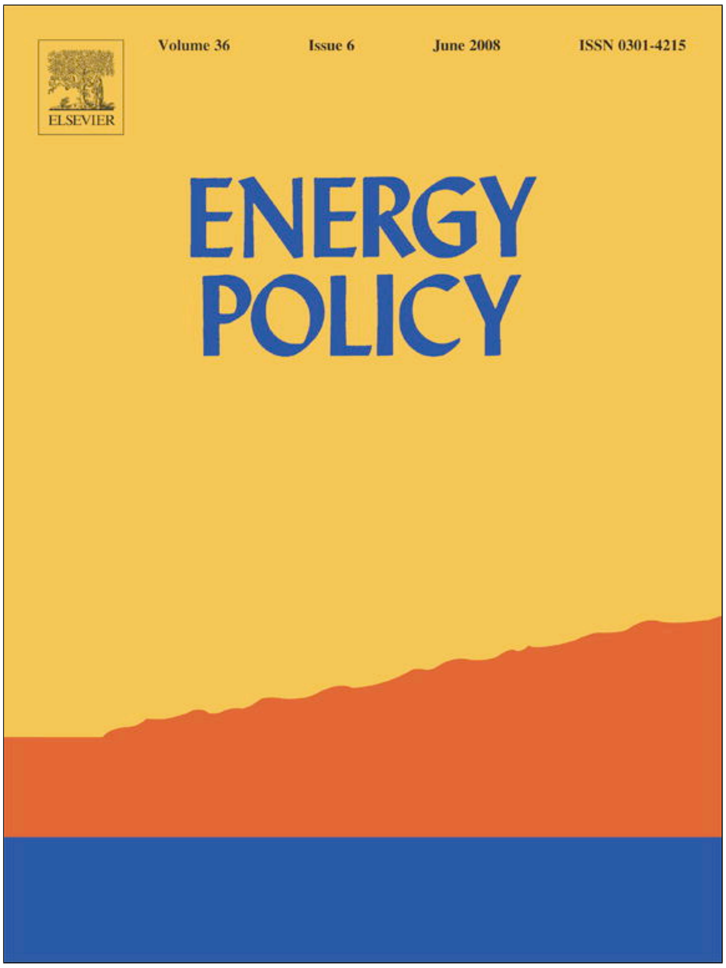
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Economic and energy impacts from participation in the regional greenhouse gas initiative: A case study of the State of Maryland

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ABSTRACT

Tradable emissions allowance systems to reduce carbon emissions are increasingly promoted as means to mitigate climate change. This paper briefly reviews the application of such systems at the global, regional, and corporate scales. Given the recent expansion of cap-and-trade systems at the regional level, the paper concentrates on energy and economic implications at that level, using the decision of the State of Maryland, USA, to join the Regional Greenhouse Gas Initiative as an illustration. The paper presents the results of an analysis of the implications for technology choice, generation capacity, energy reliability, and cost to ratepayers of that decision, combining a national electricity market model with a regional model that includes market power and an economic impact model. The results suggest several issues that will be key to the acceptability and effectiveness of cap-and-trade systems for regional climate change mitigation policy, including rules for distribution of allowances and subsidies for energy efficiency programs.

1. Introduction

Climate change has been recognized as a serious environmental problem (IPCC, 2007). Forward thinking policymakers and stakeholders are seeking policies that leave a less environmentally damaging footprint at acceptable costs. One approach is to concentrate on the environmental damages done by production and consumption, and to incorporate the costs associated with such damages into the prices of the goods and services that households, firms and the government buy. As the prices of socially undesirable products, services and activities increase, economic incentives exist to substitute away from those and toward less harmful ones (Svendsen, 1998). To the extent that price increases are triggered through the implementation of taxes or the requirement to purchase allowances for emissions, government revenues are generated, which can be used to stimulate investment in products and processes that produce less environmental harm.

Among such market-based instruments are the tradable permit systems increasingly promoted by economists to stimulate reduction of greenhouse gas (GHG) emissions. For example, a carbon emissions cap is identified for a sector of an economy or a geographic region, and then allowances are distributed and/or auctioned to emitters. If those allowances are tradable, participants in the cap-and-trade system can sell any unneeded allowances to others, creating incentives for firms to reduce their emissions and thus, improve their bottom line. Conversely, participants that are unable to reduce their emissions can purchase allowances and, by so doing, are better able to remain in business while complying with carbon emissions restrictions. An alternative way to discourage energy use would be an energy tax, which should create similar incentives for energy using firms and households to reduce energy consumption. However, in

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contrast to a tradable allowance system, an energy tax will not discriminate against the use of high carbon fuels, but only discourage purchase of fuels in general. Moreover, it can be argued that a cap-and-trade system is economically efficient from the perspective of the company (Tietenberg, 2006). However, particular rules for free distribution of allowances can cause distortions in investment that would not result from taxes (Burtraw et al., 2002).

Tradable permit systems have been discussed or implemented on a variety of geographic and regulatory scales: globally, multinationally, nationally, regionally, and even at the corporate level. In the absence of US participation in a global, international or national trading program, some states are choosing to develop regional cap-and-trade programs, such as the Regional Greenhouse Gas Initiative (RGGI) or the Western Regional Climate Action Initiative. There are numerous choices involved in a government's decision to initiate or participate in a cap-and-trade program. These include decisions on the total permit volume available for allocation, allocation mechanisms, use of revenues from emissions allowances that are auctioned off by government, and overall scale of the program, as defined, e.g., by the number of GHGs or economic sectors that are covered.

In Section 2, we first briefly review various cap-and-trade programs for carbon dioxide. Then we concentrate, in Section 3, on key features of the RGGI established by several US Northeast and Mid-Atlantic states. In Section 4, we describe key aspects surrounding the choice of a state to enter RGGI and explore, for the case of Maryland, the potential economic and energy implications of doing so. The paper closes with a summary of policy conclusions for the State, as well as broader-ranging lessons for RGGI and other such regional cap-and-trade systems.

It is important to note that, although the study that provides much of the analysis for this paper on Maryland's *potential* participation in RGGI was released on January 31, 2007 (CIER, 2007), the State has since officially joined the initiative (April 20, 2007). Nonetheless, the analysis on tradeoffs that was completed is still relevant in the policy debate. For instance, decisions still need to be made on the extent to which energy efficiency measures will be funded from allowance auctions. Moreover, this analysis may be pertinent to similar efforts, such as by other states in the US and Australia.

