dilemma. Additional actions may be taken by cities, states, companies, or individuals to reduce emissions associated with electricity consumption based not on the price of CO_2 emissions but for other environmental reasons. These additional efforts lead to an economic benefit for all RGGI states in the form of lower allowance prices, but they do not yield additional emissions reduction benefits. We refer to this as the "waterbed effect." Reducing emissions in one place simply makes available allowances to emit CO_2 in another place.

The ECR is a mechanism to make the supply of allowances entering the market more responsive to the equilibrium price in the auction. In most commodity markets, when the price of a good falls, less of that commodity enters the market. To accomplish this outcome in RGGI the ECR would establish a price step or multiple steps above the price floor. Each step would be associated with a quantity of allowances that would not enter the market for a price below that price step. This feature is different from the price floor that applies to all allowances because the ECR applies to a specified quantity of allowances. For example, if the price floor were $2.15 then no allowances would sell in the auction for less than $2.15. If there was a quantity of allowances, say 15 million tons, under an ECR priced at $4, then those specific allowances would not sell for less than $4, although other allowances might sell for less than $4 and the auction clearing price could be below the ECR price level. Hence the ECR can coexist with the price floor. There could be multiple ECR quantities with different prices associated with each, forming a series of steps above the price floor.

FIGURE 2. SUPPLY SCHEDULE WITHOUT THE ECR

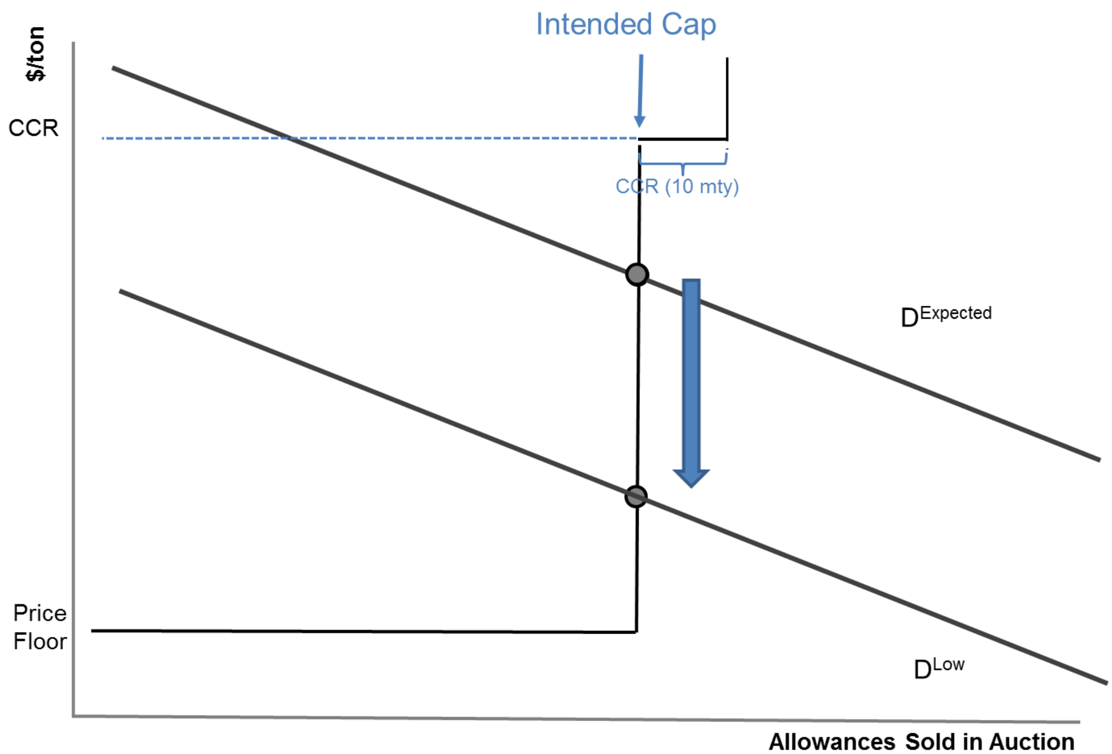


Figure 3 illustrates the influence that an ECR with a single step would have on the market if the demand for emissions allowances fell from its expected level to a low level. In this case the ECR would reduce the number of allowances entering the market, and the reduced supply would support the allowance price. As illustrated, the equilibrium allowance price would be below the ECR price in the absence of an ECR, but would be equal to the ECR price in its presence. If demand were even less, the equilibrium price would fall below the ECR price.

An ECR with multiple price steps could be implemented with specified prices and quantities of allowances associated with each price step. Figure 4 displays the same demand curves with several ECR price steps. If demand fell to a low level, the equilibrium price in the market could fall below the highest price step to the second one, or potentially fall even further. One of the characteristics of a multi-step ECR is that the chance that any one step would ultimately determine the allowance price is less than under a single-step ECR.

The ECR would help mitigate the waterbed effect because it enables a sharing of the benefits of falling allowance demand between economic savings and emissions reductions as some of the downward pressure on prices is translated into a reduction in the supply of allowances. This sharing of benefits would help preserve the incentive for policy initiatives by state and local governments, and voluntary actions by businesses and individuals, to pursue emissions reductions in addition to and beyond those required by the RGGI cap.

The ECR also might help the allowance market function more efficiently. The large vertical portion of the allowance supply schedule makes possible large unanticipated changes in allowance prices that can affect incentives to invest in clean sources of generation or energy efficiency that would help reduce emissions on an ongoing basis. If investors make decisions based on their assessment of the probability distribution over future prices, then the ECR would remove part of the risk of low prices.

In addition, when prices fall, compliance entities may purchase allowances in excess of their current compliance obligations in anticipation of a strengthening of the cap during the program review. Some observers have suggested that an ECR might proactively reduce the incentive to acquire large private banks while lessening the need for large cap adjustments during program review.

FIGURE 3. AN ILLUSTRATION OF AN ECR WITH ONE STEP AND CHANGES THAT RESULT FROM A LOW DEMAND FOR EMISSIONS ALLOWANCES

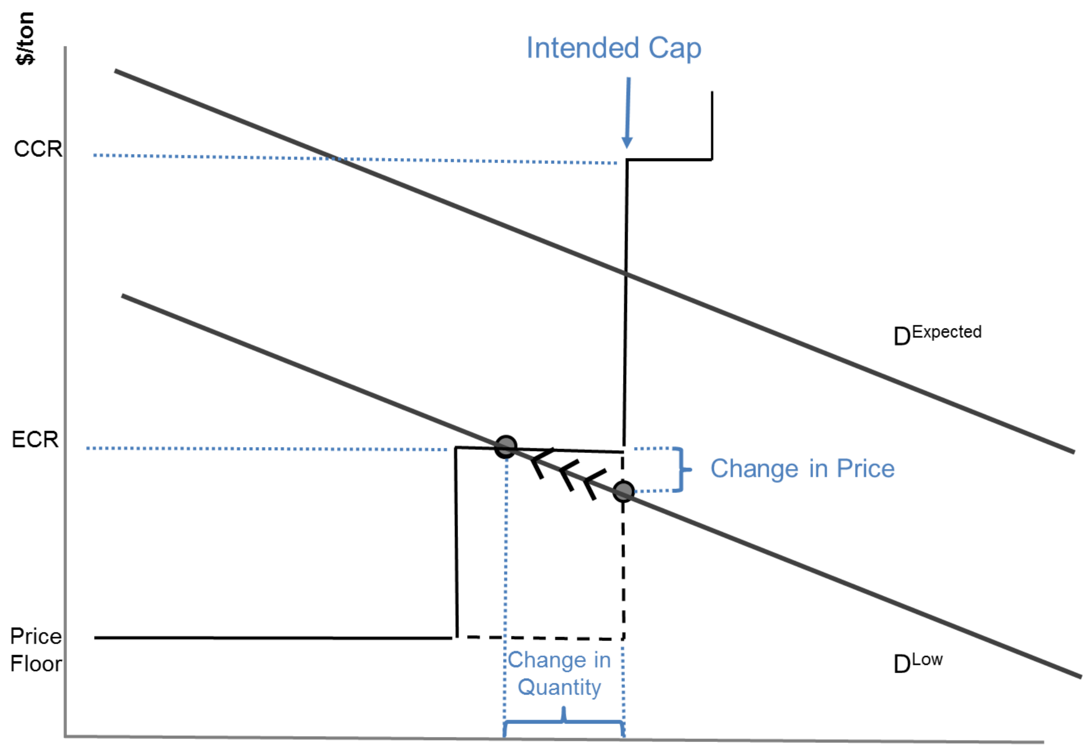
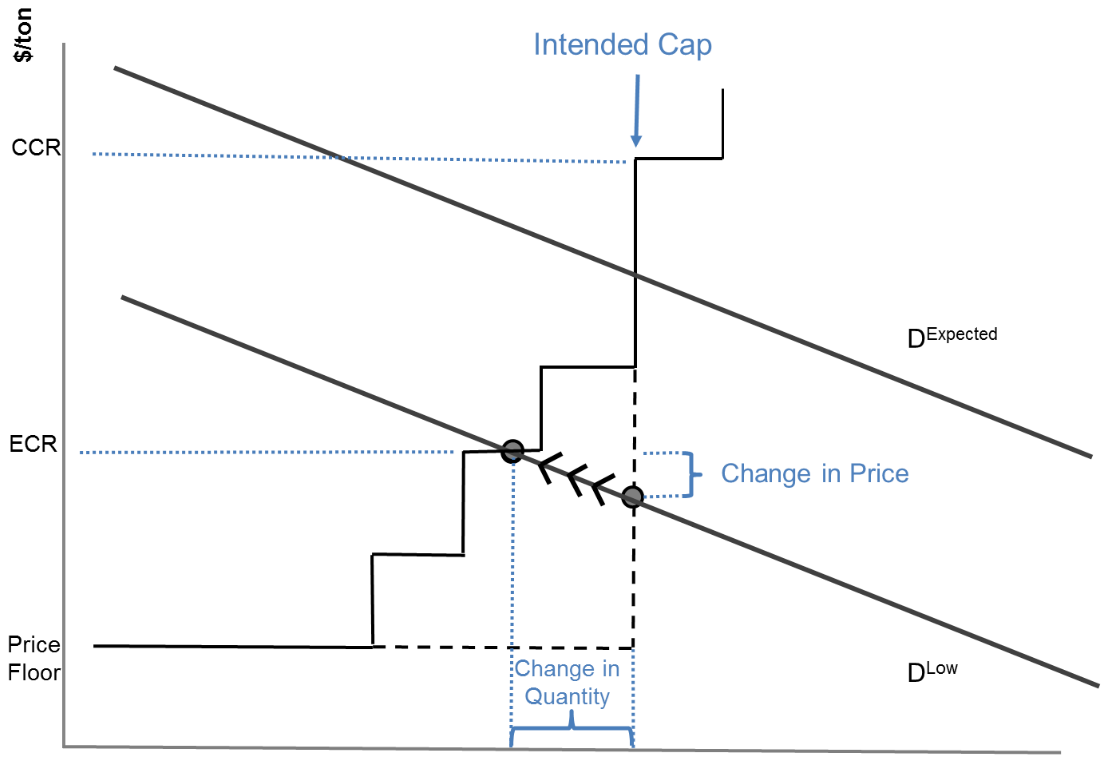


