The Role of Energy Efficiency Spending in Maryland's Implementation of the Regional Greenhouse Gas Initiative

A Study Commissioned by the
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University of Maryland

In collaboration with
Resources for the Future
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1 EXECUTIVE SUMMARY

In 2007, Maryland joined RGGI, a cooperative agreement among ten Northeastern and Mid-Atlantic states designed to reduce emissions of carbon dioxide (CO_2) from major power generators through a cap and trade program. With the first auction for RGGI allowances (permits) held in September 2008, Maryland will soon begin receiving RGGI auction proceeds and must rapidly develop and implement a program to use these funds. There are many decisions facing the State of Maryland about how to implement a program that will simultaneously achieve the goals of RGGI and those of the State.

All of the participating states have agreed, through the RGGI Memorandum of Understanding (MOU), to use at least 25 percent of their state's total apportionment of allowances to support consumer benefit programs, such as "the use of allowances to promote energy efficiency" (RGGI 2005). Participating states can either auction off the allowances and use the proceeds to support consumer benefit programs or manage the allowances themselves for consumer benefit, without auction. The remaining 75 percent of state allowances can be auctioned or managed, and used as determined by a state. The RGGI working group reports that the "clear trend among the RGGI states is to auction nearly all of their allowances and dedicate the proceeds to support consumer benefits" (RGGI 2007). This study considers the approach that entails auctioning off 100 percent of the allowances and using the proceeds to promote energy efficiency, which is the predominant approach taken by RGGI members.

Some of the new expenditures will likely go to efficiency improvements in end-use consumption of electricity. This report provides considerations for Maryland's RGGI allowance expenditure with particular emphasis on expenditures to improve efficiency in electricity consumption. There are several reasons why RGGI states may choose to go beyond the minimum in funding programs to improve efficiency in electricity consumption. Such expenditures could lead to energy bill savings for consumers, increased local economic activity, and an overall reduction in the cost of the RGGI program.

Any public expenditures in Maryland (and the other RGGI states) on efficiency in end-use electricity consumption will directly affect electricity markets and consumers. These effects and the strategies for successful implementation of such programs are the subjects of this report. The intent of this report is to provide information and analysis for decision-makers working with the State of Maryland to design and implement a successful RGGI program. Specifically, the study examines the following questions:

- What would be the effects of different levels of spending in Maryland on improvements in efficiency in electricity consumption? These impacts are assessed in terms of:
  - Electricity demand
  - Electricity prices and expenditures
  - RGGI CO_2 allowance prices and revenue
  - Electricity supply in Maryland and profits for power generators
  - Generator competitiveness and market power
  - Generation adequacy and transmission import capability
  - Overall economic impacts within Maryland

- How robust are the conclusions for different modeling assumptions about:
  - energy markets and market power; and
  - transmission capability?

- What implementation, design, program effectiveness and other lessons are found in existing energy efficiency programs in comparable states?

- What considerations for implementation of efficiency programs can be identified:
  - from the academic and trade literature; and
  - through a broad range of experts and stakeholders in Maryland?

1.1 Study Approach

This study expands the modeling, research and analysis of the 2007 study "Economic and Energy Impacts from Maryland's Potential Participation in the Regional Greenhouse Gas Initiative," conducted by this research team for the Maryland Department of the Environment. That study explored the economic and energy impacts on Maryland of participating in RGGI, before Maryland's participation was finalized.

Building on the authors' previous work, this study explores the economic and energy impacts of Maryland's use of its RGGI allowance revenues for efficiency improvements in end-use electricity consumption within the state. Should Maryland choose to spend more than 25 percent of the RGGI allowance proceeds on efficiency, one can expect to observe reduced electricity consumption in the state and electricity market effects in not only Maryland, but also in the power markets that interact with the Maryland market, including the other RGGI states and the non-RGGI states that are near RGGI. This report employs a scenario approach to study these effects, modeling a baseline and two scenarios of expenditure levels in Maryland on end-use efficiency in electricity markets. All other parameters of RGGI and electricity markets in Maryland and the other states are held constant across the three scenarios. Each scenario assumes 100 percent of RGGI allowance allocation is through auction (i.e. all allowances are allocated through the auction).

Baseline: Maryland auctions 100 percent of RGGI allowances and uses 25 percent of auction revenue to stimulate efficiency improvements in electricity consumption.
50 percent Efficiency Scenario: Half of Maryland's auction revenue is allocated to efficiency improvements.
100 percent Efficiency Scenario: All of Maryland's auction revenue is allocated to efficiency improvements.

There is burgeoning academic literature on the public financing of efficiency improvements in end-use electricity consumption. Most of the models that appear in the literature are "bottom-up" type models in which electricity end-use technologies are characterized by their operational and cost parameters. These models are ideal when data are abundant and the interactions between technologies and those who adopt them can be well characterized through time. However, the variety of end-use technologies for electricity consumption is vast and the technologies that will emerge in the coming decades are difficult to anticipate. Furthermore, the characterization of consumer behavior with respect to electricity end-use technology is fraught with problems as consumers often fail to make technology choices that accord with the economic theory that underpins such models and the limited data that are available to parameterize them. Also, many end-use electricity consumption technologies are long-lived investments that affect electricity markets for many years after the technology choice is made. Current bottom-up technology type models generally do not perform well in capturing the capital dynamics that are introduced by such long-lived investments.

This study introduces a new, "top-down" approach to projecting the effects of public financing for efficiency programs. A functional form for demand modeling, known as habit formation, which was first set forth by Houthakker and Taylor (Houthakker and Taylor, 1970) is used in this study. This habit formation demand function is estimated to capture consumer price responsiveness in electricity markets simultaneously with the long-run effects of end-use electricity consuming capital choices. These parameterized demand functions are then implemented inside of the Haiku Electricity Market Model in conjunction with a model of consumer response to financial incentives for electricity conservation through capital choice. This is a "top-down" model in the sense that it need not rely on the parameterization of the vast array of technologies that are already in the market or the unknown technologies that will emerge in the future.

The top-down perspective of this demand system captures aggregate consumer behavior, but does not explicitly address individual technologies and their performance. The model assumes that program administrators can identify cost-effective efficiency improvements. Some of the barriers faced by program administrators are explicitly captured. In particular, the model accounts for inaccessible consumers, free-riders and program administration costs. To the extent that program administrators are limited in identifying cost-effective improvements, in this model results overstate the electricity consumption reductions that will occur under all three scenarios of efficiency funding. Sections 10 and 11of this report informs the administrator on where to find these efficiency improvements.

1.1.1 Research Team

The Maryland Department of the Environment contracted with the University of Maryland through its Center for Integrative Environmental Research (CIER, www.cier.umd.edu) to study and report on the impacts of energy efficiency spending in Maryland and lessons from existing programs in order to inform implementation and program design decisions for Maryland's new RGGI program. UMD is the primary contractor for this project, drawing upon scientific experts from both inside and outside the University. CIER functions as the focal point for cross-cutting environmental research at the state's premier public university and specializes in the development and use of new knowledge and tools to inform policy and investment decision makers. The successful team for the first Maryland RGGI study was brought together again for this study. It includes Resources for the Future (RFF), the Johns Hopkins University (JHU), and the Regional Economic Studies Institute (RESI) of Towson University as partners with CIER. These institutions have extensive and complementary expertise in economic and engineering modeling necessary to answer all of the questions posed by this study.

1.1.2 Models

This study uses three models to assess the effects of energy efficiency spending in Maryland on the electricity sector and the economy of Maryland. The baseline and two scenarios described above were examined by all three models. The study analyzed how varying the percentage of RGGI CO_2 allowance revenue in Maryland that is spent on energy efficiency in the electricity sector affects electricity consumers, electricity producers and the performance of electricity markets in Maryland and the surrounding Pennsylvania-New Jersey-Maryland (PJM) regions. PJM is a regional transmission organization which manages the wholesale electricity market for an interconnected power grid of 13 states and the District of Columbia. The study also addresses the effects of efficiency spending and associated changes in electricity markets on the Maryland economy.

Updated and advanced versions of the same models from the first Maryland RGGI study were employed in this project. The models are:

- The Haiku model, created by Dallas Burtraw, Karen Palmer, and Anthony Paul, all of RFF, is a national economic simulation of electricity markets based on market equilibrium concepts. This model helps to answer questions such as: How will Maryland's electrical power prices and fuel mix for power generation change at different levels of energy efficiency investment? This model also provides input data to the other two models.
- The JHU-OUTEC model (Johns Hopkins University Oligopoly Under Transmission and Emissions Constraints), developed by Professor Ben Hobbs (JHU) and Professor Yihsu Chen (UCM), is a regional market equilibrium model for the Pennsylvania-New Jersey-Maryland (PJM) area allowing for market power in the generation sector. It helps answer questions such as: How would the market power of generation companies be affected by Maryland's investment in energy efficiency and changes in the transmission grid?
- The IMPLAN model, adapted by Daraius Irani, of RESI of Towson University, is an input-output model that takes into account changes in employment levels, among other important economic indicators. This model helps answer questions such as: How will different levels of energy efficiency funding from RGGI affect the average annual electricity bill, the state economy, etc. Details on these models appear in the Appendix to this report.

Included in the study were impacts within other RGGI states and related areas.

1.1.3 State Case Studies and Stakeholder Research Approach

In assessing possible approaches for Maryland's investment in energy efficiency, it is useful to examine lessons and results from other states. Researchers from the Center for Integrative Environmental Research, including Joanna Mauer, Iván Darío Valencia, Nate Hultman, Nicolai Herrmann, Matthias Ruth and Kim Ross conducted these state studies. For this report, efficiency programs for New York, Vermont and Maine were analyzed, with a focus on program design and costs, electricity savings, and lessons learned. These three states are all part of RGGI, have established programs, and share some characteristics with Maryland that could be helpful in understanding factors that might lead to success in Maryland.

In researching Maryland's current programs, practices and needs, this report used information gathered through conversations with a wide variety of stakeholders, from officials at state agencies administering and regulating energy efficiency programs to representatives from the farming and manufacturing sectors, energy consultants and renewable energy businesses, plus energy efficiency advocates and environmental organizations. Future research will need to extend the number of interviewees and subject them to questions that are structured in ways that provide opportunities for quantitative analysis and more rigorous cross-state comparison.

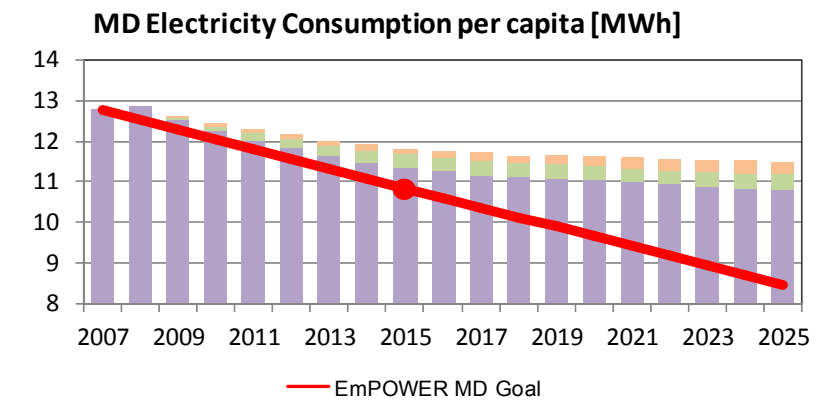
1.2 Findings Related to Different Levels of Efficiency Spending on Electricity Markets in Maryland

Larger investments of Maryland's portion of RGGI CO_2 allowance revenue in efficiency improvements in electricity consumption will result in significant reductions in electricity demand in Maryland. Because Maryland's electricity market is embedded within the larger PJM electricity market, the effects of demand reductions in Maryland will be felt beyond the state line and the changes in other states will in turn partly offset the effects within Maryland. Overall, the welfare of the residents of Maryland will be improved by more investment of RGGI allowance revenue in electricity consumption efficiency. Following is a summary of the anticipated effects on electricity markets in Maryland from the expenditure of RGGI allowance revenue on improvements in electricity consumption efficiency.

Electricity Demand

- Electricity demand in Maryland will be substantially reduced by spending on electricity consumption efficiency. The baseline for comparison of alternative efficiency expenditures is 25 percent of auction revenues dedicated to efficiency programs. Increasing the share of revenues spent on efficiency from the baseline of 25 percent to 50 percent will reduce demand for electricity by 1.3 percent annually in 2015 and 2.6 percent annually in 2020 compared to baseline levels. If 100 percent of the allowance revenues are spent on efficiency, demand will be 4 percent below baseline levels in 2015 and nearly 6 percent below in 2025.
- These demand reductions would help achieve the goal, set forth under the EmPOWER Maryland plan, of reducing per capita electricity consumption in the state by 15 percent from the 2007 level by 2015 as shown in Figure 1.1. At a spending level of 25 percent of RGGI allowance revenue, Maryland will reduce per capita electricity consumption by 7.4 percent from the 2007 level, or nearly half of the EmPOWER Maryland goal. Greater spending will reduce per capita consumption further, by 8.7 percent under 50 percent spending and by 11.2 percent if all allowance revenue is spent on electricity consumption efficiency.

Figure 1.1. Maryland Electricity Consumption per Capita Related to EmPOWER Maryland Goal



	2010	2015	2020	2025
100%	4.1%	11.2%	13.5%	15.4%
25%	2.5%	7.4%	8.8%	10.0%
50%	3.2%	8.7%	10.8%	12.4%

Electricity Prices and Expenditures

- Increasing the share of allowance revenues devoted to efficiency will reduce the expenditures on electricity by Maryland consumers. Due to a combination of small effects on electricity prices and reduced electricity demand, total electricity bills in Maryland will be 2 to 3 percent lower in most years after 2010 if 50 percent of the revenue is spent on efficiency, compared to the baseline scenario. Depending on the year, electricity expenditures in Maryland will be between 2 and 7 percent lower than the baseline if 100 percent of the allowance revenue is spent on efficiency.

- The 50 percent efficiency scenario is estimated to save a typical household $15 annually in 2010 and about $25 annually in 2020. The 100 percent efficiency scenario will save an average household $32 annually in 2010 and $72 annually by 2020 compared to the 25 percent baseline efficiency spending.

RGGI Allowance Prices and Revenue

- Greater spending on energy efficiency in Maryland generally will reduce the RGGI CO_2 allowance price relative to baseline levels. RGGI allowance prices will be 4 percent lower than baseline levels if 50 percent of the allowance revenue is spent on efficiency and up to 9 percent lower than baseline levels if 100 percent of the allowance revenue in Maryland is spent on efficiency. Lower RGGI allowance prices will result in less RGGI allowance revenue for Maryland and the other RGGI states. This decline in revenues that results from a decline in prices follows from the decline in electricity demand that is caused by spending on efficiency in Maryland.

Electricity Supply in Maryland and Profits for Power Generators

- The reductions in electricity demand resulting from greater efficiency spending will reduce Maryland in-state electricity generation and reduce electricity imports from the states that supply Maryland. The majority of the supply reductions will come from reduced imports. These supply reductions will have minimal effects on profits for Maryland generators.
- On average the 100 percent efficiency spending scenario has a smaller effect on profits than does the 50 percent efficiency spending scenario, due in large part to the lower RGGI allowance prices at the higher spending level. However, in both scenarios, annual changes in total profits are equal to substantially less than 1 percent of total electricity revenues.

Generator Competitiveness and Market Power

- The 50 percent and 100 percent energy efficiency scenarios do not consistently lower price-cost mark-ups according to the JHU-OUTEC model. In order for such effects to occur, it is necessary for energy efficiency programs to include significant elements of "demand response" mechanisms that lower energy use when price is high.
- Generation capacity retirement and investment are projected to have little dependence on efficiency spending. Coal and nuclear capacity in Maryland are projected to remain unchanged through the modeling horizon with only natural gas increasing, with that increase being delayed until 2025. The operating profits of the generators are also not meaningfully affected by efficiency spending, with the exception of coal generators, whose profits are projected to fall in time as RGGI compliance becomes increasingly more expensive.
- If the peak reductions projected by the Haiku analysis are realized, payments to power generators through the PJM RPM mechanism by central Maryland consumers could be decreased by several tens of millions of dollars annually.