2. Scale of cap-and-trade programs

Coalitions of decision makers at different levels and scales are responding to climate change through the use of cap-and-trade programs for GHGs at global, international, national, subnational, and corporate levels. At the global level, the Kyoto Protocol (UNFCCC, 1997) allows for global trading of emissions, although a formal trading program has yet to be designed. However, some have expressed doubt whether a global system could ever be successfully implemented or maintained due to the complexity and coordination costs of allocating emissions allowances as well as the difficulty in permanently changing institutional and technological opportunities and constraints (Sagoff, 1999; Ruth, 2006).

At the international level, Europe launched the European Union Emissions Trading System (EU ETS) in 2005 to meet their commitments to the Kyoto Protocol (Haar and Haar, 2005). At this time, 25 countries are participating in the program. This effort is significant, as it is the first attempt to coordinate national GHG trading schemes into one program. The EU ETS initially covers four industrial sectors: energy, minerals (including cement, glass, and ceramics), iron and steel, and pulp and paper (Kruger and Pizer, 2004). The program is being implemented in phases, with the first "warm-up" phase running from 2005 to 2007, and the second phase operating concurrently with the first commitment period of the Kyoto Protocol from 2008 to 2012. After that time, phases will function in 5-year increments (Kruger and Pizer, 2004). Emissions allocations were agreed upon by the European Union based on the emissions reduction burdens specified by the Kyoto Protocol. These allocations are detailed in each country's National Allocation Plan, which is submitted to the European Union. Table 1 provides the total reduction commitment over both phases from various participants.

Prior to joining the EU ETS, a few European nations had national cap-and-trade programs for carbon dioxide. The UK implemented a program for GHGs in 2002 (DEFRA, 2002). Denmark passed legislation in 1999 that capped emissions from coal-fired power plants from 2001 to 2003 (Olesen, 2003).

In June 2007, the Australian prime minister announced that his nation would create a cap-and-trade scheme for carbon by 2012 (Cole, 2007). Prior to this announcement, the Australian states and territories banded together to design their own emissions trading scheme through the National Emissions Trading Taskforce (NETT, 2007). They are currently in the process of designing a program and hope to start trading by the end of 2010. In the meantime, specific states and territories in Australia are setting emissions reduction targets. For example, the Australian Capital Territory has set a goal of stabilizing emissions at 1990 levels by 2008, and reducing emissions 20 percent below 1990 levels by 2018 (Australian Greenhouse Office, 2007). New South Wales has committed to stabilizing emissions at 2000 levels by 2025 and reducing emissions 60 percent by 2050 (New South Wales Greenhouse Office, 2007). Queensland, South Australia and Tasmania have not set their own targets, but have committed to achieving the targets negotiated by Australia in the Kyoto Protocol, which is to limit emissions to 108 percent of 1990 levels during 2008–2012, and then reduce emissions to 60 percent below 1990 levels by 2050 (Government of South Australia, 2007). Victoria and Western Australia do not have emissions reduction targets at this time.

At the corporate level, several companies, such as BP, Royal Dutch Shell, Alcoa, and DuPont, have voluntarily participated in cap-and-trade, either through internal systems or external trading and offset purchases (e.g., via the Chicago Climate Exchange (CCX)) (Sandor et al., 2002). For example, through a modified cap-and-trade mechanism, implemented first in 12 key business units in the fall of 1998 and then for the entire company in 2000, BP cut carbon emissions to more than 10 percent below 1990 levels by

Table 1
2008–2012 GHG reduction targets for EU ETS participants

Country	2008–2012 target (%, all GHG)
Luxembourg	−28
Denmark	−21
Germany	−21
Austria	−13
UK	−12.5
Belgium	−7.5
Italy	−6.5
Netherlands	−6.0
Finland	0
France	0
Sweden	+4
Ireland	+13
Spain	+15
Greece	+25
Portugal	+27
EU Total	−8

Source: Mace (2007).

the end of 2001. This represented an almost 15 percent drop from 1998 levels. Despite lacking key features of a "conventional" trading system (e.g., a binding cap) and including a generous safety valve that allowed the ETS's manager to relax the cap or compliance when the costs of the system exceeded the direct benefits to the company, BP's success with cap-and-trade probably cemented the credibility of the concept and, perhaps, staved off the implementation of a carbon tax in Europe. However, the company abandoned its program, without internal dissent, because of the higher costs of further cuts and the inherent challenges of complying with both an internal program and external regulations (i.e., EU ETS) (Victor and House, 2006).

Nevertheless, the commitment from many corporations to cutting emissions through participation in voluntary emissions markets remains strong. Dupont, for instance, made a commitment in 2006 to participate in a second phase of the CCX, a voluntary but legally binding GHG emissions trading exchange, of which it was a charter member (Dupont, 2007). Although like BP, Royal Dutch Shell had switched its emphasis from internal emissions trading pilots to external systems, it reaffirmed its commitment to tradable permit systems by entering the UK ETS, which placed a GHG emissions cap on many of its production facilities (Pew Center, 2007). Decisions like these have sparked further interest in private sector experiments with tradable permit systems and may lead to further voluntary corporate reductions of GHG emissions. For example, in April 2007, Intel also joined the second phase of the CCX (Chicago Climate Exchange and Intel Corp., 2007).

In the US, due to the absence of a national policy or US participation in international regimes, regional coalitions have developed GHG cap-and-trade programs. In 2001, a group of New England governors and provincial premiers in Eastern Canada came together to develop a coordinated action plan on climate change. Among its strategies was a call for an "exploration of a trading mechanism" for emissions (NEG/ECP, 2001). In 2003, New York's Governor George Pataki sent letters to 11 governors in the US Northeast and Mid-Atlantic regions, inviting them to create a regional cap-and-trade program, now known as the RGGI, for carbon dioxide from electric-generating sources (RGGI, 2007). In 2007, the governors of five western states established the Western Regional Climate Action Initiative, the goals of which include designing a regional cap-and-trade program for GHGs (Western Regional Climate Action Initiative, 2007). As regional cap-and-trade initiatives proliferate, both in the US and abroad, they may prove more durable than both global and corporate schemes because of the high transaction costs of the former (noted in Sagoff, 1999) and the challenge of fulfilling multiple, potentially conflicting regulatory mandates inherent in the latter (Victor and House, 2006).

Thus, in our remaining discussion, we focus at this subnational, regional level, using the RGGI as a case study. In Section 3, we describe the main features of RGGI before we explore (in Section 4), some of the underlying economic, regulatory and energy-supply-related concerns that must be addressed by a state when considering joining a cap-and-trade system. Our analysis in that section concentrates on the State of Maryland as it recently sponsored our research into the impacts associated with it joining RGGI.