FIGURE 4. AN ILLUSTRATION OF AN ECR WITH MULTIPLE STEPS AND CHANGES THAT RESULT FROM A LOW DEMAND FOR EMISSIONS ALLOWANCES



4. How Would the Emissions Containment Reserve Be Implemented?

The implementation of an ECR is simple and reproduces the mechanism of the current price floor and the cost containment reserve, but with additional price levels. All of these mechanisms associate a minimum price with a specified amount of allowances. For example, no allowances will be sold below the price floor. The CCR introduces allowances in addition to the cap that enter the market only at a price equal to or greater than the CCR price. The ECR introduces intermediate price steps that reproduce this function by enabling the sale of some allowances only at prices at or above the ECR price. All of these mechanisms — the price floor, CCR and ECR — have minimum prices that are implemented as specific reserve prices in the auction, that is a minimum acceptable bid on a specified quantity of allowances. This is a familiar feature on platforms that sell goods in an auction setting. For example, one can observe the same kind of feature on eBay, where one can specify a minimum acceptable bid for items that are posted for sale.

5. Simulating the Emissions Containment Reserve in the RGGI Program

The RGGI program is represented in the Haiku electricity market model, which has been used in numerous other analyses of economic proposals and regulatory policies for two decades, and has supported over two dozen publications in scholarly journals, including early analysis of the RGGI program. A detailed description of the model appears in Appendix A. In brief, the model provides an economic representation of investments and retirement of generation resources in 26 regions linked by transmission capacity, and operation of the electricity system over three seasons and four times of day through 2035. Fuel supply and electricity demand respond to prices that emerge in an equilibrium context. The model is calibrated to the AEO 2016.

In the 2012 Program Review, RGGI implemented an adjustment to the allowance cap to account for the large privately held bank of emissions allowances. Some of that bank consists of allowances issued under the cost containment reserve that were additional to the intended emissions cap. The adjustment was implemented annually from 2016 through 2020, and amounted to a reduction from the original emissions cap in 2020 from 78,175,215 tons to 56,283,807 million tons, a reduction of about 28 percent in that year. In addition, the bank of publicly state-held allowances that did not sell when prices were at the price floor was permanently retired.

The base case assumptions in the simulation model are comparable to the ICF assumptions used in the Integrated Planning Model (IPM) in results presented to RGGI stakeholders in November 2016.[1] The Haiku model achieved comparable emissions allowance prices as IPM for our reference case scenario that imagined an annual reduction in the emissions cap equal to 3.5 percent of the emissions cap in 2020 (before the adjustment to the emissions cap that occurred as part of the previous program review), or 2,736,132 million tons each year between 2021 and 2030.

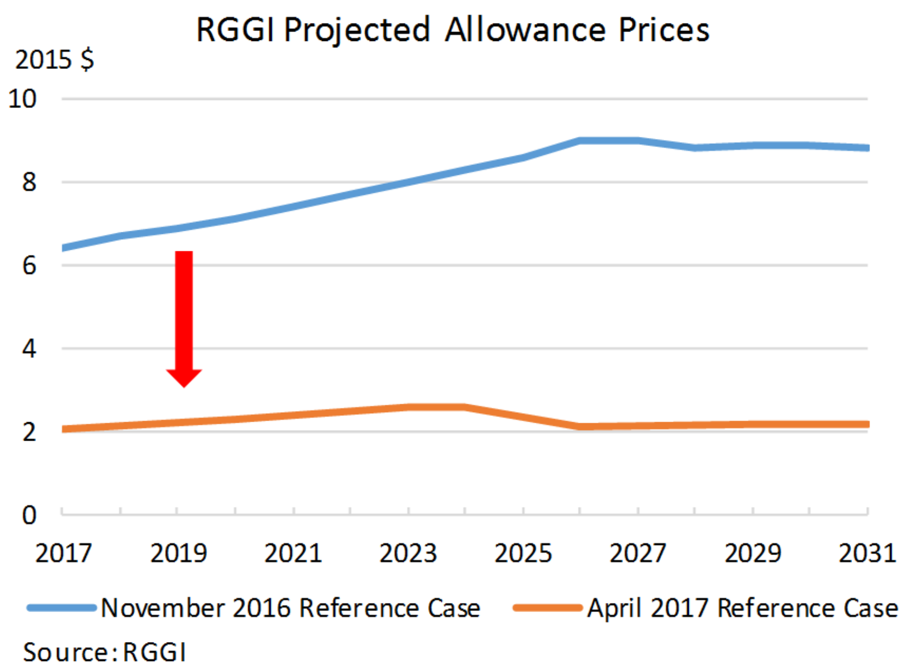
The path of allowance prices anticipated by the IPM model in November 2016 is illustrated in the top line in Figure 5. In 2020, the price was projected to be about $7 per ton, rising to about $ 9 per ton in 2026. However, in the update to the modeling that was shared with RGGI stakeholders in April 2017, the revised projected price fell to near the price floor in 2020 and remained near that level throughout the decade. Several changes in the assumptions and information in the model contributed to this outcome, including:

- Natural gas price projections (updated from AEO 2015 to AEO 2017)
- Regional energy demand projections
- Projections for cost and performance of renewables and natural gas
- The April 2017 model incorporates imports of renewables from Quebec and Ontario.

The changes in the assumptions were reasonable and directly in line with changes that have been observed in the industry. Indeed, they help make a case for considering an ECR because they reflect the influence that unanticipated changes in market factors can influence the price of emissions allowances. It is interesting to note that one important justification for updating the modeling was the expected withdrawal of the Clean Power Plan. The April 2017 Reference Case result displayed in Figure 5 does not include the Clean Power Plan, but a comparison with a model scenario (not displayed in Figure 5) that included the other model changes and also included the Clean Power Plan shows that removing the Clean Power plan had virtually no effect on allowance price projections.

[1] Meeting materials for RGGI can be found at: http://www.rggi.org/design/2016-program-review/rggi-meetings.

FIGURE 5. IPM PROJECTIONS OF RGGI PRICES CHANGED WITH NEW ASSUMPTIONS



Our reference case using the Haiku model has a cost profile similar to that anticipated in November 2016 by IPM. In modeling the 3.5 percent annual reduction in the allowance cap, we project allowance prices in 2020 of $8.10 that rise at 5 percent per year over the decade, in alignment with the opportunity cost of holding emissions allowances in the allowance bank. We assume the allowance bank is exhausted in 2030. We have no representation of the cost containment reserve because we are not aware of the status of the CCR in the future and unanticipated high prices are not relevant to the questions we explore. Allowances that are not sold due to the implementation of the ECR are not returned to the market in the simulation scenarios.

5.1. Modeling Unanticipated Outcomes in the Electricity Market

We explore explicit factors that could put a downward pressure on allowance prices, in the same way that the factors modeled by IPM in April 2016 did so, by organizing six possible unanticipated outcomes in three conceptual groups. It is noteworthy that the "unknown unknowns" constitute potentially important additional influences on the allowance price and should be expected to occur, but they are hard to model.

Secular Outcomes

- Low Demand Growth: electricity demand growth is based on the AEO 2016 "Low economic growth" case which has lower demand nationally than in the AEO Reference case
- High Natural Gas Prices: natural gas supply is based on the AEO 2016 "Low oil and gas resource and technology" case which has higher natural gas prices than the AEO Reference case

Policy Outcomes

- More Energy Efficiency: $2.5/MWh system benefit charge funds energy efficiency programs for electricity end-users in 2020 and thereafter in all RGGI states

- Expanded RPS: RPS targets are 5% above currently stipulated targets in 2020-2024 and 10% above in 2025 and thereafter in all RGGI states

Resource Outcomes

- Hydro: expanded hydro (1050 MW @ 100% capacity factor) power imports from Quebec to New England
- Nuclear: delayed retirement of nuclear facilities that are otherwise scheduled for retirement during the 2020s

Each of these potential unanticipated outcomes are modeled separately and in groups of two (as indicated under the headings above), in groups of four (combining pairwise combinations of the headings above) and altogether as one group. The RGGI allowance price outcomes are reported in Table 1 for the year 2020 assuming that there is no ECR in the RGGI allowance auctions. The numbers in the first row show the allowance prices in 2020 when each scenario is modeled separately. The other rows show results of the scenarios in combinations.

In the reporting our modeling results, we want to illustrate changes from the reference case that have a large effect on the allowance price and provide an important possible role for the ECR. For this purpose, we focus on the scenarios in the bottom two rows of Table 1.

TABLE 1. ALLOWANCE PRICES [$/TON] WITH NO ECR IN 2020 UNDER VARIOUS UNANTICIPATED OUTCOMES (2011 DOLLARS)

<table>
<tr><th>Ref Case</th><th>Low Demand</th><th>High NG Prices</th><th>More EE</th><th>Expanded RPS</th><th>Hydro from Quebec</th><th>Delay Nuke Retirement</th></tr>
<tr><td>8.2</td><td>8.0</td><td>8.6</td><td>7.4</td><td>7.5</td><td>7.7</td><td>7.0</td></tr>
<tr><td colspan="7">Uncertainties modeled as packages</td></tr>
<tr><td>Secular</td><td colspan="2">7.4</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Policy</td><td></td><td></td><td colspan="2">7.0</td><td></td><td></td></tr>
<tr><td>Resource</td><td></td><td></td><td></td><td></td><td colspan="2">7.0</td></tr>
<tr><td>Sec+Pol</td><td colspan="4">5.2</td><td></td><td></td></tr>
<tr><td>Sec+Res</td><td colspan="2">5.2</td><td></td><td></td><td colspan="2">5.2</td></tr>
<tr><td>Pol+Res</td><td></td><td></td><td colspan="4">5.5</td></tr>
<tr><td>All</td><td colspan="6">4.0</td></tr>
</table>

5.2. High-Level Results

Across over two dozen exploratory scenarios that incorporate various unanticipated outcomes that reduce the demand for emissions allowances with various formulations for the ECR, several high level results emerge.