Generation Adequacy and Transmission Import Capability

- Larger allocations of allowance auction revenue to efficiency programs do not adversely impact generation adequacy in the state. At the same time, larger allocations reduce electricity imports.
- The effects of the estimated benefits of the 100 percent energy efficiency scenario are not appreciably changed if import capability is significantly decreased in 2015 relative to base case assumptions.

Overall Economic Impacts

- *Impacts on Economic Activity:* Overall, the 100 percent efficiency spending scenario is estimated to have the greatest positive impact on gross state product, employment and wages. Compared to minimum (25 percent) efficiency spending, the 100 percent efficiency scenario boosts GSP by $150 million in 2010 and more than $500 million in 2020. The 50 percent efficiency scenario provides less than half the boost, increasing GSP by around $25 million in 2010 and over $250 million in 2020. Although positive, these impacts are small relative to the overall state economy, equaling about 0.1 percent or less of GSP in each period.
- *Employment Impacts:* Both scenarios have a net positive impact on jobs and total wages. 100 percent efficiency spending will create about 4,300 new jobs in 2020, whereas 50 percent efficiency will result in 1,700 more jobs than the baseline scenario. While these employment gains are large, in the context of the Maryland's 2.5 million jobs, they are fairly small.
- *Fiscal Impacts:* Committing more allowance revenue to energy efficiency spending reduces the revenue available to other state programs. It also impacts revenue by decreasing pollution allowance prices while increasing energy efficiency in Maryland's economy. The 50 percent efficiency scenario redirects $26 million in allowance revenue in 2010 increasing to over $50 million in 2020. 100 percent efficiency spending dedicates an additional $74 million to efficiency in 2010 and over $140 million in 2020. By 2020, 20-30 percent of these revenues will be offset by new tax revenues generated from growth in the state economy resulting from the energy efficiency investment.

Robustness of Results to Model Formulation

- The effects of the 50 percent and 100 percent efficiency spending scenarios on wholesale energy costs for Maryland consumers are very similar in the analysis performed using the Haiku model and that using the JHU-OUTEC model. The JHU-OUTEC model has a more detailed representation of mid-Atlantic power transmission constraints and allows for market power in the formation of wholesale electricity prices. The similar results obtained in the two models build confidence in the calibrated, aggregate results obtained by the Haiku model.

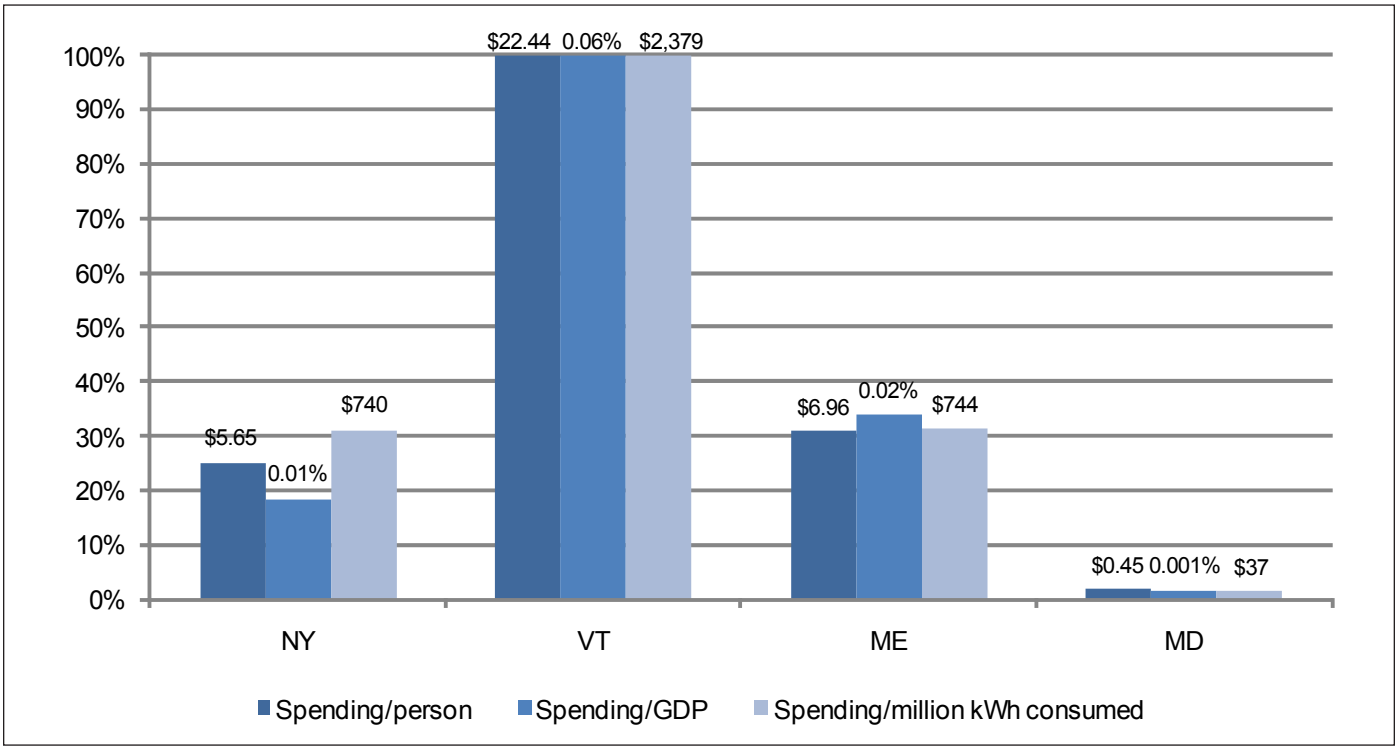
1.3 Considerations for Program Design and Implementation

Sections 5-9 of this report detail the effects on electricity markets and the broader Maryland economy of programs within Maryland designed to encourage efficiency in electricity consumption. In particular, three scenarios that vary according to funding levels were analyzed and the results were presented in the previous section. Section 10 discusses three case study states that have implemented successful energy efficiency programs and analyzes and compares them in terms of overall program costs, program component costs and cost-effectiveness. Section 11 addresses the matter of program design and implementation from a policy level. Decisions regarding program design, regardless of the funding level for such programs, can have implications that affect the ability to achieve environmental, economic, fiscal and social policy goals. Insights from other programs and states - their levels of funding, program structures and administration – can help reveal opportunities for achieving policy goals. These insights, learnings and observations are summarized below.

Rates of efficiency spending across states

- New York and Maine, two of the featured case study states, spent 0.01 and 0.02 percent of State GDP for energy efficiency, respectively, while Vermont, another case study and number one in the nation in energy efficiency expenditures, spent 0.06 percent of State GDP. In the same year (2006), Maryland spent 0.001 percent of State GDP. (Figure 1.2)

Figure 1.2. Comparison of 2006 efficiency spending across states studied

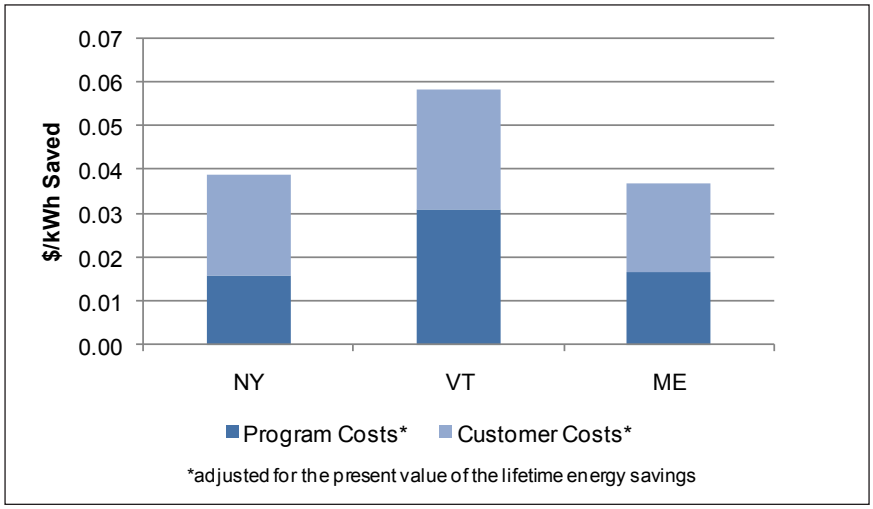


Sources: NYSERDA, Efficiency Vermont, Efficiency Maine, MD General Assembly

Program Cost-Effectiveness

- Not only the rate of spending as a percentage of GDP, but also the cost per kWh of saved electricity is highest for Vermont (Figure 1.3). Program costs show that they are, at $0.016 and $0.017 per kWh saved, almost identical for New York and Maine, respectively, while Vermont's program costs are at $0.031/kWh nearly twice that amount. Yet, the customer portion of the cost per kWh of saved electricity is similar for all three states, ranging from $0.02/kWh for Maine to $0.027/kWh for Vermont.

Figure 1.3. Total Cost/kWh of Efficiency Initiatives (2006)



Sources: NYSERDA, Efficiency Vermont, Efficiency Maine

1.3.1 Financing and Administrative Considerations

A variety of considerations can help guide states in their decisions about efficiency programs. Interviews with stakeholders suggest the following insights for the financing and administration of efficiency programs:

Financing

- To go beyond the "low-hanging fruit" of energy efficiency, programs can construct a diversified portfolio of investments to balance investment risks and returns. For example, programs designed to deliver immediate electricity savings, such as rebates for efficient appliances, could be coupled with market transformation strategies, including education and training, designed to deliver lasting, but more uncertain, savings in the long term.
- Addressing uncertainty and instability in program funding from year to year, for example from variations in RGGI revenue as allowance prices fluctuate in the market, can significantly improve participation and results.

Governance and Administration

- Any governance model for energy efficiency programs -- administered by utilities, a state agency, or an independent agency -- can be successful if there is effective oversight, transparency in the administration of funds, and comprehensive monitoring and evaluation.
- For a successful utility-state partnership, as currently planned in Maryland, it is important to have sufficient coordination so the programs complement each other rather than overlap or leave gaps, avoid confusion among clients, and leave room for flourishing private sector involvement. Experience shows that this will require good communication, aligned incentives to encourage cooperation, clear accountability, and oversight by one group.
- Since efficiency programs are typically targeted towards a wide range of activities – from lighting to weather proofing to retrofits of heating and cooling systems and beyond – customers frequently feel lost in the wealth of information available to them when trying to decide on efficiency investments. According to the experts interviewed, providing seamless access, such as through one over-arching program "brand" and online portal, for customers to choose from all available energy efficiency programs in a state (whether delivered by a state agency, utilities or others) increases coordination, participation, and success of programs.

- Comprehensive energy efficiency programs include energy audits, technical assistance, education and training, marketing (e.g., an energy efficiency "brand" for the state), as well as monitoring and evaluation (including identification of free rider/ spillover effects).

1.3.2 Experiences From Other States

Assuming that the state wishes to play an active role in the promotion of energy efficiency, the following experiences from state-run programs may help inform Maryland's decisions to expand its role in the energy efficiency field:

Residential Programs

- Partnering with retailers, manufacturers, contractors, and design professionals can improve delivery of programs and expand their reach.
- Providing technical assistance for existing and new buildings can encourage program participation, especially among builders.
- Targeting new construction with educational efforts and incentives can result in energy savings for the life of the building.
- Developing education and outreach programs can raise awareness about energy use and encourage behavior change.

Commercial/Industrial Programs

- Cultivating strategic relationships with trade and business associations can increase access to customers and assist with the marketing of programs.
- Focusing on ways to influence upstream market suppliers, contractors, and installers can encourage market transformation.
- Measuring and verifying energy savings can improve program evaluation.
- Meeting regularly with stakeholders can help to continually understand and adapt to commercial and industrial sector needs.

1.4 Additional Research Needs

The Maryland Department of the Environment and the State of Maryland are interested in shrinking the state's carbon footprint and lowering overall greenhouse gas emissions while stimulating economic activity and improvements in the quality of life of Maryland citizens. RGGI addresses CO_2 emissions from electricity generators with a capacity of at least 25MW. Other targets for reductions of greenhouse gas emissions could include industrial generation of electricity, natural gas combustion for purposes other than electricity generation (e.g. home heating), and the transportation sector. To date, no comprehensive assessment exists of such opportunities for reductions outside of the RGGI targets. This assessment would include analysis of the implications for energy markets, their effects on consumers and associated business enterprises, as well as overall economic, social and environmental dynamics.

Unfortunately, some climate warming due to increasing atmospheric greenhouse gas concentrations appears unavoidable, and therefore humanity will need to adapt to new climate conditions. Several strategies aimed at lowering emissions (such as decentralization of the power grid and expanded use of renewable resources) may also help promote adaptation (for example, by diversifying supply portfolios and reducing the risks of vulnerabilities to extreme weather events). Economic assessments of the desirability of those mitigation strategies should include benefits that come from improved adaptation. To date, such co-benefits of adaptation are typically not included in cost-benefit comparisons, nor are "co-costs" among alternative mitigation and adaptation strategies, and as a result, desirable investments may not be carried out.

2 INTRODUCTION

2.1 Maryland's Use of RGGI Funds for Energy Efficiency

The auction of carbon emissions allowances under the Regional Greenhouse Gas Initiative by the State of Maryland will likely generate considerable state revenues. One strategy to use these revenues for the benefit of citizens in the state is to facilitate the transition towards higher efficiency uses of electricity. This would help buffer possible increases in electricity prices by encouraging an end-use infrastructure that requires less electricity to provide a given level of energy services. A reduction in electricity demand can lead to reduced emissions of any uncapped pollutants associated with electricity generation. Emissions reductions, in turn, will help lower allowance prices of capped pollutants and improve environmental quality.

Participating RGGI states have agreed, through the RGGI Memorandum of Understanding, to use at least 25 percent of total state allowances[1] in support of consumer benefits such as end-use efficiency improvements. What are the energy and economic implications of that level of allocation, and how do the results differ if half or all of the revenues go to efficiency improvements? What lessons can be learned from other states' experiences with fostering energy efficiency, and how may those lessons inform decision making in Maryland? These are the overarching questions addressed in this report. The following more detailed questions are studied:

1. What would be the impact of different levels of energy efficiency spending in Maryland on:
   – Electricity demand,
   – Electricity supply,
   – Generator retirements and investments,
   – Generator profits,
   – Generation fuel mix and power imports,
   – Electricity prices,
   – RGGI CO_2 allowance prices,
   – Generator competitiveness and market power,
   – Generation adequacy,
   – Electricity bill impacts for residential, commercial and industrial sectors,
   – Overall economic impacts within Maryland?

2. How robust are the conclusions for different modeling assumptions about:
   – energy markets and market power; and
   – transmission capability?

3. What implementation, design, program effectiveness and other lessons are found in existing energy efficiency programs in other states?

4. What considerations for implementation of efficiency programs can be identified:
   – from the academic and trade literature; and
   – through interviews with a broad range of experts and stakeholders in Maryland?

To answer these questions, this study builds on prior modeling and analysis of RGGI for the State of Maryland (Ruth et al 2007), drawing on the complementary expertise of researchers and models at the Center for Integrative Environmental Research at the University of Maryland, The Johns Hopkins University, the University of California, Merced, Towson University and Resources for the Future.

[1] This study considers the approach that entails auctioning off 100 percent of the allowances and using the proceeds to promote energy efficiency versus managing the allowances for consumer benefit, which is the predominant approach taken by RGGI members. The remaining 75 percent of state allowances can be auctioned or managed, and used as determined by a state. The RGGI working group reports that the "clear trend among the RGGI states is to auction nearly all of their allowances and dedicate the proceeds to support consumer benefits (RGGI 2007).