Maryland's decision to join RGGI is significant because its power sector heavily relies on coal, unlike the other RGGI states. Investments in coal-based electricity generation capacity have varied over the years, with one 35 MW generator operating since the late 1940s, and larger additions of over 600 MW having occurred during the 1970s–1990s. With its pursuit of coal-based electricity during the last 30 years, Maryland is not unlike many other states that historically relied on coal as a major source for power generation. The State represents the kind of player that has traditionally shied away from joining a cap-and-trade system.

3. The Regional Greenhouse Gas Initiative

In December 2005, the governors of seven US states (Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont) entered into a Memorandum of Understanding (MOU), which specified the general framework of RGGI. By January 2007, nine states were participants in the RGGI process (RGGI, 2007)—Massachusetts and Rhode Island joined in January 2007. According to 2003 figures from the US Environmental Protection Agency, the region emits over nine percent of total US CO_2 emissions from fossil fuel combustion (EPA, 2003). Hence, the RGGI region represents a non-trivial portion of US and global emissions.

The RGGI cap-and-trade program will start in 2009 and apply to coal-fired, oil-fired, and gas-fired electric-generating units with a capacity of at least 25 MW (RGGI, 2006). In 2009, emissions of CO_2 from power plants will be capped at approximately current levels (roughly 171 million metric tons of CO_2 annually for the entire region and 34 million annually in Maryland specifically (Lee, 2007; RGGI, 2007b)). This cap will remain in place until 2015. Then, over the following 4 years, the RGGI states will reduce emissions incrementally to achieve a 10 percent reduction by 2019. Plants will need one allowance for each ton of CO_2 emitted and can buy and sell allowances. The total number of allowances made available each year will be equal to the yearly emissions cap for the region. Banking of allowances for use in future compliance periods is allowed. Although the cap-and-trade program is regional, each state will receive an individual annual "emissions budget." In total, it is estimated that RGGI will result approximately in a 35 percent reduction of CO_2 by 2020 in the original RGGI states (excluding Maryland), compared with projected emissions in that year without the cap-and-trade program (i.e., business as usual) (RGGI, 2006). This represents an approximately 13 percent reduction from 1990 levels (Litz, 2007).

A first key issue in designing any cap-and-trade program concerns the initial distribution of emissions allowances. One possibility is to give allowances away for free, based on some measure of past or current performance. A second alternative is to auction off the allowances. Since RGGI stipulates that each state allocate a minimum of 25 percent per state of its allowance budget to "consumer benefit or strategic energy purpose" (RGGI, 2007a), an auction of allowances can be used to generate government revenues to stimulate direct benefit and support energy efficiency goals. However, some RGGI states have decided that they will increase this percentage to as much as 100 percent, as in the cases of Vermont, New York, Maine, and Connecticut (the last two after small set asides) (Lee, 2007; NYSDEC, 2006; Vermont Legislature, 2006).

In contrast, in the EU ETS for CO_2, member states had been precluded from auctioning any more than 5 percent of the allowances during the first phase of that program (2005–2007) and no more than 10 percent in the second phase (2008–2012) (Kruger and Pizer, 2004), a rule which proved very controversial (Kruger and Pizer, 2005) and was changed since. It led to allegations that electricity producers earned "windfall profits" because they charged electricity customers for the value of emission allowances even though they received the majority of allowances for free (Mortishead, 2006; Sijm et al., 2006).

The RGGI market area and much of the surrounding region, including Maryland, largely has market-based electricity prices. Since these prices are competitively determined and Maryland electricity supply is part of a larger regional system, it is not expected that the allowance allocation method (free allocation or auction) will make a difference in electricity prices for consumers. However, there would be a difference in who captures the newly created value of the allowances created by the program.

Thus, a second crucial issue in designing and administering a cap-and-trade program concerns the use of proceeds from auctioned allowances. The decision on how much of the proceeds to use from permit auctions for energy efficiency improvements has important implications for the cost to utilities and rate payers alike. As discussed in more detail below, this study explicitly captured the relationship between auction revenues and expenditures on end-use efficiency. Overall electricity demand is anticipated to decrease when the percentage of allowances that are auctioned off is increased, due to energy efficiency programs to be funded by auction revenues. Consequently, as Maryland joins RGGI, there are different effects on electricity prices and profitability of various types of generation depending on the share of allowances that is auctioned and how the revenues are spent.

RGGI is designed to give generators flexibility in meeting their obligations at the lowest cost. For example, power plants are allowed to offset GHG emissions—measured in CO_2 equivalent (CO_2e) units—from outside the electricity sector to a limited extent (RGGI, 2007a). Examples of offset projects include: natural gas end-use efficiency, landfill gas recovery, reforestation, and methane capture from farming facilities. At first, these offsets can account for up to 3.3 percent of their emissions, which translates to approximately 50 percent of the average CO_2 reduction obligation under the program (RGGI, 2005a, b). However, the maximum percentage allowable for offsets can change depending on the cost of allowances. If the CO_2 allowance price equals or exceeds 7 dollars/ton, (adjusted to 2005 dollars) for a 12-month period, emitters can cover up to five percent of emissions with offsets; if it equals or exceeds 10 dollars/ton (adjusted 2005 dollars), offsets can account for up to 10 percent of a source's emissions (RGGI, 2005a, 2006). Offset credits can come from anywhere in the US, but states or other US jurisdictions that are not part of RGGI are required to enter into a MOU with RGGI state agencies to ensure the credibility of the offset projects (RGGI, 2006). At CO_2 permit prices in excess of 10 dollars, sources in RGGI may purchase certified emission reductions (CERs) from the international Clean Development Mechanism (CDM) process (RGGI, 2007a).

4. Economic and energy implications of joining RGGI—the case of Maryland

In 2006, Maryland enacted the Healthy Air Act (HAA) (Maryland General Assembly, 2006), mandating reductions in three major pollutants from coal-fired power plants: nitrogen oxides (NO_x), sulfur dioxide (SO_2), and mercury. In addition, the HAA addresses CO_2 emissions from power plants by requiring Maryland to become a full participant in RGGI (which as noted above, it officially did in April 2007), after performing the impact study reported herein. Although New Hampshire was the first state in the US to adopt a comprehensive four-pollutant approach to regulating power plant emissions (NCEL, 2002), the HAA puts Maryland at the forefront of a multi-pollutant approach for states, which derive most of their electricity from coal. Recognizing the potential economic impacts of the legislation, however, the HAA allows for withdrawal from RGGI after January 1, 2009, if reliability and cost issues emerge and are not resolved. In that case, per legislation, an alternative program would need to be established. Following a brief review of Maryland's energy efficiency efforts and regulatory baseline, the remainder of this section presents the approach and findings of an independent scientific study carried out to assist the state in its decision-making.