1. Across all the scenarios, the ECR has virtually no effect on electricity prices.
2. With the ECR in place, compared to no ECR, the change in the mix of resources used for electricity generation is small and the changes move in predictable directions. For example, when the allowance price is supported at a higher level than it would otherwise be due to the ECR we find incrementally less use of emissions intensive resources.
3. The model results regarding the impact of the ECR on the size of the bank are unpredictable. The changes in allowance demand are unanticipated by the policy maker, but they are anticipated in the model, which solves in a forward looking way to minimize costs. Banking behavior in the model responds to the timing of when "unanticipated outcomes" occur. For example, if the influences that exert downward pressure on electricity demand accumulate over time, then the ECR will be more relevant later in the decade and the reduction in allowances will be anticipated in the model. This effect is the prevailing trend we see under the scenarios we have constructed; that is, there is typically more banking due to the ECR. Interestingly, this finding is the opposite of the result in the laboratory experiments, which are discussed below. We pursue this issue further in our analytical discussion.

In scenarios where the ECR plays its most influential role by supporting the allowance price we find:

4. SO_2 emissions decline by up to 9 percent compared to no ECR, as the use of coal responds negatively to the increase in allowance prices under the ECR.
5. Allowance value increases by up to 20 percent compared to the absence of the ECR. Note that the change in the allowance value is not the same thing as the change in the allowance price because the quantity of allowances that are sold will vary when the ECR is triggered. The allowance value is allowance price multiplied by the quantity of allowances that are sold.
6. Program related spending increases proportionately to the change in allowance value.
7. Incremental leakage from ECR hovers around 30 percent, which is a familiar value based on previous modeling using Haiku and other models. This leakage number means in effect the cost of a ton of emissions reductions is 30 percent higher than is reflected by the allowance price, or equivalently that RGGI has to reduce emissions by 1.3 tons in order to achieve 1 ton of emissions reduction from a global perspective.
8. Advantageous changes in the demand for emissions allowances are shared between the economy and the environment. We describe this sharing effect in greater detail in the analytical discussion below.

5.3. Results without an Emissions Containment Reserve

We evaluated the scenarios identified in Table 1 and several others to be able to identify the high level results reported above. In this and the following sections, we provide results for the last scenario in the table, which includes all the potential unanticipated outcomes we have discussed assuming an annual reduction in the emissions cap over the next decade equal to 3.5 percent of the current size of the unadjusted 2020 emissions cap. We focus on this scenario because it has the most significant effect on the demand for allowances and thereby illustrates most clearly the potential role of an ECR.

We explore three possible designs for the ECR in this and the next two sections. The results for all these cases are reported in Table 2.

The first column of results in the table indicates the model outcome in 2020 under the reference case with expected allowance demand. The other columns describe reduced demand. In the absence of the ECR the electricity price falls from $143/MWh to $140/MWh. This occurs because the low demand for allowances is motivated by an assumption of reduced demand for electricity on a national basis and increased spending on energy efficiency with RGGI, among other policies. The model anticipates reduced fossil generation in RGGI, but a larger share of that generation is achieved with coal, as indicated by the 29 percent increase in SO_2 emissions. In effect, the lower electricity demand and lower allowance price make room for more emissions intensive generation under the cap yielding a greater role for coal, even as nonemitting generation also increases due to assumptions under this scenario. With no ECR in place, the same number of allowances are issued as under the reference case, but intertemporal banking leads to a reduction of emissions from covered sources. The lower allowance price leads to a reduction in the allowance value of over 50 percent, with implications for funding of various program-related activities.

TABLE 2. SIMULATION MODEL RESULTS FOR 2020 UNDER THREE ALTERNATIVE ECR DESIGNS

3.5% Annual Cap Reduction 2020 Results (2011 dollars)	**Reference Case**	**Low Allowance Demand**: Policy, Resource and Secular Unanticipated Outcomes			
	No ECR	No ECR	One Step ECR (10Mtons)	Three Step ECR (15 Mtons)	Ramp ECR (17.5Mtons)
Retail Electricity Price ($/MWh)	143	140	141	141	141
Fossil Generation (TWh)	143.5	112.1	101.7	107.6	106.4
Nonemitting Generation (TWh)	152.6	160.3	166.4	162.6	163.3
Allowance Price ($/ton CO_2)	8.2	4.0	5.3	5.0	5.0
RGGI Covered Emissions (Mtons)	72.3	70.1	62.5	66.6	65.8
SO_2 Emissions (Mtons)	10.4	13.4	11.8	12.8	12.7
Allowance Value (M$)	463	226	246	253	250
Incremental Leakage (%)	--	--	24%	26%	28%

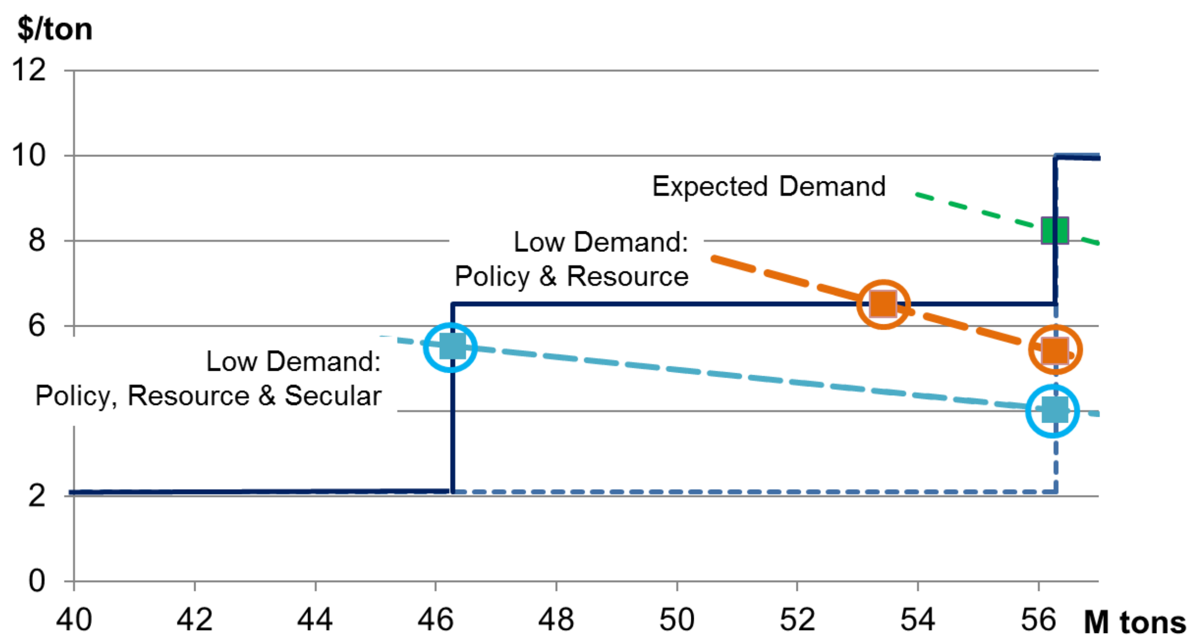
5.4. Results with a Single Price Step

The first design we examine is a single step ECR that would associate a minimum price of $6.50/ton with ten million tons per year beginning in 2020. Figure 6 illustrates the influence of the ECR under two demand scenarios. The policy and resource scenario would yield an allowance price of $5.50 in 2020 in the absence of an ECR. The one-step ECR reduces the number of allowances entering the market and supports a market-clearing price equal to the ECR price step at $6.50.

The policy, resource and secular scenario leads to even lower allowance demand. As reported in Table 2, the allowance price falls to $4 in the absence of the ECR, but with the ECR the allowance price increases to $5.30. Figure 6 illustrates that all of the ECR allowances are withheld from the market and the price falls below the ECR price level.

The one-step ECR leads to a small recovery in the electricity price to $141/MWh, still below the level anticipated in the reference case. The constrained supply of allowances contributes to a reduction in fossil generation and a slight increase in nonemitting generation. Emissions of SO_2 are reduced by over half of the increase that resulted from low allowance demand in the absence of the ECR, but they are still 13 percent greater than in the reference case. Allowance value recovers by $20 million with this version of the ECR. Finally, we observe incremental leakage of 24 percent; e.g. the emissions reduction in RGGI associated with the ECR leads to a bounce back of emissions from uncovered sources in RGGI and in neighboring regions of 24 percent. That value is familiar and compares with the rate observed in many studies of RGGI.

FIGURE 6. ONE-STEP ECR OUTCOME WITH UNANTICIPATED DEMAND CHANGES



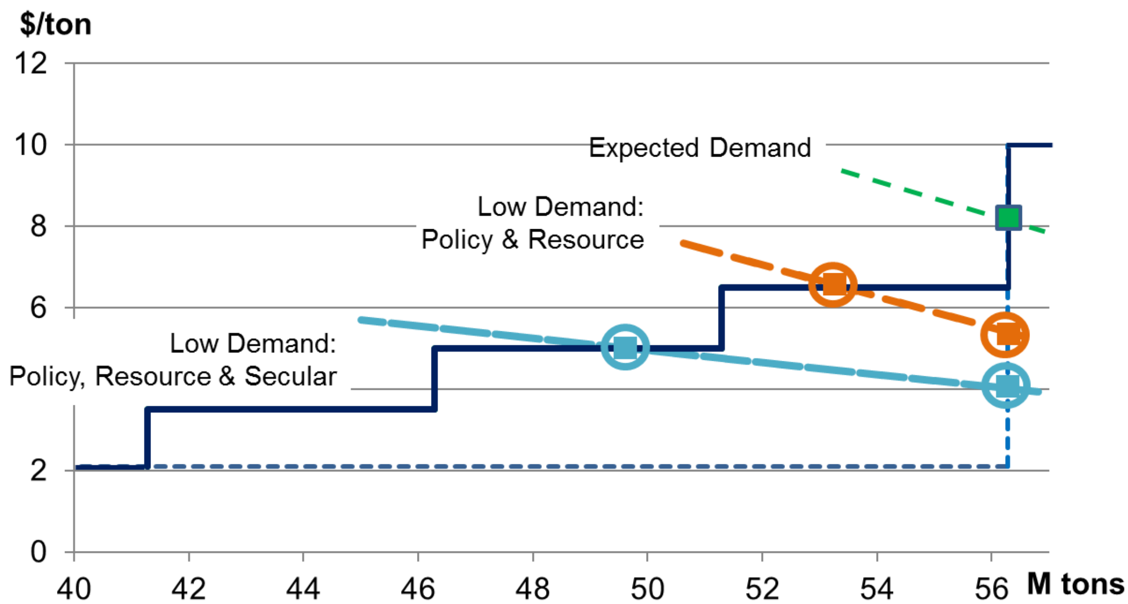
5.5. Results with Multiple Price Steps

In this section, we describe the results from the same demand scenarios but with an ECR that has three steps implemented at $6.50, $5.00 and $3.50. Each step applies to 5 million tons in the auction. We note that this design is not necessarily more or less stringent than the one-step approach, but it can lead to different outcomes.