2.2 Policies to target electricity efficiency

2.2.1 Benefits of electricity consumption efficiency

Reducing electricity use can achieve multiple benefits. Many of these benefits accrue as public goods and are, therefore, appropriate candidates for public policy interventions. Some RGGI states, including Maryland, may spend more than the RGGI minimum to promote energy efficiency for reasons such as:

Energy bill savings for consumers

End-use energy efficiency can reduce consumption of electricity (and natural gas) and therefore reduce the bills faced by consumers. Such consumer savings make a direct impact on household budgets and allow for increased consumption of other goods, savings, or debt servicing. Increased consumption will marginally increase tax revenues while some tax revenues will be foregone because of reductions in the amount of energy consumed.

Energy efficiency funding will help to lower the high electricity bills that are recently predominant in the RGGI region. In Maryland, the average retail price of electricity increased by 17 percent between the summer of 2006 and the summer of 2007 (MEA 2008). Recent price increases were brought on by the combination of the removal of caps on retail electricity prices in 2006 and the results of the standard offer power auctions that produced substantially higher wholesale electricity prices than in recent experience. In this environment, policy makers are facing a great deal of pressure to reduce electricity bills and the RGGI allowance auction revenue stream affords that opportunity.

Reduced fuel use

Decreases in electricity production because of efficiency will translate directly into reduced fuel usage. The specific savings of such reductions will depend on the fuel mix and time of day, and will accrue to producers and/or consumers depending on the regulated electricity pricing structure. If efficiency is adopted widely enough to impact overall demand for input fuels, such measures could conceivably even lead to fuel price reductions.

Improved utility load economics

If efficiency measures are implemented in a way that reduces peak demand, the resulting smoother daily and annual load fluctuations can enable a more efficient use of generation assets. Such an outcome could improve the economics of providing reliable electricity to the grid and result in lower prices for consumers and higher profits for generators. Many of the RGGI states are facing potential shortages of capacity for supplying electricity in the next few years. The NERC 2007 reliability assessment report (NERC 2007) identifies both the mid-Atlantic states and New York as having insufficient capacity to meet reserve requirements at some point in the next 3 or 4 years. Expanding energy efficiency programs provide a way to help bring electricity supply and demand back into balance. In response to both anticipated capacity shortages and high prices, the governors of Maryland and New York have announced ambitious energy efficiency targets for 2015. RGGI allowance auction revenue could be used to help meet those goals.

Demand response (demand side measures that reduce electricity use when the system's load is very high) has twofold benefits and therefore often is part of enhanced efficiency measures in the electricity sector. On one hand, network operators benefit from lower peak-load as network congestion is decreased and load economics are improving; implementing demand response on a large scale also adds to prognosis quality and controllability of utility load profiles as load can be actively dispatched. On the other hand end-users may also benefit from demand response measures if load shedding is organized by a price-driven algorithm (variable tariffs) that increases the electricity price for households in peak hours but offers considerably lower prices when network load is low. Finally demand response measures as well as smart metering generally improve consumer awareness for energy use and thus may lead to additional energy savings.

Reduced RGGI compliance cost and CO_2 emissions leakage

Improvements in electricity consumption efficiency will lead to reduced electricity demand. Electricity generators are able to meet lower levels of demand with less reliance on the fossil fuels that are the target of the RGGI program. With reduced reliance on fossil fuels, RGGI allowance scarcity is reduced. As allowance scarcity is reduced, RGGI allowance prices will fall.

The cost of compliance with the RGGI program is directly related to the price of allowances. Lower prices beget lower compliance costs. High allowance prices are the driver of CO_2 emissions leakage and lower prices lead to lower RGGI compliance costs. On the one hand, the lower the CO_2 allowance price, the more likely it is that the RGGI program will

achieve the long-term goals of expanding the program to include other sectors of the economy or regions of the country. Low allowance prices may also help to generate support for a broader federal program to reduce greenhouse gases. On the other hand, if allowance prices are too low, their ability to trigger changes in behaviors and technologies may be reduced, thus rendering RGGI ineffective.

One common misconception is that reductions in electricity demand within the RGGI region (from efficiency projects or otherwise) will lead to a reduction in CO_2 emissions within RGGI. However, with a cap and trade type program such as RGGI, the allowance market will adjust to maintain a fixed level of the targeted pollutant (in this case CO_2) at the level of the cap. The market will accomplish this through the allowance price. Unless the allowance price falls to zero, emissions will neither exceed nor fall below the cap level.[2] Therefore, the effect on RGGI of energy efficiency policies will be not a reduction in emissions, but a reduction in the allowance price.

Because RGGI is a regional cap and trade program that partially overlaps with the regional PJM electricity market (covering an area including Pennsylvania, New Jersey, Maryland and parts of other nearby states), capping emissions from a subset of PJM generators raises concerns for RGGI members that emissions leakage will follow increased electricity generation from PJM generators located outside of RGGI, both within PJM and beyond. In other words, if power generation is increased from generators within PJM that are not under the cap, emissions in those states and potentially overall emissions in the region, could go up or "leak" out of the RGGI states into nearby states. By increasing the costs of generation using fossil fuels from within the RGGI region, the RGGI program increases demand for less expensive generation not subject to the RGGI CO_2 emissions caps. One means to mitigate leakage is to reduce demand for electricity within RGGI. The RGGI program creates a revenue stream through the allowance auction that could be used for this purpose. This mechanism is recognized in a report released in early 2008 on how to address emissions leakage in RGGI (RGGI 2008).

Increased local economic activity

The net impact on GDP and jobs from new efficiency measures depends, among other things, on how much of their savings the consumers end up spending. However, the activities related to purchasing and installing new efficiency technologies will tend to increase local employment by engaging workers in energy audits, installations, and retrofits.

2.3 Developments in Carbon Emissions Markets

Carbon emission trading is a market based approach to reduce greenhouse gas emissions. Under the system, a carbon emissions cap is identified for a sector of an economy or a geographic region, and then permits are offered to emitters. If those permits are tradable, they can sell unneeded permits to others, creating incentives for firms to reduce their emissions and, thus, improve their bottom line. Conversely, firms that are unable to meet emissions reduction goals can purchase permits and, by so doing, are better able to remain in business while complying with carbon emissions restrictions. Since the emission trading approach provides cost effective emission reduction alternatives, it is an economically efficient way to reduce emissions.

Carbon markets have been called for by international conventions and world wide communities. For example, the Kyoto protocol, which is an international climate treaty under United Nations Framework Convention on Climate Change implemented in 2005, has set up a market based approach to reduce greenhouse gases. The protocol assigns caps to emissions from developed countries or the Annex I countries. Based on the cap, each country develops their emissions targets for individual industrial entities, such as power plants or metal industry. Following are the major developments in the cap and trade system worldwide and within the United States

2.3.1 Carbon Market in European Union (EU ETS)

The European Union launched an EU emissions trading scheme (EU ETS) in January 2005. During its first phase from 2005 to 2007, it covered CO_2 emissions from big industrial emitters (with generation capacity of 20 MW electrical and above), which accounted for 50 percent of the EU's total CO_2 emissions and 40 percent of the total greenhouse gas emissions (EU 2007). In its second phase from 2008 to 2012, which are also the years covered by the EU's participation in

[2] Some year-to-year fluctuations away from the annual cap level will be possible due to allowance banking.

the Kyoto protocol on Climate Change, the emissions from nitrous oxide are also included. Furthermore, the EU is aiming to integrate additional sectors like aviation into the trading scheme. EU ETS distributed about 95 percent of the allowances free of charge in its first phase and are distributing at least 90 percent in its second phase. The high rate of grandfathering of allowances generated considerable windfall profits for European power generators that rationally added the allowance price as opportunity costs to their generation costs without having to pay for the allowance. Therefore EU ETS is now aiming to increase the rate of auctioning to redirect revenues to the member states instead.

The scheme accepts transactions based on allocations as well as specific projects including projects from the Clean Development Mechanism (CDM) and Joint Implementation under the Kyoto mechanism. This provision has brought the developing countries into the reduction table. Emission reductions that are achieved outside of the EU (e. g. in developing countries) can be transferred into the ETS and then be exchanged for European Emission Allowances. "The market share of CDM credits from developing countries was about 49.2 percent of overall volume transacted globally" (World Bank 2006). Nevertheless, the overall share of allowances from CDM within the ETS is minor and is additionally limited to a maximum of 10% by law in the current trading period. During its initial phase (2005-2007), EU ETS faced challenges especially due to excessive price volatility with peak prices just above 30 Euro per allowance and some sudden price drops. Critics argue that government overallocation of carbon allowances and the prohibition on allowance banking were responsible for price dropping in May 2006. This was the time when exact data on real emissions in comparison to issued allowances became publicly available for some of the EU member states. These data revealed an overallocation for some member states (mainly France and Spain) and consequently led to a price correction and periods at which hardly any allowances were traded (figure 2.1). As a transfer of remaining allowances to the next trading period (which is known as banking) was not possible in EU ETS, the price of allowances decreased to become zero when the first trading period ended in early 2008 (see figure 2.1). Additionally, there was uncertainty about the long-term perspective of reduction efforts as reduction targets were not clearly stated by the regulator until the European Green Package was issued in 2008. Therefore, experts have suggested that greater transparency as well as more structured and regular information disclosure and more certainty on post 2012 commitment can help increase the long term investment in the market and stabilize the price (Betz 2006).

Figure 2.1. German Power Exchange: Spot Prices and Daily Trading Volumes for European Emissions Allowances (September 2005 – February 2008)

Source: EEX 2008

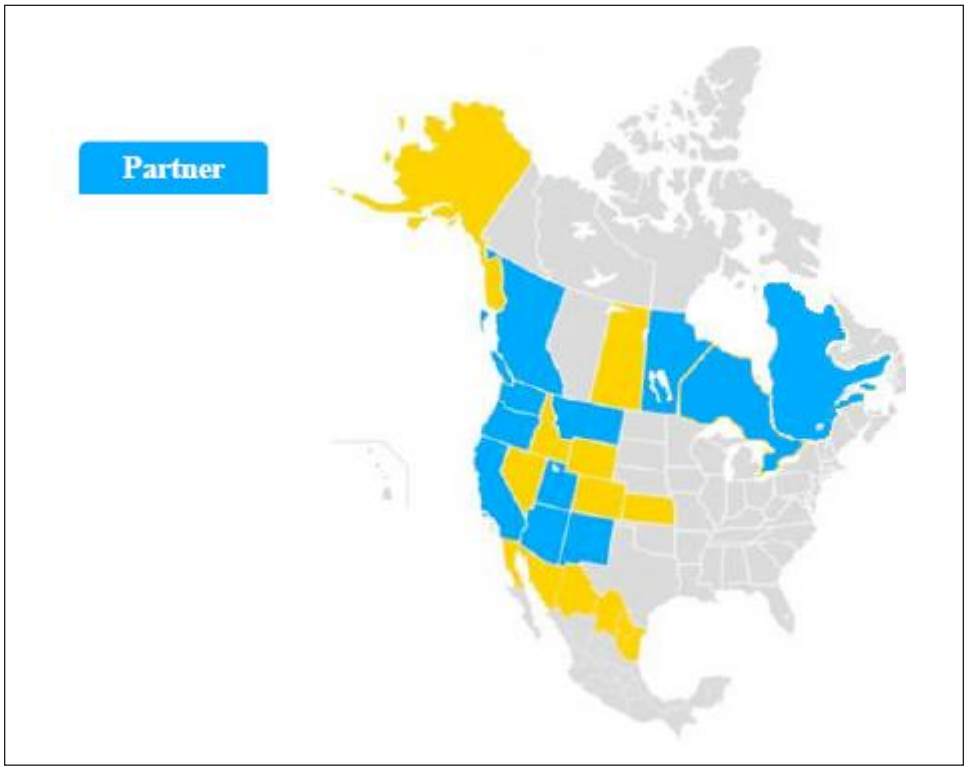
2.3.2 Developments of Carbon Markets in the United States at the Federal Level

Climate change has been a top issue for leaders in both the House and Senate in 2007-2008. As of July 2008, more than 235 bills, resolutions, and amendments specifically addressing global climate change and greenhouse gas emissions have been introduced (Pew 2008). Of these bills, the Lieberman Warner Climate Security Act, made it to the US Senate floor in June of 2008, but was halted on procedural grounds. The Bill would set a declining cap on US emissions of greenhouse gases, covering 86 percent of the country's emissions. The Bill would bring emissions down to 4 percent below the year 2005 level by 2012, 31 percent below the 2005 level by 2030, and 71 percent below the 2005 level by 2050 (Lieberman 2008). These reductions would be achieved by a number of flexible mechanisms designed to keep the cost of compliance low: banking of allowances for future use, international trading of allowances with appropriate entities, borrowing from future allowances, and credit for offsets and carbon sequestration through biological processes (such as growing plants to absorb carbon dioxide) or underground storage. To promote clean technology, the Bill would allocate funds to mitigate impacts on low-income consumers, promote energy efficiency, improve public transportation, and promote advanced technology in carbon capture and geological sequestration.

2.3.3 Developments of Carbon Markets in the United States at the Regional Level

In recent years, a number of regional initiatives to reduce greenhouse gas emissions via some form of market based mechanism have begun. The Western Climate Initiative (WCI), previously known as the Western Regional Climate Action Initiative, is the largest partnership to reduce greenhouse gases in which the US is involved. Currently, the initiative partners include seven US states: Arizona, California, Montana, New Mexico, Oregon, Utah, Washington, and the Canadian provinces of British Columbia, Manitoba, Ontario, and Quebec. As observers to WCI's deliberations, there are presently six other US states (Alaska, Colorado, Idaho, Kansas, Nevada, and Wyoming), the Canadian province Saskatchewan, and six Mexican states (Baja California, Chihuahua, Coahuila, Nuevo Leon, Sonora, and Tamaulipas). The Initiative set an overall goal in August 2007 to reduce greenhouse gas emissions to 15 percent below 2005 levels by 2020. To help reach the goal, members agree to establish a multi-sector market-based mechanism by the end of August 2008 (WCI 2008). All WCI members joined The Climate Registry, a greenhouse gas emissions registry which consists of more than forty US states, tribes, Canadian provinces and Mexican states.

Figure 2.2. States and Provinces participating in Western Climate Initiative (The Western Climate Initiative, 2008)



In November 2007, six US mid-western leaders who are members of the Midwestern Governors Association and a Canadian province Premier signed the Greenhouse Gas Accord as an agreement to reduce greenhouse gases. Signatories to the Accord are Minnesota, Wisconsin, Illinois, Iowa, Michigan, Kansas, and the Canadian Province of Manitoba while Indiana, Ohio, and South Dakota are Observers of the Accord. Under the Accord, the members agreed to establish regional greenhouse gas reduction targets, and develop a multi-sector cap and trade system to help meet the targets. The cap and trade module is proposed to be developed by November 2008 and implemented by May 2010 (MGA 2007).

2.4 Electricity in Maryland

Electricity generation capacity in the state is heavily reliant on coal-fired (60.1 percent) and nuclear plants (28.3 percent). Natural gas and petroleum power plants account for 4.8 percent of generation, whereas hydroelectric power contributes 4.3 percent and other renewables 1.3 percent (EIA 2006). The most noticeable changes in energy generation between 1990 and 2006 have been the decrease in coal and petroleum generation by roughly 10 percentage points each, and a corresponding increase in nuclear power by almost 25 percentage points.

Electricity capacity in Maryland is strained and the state faces the threat of rolling blackouts as of 2011, according to the Maryland Energy Administration. From 1999 to 2005, electricity consumption increased by 15.7 percent, while capacity increased by 6-7 percent and generation by 1.5 percent. In 2006, 30 percent of the 63 million MWh sold in the state were imported from out of state (MEA 2008). At the beginning of this period, in 1999, Maryland passed the "Electric Customer Choice and Competition Act", which deregulated the generation and sale of electricity within the state. Investor-owned and cooperative utilities, but not municipal utilities, were required to offer their customers a choice of energy suppliers.