4.1. *Maryland's energy efficiency efforts and regulatory baseline*

From 1991 to 1998, Maryland offered Demand-Side Management (DSM) programs through customer fees collected by utilities. More than $850 million was spent by these programs with a corresponding 3.5% reduction in electricity sales. With deregulation of utilities in 1999, these programs were abandoned and electricity consumption increased. Currently, the Maryland Energy Administration administers several energy efficiency programs of limited scale. In contrast to other states, no public benefits fund to finance these programs was instituted in Maryland after deregulation.

In 2006, Maryland's public spending for energy efficiency was $7.2 million, concentrated in weatherization subsidies for low-income households and revolving loan efficiency programs for government agencies and non-profit organizations. The spending ratio per person per year is around $1.42, which is significantly lower than in other states participating in RGGI, most notably Vermont ($22.44), New York ($9.28), or Maine ($6.96).

Maryland regulation has so far concentrated on leading by example in the state government, with a good base of policies, mandates and mechanisms for energy efficiency, green procurement, energy consumption caps, and incentives for high-performance buildings at state agencies. Maryland has additional appliance standards and has already allowed decoupled electricity profits from energy consumption to eliminate the disincentive for utilities to encourage energy conservation.

Additional incentives for energy conservation can come from allocating revenue that is generated by auctioning off emissions allowances. In Maryland, as in other RGGI states, the majority of the auction revenue will likely be invested in energy efficiency. Most states are still working through proposed statutes. For example, Connecticut's draft regulation calls for investing almost 70% of the revenue in energy efficiency (Connecticut, 2007). Maine has committed the first $5 of every allowance to energy efficiency, at least 85% of which will go to electric efficiency (Maine, 2007). Vermont's statute says that RGGI revenue should be "managed for the benefit of electric consumers, particularly benefits that will result from accelerated and sustained investments in energy efficiency and other low-cost, low-carbon power system investments" (Vermont, 2007).

Much like Maryland, other states are still exploring alternative models for the use of auction revenues. At the time of analysis, we applied what has been known about the decisions of individual states. Specifically, for Maryland we assumed that all of its revenue from permit auctions is used to support energy efficiency. Future research will revise these assumptions as needed.

4.2. *Modeling economic and energy impacts of joining RGGI*

A study of Maryland's potential participation in RGGI was conducted by the authors in 2006–2007. It served as one of the inputs for the eventual decision by the State to join RGGI. To determine a variety of impacts on the economy and the electric power grid, the study employed three models. These models were: Haiku, JHU-OUTEC, and IMPLAN®.

Haiku is a national economic simulation model of interregional trade among regional electricity markets based on market equilibrium concepts (CIER, 2007; Paul and Burtraw, 2002). Its solution identifies a market equilibrium for investment and operation of the electricity system that meets demand given a wide set of regulatory institutions. Generating companies are assumed to minimize cost, and to be price takers in the market. Electricity demand is sensitive to the level of the electricity price. The model uses a series of modules that simulate a number of factors and policies, such as capacity investment and retirement, compliance with emissions regulations, and fossil fuel markets (CIER, 2007; Paul and Burtraw, 2002).

JHU-OUTEC (The Johns Hopkins University Oligopoly Under Transmission and Emissions Constraints) is a regional market equilibrium model that allows for market power in the generation sector. It covers the eastern market area of PJM, the regional transmission organization that manages the wholesale electrical market and long-term transmission planning for 13 US states and the District of Columbia and whose central purpose is to maintain the reliability and economic efficiency of electricity supply. The JHU-OUTEC model was previously used to assess the ability of generators in the PJM regional electricity market to manipulate power prices through the NO_x allowances market (Chen and Hobbs, 2005). It contains more geographic detail than Haiku, but is regional rather than national in its scope. In particular, in contrast to Haiku's representation of Maryland as a single node, JHU-OUTEC separates Maryland into four nodes based on flow patterns and network constraints (Chen et al., 2007).

IMPLAN® is an economic impact assessment software system that combines a set of extensive databases concerning demographic statistics, economic factors, and multipliers into a highly detailed regional economic model (Minnesota IMPLAN Group, 2006). IMPLAN enables users to develop input–output models at a local level to capture a set of direct, indirect and induced impacts by sector through the use of industry-specific multipliers, local purchase coefficients, income-to-output ratios, and other economically and statistically established relationships (CIER, 2007).

Our modeling procedure involved running the Haiku model first. This strategy was adopted for two reasons. First, the Haiku model provides needed preliminary insights into the impacts of Maryland joining RGGI. Second, the Haiku results would provide key boundary conditions necessary for the other two models. In this way, all of the models would be consistent with each other while still providing a different perspective on each of their relative issues (CIER, 2007). Further, this would allow an analysis of any differences in results created by the different spatial aggregations of the models (Chen et al., 2007). Fig. 1 depicts the flow of information among these three models.

To assess the potential economic and energy impacts of joining RGGI first required the establishment of a baseline scenario representing "business as usual" in the present and near future, up to the year 2025. This baseline scenario was developed by the authors in consultation with over 60 stakeholders as well as representatives from the Maryland Department of the Environment. A second scenario assumed that RGGI rules on power generators were enforced in Maryland but kept the other assumptions the same to the extent possible. This scenario was called "Maryland Joins RGGI." Consequently, the difference in model output between these two scenarios reflects the impacts of Maryland joining RGGI. Key features of each of these scenarios