Figure 7 shows that under the policy and resource demand scenario the outcome is effectively the same as under the one-step scenario. That result occurs because we constructed the top step of the three-step ECR at the price level of the one-step scenario, and the auction clearing price lands on this portion of the ECR. However, the result is different with still lower allowance demand under the policy, resource and secular scenario. As we constructed the three-step ECR, more allowances are issued, and the auction clearing price is lower, than under the one-step ECR.

The three-step ECR results in virtually no change in electricity price compared to the one-step ECR. Fossil generation recovers about halfway, compared to the one-step ECR, reflecting the lower allowance price, and RGGI covered emissions are slightly higher. Emissions of SO2 increase almost to the same level as in the absence of the ECR, allowance value grows slightly, and leakage is roughly the same as in the one-step ECR.

FIGURE 7. THREE-STEP ECR OUTCOMES WITH UNANTICIPATED DEMAND CHANGES



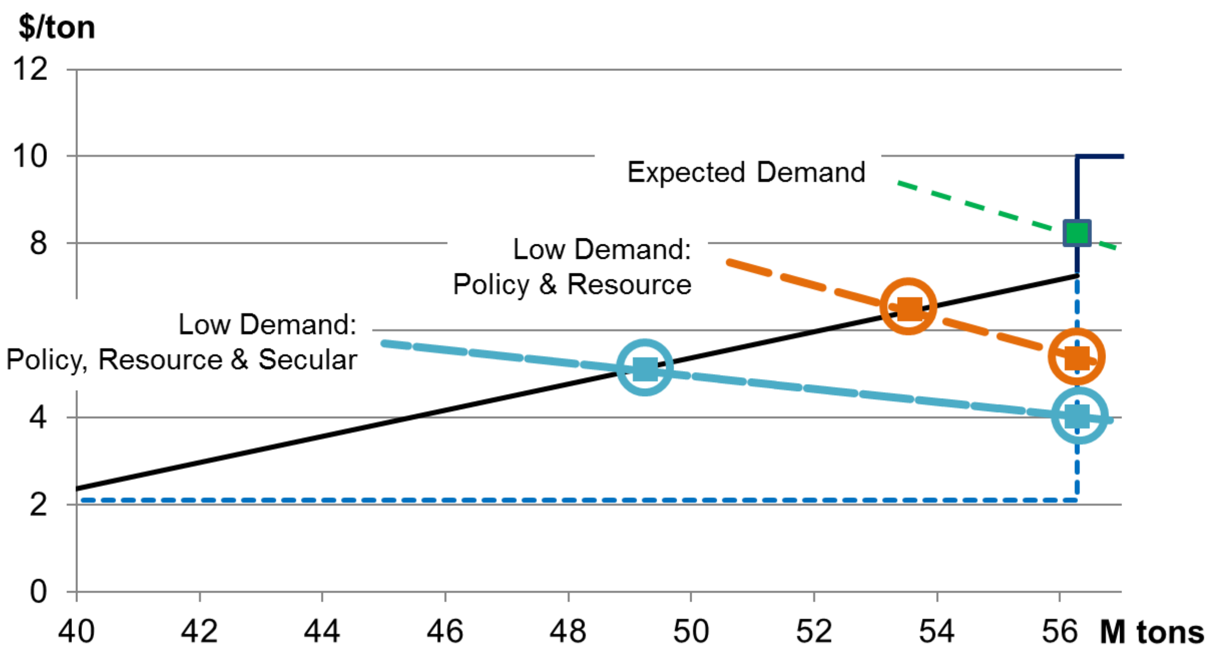
5.6. Results with an Allowance Supply Ramp

The third design we describe in detail is a continuous schedule, or ramp, that begins at $6.50, the same value as the other two ECR designs we have discussed. The ramp declines linearly over 17.5 million tons until it meets the price floor. Figure 8 illustrates that virtually the same outcome is achieved under the policy and resource demand scenario. This is by construction and for illustrative purposes. However, with still lower allowance demand under the policy, resource and secular scenario the outcome varies from the other scenarios.

Slightly different levels of fossil and nonemitting generation result under the ramp, compared to the three-step ECR. The ramp achieved almost the same allowance price as the three-step ECR (the difference is obscured due to rounding), consequently, the ramp ECR has similar emissions outcomes, similar allowance value is obtained and leakage is also comparable.

It is important to emphasize that any one of these ECR designs is not necessarily more stringent than the other. However, they have different effects under various profiles for allowance demand and the comparison illustrates how the market equilibrium is achieved.

FIGURE 8. RAMP ECR OUTCOMES WITH UNANTICIPATED DEMAND CHANGES



6. Exploring the Emissions Containment Reserve in a Behavioral Context

The second approach to investigating the role of an ECR considers the way that individuals and market dynamics respond to the introduction of the ECR. We pursue this using experiments to examine how the implementation of an ECR might affect trader behavior in the stylized setting of the economics laboratory. Laboratory tests of market mechanisms are now a standard tool in economic analysis. Experiments have been used to explore the likely effects of market designs in all of the key emission markets implemented to date, including RGGI, the SO_2 allowance trading program, the eastern US NO_x market, the EU ETS, and the California CO_2 cap-and-trade program.

These experiments typically use college students as research subjects. The subjects act as participants in a simulated market exercise through a set of networked computers in a controlled laboratory environment. The market simulation presents each subject with a set of carefully structured incentives, where each subject's pay-offs are established by the researcher. By making specific changes to the simulated market environment, but holding everything else constant, the researcher can observe the response of the laboratory participants to the changes in incentives. In the case before us, we are interested in measuring the effect of adding an ECR to a simulated market designed to mimic essential features of the current RGGI market.

6.1. Making It Look Like RGGI

An experiment comprises a set of treatments, where we vary only the particular features of interest to observe the differences in outcomes that arise from changing just the one market feature. Each treatment has a series of sessions. A session is the implementation of one of the treatments with a set of laboratory subjects. By running a series of sessions for each treatment, we can test for differences in outcomes that arise from the specific changes to market design under examination.

In the current context, we want to examine the addition of an ECR to the existing RGGI market model, our base case. In fact, we implement two different implementations of the ECR, the single-step ECR and an ECR that declines smoothly from the ECR trigger price to the auction reserve price. Each of these three treatments - baseline, step and linear - has precisely the same structure except for the introduction of an ECR and the way it is characterized.

Our laboratory setup presents subjects with a simplified version of the RGGI market, where the focus of the simulation is on essential features that drive trader behavior. Bidders can only acquire allowances in the auction; there is no spot market. However, the bidders interact through the determination of the equilibrium allowance price, which in turn affects the possibility that the ECR will be triggered. Subjects control a portfolio of four capacity units (power plants) that are a mix of coal and natural gas, with different costs and emissions rates. Banking is unlimited. The price of electricity output varies in an uncertain way, as does the cost of production. Each session has 30 periods with a cap that is declining over time. Thus, the cap starts relatively slack but tightens over the session. This feature gives participants incentive to anticipate future increased scarcity and smooth the availability of permits over time by banking in early periods and then using their bank in later periods. Past RGGI experiments have shown participants to be very adept at smoothing the supply of permits over time. What this implies for our sessions is that the price in early sessions will give a good signal about the long-range tightness of the cap. If there were no smoothing, we would expect to see the price rise as the cap falls, but with effective smoothing, the price in early periods will be very similar to the price in later periods.[2]

Since we know that subjects will smooth permit availability, and hence permit price, then if we observe a high permit price, we can infer a relatively tight long-run cap. If we observe a low permit price, then we would conclude that there is a relatively slack cap. In a permit market like RGGI's, with a price containment reserve, then a tight cap would have a relatively high probability of triggering a release of permits from the reserve. At the other extreme, a very slack cap would have a relatively high probability of having the auction close at the reserve price with some permits unsold.

Market participants know about the presence of the ECR and the reserve price. And since participants are forward looking, the possibility that either the ECR price or the auction reserve will be reached sometime in the future reaches back to the present through the participants' interest in anticipating future scarcity.

The purpose of the proposed ECR is to take account of the information that a chronically low price provides to the RGGI states. It is a signal that participants do not see the future scarcity of permits rising so much that the declining cap cannot be managed and that future compliance costs can be held down through banking. If today's price is on the low end of expectations, then one can infer that market participants do not anticipate rapidly increasing scarcity.

Given the ability of market participants to consider future scarcity in today's actions, the presence of the ECR and the likelihood that it will be triggered and will reduce the long-term supply of allowances should have a predictable effect: it should raise today's price relative to a market without the ECR because it lowers long-run supply on average. Another possible effect of the ECR is to change the incentive people have to bank permits for the future. This is a somewhat more complicated issue compared to the effect on price. In theory, early banking could go either up or down in response to the presence of the ECR. If participants anticipate the future triggering of the ECR would make banked allowances more valuable in the future, then participants will prefer to bank additional permits for the future. On the other hand, participants may see the ECR as lowering the total supply of allowances, so banking could conceivably fall. Intuitively, it may seem more likely that the increasing long-run scarcity of permits would tend to reduce the number of permits banked. As we shall see, this outcome is what we observe in our preliminary experimental sessions.

Whatever happens to the pattern of banking, prices should rise in a market with an ECR relative to a market without an ECR. A key point here is that this effect should occur even in sessions where the ECR is not actually triggered. Market participants will view the triggering of the ECR as a possible future outcome and will adjust their behavior accordingly. The presence of the ECR actually makes it somewhat less likely that the price level that would trigger the ECR will ever be observed.

6.2. Results from Preliminary Rounds

As of this writing, we have been able to run two sessions in each of our three treatments: no ECR, step ECR and linear ECR. The key results are presented in Figures 9 through 11. Figure 9 clearly shows a pattern

[2] In the experiments we are assuming a zero discount rate for simplicity. This does not change the key results.

of higher average prices for sessions with an ECR than in the sessions without an ECR. This is true for both types of ECR. Both show prices higher than the no ECR case in almost all periods.