Maryland belongs to the PJM (Pennsylvania-New Jersey-Maryland) Interconnection grid, which covers 13 states and the District of Columbia. PJM is the regional transmission organization and manages the wholesale electricity market. Because of the heavy reliance on power imports in Maryland, the Baltimore-Washington corridor is one of the most congested transmission corridors as identified by the US Department of Energy (MEA 2008). PJM forecasts for peak loads from 2006 (Ruth et al 2007) were 19,316 MW for the summer and 17,225 MW for the winter.

Due to recent price increases, electricity prices in Maryland are now the second highest in the South Atlantic region. Between July 2006 and July 2007, prices increased by 17.1 percent for residential customers while the average price increase for the region was 3.0 percent (MEA 2008).

2.4.1 Energy Efficiency Programs in Maryland

Maryland currently administers a number of efficiency programs and regulations out of multiple state offices, with diverse budgets, and at different jurisdictional levels (see Appendix G for additional information). Currently, MEA is the leading agency for most energy efficiency programs. The Department of Housing and Community Development runs low-income weatherization and the Department of Human Resources runs energy assistance services. In contrast to other states, no public benefits fund to finance these programs was instituted in Maryland at the time of utility restructuring.

During the 1991 to 1998 period, Maryland utilities offered Demand-Side Management (DSM) programs through customer fees collected by utilities. More than $850 million were spent during this period by these programs, funded by bill assessments. Demand growth was kept below 1 percent per year over that time, and in 1998, there was a documented savings of 3.5 percent in electricity consumption. With restructuring of utilities in 1999, often deemed deregulation, these programs were abandoned and electricity consumption increased (MEA 2008). From 1998 to 2004, sales per residential customer increased by 2.4 percent per year (Energy Transition Team 2007). The American Council for an Energy Efficiency Economy (ACEEE) ranked Maryland 20th in energy efficiency on its State Ranking of Energy Efficiency (Eldridge et al., 2007).

In 2006, Maryland's public spending for energy efficiency was $7.2 million (MD General Assembly 2006), concentrated in weatherization subsidies for low-income households and revolving loan efficiency programs for government agencies and non-profit organizations. These expenditures did not include the operating budget of the Maryland Energy Administration, which would include expenditures for other programs such as outreach, and tax credits.

ACEEE ranks Maryland 41st in ratepayer funded energy efficiency spending nationwide for 2006 (Eldridge et al., 2007).

2.4.2 Related Energy Efficiency Policies

Mandates for state agencies

Maryland's energy efficiency investments in recent years have focused on the state government to a large extent, appearing among the top 15 states in the country in terms of state-lead-by-example efficiency policies (Eldrige et al., 2007). Maryland has in place various mandates for state agencies to implement energy efficiency and renewable energy programs. The Life Cycle Cost Analysis Standard is a mandate to evaluate the energy efficiency and renewable energy potential in state buildings as part of life-cycle cost analysis. The State Buildings Energy Efficiency and Conservation Act is a mandate to reduce state building energy use by 10 percent by 2005 and 15 percent by 2010 from 2000 levels. Also, new procurement must carry the Energy Star label. Additionally, the Clean Energy Procurement executive order of 2001 instructed agencies to procure at least 6 percent of the electricity for state-owned facilities with green power (wind, solar, landfill gas and biomass) (NCSU 2007). See Appendix G for additional information.

2.4.3 Recent Developments in Maryland

2.4.3.1 Maryland Strategic Electricity Plan

The Maryland Strategic Electricity Plan, released in January 2008 by the MEA, outlines recommendations to address the main electricity challenges in Maryland. Two centerpieces of the plan, the EmPOWER Maryland goal and the Maryland Strategic Energy Investment Fund, were approved by the legislature in the 2008 session.

2.4.3.2 EmPOWER Maryland Energy Efficiency Act of 2008

Governor Martin O'Malley announced the goal of reducing electricity consumption in Maryland by 15 percent per capita by 2015 and 15 percent reduction in peak demand by the same year, under the title of EmPOWER Maryland. The legislature codified this with base electricity consumption from the year of 2007 electricity consumption. This is an ambitious goal for the state and one that is directly linked with greenhouse gas reduction objectives, but also with the need to reduce stress on the already strained Maryland grid.

The act requires utilities to implement energy efficiency and conservation programs targeting all sectors as appropriate, so as to achieve a 10 percent per capita electricity consumption reduction by 2015 as compared to 2007, 2/3 of the EmPOWER goal, and 15 percent of peak demand reductions, 100 percent of the EmPOWER goal.

2.4.3.3 Maryland Strategic Energy Investment Fund

The Maryland Energy Administration proposed the creation of the Maryland Strategic Energy Investment Fund from the RGGI auction proceeds. The Maryland legislature approved this in the 2008 legislative session. (MD General Assembly 2008)

The stated goals of the fund are as follows:

1. Invest in the development and promotion of:
   a. Energy efficiency and conservation programs
   b. Renewable and clean energy
   c. Climate change programs to mitigate the effects of climate change
   d. Demand response programs to promote lower electricity usage during peak demand.
2. Carry out programs to reduce electricity consumption by customers in low and moderate-income residential sectors.
3. Supplement funding for the Electric Universal Service Program.
4. Provide rate relief by offsetting electricity rates on residential consumers.
5. Provide grants, loans and other assistance and investment necessary for those purposes.
6. Pay the operating expenses of those programs.

The yearly revenue in the fund was allocated as follows: 17 percent will be transferred to the Electric Universal Service program and other direct electricity assistance programs for low-income residents administered by the Department of Human Resources; 23 percent will be given to rate relief for residential customers; at least 46 percent will go towards energy efficiency and conservation, of which at least half shall go to the low-income residential sector at no cost to project participants, and to the moderate-income residential sector; up to 10.5 percent will be granted to renewable energy, energy public education, and climate change programs; and up to 3.5 percent but not more than $4 million will be dedicated to administration of the fund by MEA.

Energy efficiency programs contemplated in the fund include low income, residential, small business, commercial, industrial, state and local programs. Demand response programs, loans and alternative financing are also included, as well as grants for training in energy efficiency and energy conservation.

Renewable energy programs include production incentives, expansion of existing solar, geothermal and wind grants, loans and alternative financing.

Under the Act, the existing Maryland Renewable Energy fund is to be repealed and incorporated under the new fund. The Maryland Renewable Energy fund collected the compliance payments of the Renewable Portfolio Standard, and the new investment fund will collect these as well.

The Maryland Energy Administration will administer the new fund and they will be advised by a strategic energy investment board. Expenditures of the fund will start in Fiscal Year 2009.

Provisions under the Act establish that the fund will be a special, non-lapsing and separate account, whose earnings cannot be used as general government funds but solely for its specific purposes. However, spending will have to be approved by annual appropriations from the state legislature or by a budget amendment.

2.4.3.4 Demand Response Proposals by Utilities

As of February 2008, Maryland's Public Service Commission (PSC) was reviewing proposals filed by Maryland utilities for demand response and peak-load management programs. The EmPOWER act formalizes the requirements for utilities to implement energy efficiency programs. The PSC is requesting utilities to estimate expected reductions in electricity consumption from the implementation of these programs to evaluate their contribution towards the EmPOWER Maryland goal.

The PSC is evaluating the cost-effectiveness and cost-recovery mechanisms requested by the utilities to implement those programs. The utility proposals can be found on the website of the Maryland Public Service Commission.[3]

[3] Maryland Public Service Commission. Case 9111. http://webapp.psc.state.md.us/Intranet/CaseNum/CaseForm.cfm

3 The Regional Greenhouse Gas Initiative in Maryland

Maryland joined RGGI in 2007. From the 10-state annual CO_2 emission cap of 188 million tons from 2009 to 2014, Maryland was allocated 37.5 million tons per year, with one ton of CO_2 corresponding to one allowance. There are sixteen affected sources in Maryland, which include coal, natural gas, oil, and combined-fuel power plants with capacities greater than 25 MW. The cap will decrease by 10 percent from 2015 to 2018, with an annual decrease of 2.5 percent. In 2018, Maryland's allowance allocation will be 33.75 million tons (MDE 2008).

The latest plan at the time of this study, is for Maryland to auction the CO_2 allowances in the auction pool (85.3 percent of the total) at the quarterly auctions (MDE 2008). The Maryland CO_2 Budget Trading Regulations (COMAR 26.09 Chapters 1-3), adopted at the time of this study, provide a small number of allowances in three set-asides for the following: (1) limited industrial cases in which a source provides less than 10 percent of its electrical power to the grid (3.47 million tons); (2) sources with long-term power purchasing contracts if such sources can demonstrate financial hardship from the institution of carbon pricing (1.7 million tons); and (3) voluntary renewable energy purchases which can be exchanged for renewable energy credits for CO_2 allowances at a set ratio, (0.35 million tons). If allowances in these set-asides are not allocated to one or more of the set-asides the state may return them to the auction pool at the end of the year.

The proceeds will go to the Maryland Strategic Energy Investment Fund, which was established by the state legislature in its 2008 session and will be administered by the Maryland Energy Administration (MEA), as discussed above. Table 3.1 shows the expected annual auction revenue based on varying allowance prices during the first several years of the program.

Table 3.1. Expected annual auction revenue

Allowance Price ($/ton CO2)	Auction Revenue ($million)
1	32.0
2	64.0
3	96.0
4	128.0
5	159.9
6	191.9
7	223.9

Source: MDE 2008

Monitoring of emissions is not expected to place a high burden on facilities because the equipment installed to comply with both the federal Acid Rain Program and the Clean Air Interstate Rule are capable of accounting for CO_2 emissions.

Sources can cover up to 3.3 percent of their emissions through offset allowances. This percentage may rise to 5 percent if the allowance price has remained above $7 for 12 months, or to 10 percent if the price exceeds $10 for two consecutive 12-month periods. At present, five categories of offset projects are allowed:

A. Landfill methane gas (CH_4) capture and combustion;

B. Sulfur hexafluoride (SF_6) capture and recycling, storage, or destruction;

C. Sequestration of carbon through afforestation, the transition of land from a non-forested to a forested state;

D. Reduction or avoidance of CO_2 emissions through end-use energy efficiency projects in buildings that combust natural gas, propane, or heating oil for their use; and

E. Capture and destruction of CH_4 from farming operations.

Emission banking is allowed, giving sources the possibility of carrying over unused allowances into future compliance periods without restrictions. (MDE 2008)

3.1 Impacts of the cap and trade program

In a previous study undertaken in 2007 (Ruth et al 2007), CIER projected the following impacts from Maryland's participation in RGGI:

1. Net electricity demand in Maryland would decrease by 1.5 percent in 2010 and 3 percent in 2025 relative to a "Maryland not in RGGI" baseline.
2. Maryland would diminish its electricity exports and increase reliance on imports from out of state.
3. There would be no increase in retirement of existing generators, although the profits of existing generators, particularly coal-fired power plants, would be reduced because allowance costs could add up to several million dollars per year.
4. There would be virtually no effect on electricity prices in Maryland.
5. There is no evidence that these regulations would amplify market power from any source in the electricity generation market.
6. Emissions of CO_2 from electricity generation in Maryland would fall substantially – 26 million tons including offsets.
7. Electricity bills would be expected to decrease by $100 million by 2010 and $200 million by 2025 due to efficiency gains and decrease in demand.
8. Joining RGGI would have little overall economic impact in Maryland.

3.2 Usage of RGGI Revenue

Maryland's decision to auction a majority of allowances aligns the State with commitments to full auctioning in other RGGI states including New York, Vermont, Maine, and Connecticut. A rationale for this approach, instead of grandfathering allowances, is that in restructured power markets the allowance prices would be reflected in the prices paid by electricity consumers in either case. This effect was observed in European emission trading where the market price of grandfathered (i.e., free) emission allowances was still added to generation costs and passed on to end-users, which led to large windfall profits for generators. With auctioning, the government claims title to the value of emissions allowances.

Many RGGI states have indicated that the majority of their auction revenue will be invested in energy efficiency. In addition, laws in Connecticut, Rhode Island and Maine require the procurement of all cost-effective energy efficiency. For example, Maine passed a law directing the Maine Public Utility Commission to pursue all cost-effective energy efficiency opportunities that are cheaper than adding regular power supply (Environment Northeast, 2007).

In Vermont, the RGGI statute states that the 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 (The State of Vermont Legislature, 2008)." Delaware has recently formed a "Sustainable Energy Utility" (SEU) similar to Efficiency Vermont. Legislation passed in Delaware directs 65 percent of the auction revenue to the SEU to be used for energy conservation, energy efficiency, renewable energy, and energy financing (Delaware General Assembly, 2008). In New Hampshire, at least 10 percent of the revenue will be used to assist low-income residents. The remaining revenue will be used to support energy efficiency, conservation, and demand response programs to improve both electrical and thermal energy efficiency (New Hampshire General Court, 2008).

The diversity of funding levels and uses for efficiency programs reflects the relative newness of opportunities presented by RGGI and some uncertainty about the potential, state-specific benefits. The following sections of this report quantify for Maryland the energy and economic implications of alternative funding levels for efficiency, and explore lessons from the design and implementation of efficiency programs in other states.

4 STUDY DESIGN

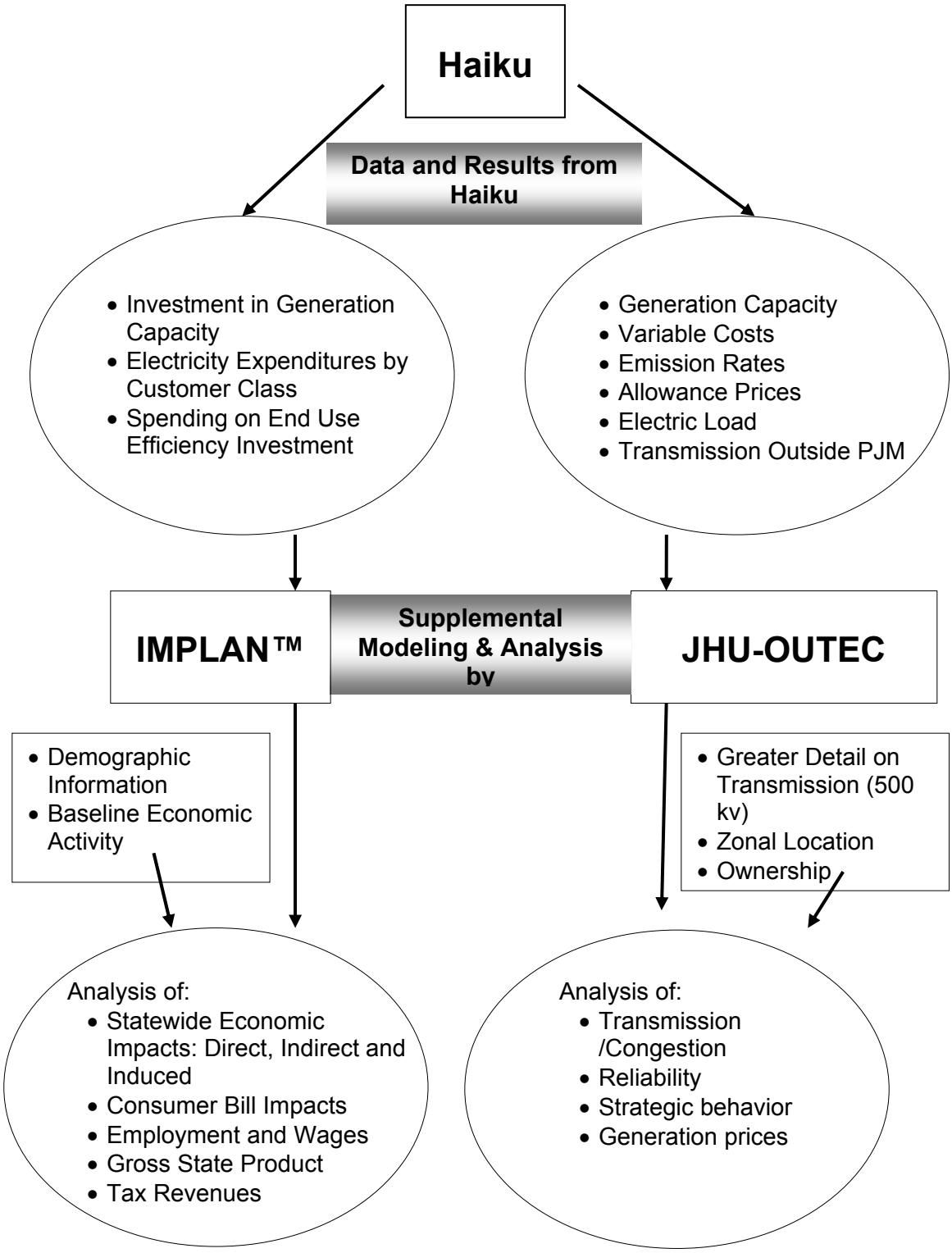
4.1 Modeling Study Design

This study uses three models to assess the effects of energy efficiency spending in Maryland on the electricity sector and the economy of Maryland. The three models are used to analyze how varying the percentage of RGGI CO_2 allowance revenue in Maryland that is spent on energy efficiency in the electricity sector affects electricity consumers, electricity producers and the performance of electricity markets in Maryland and the surrounding PJM regions. The study also addresses the effects of efficiency spending and associated changes in electricity markets on the Maryland economy.