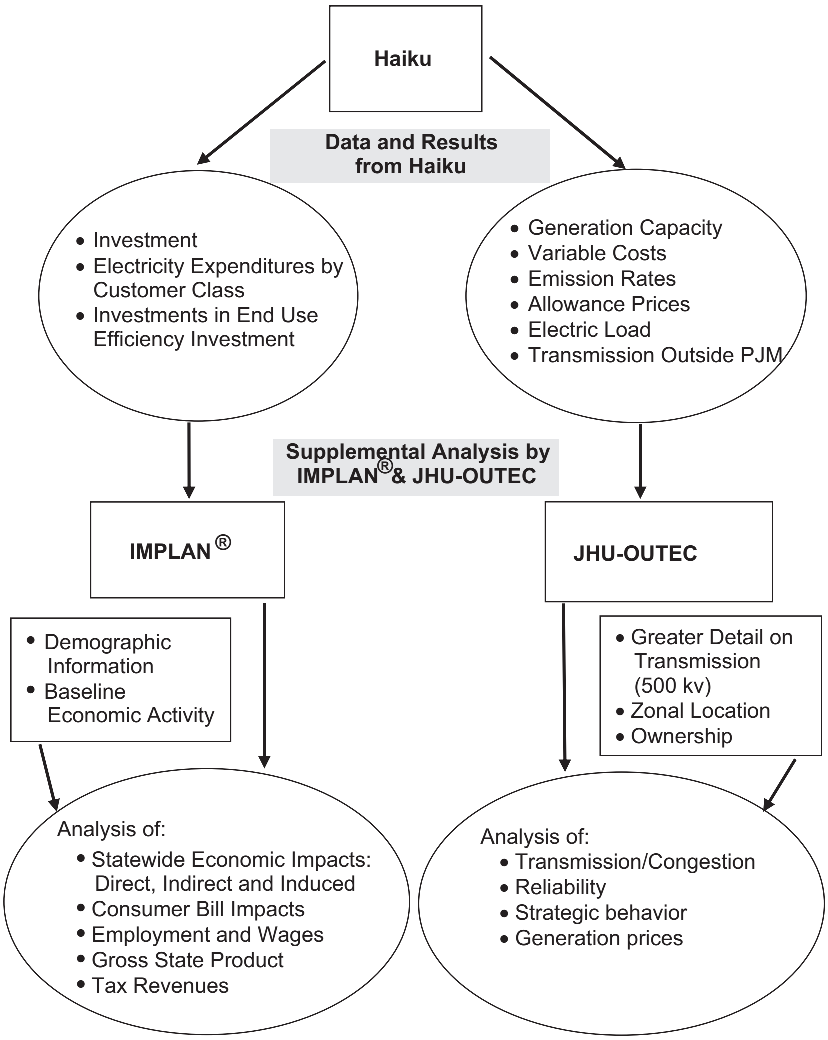

Fig. 1. Flowchart of information flows between the models used in this study. *Source*: CIER (2007).

and the implications of their differences are discussed in detail below.

4.3. Key model assumptions and scenarios

4.3.1. Baseline scenario ("business as usual")

The economic simulation was carried out for the years 2010, 2015, 2020, and 2025, with estimates for the intervening years derived by interpolation. In each of these, three seasons were modeled in Haiku and JHU-OUTEC: summer (May–September), spring/fall (October, November, March, April), and winter (December, January, February).

Prices for fossil fuels, including international oil, and nuclear power came from Annual Energy Outlook (AEO) 2006 estimates (US Energy Information Agency, 2006). Costs for renewable technologies came from the AEO 2006 initially; national laboratory data supplemented cost information for certain fuels (e.g., biomass and wind). Concerning retail electricity prices, regions were classified according to one of two approaches to setting those prices: regulated (average cost-based pricing) and market-based (marginal cost-based for wholesale, average of marginal costs for generation portion of the retail price).

The following states were modeled as the "Classic RGGI region": Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, Vermont, Massachusetts, and Rhode Island (the last two were technically observers when the models were run, but officially joined in January 2007, as anticipated).

A number of environmental policies at the federal and state level were included. Federal environmental policies included the Clean Air Interstate Rule (CAIR) and Clean Air Mercury Rule (CAMR) policies as well as the Title IV cap upon SO_2 emissions outside the CAIR region. Also included was the Renewable Electricity Production Tax Credit (REPC), which provides for a 1.9 cent/kWh (.528 cent/MJ) tax credit for qualified renewables for the first 10 years of operation with the credit escalating over time to account for inflation (2005 dollars). Uncertainty in the REPC was taken into account by applying appropriate discount factors.

The assumptions accounted for provisions of the Maryland HAA including the plant-specific emissions restrictions on NO_x, SO_2, and mercury (provided by Maryland Department of the Environment (MDE)), intra-firm trading of emissions for NO_x and SO_2 only, and sale by Maryland firms of unused CAIR (NO_x) and Title IV (SO_2) allowances out of the state.

Information on expected investments in renewables in response to state renewable portfolio standards and other state policies and programs came from NEMS AEO 2006 for all states except Maryland. For Maryland, the models used cost and location data from Exeter Associates and Princeton Energy Resources International (2006). The Maryland Renewable Tax Credit was also represented.

The assumed emissions allocation rule was to assign 75 percent of the emissions allowances to facilities according to output at the generating unit in 2004. The remaining 25 percent of allowance value was used for public benefit unless stated otherwise by state policy. For example, 100 percent of Vermont's allowances were assigned to public benefit to comply with existing Vermont state law. The models assumed that all public benefit funds generated would go to energy efficiency efforts.

The default RGGI formulas for emissions accounting were used for completeness. Emissions were counted only from electric power generation for sale to the market. CO_2 emissions associated with electricity for own use (customer side of the meter) were not counted. The study did not model industrial facilities (e.g., steel mills) that generate power for primarily their own internal use. However, industrial facilities that sell the majority of the power they generate to the grid were included (e.g., some paper mills in Maine).

Through 2010, only planned and approved transmission capacity investments were included. Beyond 2010, a one percent per year rate of growth in transmission capacity was assumed in the Haiku model. Additionally, starting in 2014, the models included the incremental transfer capability associated with two new 500 KV transmission lines into and, in one case, through Maryland, which were based on one line proposed by Allegheny Electric Power and one proposed by PEPCO Holdings. Imports from Canada were exogenously determined.

AEO 2006 values were used for demand growth for electricity. Lastly, the models assumed that there would not be a national policy of caps on GHG emissions.

4.3.2. Maryland joins RGGI scenario

The Maryland Joins RGGI case included all the assumptions of the Baseline scenario and expanded the Classic RGGI region to include Maryland. Under this scenario, the total annual amount of RGGI CO_2 emission allowances issued under the program grew by roughly one third. Increasing the size of the program also increased availability of CO_2 emission offsets (certified emission reductions) from inside and outside the RGGI region that could be used in addition to emission allowances to comply with the regional cap-and-trade program. Implementing this policy also created a pool of money used to support energy efficiency improvements for customers in Maryland.

4.4. The stakeholder process

One approach to reducing uncertainty surrounding model assumptions and to generate consensus on model inputs and results is to develop a formal process of data and model review as part of a project. To that end, stakeholders were encouraged to submit formal comments at key decision points in the research and modeling process. Over 60 stakeholders, representing more than 30 institutions, responded to open invitations to provide comment and input.

The first opportunity for input occurred at the beginning of the project, where stakeholders were asked to review modeling assumptions that would be used by the Haiku, JHU-OUTEC and IMPLAN models. Suggestions included the use of specific data sources for the study, such as updated AEO data from the Energy Information Administration and load growth forecasts from PJM. Others concerned the validity of the results, for example when the assumption was made that imports from Canada would be exogenously determined.