In our sessions, the increased scarcity of permits reduces the amount of banking relative to the no ECR treatment. The difference between the two types of ECR is not significant.Interestingly, while the ECR does result in a smaller number of permits sold on average, the rise in price makes up for the reduces sales. There do not appear to be differences in revenues earned in the auctions in the two treatments, although there is some suggestion that the linear ECR results in somewhat higher revenue, more sessions are needed to know if this difference is statistically significant.

FIGURE 9. AVERAGE AUCTION PRICE BY TREATMENT BY ROUND

FIGURE 10. TOTAL BANKED PERMITS BY TREATMENT BY ROUND

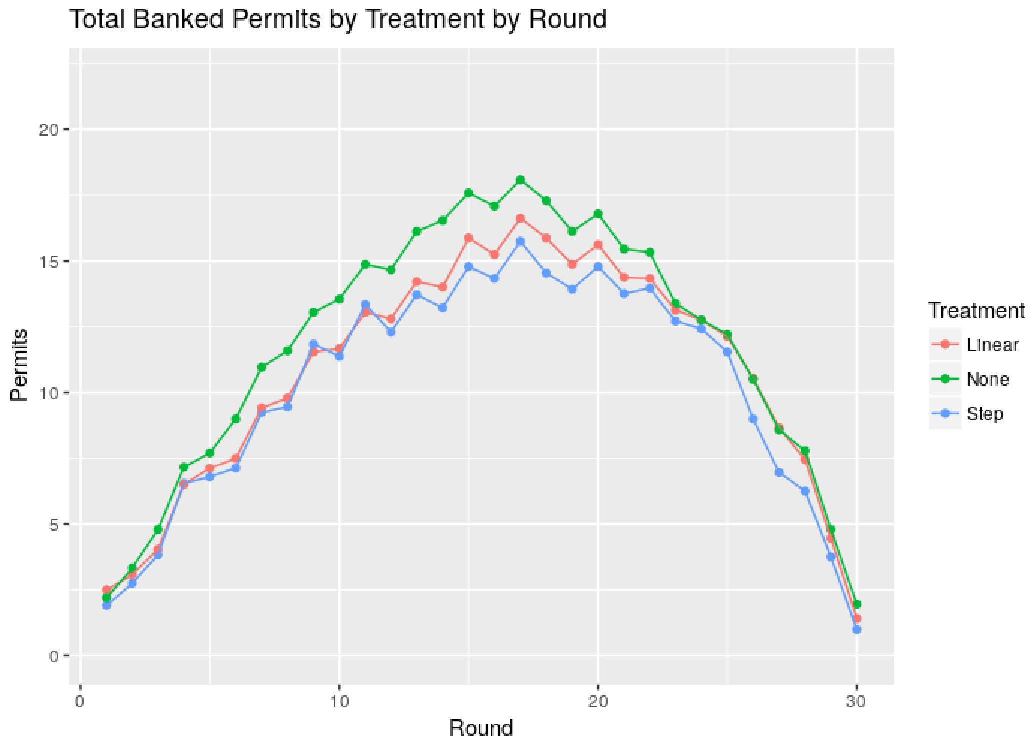
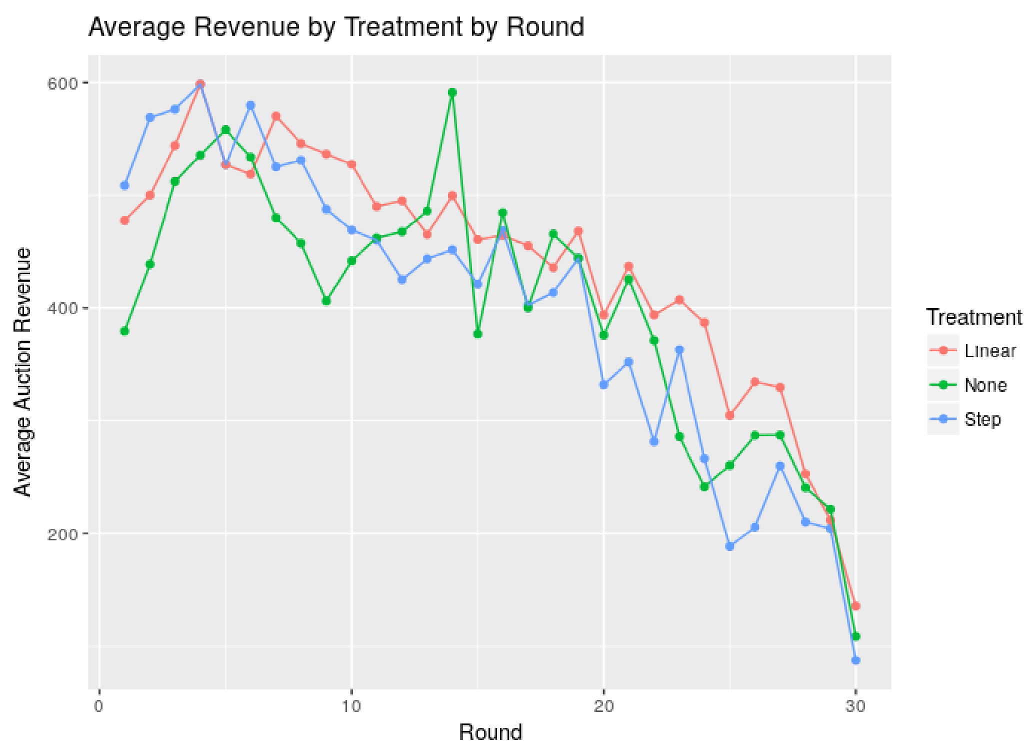


FIGURE 11. AVERAGE REVENUE BY TREATMENT BY ROUND



7. Analytical Considerations in the Design of the Emissions Containment Reserve

In addition to simulation modeling and laboratory experiments we reviewed the design of an ECR from a conceptual perspective. Several considerations and observations emerged.

7.1. Emissions Containment Reserve Prices and Banking

An important consideration in designing an ECR is the way that the price of the ECR will evolve over time. Because the ECR, like the price floor, is intended to deal with unexpectedly low compliance costs, the ECR price should take account of expected costs and how they might change over time.

Economic theory posits that in a trading program that enables banking of allowances, the price of allowances will rise steadily at the real intertemporal opportunity cost of capital[3]. This conclusion is known as Hotelling's rule and emerges from all models that simulate allowance banking including Haiku and IPM. Thus the models project allowance prices rising in real terms at an assumed rate; Haiku assumes that rate is 5 percent per year. If inflation were assumed to be 2.5 percent per year then the models would project allowance prices rising in nominal terms at 7.5 percent per year. A policy maker that uses the model-identified price as a reference point for might stipulate that the ECR price also rises at this rate. If the ECR price were to rise at a smaller rate and Hotelling's rule prevails, then we can expect that the ECR is more likely to bind in the near term than in the long term and will be of decreasing relevance over time.

However, the Hotelling rule has generally not prevailed in air pollution allowance trading markets or in other commodity markets where it is posited to be relevant. This difference from theory occurs because the theoretical result is derived in a very simple environment that does not account for the many exogenous changes in technology and economic conditions and especially policy and industry choices in the future that deviate from expectations at the time the policy is established. Also, it assumes that market participants take account of the infinite future when bidding on allowances, another assumption at odds with reality. Considering that expected allowance prices tend to come from models that yield allowance prices rising per Hotelling, and that Hotelling's rule does not tend to hold empirically in allowance markets, an alternative to basing the rate of growth for ECR prices on the model-identified price path may be appropriate. If the ECR price is specified to grow at the same rate as the model- identified price path and the realized allowance price path did not grow at this rate, then the ECR would become more influential over time. Similar considerations apply to the rate at which the price floor and cost containment reserve increase over time.

[3] The reason is that an allowance appears on a firm's books as a financial asset. If the change in its price over time (adjusted for risk) were less than the opportunity cost of capital, then the firm would want to sell this asset and put its capital elsewhere, and repurchase it when needed for compliance. And conversely, if the price rose at a faster rate than the opportunity cost of capital, a firm would buy allowances as an investment, which would drive up their price in the short term until the price path over time aligned with the intertemporal cost of capital.

7.2. Sharing

As previously mentioned, an ECR yields a sharing of the benefits that are realized from compliance costs and allowance prices that are lower than expected. In the absence of an ECR, a low demand for emissions allowances yields low allowance prices and results in economic benefits for RGGI compliance entities and electricity consumers. An ECR would abbreviate the price decline by reducing the supply of emissions allowances. This transfers and shares some of the benefits of low-cost compliance from economic interests to the environment.

We have explicitly described a number of potential outcomes, modeled individually and in tandem, that could reduce the demand for emissions allowances and reduce the allowance price. These outcomes and the associated future allowance prices have various probabilities of being observed. From an ex-ante perspective informed by modeling, we conjecture that there is a probability distribution of possible allowance prices. Of course there also is a possibility that prices could be greater than anticipated, but in discussing the ECR we focus strictly on the possibility that the price could be lower than anticipated. We further conjecture that outcomes closer to the anticipated allowance prices are more likely than lower prices, at least in the near term.

The benefits of a small deviation from the anticipated allowance price that do not cause the price to fall to an ECR price step accrue entirely to economic interests. A larger deviation that led prices to fall to an ECR price step would accrue to both economic and environmental interests. If the demand for allowances falls enough that all ECR allowances are withheld from auction, then allowance prices would fall below the ECR price, leading to further gains for economic interests. The least likely outcome is that prices reach the price floor, at which point all further gains from a falling demand for allowances go to the environment.

One might think of this as a pie cut into pieces. As different outcomes across the probability distribution of unexpectedly low compliance costs are realized in the presence of a single-step ECR, economic interests get the first piece, then the environment gets the second piece, then economic interests get another piece, and finally the environment would get the last piece after the price has fallen to the price floor.

A more even way to share the benefits of low costs is to cut the pie into more pieces. This approach is represented by a multi-step ECR rather than a single-step ECR. A three-step ECR would amount to cutting the pie into eight pieces instead of four. Economic interests would get the first piece, environment the second, and so on alternating until prices reach the price floor.

In summary, we observe that the ECR has the apparent virtue of sharing the benefits of lower than anticipated demand for allowances between the economy and the environment. However, if the ECR price is set below the anticipated allowance price then the benefits initially accrue to the economy, and we observe that this may be the most likely outcome. Multiple price steps would lead to a more even and continuous sharing of benefits over the range of possible market outcomes. Moreover, multiple price steps would make the likelihood of any one price step ending up as the market price less likely.