The three models used for this analysis are Haiku, JHU-OUTEC and IMPLAN. The Haiku electricity market model, created and maintained at RFF by Dallas Burtraw, Karen Palmer and Anthony Paul, is a national economic simulation model of electricity markets based on market equilibrium concepts. The JHU-OUTEC model (Johns Hopkins University Oligopoly Under Transmission and Emissions Constraints), developed by Professors Ben Hobbs (JHU) and Yihsu Chen (UC-Merced, formerly JHU), is a regional market equilibrium model for the Pennsylvania-New Jersey-Maryland (PJM) area allowing for market power in the generation sector. Towson University's IMPLAN model, adapted by Daraius Irani, is an input-output model that takes into account changes in employment levels, among other important economic indicators. Details about these models appear in Appendix D of this report.

These three models together help answer the range of questions posed in this study. To integrate the findings, the modeling procedure involved first running the Haiku model. This provided insights into the impacts of alternative assumptions about allocations of RGGI allowance revenues on efficiency programs and generated key inputs necessary for the other two models. In this way, all of the models are consistent with each other while still offering a different perspective on each of their relevant issues. A chart depicting the flow of information among these three models appears in Figure 4.1 below.

Figure 4.1. Information Flows Among the Models Used in this Study



To address the study questions, the research team designed a baseline scenario and two alternatives to model, and developed a set of assumptions to use throughout the models as described below.

4.2 Modeling Scenarios and Assumptions

This study uses a scenario approach to quantify the effects of Maryland's expenditures on end-use electricity consumption efficiency. Funding for these efficiency expenditures will come from the quarterly auctions of Maryland's apportionment of the CO_2 emissions allowances created by the Regional Greenhouse Gas Initiative (RGGI). RGGI participating states have agreed to use at least 25 percent of their total allowances to promote strategic energy and consumer benefits. This study characterizes expenditures on end-use efficiency consumption as meeting these objectives and uses 25 percent of proceeds from the auction of all allowances as the baseline.

This research evaluates three scenarios of efficiency spending: a baseline as described above and two scenarios that assume a greater portion of the allowance revenue is spent on energy efficiency. All three scenarios assume that 100 percent of the emissions permits (allowances) are auctioned off. Section 4.2 discusses other modeling assumptions that are maintained across all the scenarios. The following subsections of section 4 describe the distinguishing features of the baseline and higher spending scenarios.

4.2.1 Modeling Assumptions

All of the scenarios that are analyzed, including both baseline and higher spending scenarios, assume the following:

4.2.1.1 Time Frame

- The electricity market model simulation has been carried out for the following years: 2010, 2015, 2020, and 2025.
- Three seasons are modeled:
  - Summer (May-September)
  - Spring/Fall (October, November, April, March)
  - Winter (December, January, February).

4.2.1.2 Fuel Prices

- Prices for fossil fuels (including international oil) and nuclear power come from the Annual Energy Outlook (AEO) 2007 estimates and are characterized as price responsive supply functions.
- Prices for renewables come from the AEO 2007 and are supplemented with data from biomass and wind potential from National Labs.

4.2.1.3 Regions

- The Haiku model treats the continental US as 20 regions, with greater disaggregation in the mid-Atlantic and northeastern regions. Relative to prices, regions of two types are considered ~~re~~gulated and market-based. The model distinguishes regions with cost-of-service regulation from those with competitive wholesale markets for electricity (see Figure 4.2). The JHU-OUTEC model covers the mid-Atlantic region (the eastern portion of PJM plus some adjacent states) with a 17 zone representation.
- The 10 state RGGI region includes the following states: ME, NH, VT, MA, CT, RI, NY, NJ, DE, and MD.

4.2.1.4 Environmental Policies

4.2.1.4.1 Federal Environmental Policies

- The Clean Air Interstate Rule (CAIR) and Clean Air Mercury Rule (CAMR) policies and the Title IV cap on SO_2 emissions outside the CAIR region were included in the analysis.

4.2.1.4.2 Federal Renewables Policies

- The primary federal policy to encourage use of renewables to generate electricity is the Renewable Energy Production Tax Credit (REPC). This credit has repeatedly lapsed and been renewed and is modeled into perpetuity with a 90 percent probability of realization. Our modeling assumption is that the value of the credit will remain at the current level, which

provides for a 1.9 cent per kWh tax credit for qualified renewables (wind, geothermal, and dedicated biomass) for the first 10 years of operation with the credit escalating over time to account for inflation (2005 dollars). Landfill gas and non-dedicated biomass generators receive 50 percent of the tax credit.

4.2.1.4.3 Maryland Environmental Policies (Maryland Healthy Air Act)

- The model accounts for:
  - Plant-specific emissions restrictions on NOx, SO_2 and Mercury provided by MDE.
  - Intra-firm trading of emissions for NOx and SO_2 only.
  - Maryland firms may sell unused CAIR (NOx) and Title IV (SO_2) allowances out of the state.

4.2.1.4.4 State Renewable Portfolio Standards (RPS) to Force Renewables to Be Built

- For outside of Maryland, National Energy Modeling System (NEMS) AEO 2007 forecasts are used, which capture some, but not all, of the new renewables expected to be brought on line in response to RPS policies.
- For Maryland, Exeter Associates and Princeton Energy Resources International report ("Inventory of Renewable Energy Resources Eligible for the Maryland Renewable Energy Portfolio Standard") is used to identify new renewables expected to be added, but RPS is not explicitly modeled (McVeigh 2006).
- The Maryland Renewable Tax Credit is represented in the model.

4.2.1.5 RGGI

- The RGGI emissions cap in 2009 for electricity generating units is represented in the model for those that operate generators that primarily sell electricity to the grid. The emissions from generators who primarily generate for their own use are excluded from this analysis. The RGGI cap for the generators that are included is modeled at 175.57 million tons of CO_2 beginning in 2009 and falling to 158.1 million tons by 2019. Maryland's share of the cap is similarly adjusted to 34.95 million tons of CO_2 in 2009, falling to 31.5 million tons by 2019. By excluding facilities that generate electricity primarily for their own use from the model, it is effectively assumed that they get the allowances they need for free and that these facilities do not contribute to the allowance revenue pool available to the states for spending on energy efficiency.
- All states participating in RGGI auction all of their apportioned emissions allowances.
- New Jersey, Delaware, Maine, New Hampshire, Vermont and Connecticut have declared intention to allocate as much as 30 percent of allowance revenues to activities other than efficiency. The remainder is assumed to be allocated to efficiency.
- 100 percent of RGGI allowance revenues in Massachusetts, Rhode Island and New York are assumed to be going to efficiency incentives in electricity consumption. The share of Maryland allowance revenue spent on efficiency is subject to change across the different scenarios.

4.2.1.6 Demand Growth for Electricity

- The US Energy Information Administration, Annual Energy Outlook (AEO) 2007 electricity demand forecasts are used to benchmark the Haiku electricity demand functions. These functions are described in the Appendix Section D.1.3.1.2. The EIA forecasts do not explicitly account for any climate change induced increases in electricity consumption and as a result may underestimate demand growth.

4.2.1.7 Transmission Expansion

- Only planned and approved transmission capacity investments through 2010 are used.
- Beyond 2010, a 0.5 cent per year rate of growth in transmission capacity is assumed. Additionally, starting in 2024, an incremental transfer capability is included, associated with two new 500 KV transmission lines into and, in one case, through Maryland. These are modeled after one line proposed by Allegheny Electric Power and one proposed by PEPCO Holdings.

4.2.1.8 Imports of Power From Canada

- Imports from Canada are exogenously specified based on the AEO 2007.

4.2.1.9 Rest of the US Greenhouse Gas Policy

- National policy of no caps on greenhouse gas emissions is assumed to remain in effect throughout the simulation time horizon.

4.2.2 Maryland Baseline and Higher Spending on Energy Efficiency Scenarios

The baseline scenario assumes that the state of Maryland auctions 100 percent of its RGGI allowance apportionment and spends 25 percent of the auction revenues on end-use energy efficiency in the electricity sector. The remaining 75 percent of the revenue is assumed to be used by the government for other purposes that don't have a direct effect on electricity markets. The efficiency spending modeled in this analysis is assumed to occur in the absence of an expansion of any efficiency program administered by the utilities. To the extent that these programs are expanded as required under the EmPOWER Maryland legislation, the analysis in this report overstates the efficiency gains that will come from state expenditure of RGGI funds.

As described in section 4.3 below, the Haiku model assumes that the size of the expenditure necessary to reduce electricity demand by a prescribed amount can be identified from the statistically estimated relationship between electricity demand by customer class, electricity price and other factors. This function tells us how much of a financial incentive electricity consumers would require to reduce their consumption of electricity by a certain amount, or, conversely, how many kWh of electricity consumption could be reduced for a given amount of expenditure. This statistical model applies to all three scenarios and is used to estimate the potential for electricity savings from RGGI allowance revenue expenditure.

The first higher spending scenario includes identical assumptions to the baseline scenario except that the assumption is made that 50 percent of the RGGI allowance revenues are spent on end-use energy efficiency in the electricity market. The remaining 50 percent of the revenues are assumed to be used by the government for other purposes that don't have a direct effect on electricity markets.

The second higher spending scenario assumes that 100 percent of the Maryland RGGI emissions allowance revenues are spent on end-use energy efficiency in the electricity sector in Maryland. All other assumptions are identical to those in the baseline scenario.

4.3 Haiku Model

4.3.1 Overview of the Haiku Model

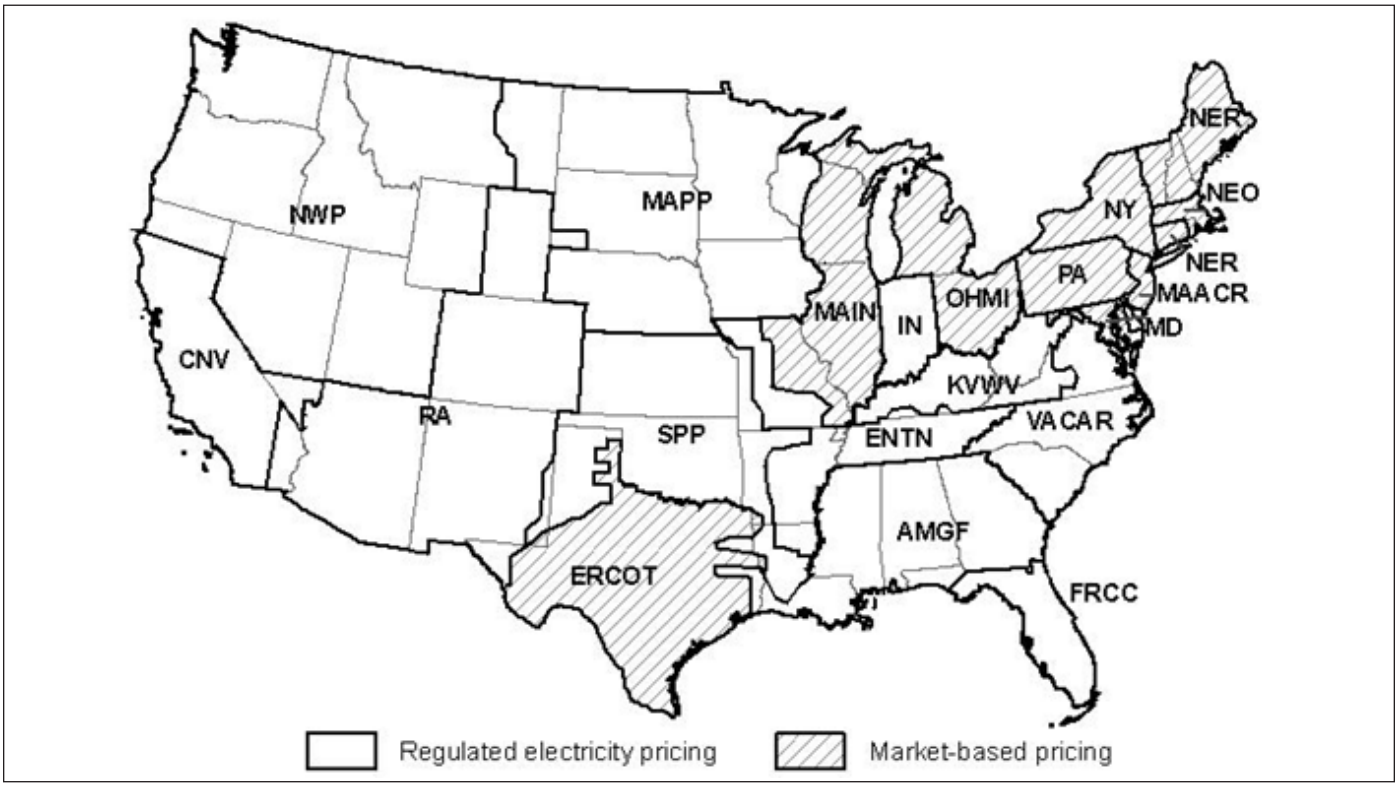
The electricity supply and market analysis conducted in this study relies on a detailed simulation model of the electricity sector known as the Haiku Electricity Market Model, which is maintained by Resources for the Future. Haiku is a deterministic, highly parameterized model that calculates information similar to the National Energy Modeling System used by the Energy Information Administration, and the Integrated Planning Model developed by ICF Consulting and used by the US Environmental Protection Agency (EPA).

The Haiku model simulates equilibrium in regional electricity markets and interregional electricity trade with an integrated algorithm for emission control technology choices for SO_2, NOx, and mercury. The composition of electricity supply is calculated using a fully integrated algorithm for capacity planning and retirement coupled with system operation in temporally and geographically linked electricity markets. The model solves for electricity market equilibria in 20 Haiku market regions (HMRs) for the continental US. Each of the 20 HMRs is classified by its electricity pricing regime as having either market-based electricity pricing or regulated pricing as shown in Figure 4.2. Electricity markets are assumed to maintain their current regulatory status throughout the modeling horizon; that is, regions that have already transitioned to market-based pricing of generation continue that practice, and those that have not made that move remain regulated. The price of electricity to consumers does not vary by time of day in any region, though all customers in competitive regions face prices that vary from season to season.

Each year is subdivided into three seasons (summer, winter, and spring-fall) and each season into four time blocks (superpeak, peak, shoulder, and base). For each time block, demand is modeled for three customer classes (residential, industrial, and commercial). Supply is represented using model plants that are aggregated according to their technology and fuel source from the complete set of commercial electricity generation plants in the country. Investment in new generation capacity and the retirement of existing facilities is determined endogenously in a dynamic framework, based on capacity-related costs of providing service in the future ("going forward costs"). Operation of the electricity system (generator dispatch) in the model is based on the minimization of short-run variable costs of generation.