The second stakeholder phase asked for feedback to guide development of scenarios to be used in future phases of the study. Most of the comments were requests for further sensitivity analysis around key model inputs such as natural gas prices, carbon offsets schemes, expected demand growth in the State, and the percentage of emissions allowances auctioned. After the study was completed, a briefing was held for stakeholders and the major findings were presented. A full description of the stakeholder process and input is provided elsewhere (http://cier.umd.edu/RGGI/stakeholder.html).

4.5. Results and findings

The main conclusions of this study indicate that, overall, joining RGGI would only have a limited impact on the economy and electric power markets in Maryland. Similar conclusions hold for the current RGGI region and affected areas outside this region. Specifically, results of this study support the following high-level conclusions:

Energy and Environmental Impacts on the state from the Maryland Joins RGGI Scenario:

1. *Electricity demand*: RGGI lowers net electricity demand in Maryland by between 1.5 percent in 2010, and nearly 3 percent in 2025, relative to the Baseline scenario. These demand reductions result mainly from energy efficiency investments funded by revenues from the sale of allowances apportioned to Maryland in an allowance auction. See Table 2 for detailed electricity supply and demand information.
2. *Energy supply*: Predominant fuel sources for power generation in Maryland include coal (56%), nuclear (28%), petroleum (7%), natural gas (4%), hydro (2%), and wood waste (2%). RGGI reduces coal and natural gas generation in Maryland as the state reduces exports to neighboring regions and slightly increases reliance on power imports from out of state (Table 3). Beginning in 2020, the scenario also reduces investment in new generation capacity in Maryland by nearly 45 percent by 2025, primarily because of the reduced loads resulting from energy efficiency programs (Fig. 2).
3. *Generating plant retirement and generator profits*: A concern expressed by some stakeholders was that if Maryland joined RGGI, then profitability of within-state generators would decrease, prompting retirements and possibly reliability problems. However, the results indicate that RGGI does not lead to significant retirement of existing generating capacity (Table 3). Total profits of existing generators fall by 13 percent in 2010 and 12 percent in 2025, compared with the baseline; see Table 4. Coal-fired generators experience the largest drop in total profits, yet the smaller profits are not expected to trigger any plant retirements, since revenues still cover going-forward costs. Aggregate revenues for coal plants remain in excess of variable costs plus the estimated carrying costs of the original construction expense.
   As a result of trading unused emissions allowances with other RGGI member states, profits from oil and gas steam plants are expected to rise in the aggregate. Only a very small number of these types of facilities will not be able to cover their going-forward costs and are expected to retire.
4. *Electricity prices*: RGGI has virtually no effect on the retail price of electricity paid by ratepayers in Maryland, as shown in Table 5. This is due largely to several offsetting effects. By imposing an opportunity cost on every ton of CO_2 emitted from electricity generators in Maryland, this scenario raises the marginal cost of electricity supply in the region, thus shifting the supply curve of electricity up and to the left. In addition, it changes the shape of the supply curve somewhat compared with that under the Baseline by making imports from outside of Maryland and Classic RGGI more attractive relative to energy generated by fossil units located in Maryland. This effect leads to greater supply of imports into the region at any given price. At the same time, the investment in efficiency funded by the auction of 25 percent of the emission allowances under the Maryland Joins RGGI scenario results in a reduction in the demand for electricity. This effectively shifts the electricity demand curve down and to the left. The result is a new equilibrium point that has a lower total quantity of electricity supplied, but at a similar price as before.
5. *RGGI CO_2 allowance price*: RGGI leads to a drop in the price of RGGI CO_2 emissions allowances in all years compared with the MDE Baseline scenario. This is because Maryland is projected to be a net exporter of allowances, as its emissions are anticipated to be reduced so that generators in Maryland will not need all of the state's allowance budget. As a result of the lower CO_2 price, RGGI states other than Maryland will increase

Table 2
Electricity demand and supply in Maryland: comparing baseline and Maryland Joins RGGI scenarios

	2010		2015		2020		2025	
	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI
Net electricity demand (TJ)	259,560	255,600	281,880	276,480	306,360	299,160	330,840	321,840
Efficiency savings (TJ)	0	3960	0	5400	0	7200	0	9000
Total demand (TJ)	259,560	259,560	281,880	282,240	306,360	306,360	330,840	330,840
Generation (TJ)								
Coal	125,892	115,344	119,916	115,272	128,988	116,064	132,660	118,980
Natural gas	14,256	10,800	14,292	8,316	15,300	8388	21,024	6084
Oil	288	108	0	0	0	0	0	0
Nuclear	48,024	48,024	48,492	48,492	48,996	48,996	49,500	49,500
Hydro	6408	6408	6408	6408	6408	6408	6408	6408
All non-hydro renewables	7884	8136	8136	8316	8388	8640	11,844	10,908
Wind	3780	3780	3780	3780	3780	3780	5652	3780
Co-fired biomass	0	252	108	288	324	576	324	1260
Dedicated biomass	0	0	0	0	0	0	1548	1548
Landfill gas	4068	4068	4212	4212	4248	4248	4320	4320
Total	202,788	188,856	197,244	186,804	208,080	188,532	221,400	191,880
Fuel consumption (TJ)								
Coal	370,536	338,779	351,651	337,935	374,546	339,623	383,303	347,853
Natural Gas	35,766	27,009	32,918	19,308	35,977	18,886	46,845	13,294
Oil	950	422	0	0	0	0	0	0
Power flows (TJ)								
Imports	83,124	92,196	118,332	116,928	135,864	139,104	146,772	154,800
Exports	10,368	10,368	17,424	11,844	19,620	11,880	18,396	7056
Net imports	72,756	81,828	100,908	105,084	116,244	127,224	128,376	147,744

Source: CIER (2007).

Table 3
Generating capacity in Maryland

	2010		2015		2020		2025	
	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI
Total capacity (MW)								
Coal	5145	5145	5145	5145	5454	5145	5557	5145
Natural gas	3443	3423	3443	3423	3443	3423	3813	3423
Oil	1855	1833	1855	1833	1855	1833	1855	1833
Nuclear	1873	1873	1873	1873	1873	1873	1873	1873
Hydro	494	494	494	494	494	494	494	494
All non-hydro renewables[a]	515	551	526	556	540	592	780	681
Wind	360	360	360	361	360	361	539	361
Dedicated biomass	0	0	0	0	0	0	63	63
Landfill gas	153	153	157	157	157	157	157	157
Total	13,330	13,290	13,340	13,300	13,650	13,300	14,360	13,360
New capacity (MW)								
Coal	0	0	0	0	311	0	414	0
Natural gas	740	740	740	740	740	740	1111	740
All non-hydro renewables[a]	380	380	384	385	385	385	625	447
Wind	360	360	360	361	360	361	539	361
Dedicated biomass	0	0	0	0	0	0	63	63
Landfill gas	18	18	22	22	22	22	22	22
Total	1124	1124	1128	1129	1437	1129	2152	1191

Source: CIER (2007).
[a] This total includes that portion of coal-fired capacity that is co-fired with biomass and is also included under the coal category, but included only once in the overall total.