Even more ECR steps would yield an even more equitable sharing of the gains from unexpected low cost outcomes. Ultimately, the most equitable sharing would come from a continuous ECR, in which any decline in allowance prices leads to fewer allowances entering the market. In pie terms, this means that for any unexpectedly low compliance costs, economic and environmental interests would take simultaneous bites from the pie.

8. Additional Design Considerations

Implementing an ECR requires specificity about a number of design parameters including the number of steps in the ECR, the price level and quantity of allowances associated with each step and the plan for what happens to allowances that do not enter the auction when an ECR price step is triggered. In comments offered to RGGI, and included in Appendix B, a subset of the authors of this report offer specific recommendations relevant to these and some other considerations as a straw proposal for consideration by the RGGI states. We abstain from specific recommendations on those decisions in the body of this report and instead describe the broader considerations and reasoning that could inform RGGI deliberations about the program design elements.

Number of ECR steps: The decision about how many steps to include in the ECR should be informed by balancing considerations of simplicity and benefits sharing. Simplicity may weigh in favor of a single-step ECR, because it may feel like a smaller departure from the current program design, however from a conceptual viewpoint it is no simpler and in some ways more abrupt in its impact than a multi-step ECR.

The sharing of benefits between the economy and the environment is achieved if the ECR is triggered, but the sharing is more even and continuous from a multi-step or continuous ECR than a one-step ECR, as mentioned in the previous section. Indeed, a multi-step or continuous approach to an ECR would result in a supply curve for allowances that more closely resembles supply curves found in markets for commodities and other goods with price responsive supply. Also, the multi-step and continuous approaches make it less likely that any particular ECR price step ends up being the price that clears the allowance market.

Level of ECR price: The ECR price(s) would be set in between the allowance price anticipated by the RGGI states and the price floor. The identification of these two values, however, is a simultaneous consideration as part of the RGGI program review. Decision theory suggests approaching this problem in a hierarchical manner, deciding first on the fundamental parameters of an anticipated price and price floor before setting the ECR. With those values in place, theory might suggest setting the ECR price to split the distance between them. For example, a single-step ECR could be priced midway between the anticipated price and the price floor. A multi-step approach could implement equal sized steps between the floor and anchor. A continuous approach could obviate the need to choose prices and simply extend the ECR from the anticipated price level to the floor. Any of these approaches will provide an adjustment in the supply of allowances should demand for allowances end up being lower than expected.

ECR step quantities: The quantity of allowances brought into the ECR is another fundamental design choice. Two features of RGGI provide some insights into past willingness to adjust the number of allowances available under the cap. We observe that that the cost containment reserve makes available up to 10 million additional allowances when it is triggered. Second, we observe the 21.9 million ton reduction in the annual cap between 2016 and 2020 that came out of the 2012 Program Review as a response to large private bank. This adjustment represents about 25% of the annual cap. These two quantities may provide useful touch points for the discussion of how many allowances to include in the ECR steps going forward.

Annual adjustments in the ECR price(s): As we discuss in further detail above, it is important to acknowledge that allowance prices are expected to increase over time due to inflation and, to some degree, due to the opportunity for allowance banking. Hence, annual adjustments in the ECR prices should account for expectations about the path of allowance prices over time, and the relevance of the ECR in the future.

Disposition of unsold allowances: When an allowance auction clears at a price at or below an ECR price level, there will be a smaller quantity of allowances sold than is available in the auction. There are several alternatives for how to dispose of allowances that are not sold. One is to roll the allowances forward to future auctions. A second is to use them to undergird the CCR. These alternatives, however, undermine the function of the ECR to provide sharing between environmental and economic benefits when compliance costs are low, which would be accomplished if the allowances were permanently retired. In practical terms, the RGGI states may want to hold the allowances out of the market until a decision is taken at the next program review, which has been the practice previously with allowances that are unsold at the price floor.

The relationship between the ECR and the cost containment reserve: The ECR and the cost containment reserve have been described in public webinars as independent features of the RGGI program and need not be formally linked in terms of quantities of allowances or price levels. The ECR is relevant at prices below the anticipated price level, and the CCR is relevant at prices above the anticipated level.

The ECR and Linking: The ECR introduces new considerations with respect to the possibility of linking with other allowance trading programs, but they are strongly analogous to the considerations that RGGI already would take into account because of RGGI's price floor. Under the ECR, as under a price floor, if allowances are not sold by the RGGI states the allowance price will be supported. Our modeling indicates that this leads to a net increase in the revenue from the auction, but the benefits accrue even more strongly to the linking jurisdiction that is able to sell all of its allowances at the higher price enabled by the ECR. Negotiation about linking may want to take this distribution of benefits into consideration.

9. Conclusion

As part of the 2016 Program Review, the RGGI states are considering implementing an emissions containment reserve. An ECR would set a minimum price on a portion of the allowances available for sale at each RGGI allowance auction. The ECR would be characterized by a price and quantity of allowances and could be multiple prices and associated quantities. The ECR price(s) would be above the auction reserve price and below the price that is expected to clear the auctions. If RGGI compliance costs are lower than anticipated (i.e., low allowance prices clear the auctions), then the ECR could be triggered and some allowances would not enter the market. Fewer allowances in the market supports the allowance price, and implies fewer emissions within RGGI and gains for the environment.

RGGI's interest in considering an ECR arises from the observation that the costs of compliance with cap-and-trade programs for airborne emissions worldwide frequently tend to be considerably lower than ex-ante expectations. This outcome has certainly been observed in RGGI as 11 of the 36 allowance auctions have cleared at the reserve price and with others clearing just above the reserve price.

In the absence of an ECR, low demand for emissions allowances leads to a reduction in allowance prices. Unless demand is so low that prices are at the auction reserve price, low demand and low prices are an economic benefit with no coincident environmental benefit. This result is a manifestation of what we call the "waterbed effect." An emissions reduction effort such as investment in energy efficiency undertaken by any entity in a RGGI state will simply make more allowances available to other RGGI entities and no additional emissions reduction is realized, at least until a potential cap adjustment as part of a subsequent program review. The waterbed effect undermines the incentive for environmentally motivated cities, states, companies, and individuals to take actions to reduce emissions associated with electricity consumption as any such actions may yield no climate benefit.

In the event that future RGGI compliance costs are lower than currently anticipated, an ECR would share the benefits of low costs between economic and environmental interests. A multi-step ECR would share the benefits more evenly than a single-step ECR. A continuous ECR, or ramp, would share the benefits completely as the benefits of any and all emissions-reducing activities and unexpectedly low costs would be shared between the economy and the environment. Indeed, an ECR ramp would most closely mimic the behavior of the supply-side of all other commodity markets in which any change in price leads to an adjustment of supply.

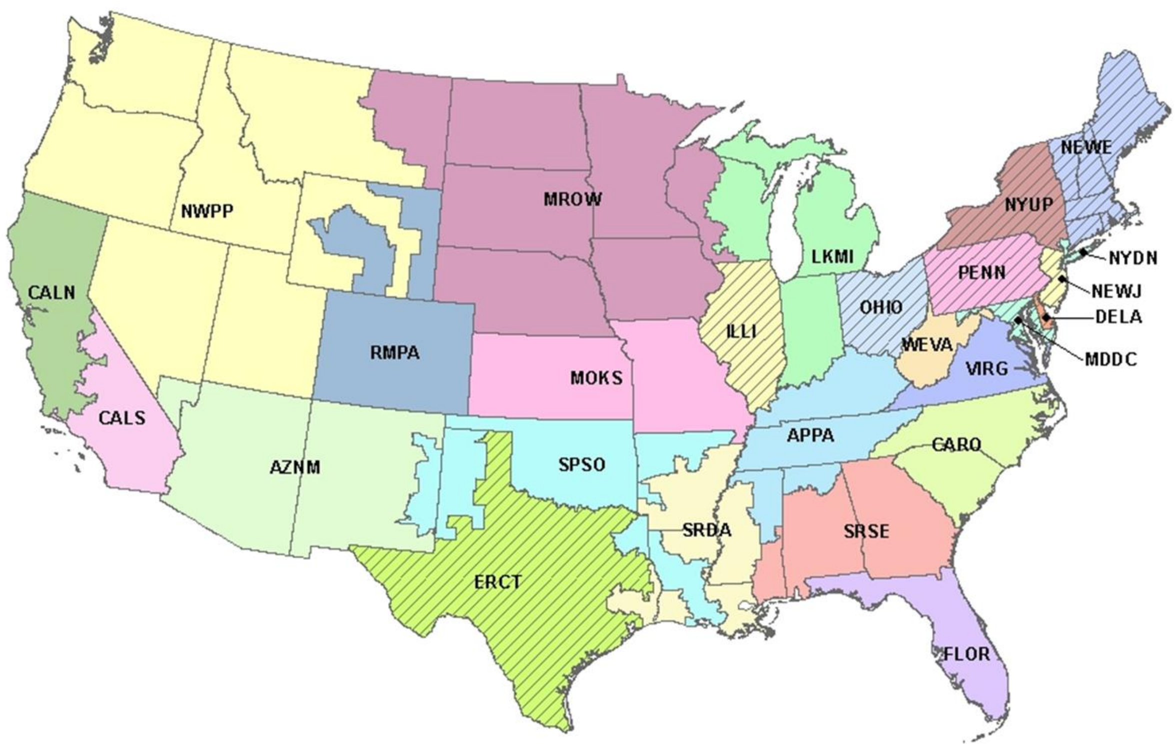
Some observers have expressed a concern that the ECR might determine the price in the allowance market. However, the ECR is a quantity control mechanism; if the market price falls to the ECR price step then some allowances do not enter the market, which in turn has an effect on allowance prices but the mechanism does not determine the price. Our simulation modeling indicates that the allowance price may end up below the ECR price step or below multiple steps. Any allowance price at or above the auction reserve price (price floor) may clear the market and the ECR merely affects the quantity of allowances that enter.

RGGI has been seminal as a market-based regulation of CO_2 emissions in the United States and across the globe for introducing features that have broad appeal. RGGI was the first program to sell almost all of the emissions allowances by auction and, as such, the first to implement an auction reserve price. These features of RGGI have found their way into California's cap-and-trade program, in Quebec (which is now linked with California), and in Ontario. An ECR would be another RGGI innovation that would better align incentives for individual actors in the region and help to better integrate cap and trade with complementary efforts in cities and states and by private actors to promote clean energy and reduce CO_2 emissions. In a world where these complementary programs will continue to exist and play an important role, the ECR could potentially serve as a model for other greenhouse gas cap-and-trade programs now and in the future.