Equilibrium in interregional power trading is identified as the level of trading necessary to equilibrate regional marginal generation costs net of transmission costs and power losses. These interregional transactions are constrained by the level of the available interregional transmission capability as reported by the North American Electric Reliability Council (2003a, 2003b).[1] Factor prices, such as the cost of capital and labor, are held constant. Fossil fuel prices are benchmarked to the forecasts of the Annual Energy Outlook 2007 (EIA 2007) and are endogenously determined in price responsive fuel supply modules. Coal is differentiated along several dimensions, including fuel quality and 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. Other fuel prices are specified exogenously.

Figure 4.2. Haiku Market Regions and Electricity Pricing



Emissions caps in the Haiku model, such as the Title IV cap on national SO_2 emissions, EPA's Clean Air Interstate Rule caps on eastern regional emissions of SO_2 and NOx, and the Regional Greenhouse Gas Initiative (RGGI) cap on CO_2 emissions, are imposed as linear constraints on the sum of emissions across all covered generation sources in the relevant region. Emissions of CO_2 from individual sources depend on emission rates, which vary by type of fuel and technology, and total fuel use at the facility. The sum of these emissions across all sources must be no greater than the total number of allowances available, including those issued for the current year and any unused allowances from previous years. Unused emissions allowances that can be banked for use in the future are supported by Haiku. To determine the rate at which the size of the allowance bank changes, the model imposes a Hotelling constraint that the rate of change in the price of emissions allowances must be no greater than the interest rate.

1 Some of the HMRs are not coterminous with North American Electric Reliability Council (NERC) regions and therefore NERC data cannot be used to parameterize transmission constraints. Haiku assumes no transmission constraints among OHMI, KVWV, and IN. NER and NEO are also assumed to trade power without constraints. The transmission constraints among the regions ENTN, VACAR, and AMGF, as well as those among MAACR, MD, and PA, are derived from version 2.1.9 of the Integrated Planning Model (EPA 2005) Additionally, starting in 2014, incremental transfer capability associated with two new 500-KV transmission lines into and, in one case, through Maryland, was included which are modeled after a line proposed by Allegheny Electric Power and one proposed by PEPCO Holdings (CIER 2007). The transmission capability between Long Island and PJM made possible by the Neptune line that began operation in 2007 was included.

4.3.2 Efficiency in End-Use Electricity Markets

For this report, the Haiku model employs the Demand Conservation Incentive (DCI) algorithm to project end-use efficiency potential in electricity markets. A demand conservation incentive is a payment to electricity consumers to encourage them to invest in energy efficient equipment that will enable them to reduce their consumption of electricity while holding consumption of energy services such as heating, lighting and clothes washing, fixed. The DCI is paid per unit of electricity conserved and the level of the payment is derived based on econometrically estimated electricity demand functions that capture the responsiveness of electricity demand to changes in price as manifest in actual data. The DCI payment should be thought of as the payment necessary to make a household or business choose a more efficient type of capital equipment than it would have chosen otherwise. The DCI algorithm is built on a habit formation specification for electricity demand (Houthakker et al 1974, Houthakker et al 1970) that accounts for the dynamics of electricity end-use capital, essentially how electricity using equipment depreciates and eventually retires and must be replaced. Habit formation refers to the fact that electricity demand is strongly related to the electricity using capital stock that is in place and changes in energy using capital will affect the level of energy demand in the future, essentially defining the habit. Initial electricity demand reductions are calculated using habit formation derived parameters on price elasticity of demand. Other dynamic parameters of the habit formation model are used to calculate the rate at which initial demand reductions persist through time. Detailed documentation on the DCI algorithm is in Appendix D.

The habit formation specification for modeling electricity demand accounts for the role of capital using a habit parameter that is a proxy for the portion of electricity consuming capital that is immobile at any time t. The model also captures the short-run demand response effects to changes in electricity prices and a set of other variables including income, population, weather, GDP, and natural gas price. The habit coefficient provides a dynamic link through time that captures the long-run effects of choices of energy-using appliances and equipment. Thus, a policy that changes the prices of end-use electricity equipment has effects that persist through time and are captured in the habit formation model used for this study.

The parameters for the habit formation demand functions are econometrically estimated. A separate estimation was performed for each of three customer classes (residential, commercial, industrial) using state level, annual electricity consumption data and its covariates (including heating and cooling degree days, personal income, population, natural gas prices, and gross state product) from the lower 48 United States between 1977 and 2004. The two key parameters that are returned by the econometric model are the habit coefficient itself and the short-run price elasticity of electricity demand, i.e. the percentage change in electricity demand in the near term for a percentage change in price. These parameters can be used to calculate the long-run price elasticity of electricity demand. The short-run and long-run price elasticity estimates that are used in this study are shown in Table 4.1. These parameters are treated as identical on a national level for each type of customer class.

Table 4.1. Price Elasticity of Electricity Demand under Habit Formation

Customer Class	Short-run Price Elasticity of Electricity Demand	Long-run Price Elasticity of Electricity Demand
Residential	-0.167	-0.649
Commercial	-0.118	-0.651
Industrial	-0.110	-0.605

In Haiku, the habit formation demand functions are benchmarked to the electricity demand projections reported in the AEO 2007 for the time period ending in 2030. The benchmarked coefficients are calculated such that, using the habit and short-run price elasticity parameters calculated in the econometric model, a Haiku simulation that achieves retail electricity prices for each customer class equivalent to those reported in AEO 2007 without any funding for end-use efficiency will also achieve electricity consumption for each customer class that is equivalent to the AEO 2007 projections.[2] The benchmark coefficients are held constant in all scenarios analyzed in this study.

[2] The AEO projections do assume some improvements in end-use efficiency of electricity using appliances and equipment as a result of changes in appliance standards and general expected trends in energy efficiency of new equipment over time. However, the AEO2007 does not incorporate higher levels of state spending on energy efficiency of the type modeled here.

The Demand Conservation Incentive (DCI) algorithm calculates the immediate annual demand reductions that are achievable using a price based mechanism to incent consumers to choose capital that is relatively efficient in end-use electricity consumption. The DCI uses the short-run price elasticity of demand estimates from the habit formation model and other parameters that characterize the market for end-use electricity efficiency. These parameters include the costs of administration of state-run efficiency programs, the proportion of efficiency funding that is typically captured by free riders (those who would have made the efficiency enhancing investment without the program) and the portion of the retail electricity market that is inaccessible to efficiency program administrators. The persistence of electricity consumption reductions that are achieved by the DCI is managed outside of the DCI algorithm by the habit formation demand functions. In other words, savings purchased today lower the current level of demand and that adjustment in total electricity demand will persist into the future for several years, but will decay over the long term.

The DCI is denominated in Haiku in $/MWh and can be interpreted as the price paid for the non-consumption of electricity. The short-run price elasticity derived for the habit formation demand function is used as the measure of consumer responsiveness to the DCI. The DCI value is determined endogenously inside of Haiku to expend all of the available funds for efficiency incentives (the applicable portion of the RGGI allowance revenue), assuming that efficiency spending can discriminate between types of equipment, but cannot discriminate between consumers who place different values on the same types of equipment. It varies in both time and scenario specification with the equilibrium DCI value increasing in efficiency spending level. This relationship between the DCI level and efficiency spending level is such because the DCI algorithm identifies the distribution of costs of demand reductions and harvests those that are cheapest in each simulated year of each model scenario. As the amount of efficiency spending increases, the set of demand reductions that can be purchased grows to include the cheapest demand reductions previously not cheap enough to be included under the DCI. Since these additional reductions are more expensive than the ones that came before, the average payment for each MWh reduced, the DCI value, also increases.

The other parameters that govern the DCI algorithm are administrative costs, the free rider rate, and the inaccessible portion of economical demand reductions. Administrative costs are expressed as a fraction of total program costs. A value of 40 percent for this parameter is assumed based on the data that informs the analysis in Section 10. Literature review also yielded a free rider rate of 20 percent[3]. This parameter should be interpreted as the fraction of demand reductions collecting the DCI payment that would have occurred even in the absence of any payment for efficient capital. The DCI algorithm assumes that the program administrator cannot distinguish among consumers who place different values on the same capital goods, thus the free rider parameter must be included. The inaccessible portion of economical demand reductions is parameterized as 40 percent[4] and accounts for consumers who will not respond to incentives for efficient capital even though they would derive economic benefit from accepting the DCI payment and reducing electricity consumption.

As depicted in Figure 4.1, the Haiku model findings are used as inputs to both the Oligopolistic Power Model and the IMPLAN models described below.

4.4 Oligopolistic Power Model

Johns Hopkins University developed an Oligopolistic Power Model (JHU-OUTEC), which was used in this study. Market models formulated as complementarity problems (a type of mathematical problem) have been applied previously by several research groups and consultants to assess the potential for market power in transmission-constrained electricity markets.[5] The

[3] The California Energy Efficiency Policy Manual reports that free ridership estimates vary from 4% to 65% across different programs. These are derived from the ratio of net to gross electricity savings under each program. We have chosen the value 20% because it is near the median of this uncertain distribution.

[4] The complement of inaccessible reductions is the achievable fraction of economical reductions. This value is reported by ACEEE for a series of studies on efficiency potential (see http://www.aceee.org/conf/04ss/rnemeta.pdf). The value 60% is generally near the middle of the distribution of reported values for the achievable fraction of economical reductions. Thus 40% is the treated as the inaccessible portion of economical reductions.

[5] Examples include: B.F. Hobbs, F.A.M. Rijkers, and M. Boots, "The More Cooperation, The More Competition? A Cournot Analysis of the Benefits of Electric Market Coupling," The Energy Journal, 26(4), Fall 2005, 69-97; K. Neuhoff, J. Barquin, M.G. Boots, A. Ehrenmann, B.F. Hobbs, and F.A.M. Rijkers, "Network-constrained Cournot models of liberalized electricity markets: The devil is in the details," Energy Economics, 27, May 2005, 495-52; and Y.H. Chen and B.F. Hobbs, "An Oligopolistic Power Market Model with Tradable NOx Permits," IEEE Transactions on Power Systems, 20(1), Feb. 2005, 119-129.

models use a complementarity approach to simulate the interaction of pollution permit markets with electricity markets, considering forward contracts and the operating reserve market. Because some power producers are relatively large consumers of permits, there could be interaction between market power in the permits and energy markets. Market power in the energy market is modeled using a Cournot game, while a conjectured price response model can be used in the permits market. In the RGGI study it was assumed that market power could not be exercised in the CO_2 market, since trade is not constrained by transmission capacity. The effect of transmission constraints upon competition was taken into account. For example, transmission constraints creating load pockets can limit the extent to which external supplies can effectively compete. This is particularly important for import-dependent states such as Maryland whose transmission facilities are often congested.

4.5 IMPLAN Model

RESI utilizes a modified IMPLAN™ input/output model to estimate the overall impact on the State's economy. To quantify the economic impact of a change in expenditures (by both businesses and households), economists measure three types of impacts: direct, indirect, and induced. The direct impacts are generated as expenditures enter and/or exit the state's retail or commercial markets. The indirect economic impacts occur as local firms either increase or decrease their purchases of goods and services from other area firms. Both the direct and indirect impacts result in a change in employment that affects household income levels (which rise and fall as job growth/loss occurs). This change in income levels drives the induced economic impacts, which occur as households alter their purchases of local goods and services.

4.6 Analysis Energy Efficiency Programs in Three Northeastern States

To identify useful considerations for Maryland's programs to increase investment in energy efficiency spending, lessons and results from other states were examined by researchers from the Center for Integrative Environmental Research. For this report, efficiency spending programs for New York, Vermont and Maine were analyzed, with a focus on cost-effectiveness and best practices. These three states are all part of RGGI, have established programs, and share some characteristics with Maryland that could be helpful in understanding factors that can contribute to program success in Maryland. The cost-effectiveness of programs was calculated using data from annual reports produced by the New York State Energy Research and Development Authority (NYSERDA), Efficiency Vermont, and Efficiency Maine. Information on best practices came from phone conversations with program managers and from annual reports.

In researching Maryland's current programs, practices and needs, this report used information gathered from a wide variety of stakeholders, ranging from officials at state agencies which are administering and regulating energy efficiency programs, to representatives from the farming and manufacturing sectors, energy consultants and renewable energy businesses, plus energy efficiency advocates and environmental organizations.

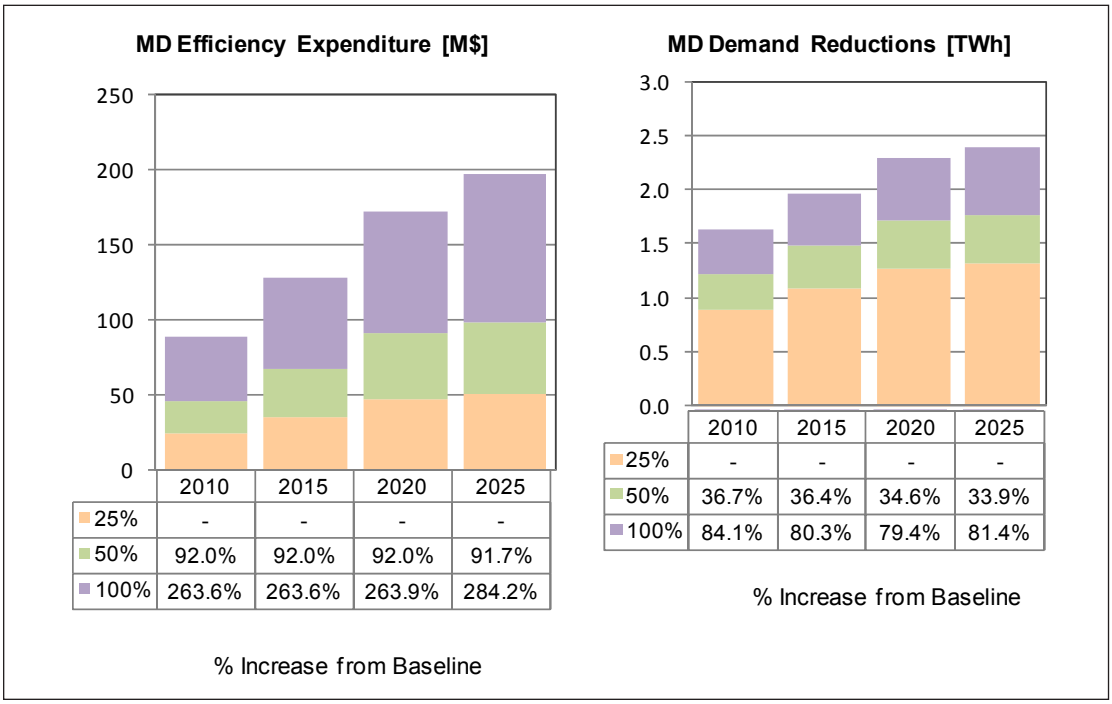
5 EFFICIENCY PROGRAM & ELECTRICITY MARKETS

Sections 5 describes the projected effects on Maryland of using RGGI CO_2 allowance revenue to fund efficiency improvements in end-use electricity consumption in terms of efficiency program costs, demand reductions and the associated electricity market responses, These effects are assessed by comparing the results of simulations performed using RFF's electricity market model, Haiku. The Haiku model is described briefly in Section 4.3 and in more detail in Appendix D. The scenarios that are compared are a baseline scenario under which Maryland spends only 25 percent of its RGGI allowance revenue on energy efficiency, a scenario where Maryland spends 50 percent on energy efficiency, and a scenario in which Maryland spends 100 percent of its allowance revenue on energy efficiency. All scenarios are described in Section 4.2 above. Other effects, such as electricity production. generation capacity, emissions, profitability, competitiveness, reliability and economic welfare, are discussed in subsequent Sections.