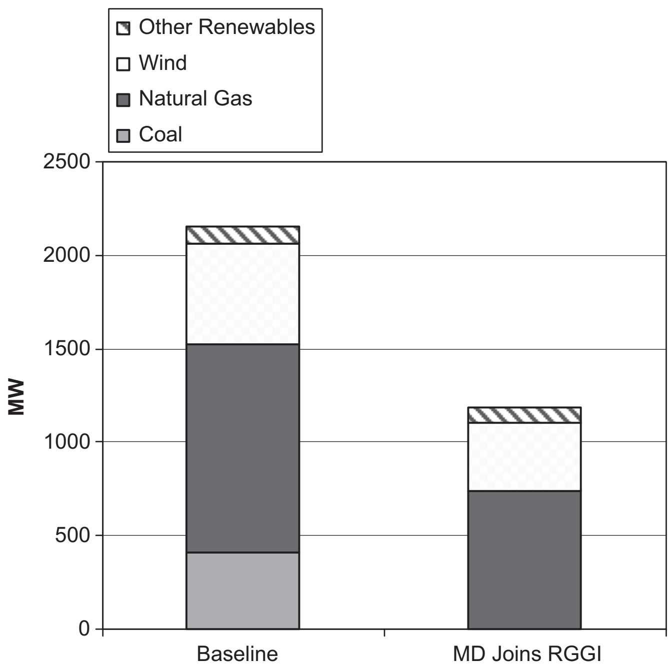

Fig. 2. Cumulative capacity additions in Maryland by 2025. *Source*: CIER (2007).

Table 4
Effect of Maryland joining RGGI on annual producer surplus for existing generating units in Maryland (US $/MW)

	2010	2015	2020	2025
All generators	−3600	−2020	−3990	−8010
Coal	−9600	−12,850	−20,530	−32,200
Natural gas	−1520	5215	4291	7390
Oil	2830	7287	12,438	15,200

Source: CIER (2007).

their emissions by the amount of allowances they buy from Maryland sources.

6. *Emissions of CO_2 and other pollutants*: RGGI results in lower emissions of CO_2 from electricity generators in Maryland, as expected. Emissions fall substantially below allocated target levels in 2010 as generation sources in Maryland, and throughout the expanded RGGI region, take advantage of opportunities to bank emissions allowances for future use. Over the entire forecast horizon, cumulative emissions of CO_2 in the expanded RGGI region, including Maryland, fall by 26 million tons (Tables 6 and 7). This decrease includes offsets that reduce GHG emissions in other sectors by the equivalent of roughly 19 million tons.
Note that because NO_x and SO_2 emissions are already capped by binding national and state legislation, there will not be any net national decrease in these emissions, although the distribution over space and time could change. However, the prices of NO_x and SO_2 would be expected to fall slightly, as reductions in Maryland coal plant production would put less pressure on allowance prices in those markets.
7. *Emissions leakage*: The term "leakage" refers to increases in CO_2 emissions outside of the RGGI area as a result of greater power imports to RGGI or other effects. Depending on how they are grouped, states outside of RGGI could either see a reduction in carbon dioxide emissions when Maryland joins RGGI, or an increase. In general, this leakage is expected to be small (4.35 MT nationally), as Table 8 shows, and only partially runs counter to the emissions reductions within RGGI and offsets (6.35+17.06 MT).
8. *Generator competitiveness*: There is no evidence that the effects of Maryland joining RGGI will amplify any potential market power in the generation market. This was evaluated using JHU-OUTEC, which simulates an oligopolistic market in which strategic generators can raise prices if profitable based on a Cournot (quantity) strategy. Table 9 shows the effect of Maryland Joins RGGI upon mark-ups, defined as the difference between market prices under oligopoly and those under a pure competition scenario, in which all producers are assumed to be price takers. The table reveals that mark-ups are higher under

Table 5
Average retail electricity prices in Maryland (2004 US $/gigajoule)

	2010		2015		2020		2025	
	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI
Aggregate average price	24.13	24.07	25.95	25.89	26.99	27.05	28.36	28.44
Residential	27.92	27.83	30.03	30.03	31.14	31.22	32.64	32.83
Commercial	23.53	23.48	25.15	25.06	26.12	26.12	27.44	27.41
Industrial	19.13	19.09	20.43	20.33	21.29	21.30	22.45	22.39

Source: CIER (2007).

Table 6
Emissions from electricity generation: comparison of baseline and Maryland joins RGGI scenarios (Mtons)

	2010		2015		2020		2025	
	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI	Baseline	MD Joins RGGI
Emissions in classic RGGI								
SO_2 (ktons)	175.18	179.44	93.26	90.99	88.11	86.26	83.77	83.21
NO_x (ktons)	82.83	86.42	65.88	69.21	62.61	67.65	57.20	61.70
Mercury (tons)	0.84	0.86	0.67	0.70	0.54	0.58	0.52	0.53
CO_2 (Mtons)	112.67	113.85	108.95	111.58	107.68	111.49	107.05	111.13
Emissions in MD								
SO_2 (ktons)	51.66	43.74	35.13	36.84	37.34	36.80	37.76	34.93
NO_x (ktons)	24.44	17.31	20.61	16.91	21.97	16.95	22.23	19.22
Mercury (tons)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
CO_2 (Mtons)	34.47	31.03	32.57	30.66	34.75	30.84	36.11	31.21

Source: CIER (2007).

Table 7
Effect of Maryland joining RGGI on cumulative emissions of CO_2 from fossil generators and emissions offsets (2010–2025) (million Mtons)

	Maryland	Classic RGGI	RGGI including Maryland	Offsets
CO_2 emissions				
Baseline	548.67	1742.34	2291.00	−91.44
RGGI joins Maryland	494.32	1790.33	2284.65	−108.50
Effect of policy	−54.34	47.99	−6.35	−17.06

Source: CIER (2007).