Appendix A. The Haiku Electricity Market Model

We use a highly parameterized capacity planning and operation model of the US electricity sector to explore the performance of RGGI and the role of an ECR. The simulation modeling uses the Haiku electricity market model,[4] a partial equilibrium model that solves for investment in and operation of the electricity system in 26 linked[5] regions of the continental United States through 2035. (See Figure A1.) Each simulation year is represented by three seasons (spring and fall are combined) and four times of day yielding 12 time blocks. Demand is modeled for three customer classes in a partial adjustment framework that captures the dynamics of the long-run demand responses to short-run price changes. Supply is represented using 53 model plants in each region, including various types of renewables, nuclear, natural gas, and coal-fired power plants. Coal model plants are defined according to installed pollution controls. Power imports from Mexico and Canada are held constant. Thirty-nine of the model plants in each region aggregate existing capacity according to technology and fuel source. The remaining 17 model plants represent new capacity investments, also differentiated by technology and fuel source.

FIGURE A1. REGIONS IN THE HAIKU MODEL



[4] Haiku is comparable in sectoral and geographic coverage to the Integrated Planning Model (IPM, owned by ICF consulting and the model of record for EPA), ReEDS (maintained at the National Renewable Energy Laboratory), and the Electricity Market Module of the National Energy Modeling System (NEMS, maintained by the Energy Information Agency). Haiku, IPM, and ReEDS model the electricity sector and partially model factor markets, like fuel, for the continental United States. NEMS also links its electricity sector model to the entire economy and models all fuel markets. For more information about the Haiku electricity market model, see Paul et al. (2009).

[5] Interregional transmission capability comes from EIA (2013).

Operation of the electricity system (generator dispatch) in the model is based on the minimization of short-run variable costs of generation. Fuel prices are benchmarked to the Annual Energy Outlook (AEO) 2016 forecasts for both level and supply elasticity. Coal is differentiated by fuel quality, sulfur content and location of supply, and both coal and natural gas prices are differentiated by point of delivery. The price of biomass fuel also varies by region, depending on the mix of biomass types available and delivery costs. Coal, natural gas, and biomass are modeled with price-responsive supply curves; prices for nuclear fuel and oil, as well as the prices of capital and labor, are held constant.

Investment in new generation capacity and the retirement of existing facilities are determined endogenously for an intertemporally consistent (forward-looking) equilibrium, based on the discounted value of going-forward revenue streams net of going forward capacity related costs using a 5 percent discount rate. Existing coal-fired facilities have plant-specific opportunities to make endogenous investments to improve their efficiency.[6] Investment and operations include pollution control decisions to comply with regulatory constraints for SO_2, NO_x, mercury, hydrochloric acid, and particulate matter, including equilibria in emissions allowance markets where relevant.

Price formation is determined by cost-of-service regulation or by competition in different regions, corresponding to current regulatory practice. The retail price of electricity does not vary by time of day in any region, though all customers face prices that vary from season to season.

The model requires that each region has sufficient capacity reserve to meet requirements drawn from AEO (EIA 2016). The reserve price is set just high enough to retain enough capacity to cover the required reserve margin in each time block. In competitive regions, the reserve price is determined separately by time block and paid to all units that generate electricity and to those that provide additional capacity services. Instead, the fraction of reserve services provided by steam generators is constrained to be no greater than 50 percent of the total reserve requirement in each time block.

The baseline scenario provides a reference point for what the electricity sector would look if RGGI returned to the anticipated cap level after completion of the so-called bank adjustment, which continues through 2020, and from the anticipated cap level it reduced emissions by 3.5 percent per year over the next decade. In the text we describe how we arrived at this baseline scenario. The important part of this research is imagining the influence of the ECR. Assumptions regarding other environmental and technology policies that are included in the baseline are maintained in the policy scenarios.

The baseline scenario is based on assumptions about electricity consumption growth and electricity, natural gas and coal prices from EIA's Annual Energy Outlook 2013. The baseline includes a representation of all major existing federal air pollution policies affecting electricity generators including US EPA's Clean Air Interstate Rule (CAIR) and Mercury and Air Toxic Standards (MATS) and California's AB32 CO_2 cap-and-trade policy. The model also includes representations of state renewable portfolio standards and state-level mercury policies. Federal and state renewable production and investment tax credits are included in the model but recent extensions to the federal

[6] Linn et al. (2014).

renewable tax credits are represented in an alternative baseline that is part of two sets of sensitivity analyses discussed below.

Demand growth assumptions from AEO are tempered by incorporating energy efficiency programs above and beyond EIA's assumption. The baseline scenario incorporates programmatic energy efficiency investments that achieve roughly a 3.4 percent cumulative reduction in electricity consumption by 2025, which is maintained thereafter. This level of energy savings from efficiency programs represents roughly half the level anticipated by EPA in its regulatory impact analysis of the Clean Power Plan (US EPA 2014). For policy scenarios the level of efficiency spending is held constant; the resulting cumulative savings are an output that can vary slightly by scenario.

The baseline scenario also includes information about lower costs for renewables from NREL (2016) as well as updates to the federal renewables tax credits included in the Consolidated Appropriations Act for 2016 that was signed into law in December of 2015. This new law extended the expiration date for the production tax credit for wind facilities commencing construction after the end of 2016 through December 31, 2019 with a gradual decline in the level of the tax credit over this time period. It also extended the investment tax credit for solar with it phasing down from 30 percent initially to 10 percent starting in 2022 and beyond.

Appendix B. RFF Comments to RGGI Offering a Straw Proposal

Comments for the Regional Greenhouse Gas Initiative Program Review on the Potential Design of an Emissions Containment Reserve (July 11, 2017)

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Resources for the Future, with colleagues Bill Shobe and Charlie Holt at the University of Virginia, is engaged in a project to examine the possible design of an Emissions Containment Reserve (ECR) for RGGI. The project involves modeling, analysis and laboratory experiments and will culminate in a report to RGGI states and stakeholders.[7] That report will provide an analysis of the design of an ECR, simulation modeling and laboratory experiments to investigate its performance in the context of the RGGI program. It will not offer opinions on specific design features of the potential ECR, such as its price and quantity levels.

However, in presentations and discussions we have been asked our opinion about specific decisions that would need to be made to implement an ECR. **These comments provide an opportunity for us to suggest specific design features of an ECR, including price and quantity levels.** We organize our comments around actual questions that we have been asked in previous stakeholder webinars and in other conversations. We then offer a specific straw proposal for consideration.

[7] For background, see the June 14 webinar and background materials at: http://www.rff.org/events/event/2017-06/emissions-containment-reserve-ecr-rggi-report-analytical-results.

1. What might be the relationship between the ECR and the Cost Containment Reserve (CCR)?

We recommend there be no necessary formulaic relationship in the specified quantities of allowances and price levels between the ECR and CCR. We view them as independent.

Nonetheless, the ECR and CCR do have similar design features and there is an advantage to making their implementations symmetric. That is, both have a reserve price in the auction that triggers the availability or decrement of a specific quantity of allowances.

We have described the ECR as a mechanism that would withhold a portion of the supply of allowances from the intended cap if the auction price fell to or below a specified level. It is different from the price floor, which applies to all allowances. However, the ECR and price floor are implemented in the same way, as a reserve price in the auction, but set at different levels.

The CCR is the converse of the ECR in that it identifies a specific quantity of allowances that would enter the market and that are additional to the intended cap. The CCR is implemented in the same way, as a reserve price in the auction associated with that extra quantity of allowances.

While the ECR and CCR are implemented in the same way, they are spoken of differently because of their relation to the cap quantity and the model identified, anticipated allowance price. The ECR is relevant at prices below the anticipated price level, and the CCR is relevant at prices above the anticipated level.

We recommend against a formal relationship between the ECR and CCR because that might imply that allowances that do not sell if the ECR is triggered would be deposited into the reserve for the CCR, and then would re-enter the market if the price rises to the CCR price level. We recommend against this design because the different mechanisms serve different purposes. If there is to be a CCR, it would make additional allowances available whether the ECR has been binding (i.e., triggered) previously or not. Conversely, if the ECR is triggered there is an explicit decision required about what to do with unsold allowances. However, we recommend against the idea that those unsold ECR allowances be deposited in the CCR.

2. What should be done with allowances that do not sell under the ECR?

Allowances that do not sell under the ECR are analogous to allowances that do not sell if the price falls to the price floor. We recommend they be treated in the same way; presumably they would be permanently retired as has occurred previously with unsold allowances under the price floor.

3. Might the ECR anchor bidding behavior and cause auctions to clear at the ECR price step(s) when they otherwise might have cleared at a different price? Might the ECR unintentionally determine the price in the market?

We do not believe the ECR will anchor bidding behavior.

The view has been articulated previously that the CCR had the effect of shaping expectations in the market and bidders anchored to that price level in previous auctions. If bidders are working with poor information about their own marginal costs of emissions reductions or the marginal cost for the market as a whole, it makes sense that they might make an inference based on signals from the RGGI program review and decisions. In that situation, the CCR might be a point of interest. However, the evidence is mixed on whether the CCR has been focal in shaping expectations because there were other important events unfolding with regard to the

Clean Power Plan during the last compliance period when the CCR was binding, and the price fell far below the CCR level as these events unfolded.

The literature in economics is not decisive but the idea supported in ongoing research of market bidding behaviors (separate from our ECR research) by our colleagues at the University of Virginia is that price constraints such as a price floor or a CCR might actually tend to repel rather than attract bids. That finding occurs simply because by censoring the range of possible outcomes, the price floor or CCR changes the expected outcome and thereby affects bidding behavior in a way that pushes away from those price limits.

In summary, we do not think the ECR anchors bids. However, if there is concern that the ECR price step might determine the price in the market, then the ECR might be implemented with multiple steps rather than a single step. Multiple steps would ensure the price does not land on a specific ECR price trigger and should reduce the anchoring effect if it is present.

4. How many allowances should be associated with the ECR?

In one sense the quantity of allowances in the ECR is arbitrary but some guideposts can be identified. We identify two possibilities.

There may be an advantage to apparent symmetry of the ECR and CCR with respect to the quantity of allowances that are in each mechanism. The CCR currently offers a reserve of 10 million tons at its trigger price. For parallelism in our modeling, one of the scenarios we explored had 10 million tons associated with the ECR. This might be a useful approach because it might appear to be a simple extension of the existing program design, adding an ECR to balance the CCR, even though they function independently.

On the other hand, as an outcome of the last program review, in 2016 and through 2020 the annual adjustment to the cap is 21.9 million tons, which is approximately 25 percent of the RGGI cap. That quantity represents a signal of the willingness to constrain supply in order to support the program goals.