5.1 Efficiency Program Costs & Demand Reductions

RGGI allowance revenue spending for efficiency improvements in end-use electricity consumption will have a substantial impact on electricity consumption in Maryland. The magnitude of this effect will grow over the time as the value of RGGI CO_2 allowances increases simultaneously. RGGI allowances will increase in value because of anticipated growth in electricity demand in the RGGI region and the tightening of the RGGI CO_2 emissions cap beginning in 2015. The amount of spending on end-use efficiency in each scenario and the associated amount of demand reductions purchased in each simulation year are shown in Figure 5.1 with total efficiency spending in the left hand graph and associated purchased energy savings in the right hand graph. Note that efficiency spending does not vary strictly in proportion to the share of allowance revenue being spent on efficiency. For example, in 2010 under the baseline scenario (25 percent efficiency spending) $24 million is spent on efficiency but in the 100 percent efficiency spending scenario only $89 million is spent on efficiency. This relationship is generally not proportional because greater spending on efficiency will have an effect on the RGGI allowance price, which is discussed below, and thus on allowance revenue.

Figure 5.1. Total Spending on Energy Efficiency and Contemporaneous Reductions in Electricity Demand in Maryland

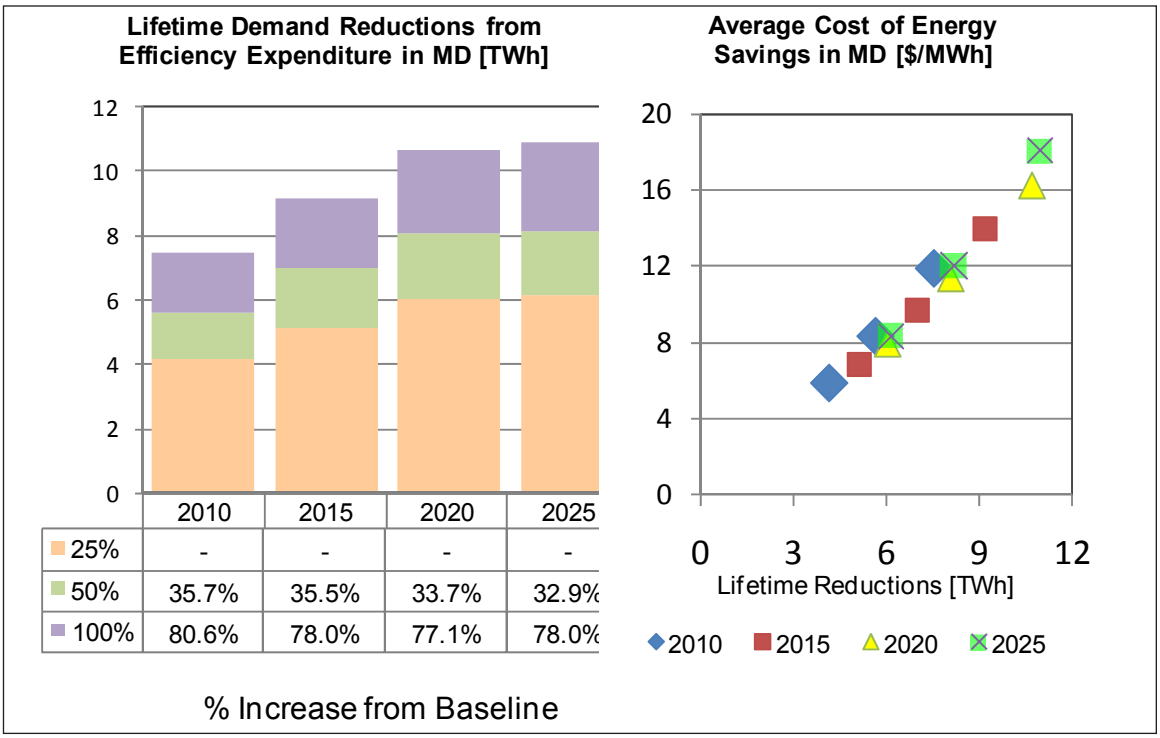


The right hand side of Figure 5.1 clearly shows that greater spending on efficiency enables greater purchases of demand reductions. Not unexpectedly, demand reductions directly attributable to efficiency spending in any given year increase less than proportionately with efficiency spending in any given year. For example in 2020, efficiency expenditures under the 100 percent scenario are 3.6 times as large as in the 25 percent scenario, but the purchased savings are only 1.8 times as large as in the baseline scenario. This result occurs because the next megawatt hour of demand reduction becomes more expensive as the amount of megawatt hour reductions being purchased increases. This is consistent with economic theory and also with the analysis of state energy efficiency programs detailed in Section 10[6].

The demand reductions in the right hand graph of Figure 5.1 represent the immediate megawatt hours of avoided consumption from the efficiency expenditures from the left hand graph in the corresponding year on the horizontal axis. The full stream of demand reductions that are achieved by the efficiency expenditures is greater than these immediate reductions because the capital investments in efficiency end-use electricity technologies are long lived. The lifetime reductions are calculable using the model parameters to incorporate the electricity market equilibrium effects of efficiency investment. The lifetime reductions of the annual expenditures on efficiency under each model scenario are shown in the left hand side of Figure 5.2.

One measure of the cost of a state program that funds efficiency measures for end-use electricity consumption is the cost per reduction MWh including the demand reductions that accrue through the lifetime of the capital. The quotient of the efficiency expenditures in the left hand side of Figure 5.1 and the lifetime reductions shown in the left hand side of Figure 5.2 is a measure of the average cost of efficiency reductions that can be expected under the scenarios of efficiency spending modeled. These values are shown in the right hand side of Figure 5.2 and suggest that all of the scenarios of efficiency spending analyzed here will likely yield gains for consumers as a price of less than $20/MWh is well below the retail electricity prices that will prevail in Maryland. Comparisons such as this should be made with caution however, as the marginal cost of these lifetime electricity savings is higher than the average cost identified in this graph and thus the cost of the next MWh of energy savings is likely higher than the cost identified here. Furthermore, these are just the program costs, and do not account for out-of-pocket or opportunity costs incurred by the consumer in installing efficiency measures.

Figure 5.2. Electricity Demand Reductions and Average Cost of Energy Savings

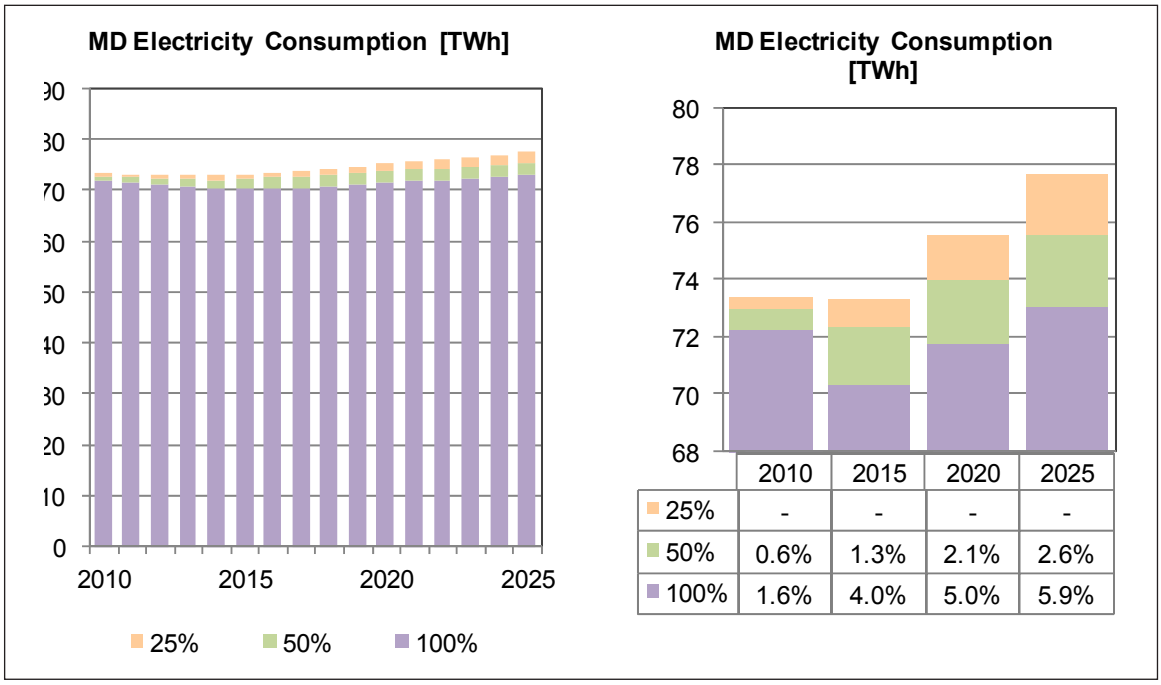


[6] Figure 10.1 shows that efficiency spending per unit is much greater in VT than in ME or NY. Figure 10.11 shows that the VT program is the least cost-effective of the three. This is consistent with the result presented here that the marginal cost of efficiency reductions is increasing in the size of the program.

5.2 Electricity Consumption, Prices, and Expenditure

The electricity consumption reductions that will follow efficiency expenditures using RGGI allowance revenue will accumulate through time as reductions are persistent in long-lived capital and an increasing stream of funding will continually purchase new reductions in each subsequent year. In comparison to the entire electricity market in Maryland, the effects of efficiency funding on consumption will be small, but it is clear that increasing efficiency funding will lead to electricity consumption reductions. Figure 5.3 shows the projected electricity consumption in Maryland in each of the model scenarios. The right hand side of Figure 5.3 shows also that if all RGGI revenues are used to fund an efficiency program in Maryland then electricity consumption will fall relative to the baseline scenario by about 1.5 percent in 2010 and by nearly 6 percent in 2025.

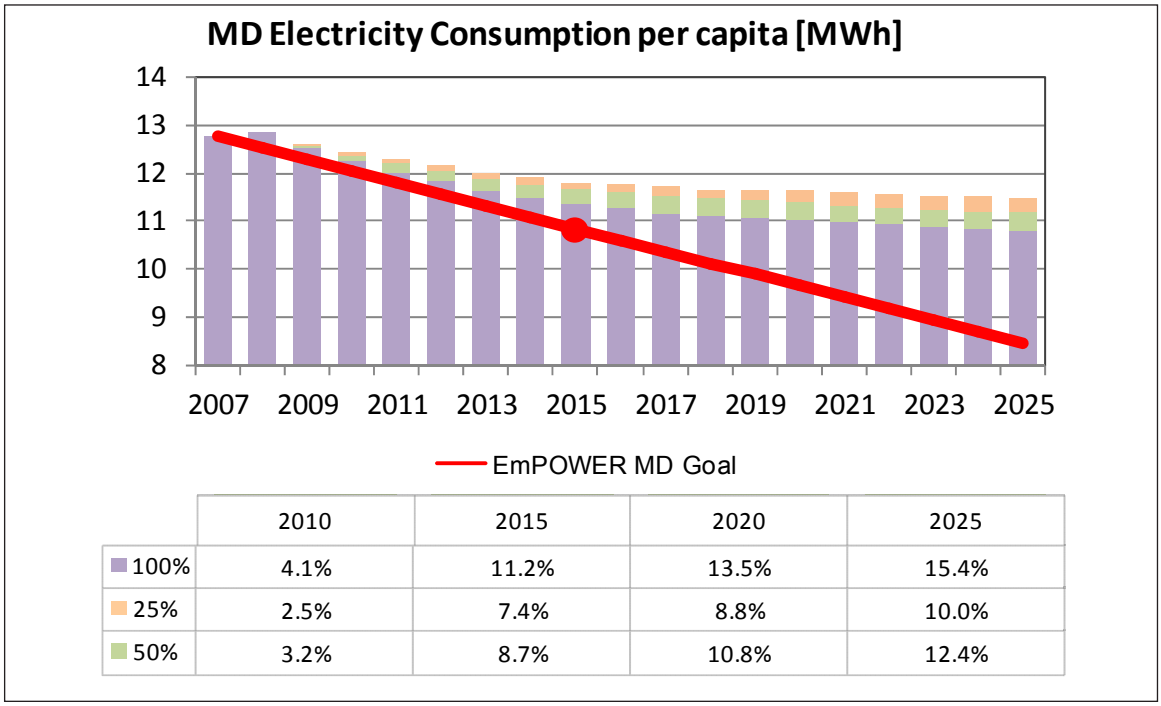
Figure 5.3. Electricity Consumption in Maryland under Different Efficiency Spending Scenarios



As part of Maryland Governor O'Malley's program to manage the recently high retail electricity prices in the state and projected reliability problems that threaten the electricity system in Maryland, the legislature recently codified in legislation the governor's EmPOWER Maryland plan[7]. One of the components of EmPOWER Maryland is a goal to reduce per capita electricity consumption in the state by 15 percent from the 2007 level by 2015. The results of this modeling exercise suggest that Maryland can make substantial progress toward that goal if all of the revenues from RGGI allowance auction are spent on efficiency in end-use electricity consumption. Figure 5.4 shows electricity consumption per capita in Maryland under each model scenario and also indicates the EmPOWER Maryland goal of 15 percent reduction in per capita consumption by 2015. The column for 2015 is comparable to 15 percent for evaluating the goal. More than half of the goal would be met by using 50 percent of RGGI funds for efficiency funding and about three-quarters of the goal would be met if all of RGGI allowance revenue is spent on energy efficiency in end-use electricity consumption.

[7] See http://www.energy.state.md.us/documents/NEWSRELEASE.pdf for a press release describing the features of this legislation.

Figure 5.4. Electricity Consumption Per Capita and EmPOWER Maryland Goals



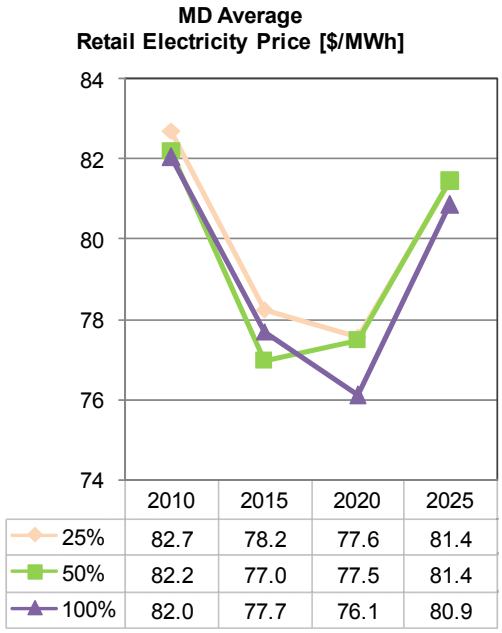
	2010	2015	2020	2025
100%	4.1%	11.2%	13.5%	15.4%
25%	2.5%	7.4%	8.8%	10.0%
50%	3.2%	8.7%	10.8%	12.4%

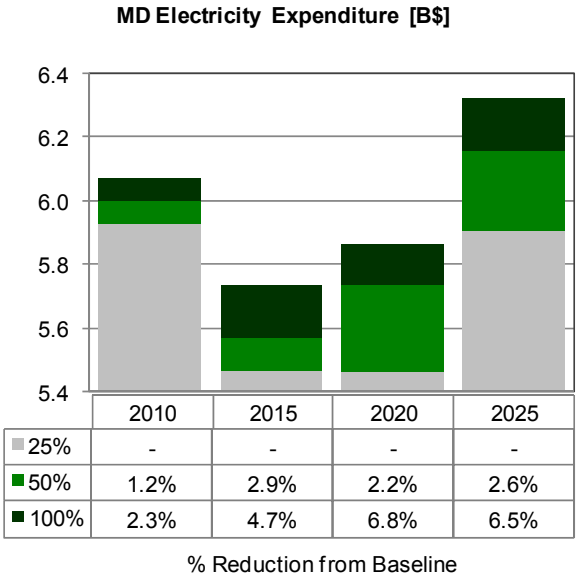
Increasing the share of allowance revenues devoted to energy efficiency will have a substantial effect on electricity consumption, but very little effect on the average price of retail electricity in Maryland or on the price paid by any single customer class[8]. The left hand side of Figure 5.5 shows the projected average retail electricity price for Maryland consumers under each model scenario. In every year the prices for each scenario are within 2 percentage points of each other and do not vary directly with the fraction of auction revenues spent on efficiency. These prices should be interpreted as being essentially constant in their level of efficiency expenditure. The retail electricity price in Maryland is not sensitive to efficiency spending because Maryland is embedded within the PJM power market. The potential price responsiveness of Maryland electricity markets to efficiency spending is projected to be absorbed by Maryland's neighbors. This is not evidence of net emissions leakage, but simply demonstrates the PJM market equilibrium effects that dominate Maryland's power markets.