Table 8
Looking for leakage: effect of Maryland joining RGGI on cumulative emissions of CO_2 from fossil generators 2010–2025 (million Mtons)

	Expanded RGGI (including Maryland)	Offsets purchases	Ring[a] around RGGI	Eastern interconnect excluding expanded RGGI	Nation excluding expanded RGGI
CO_2 emissions					
Baseline	2291.00	−91.44	14,899.97	32,821.58	42,056.27
Maryland Joins RGGI	2284.65	−119.6	16,410.00	36,188.70	46,354.30
Effect of Policy	−6.35	−17.06	−13.06	8.26	−4.35

Source: CIER (2007).
[a] The ring includes Pennsylvania, Ohio, Michigan, Indiana, Kentucky, West Virginia, Virginia, and North Carolina.

Table 9
Impact of Maryland Joins RGGI on Maryland oligopolistic price mark-ups

	2010	2015	2020	2025
Maryland Joins RGGI as a percent of baseline mark-ups	100	96	116	96

The table provides the following ratio: $[(I-J)/(K-L)] \times 100\%$ for the scenario years where: I = oligopoly price, given Maryland Joins RGGI, J = competitive price, given Maryland Joins RGGI, K = oligopoly price, given Baseline scenario, L = competitive price, given Baseline scenario.
Source: CIER (2007); Chen et al. (2007).

Maryland Joins RGGI only for one of the 4 years. This justifies a conclusion that Maryland joining the RGGI market will not appreciably exacerbate any existing market power problems within Maryland.

9. *Generation adequacy*: The effect of Maryland joining RGGI on generation capacity prices in the central Maryland area under the newly revised PJM capacity market system was also analyzed. The analysis indicates it is unlikely that generation capacity prices would significantly rise in that area due to Maryland joining RGGI. One reason is that energy efficiency programs under RGGI would at least partially compensate for

the losses of Maryland capacity that arise from more plant retirements under RGGI.

Economic impacts on the state from the Maryland Joins RGGI Scenario:

1. *Electricity bill impacts*: Overall, electricity bills decrease over $100 million in 2010 and more than $200 million by 2025 if Maryland joins RGGI (Table 10). This is a result of increased energy efficiencies, which will lower customers' demands. Since the heaviest users will save the most, more than half the savings (between 53 percent and 63 percent) will go to industrial and commercial customers. On average, a residential ratepayer will see a modest bill reduction—about $22 annual savings per household by 2010.
2. *Overall economic impacts*: The predictions from the HAIKU model were analyzed using IMPLAN to determine the overall impact of RGGI on the state economy. The results show that RGGI will have little net impact on the Maryland economy. The positive economic impacts from reduced electricity costs and energy efficiency investments are partially offset by reduced investment and profits in the electricity-generating sector. Overall, RGGI is predicted to have a positive economic impact on Gross State Product of approximately $100 million in 2010, increasing to about $200 million in 2015 and subsequent years. This impact is expected to result in a net gain of approximately 1800 jobs across the state by 2010, increasing to roughly 4000 jobs by 2025. Such positive impacts are less than 0.1 percent of overall Maryland gross state product and employment in all years, as Tables 11 and 12 show.

Table 10
Estimated decrease in overall electricity bills by customer class if Maryland Joins RGGI (US $)

Period	Commercial	Industrial	Residential	Total
2010	30,952,150	27,375,363	50,748,682	109,076,195
2015	49,695,645	40,002,297	66,110,479	155,808,421
2020	63,154,830	42,666,918	77,234,050	183,055,798
2025	90,252,627	55,857,044	91,487,400	237,597,071

Source: CIER (2007).

Table 11
Total economic impact of RGGI if Maryland Joins RGGI

Employment	Direct	Indirect	Induced	Total
2010	1158	244	419	1821
2015	1770	406	720	2896
2020	1925	423	729	3077
2025	2510	522	883	3915
Gross state product (US $)				
2010	76,894,824	30,149,489	40,598,432	147,642,745
2015	157,448,311	49,856,366	70,117,000	277,421,677
2020	147,637,571	51,800,620	70,751,778	270,189,969
2025	156,063,712	63,758,123	85,778,038	305,599,873
Wages (US $)				
2010	40,582,563	11,164,190	14,253,209	65,999,962
2015	70,510,701	18,608,208	24,734,292	113,853,201
2020	71,038,956	24,353,186	24,976,621	120,368,763
2025	86,162,255	23,394,531	30,277,450	139,834,236
Taxes (US $)				
2010	2,656,041	1,478,824	1,834,583	5,969,448
2015	7,564,406	2,631,934	3,556,028	13,752,368
2020	6,655,720	2,647,797	3,398,174	12,701,691
2025	5,056,649	3,022,525	3,682,105	11,761,279

Source: CIER (2007).

Table 12
Total statewide employment impacts if Maryland Joins RGGI

Employment	2010	2015	2020	2025
Consumer savings impact	1487	2168	2582	3418
Efficiency investment impact	633	913	1234	1588
Generator investment and profits impact	(299)	(185)	(739)	(1091)
Total impact on employment	1821	2896	3077	3915

Source: CIER (2007).

5. Summary and conclusions

Cap-and-trade regimes for CO_2 emissions have been considered at multiple regulatory levels ranging from the global to the corporate. Among the cap-and-trade regimes *en vogue* today are those established at regional levels. One is the Regional Greenhouse Gas Initiative, which will function at both a state and regional level within the US. Although the trading program functions throughout the RGGI region, each individual state will receive an allocation of emissions allowances to distribute to its covered facilities.

In an effort to understand the effects of RGGI on a particular state and, to a lesser extent, the entire region, the potential impacts of Maryland joining RGGI were examined. The findings suggest that Maryland joining RGGI will result in a distinct but modest decrease in CO_2 emissions, in the State and the RGGI region as a whole, and modest emissions allowance prices. Moreover, Maryland joining RGGI will, on net, have a slightly positive economic impact on the State with a small increase in jobs and a small decrease in electric bills. Profits for electricity generators using coal will fall, but plants will not be retired. In addition, Maryland joining RGGI will probably have little net effect on emissions leakage to states outside the RGGI region.

An obvious policy implication is that a program like RGGI, with modest goals and a flexible structure (i.e., generous offset policy), will have relatively small effects on CO_2 emissions and the economy. The study further showed that the energy efficiency investments funded by the allowance auction revenues made possible by the cap-and-trade system can be an important influence on emissions reductions without compromising economic competitiveness. According to model results, the investment of proceeds generated by auctioning 25 percent of emissions allowances into energy efficiency shifted energy demand curves down and to the left, resulting in lower energy demand at similar prices.

Several issues, however, have not been explored here, yet may be key in judging specific arrangements in RGGI and related trading schemes. One key unanswered question, for example, concerns the use of auction revenues to promote energy efficiency improvements, the mechanisms to achieve these improvements, and the sensitivity of the study's finding to assumptions about the cost of delivering energy savings. We are currently exploring these issues in ongoing research projects.

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