The size of the ECR might be related to whether there is a single or multiple steps to the ECR. If there were multiple price steps the ECR could accommodate a larger quantity of allowances without any one price step being likely to determine the market outcome. (A similar reasoning might apply to the CCR. We note that California has two steps in its CCR, rising to high price levels at its top step.)

5. Is the ECR quantity an annual number, and if so does it apply in each auction?

The ECR quantity that we describe is an annual number. The quantity would be divided by four to calculate the quantity that is available in each quarterly auction.

6. How should the price level(s) of the ECR be determined?

We believe the focal point for the ECR could be organized around the midpoint between the price floor and the model-identified, anticipated allowance price, given the modeling results for the intended level of the emissions cap. This midpoint, halfway between the price floor and the anticipated price, provides symmetry and a gradual adjustment to the supply of allowances in the event that prices are lower than expected.

If there are multiple steps in the ECR, they can also be organized around the midpoint between the expected price and the price floor. For example, if there were three steps, they could be one-quarter, one-half and three-quarters of the way between the anticipated price and the price floor.

7. As was mentioned in the ECR webinar, how are the benefits "shared" between the economy and the environment?

RGGI's emissions cap is determined through a scientifically-informed negotiation among the RGGI states and in the presence of uncertainty about compliance costs. If the price is lower than anticipated, this means the cost of achieving emissions reductions is less than expected. If the RGGI states had known about this price outcome ahead of time, they might have chosen a cap that would achieve more emissions reductions. However, in the absence of the ECR, all the benefit from the advantageous trend in the costs of emissions reductions accrue to compliance entities and electricity consumers without harvesting any additional environmental benefits. The ECR would lead to some of those benefits being realized as fewer emissions. So in effect the benefits are shared, with a lower price benefiting compliance entities and consumers and fewer emissions benefiting the environment.

If the ECR price step is below the model-identified allowance price, the initial benefits of a falling demand for allowances accrue entirely to compliance entities and consumers because for small changes in the price, before the ECR is triggered, there is no change in the supply of allowances. Then, over some range when allowances associated with the ECR are not sold, all of the incremental benefits of a downward trend in the demand for allowances accrue to the environment with no change in the price of allowances. Then if all of the ECR designated allowances are withheld, the allowance price can fall below the ECR price step and more benefits accrue to economic interests.

A multi-step ECR would achieve more continuous sharing of benefits between the economy and the environment. Over a smaller range initially, benefits would accrue to the compliance entities. Then benefits would accrue to the environment until the ECR at the highest price step is exhausted. Then the allowance price would begin to fall again and compliance entities would benefit until the next price step is achieved, and so on.

8. How should the ECR price level(s) adjust over time?

We recommend that the ECR price level(s) adjust at the same rate (at least) as the price floor, which currently is 2.5% per year. If the ECR does not adjust at this rate, then the distance between the ECR and the price floor would change over time.

It is noteworthy that the allowance price might be expected to grow at a faster rate than 2.5% because of the role of allowance banking, which propagates and adjusts the value of an allowance over time in light of the opportunity cost of holding the allowance as a financial asset (versus buying one at a later point in time). So, in a model the allowance price is predicted to grow at the firm's opportunity cost of capital over time, which is typically represented at around 5% per year, in addition to inflation (which has been about 1% per year recently). Hence, at an annual price floor adjustment of just 2.5% the allowance price might be expected to increase faster than the price floor over time. In order to preserve the relevance of the ECR, the RGGI states might decide that its price triggers grow at 5% per year plus inflation.

9. Does the introduction of an ECR affect what the level of the price floor should be?

We recommend approaching these questions sequentially. First, the RGGI states may want to address the familiar question of a minimum price in the program below which no allowances should sell – that is, the price floor. The RGGI states might want determine the ECR after the price floor is determined because it simplifies and organizes the decision making process. We note that the current price floor has increased only at the rate of inflation and has not increased in real terms since the first auction in 2008.

10. Does the ECR affect whether there should be a bank adjustment, or what the level of the cap should be?

Again, we recommend approaching these questions sequentially. First, the RGGI states may want to determine the intended level of the cap. That may involve an adjustment to account for the size of the privately held banked allowances. These decisions will influence the model-identified price in the allowance market, which is helpful information in setting the level of the ECR.

With this recommendation in mind, we acknowledge that the ECR provides an opportunity not only for the sharing of benefits of falling prices but also for sharing of risks when it is considered in tandem with the emissions cap. A relatively less stringent emissions cap might be expected to lead to greater emissions and also a lower allowance price, potentially making the ECR more important. RGGI states might harbor greater ambition but might be concerned about potentially unexpectedly high prices. There may be an opportunity for compromise by designing the ECR so that its price trigger is closer to the anticipated price in the market. Previously, we suggested the ECR be centered around the midpoint between the price floor and the model-identified price. But a higher ECR price relative to the model-identified price would make the ECR more likely to be triggered and thereby limit allowance supply. Hence, one can imagine a compromise with a relatively higher ECR price or prices accompanying a relatively less stringent emissions cap.

11. How would the ECR affect the availability of auction revenue for program-related investments?

If the ECR is triggered it will lead to fewer allowances sold but those that sell would have a higher price. In simulation modeling we find a slight increase in revenue that is raised.

12. Transparency and relative simplicity have been virtues of RGGI. What approach to the ECR would yield the most transparent and simplest design?

The ECR adds transparency to RGGI because potential adjustments to the supply of allowances could be anticipated by observers of the market to follow from the path of allowance prices. Currently adjustments occur as part of the program review and with greater consequence and less predictability. Of course, RGGI's administrative program review always remains of central relevance, but the ECR adds predictability for compliance entities about how the program may evolve on a real-time basis as they make compliance decisions, rather than exclusively having to anticipate ex post adjustments at the end of the compliance period in the program review.

The ECR is a simple mechanism and is implemented in a parallel manner to the price floor and the CCR, as we have already discussed. Some observers have suggested that a single step ECR would be simpler because it involves a single rather than multiple steps. However, under an ECR with multiple steps, the price would be less likely to land on any individual step and compliance entities could anticipate a more continuous and gradual adjustment to supply.

13. The ECR sounds like the best thing since sliced bread. What could go wrong?

We have examined the ECR from an analytical and modeling perspective and have not identified potential unintended consequences. With our colleagues at the University of Virginia we have stress-tested the ECR in a laboratory setting. There we found that human subjects were able to understand the market design and make coherent decisions. We did not observe a difference in bidding behavior with respect to collusion, bidding true willingness to pay, or market price formation without or with the ECR. In summary, we believe the ECR is a simple enhancement to the program that helps the RGGI states better accomplish their program goals, with no identified downside risk, assuming the mechanism is implemented properly.

14. What are *do's* and *don'ts* in designing the ECR?

We identify just a few basic issues. One is the implementation of the ECR as a reserve price in the auction. This is the simplest approach and we believe bidding behavior in the auctions will be least affected if the ECR is implemented as part of a regular auction and using a reserve price approach comparable to what is used already for the price floor. Second is how the ECR adjusts over time. For it to remain relevant it should increase over time, at least at the same rate as the price floor although a higher rate can be justified. We have addressed other considerations in these comments that might improve the performance of the ECR, but we have not identified any considerations that would have a negative effect on the market.

15. How would the ECR, as part of the RGGI design, affect the opportunity for other states to trade with or to join RGGI?

The ECR would be implemented in a parallel fashion to the price floor and the CCR, so it does not complicate the implementation of the program for a state considering joining RGGI or participation through other linkage mechanisms. The ECR has the benefit of sharing the benefits of potentially low allowance prices among compliance entities, consumers, and the environment, which may appeal to states interested in participation or linking with the RGGI program.

16. How can the ECR help RGGI to magnify its influence on other states and nations?

RGGI has been a testbed for the design of emissions cap and trade and has had outsized influence in North America and Europe. That influence includes the spreading of the use of an auction and the role of a price floor in the auction. The ECR represents a similarly valuable aspect of program design. The adoption of a well-designed ECR might influence other programs, especially in Europe, where prices are far below anticipated levels. The European trading system has not been able to implement a price floor, despite many proponents for this approach, because of perceived legal constraints. Some argue a price floor would require unanimity of all member states because the price floor might actually determine the price in the market, thereby constituting a tax. The ECR has the feature that it explicitly does not determine the price. If the ECR is triggered, the supply of allowances is reduced, but the price can continue to fall below the ECR level. European policymakers we have talked to are keenly interested in the decision RGGI might make with respect to the ECR because of the precedent it would represent.

A Straw Proposal

We offer a straw proposal for the consideration of the RGGI states. Our working assumption is that the model-identified price under the intended emissions cap is $8 per ton in 2020. This is the approximate value resulting in our modeling associated with an assumed annual reduction in the cap through 2030 equal to 3.5% of the 2020 cap (excluding the cap adjustment for that year) which was a focal part of the discussion among the RGGI states in 2016. New information and assumptions since 2016 have already made these model results out of date and, indeed, that fact makes a strong case for the ECR. The modeling is always done with underlying uncertainty about the cost of compliance and without complete foresight of future policy and technology developments. Hence, in the face of such uncertainty, we take the dialogue about cap stringency and the associated allowance price identified by the model as a measure of the willingness to accept an expected allowance price among the RGGI states.

We assume the price floor remains as it is currently configured, rising at 2.5% per year, although we do not claim this as our preferred outcome with respect to the price floor. We suggest the ECR rise at a rate that is equal to whatever rate applies to the price floor.

We suggest allowances that do not sell under the ECR are treated in the same way as allowances that do not sell under the price floor. These allowances would be held out of the market until the next scheduled program review, where a decision would be taken by the RGGI states. Previously allowances unsold under the price floor have been permanently retired. We assume the ECR mechanism would be in effect each year.

We propose a three-step ECR be organized around the $5 midpoint between the model-identified allowance price of $8 in 2020 and the current price floor of about $2. This is the price identified in our model representation of choices that were being considered in 2016. The ground keeps shifting in the modeling (making a case for the ECR); we assume the level of effort that is expected will involve a model-identified price of around $8 in 2020. The important point of reference for the RGGI states is the model-identified price associated with the policy scenario that is ultimately selected for the RGGI design through 2030. That “price” will inform the choice of the ECR price step(s).

We propose that a total of 21.9 million tons per year would be associated with the ECR, distributed in equal shares of 7.3 million tons at price triggers of $6.50, $5.00 and $3.50 in 2020. This aggregate quantity would mirror the size of the annual cap adjustment from 2016 through 2020.