Although efficiency spending cannot be expected to yield benefits to consumers via price effects, it does yield benefits via reduced electricity consumption. These benefits accrue through reduced electricity bills that follow from investment in efficient electricity end-use capital. The right hand side of Figure 5.5 is a projection of retail expenditure on electricity in Maryland under each scenario. Expenditure is linear in price and so the pattern of expenditures over time closely mirrors the electricity price pattern. Expenditure is monotonic in efficiency funding with funding beyond the baseline level capable of reducing aggregate Maryland electricity bills by more than 5 percent by the next decade.

[8] The projected retail electricity prices for each customer class are in Table E.1 in Appendix E.

Figure 5.5. Average Retail Electricity Price and Electricity Expenditure in Maryland





6 Electricity Supply

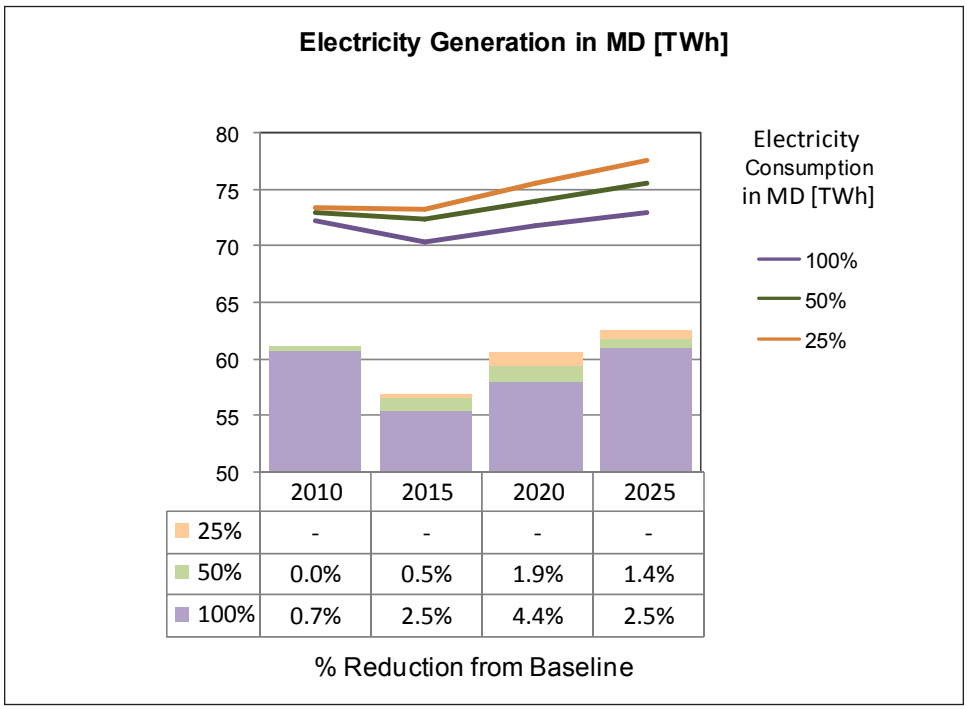
This section of the report describes the effects of end-use efficiency funding in Maryland on the electricity production side of the market. Technology, resource and environmental effects of efficiency funding as well as effects on generator profits are considered. These effects are captured using the Haiku model simulation analysis of the scenarios under consideration in this study. The scenarios are described in Section 4.2 and the Haiku model is described briefly in Section 4.3 and in more detail in Appendix D.

The portfolio of fuels and technologies used for power generation, as well as the aggregate level of electricity generation in the state, are evaluated under the different scenarios. Interactions between the Maryland markets for electricity and the larger regional electricity markets are considered for their effects on power flows between Maryland and its neighbors. These supply-side effects of efficiency funding will have small effects on the RGGI allowance price.

6.1 Electricity generation, emissions, and allowance prices

The changes in electricity consumption in Maryland brought about by different levels of efficiency expenditure will lead to changes in the portfolio of fuels and technologies used for power generation, as well as the aggregate amount of generation in the state. In aggregate, electricity generation in Maryland will fall under increased levels of state funding for efficiency measures, as illustrated in Figure 6.1. Generation will fall from the baseline under both scenarios of increased efficiency funding. In the 50 percent scenario, these reductions will be less than 2 percent of the baseline level and under the 100 percent scenario the reduction could reach nearly 5 percent of baseline generation. Figure 6.1 also shows electricity consumption in Maryland, which significantly exceeds generation. The pattern of generation over time closely mirrors the pattern of consumption. The difference between consumption and generation is made up by imported power from other states.

Figure 6.1. Electricity Generation and Consumption in Maryland under Different Scenarios

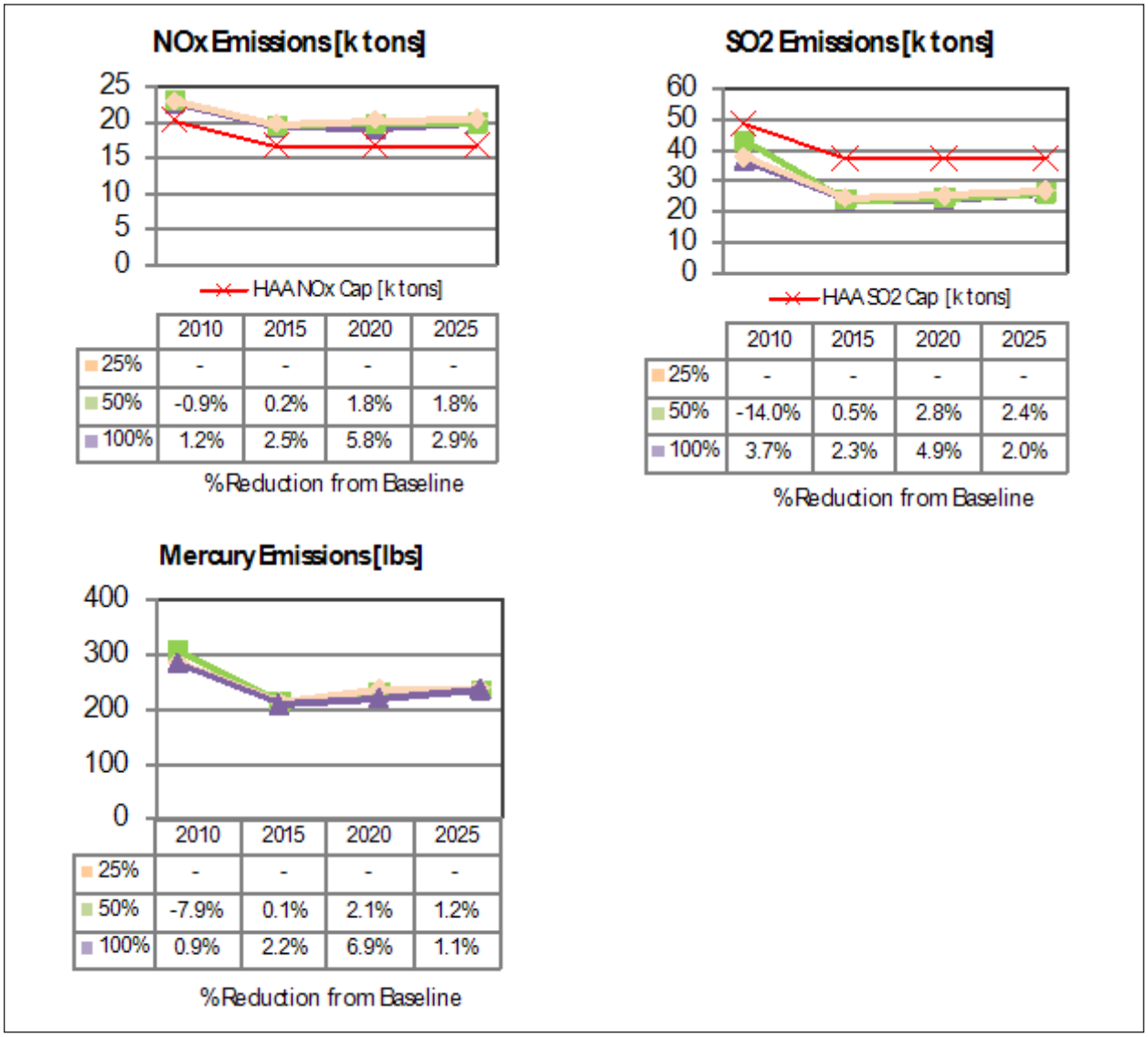


As electricity consumption and generation in Maryland fall with efficiency spending, the composition of electricity supply will also adjust slightly in some years. The two types of generators that will experience a decline in generation due to higher levels of efficiency spending will be those fired by coal and natural gas. These local generation reductions will be complemented by even larger reductions in power imported from other states. The components of electricity supply are shown in Figure 6.2 broken down by coal generation, natural gas generation, net power imports, and other generation (primarily nuclear). Efficiency expenditure is projected to have little impact on the overall composition of the electricity supply in MD with coal continuing to provide most of the power and imports remaining the second largest component under all scenarios of efficiency spending.

Figure 6.2. Generation from Maryland Generators by Fuel Type

Increased spending on energy efficiency does not have much effect on emissions of SO_2, or NOx from electricity generators in Maryland, but to the small extent that there is an effect, it is to lower emissions. These reductions could amount to less than 5 percent of baseline emissions. The top half of Figure 6.3 shows the projected NOx and SO_2 emissions from fossil fuel fired generators in MD and the Healthy Air Act (HAA) caps that constrain emissions of these pollutants from coal fired generators. NOx emissions exceed the HAA caps because of emissions from non-coal generators. Emissions from HAA covered facilities are projected to fall under the caps beginning in 2015 for both pollutants. If, in contrast to the model results, the HAA caps do continue to bind beyond their projected slack date in 2015, then emissions of NOx and SO_2 would be even less sensitive to efficiency spending because emissions from coal generators would be constant in spending level. Projected emissions of mercury are shown in the bottom half of Figure 6.3. The pattern of mercury emissions is similar to those for NOx and SO_2.

Figure 6.3. Emissions from Maryland Generators

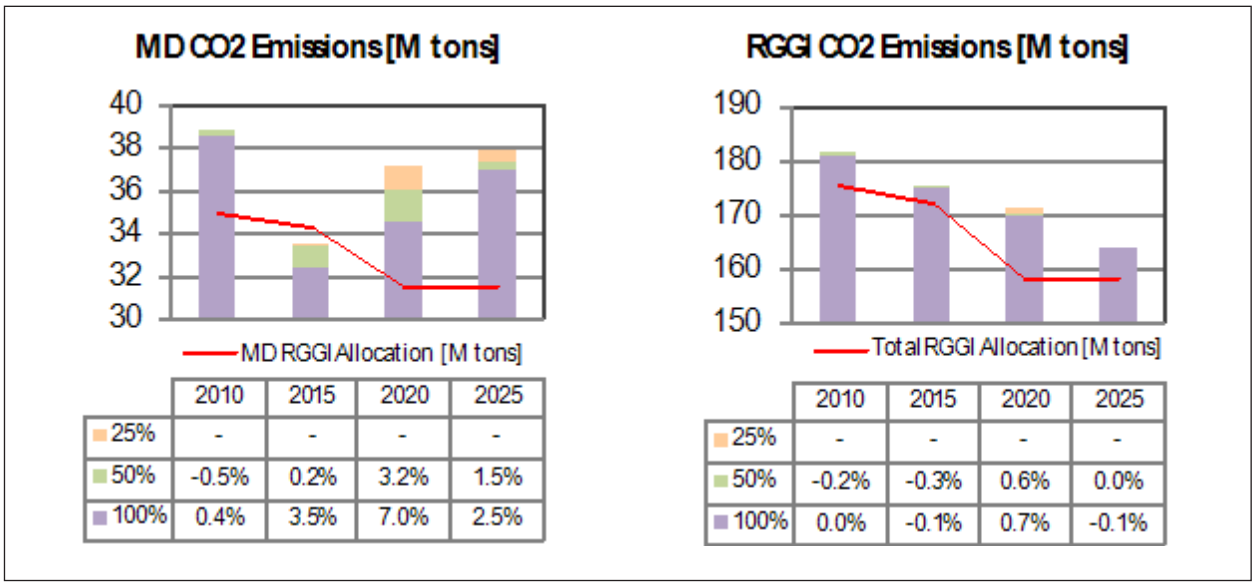


*Data table in decimals

Expenditure on efficiency also has a small effect on emissions of CO_2 from electricity generators in Maryland, but not on total emissions in RGGI regions. Figure 6.4 shows CO_2 emissions in MD and in the entire RGGI region. The left hand side of the figure shows that Maryland will tend to be a net importer of RGGI allowances since emissions tend to be greater than allocation. Furthermore, emissions of CO_2 will fall in MD at higher levels of spending for efficiency in end-use electricity consumption. CO_2 emissions in the entire RGGI region do not change as a result of efficiency spending because emissions are capped region-wide and the cap is always binding. RGGI emissions of CO_2 will exceed the cap at all times because of allowance offsets.

Scarcity of RGGI allowances is decreased by increased efficiency spending in Maryland (since Maryland emissions fall in efficiency spending) and this change manifests itself in lower RGGI allowance prices. Projected RGGI allowance prices are shown in Figure 6.5. These results show that by increasing spending on energy efficiency, Maryland can help to lower the CO_2 allowance price slightly for all RGGI participants.

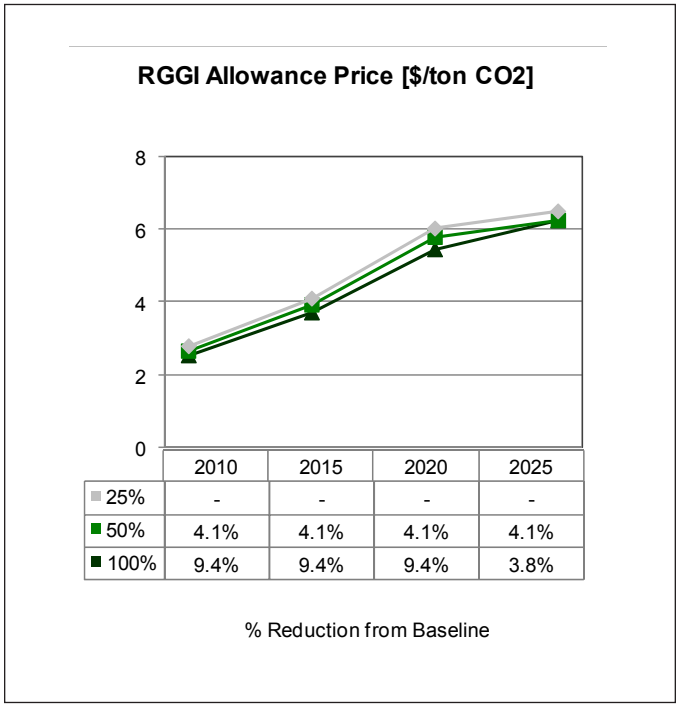
Figure 6.4. CO_2 Emissions in Maryland and in the RGGI Region



	2010	2015	2020	2025
25%	-	-	-	-
50%	-0.5%	0.2%	3.2%	1.5%
100%	0.4%	3.5%	7.0%	2.5%

	2010	2015	2020	2025
25%	-	-	-	-
50%	-0.2%	-0.3%	0.6%	0.0%
100%	0.0%	-0.1%	0.7%	-0.1%

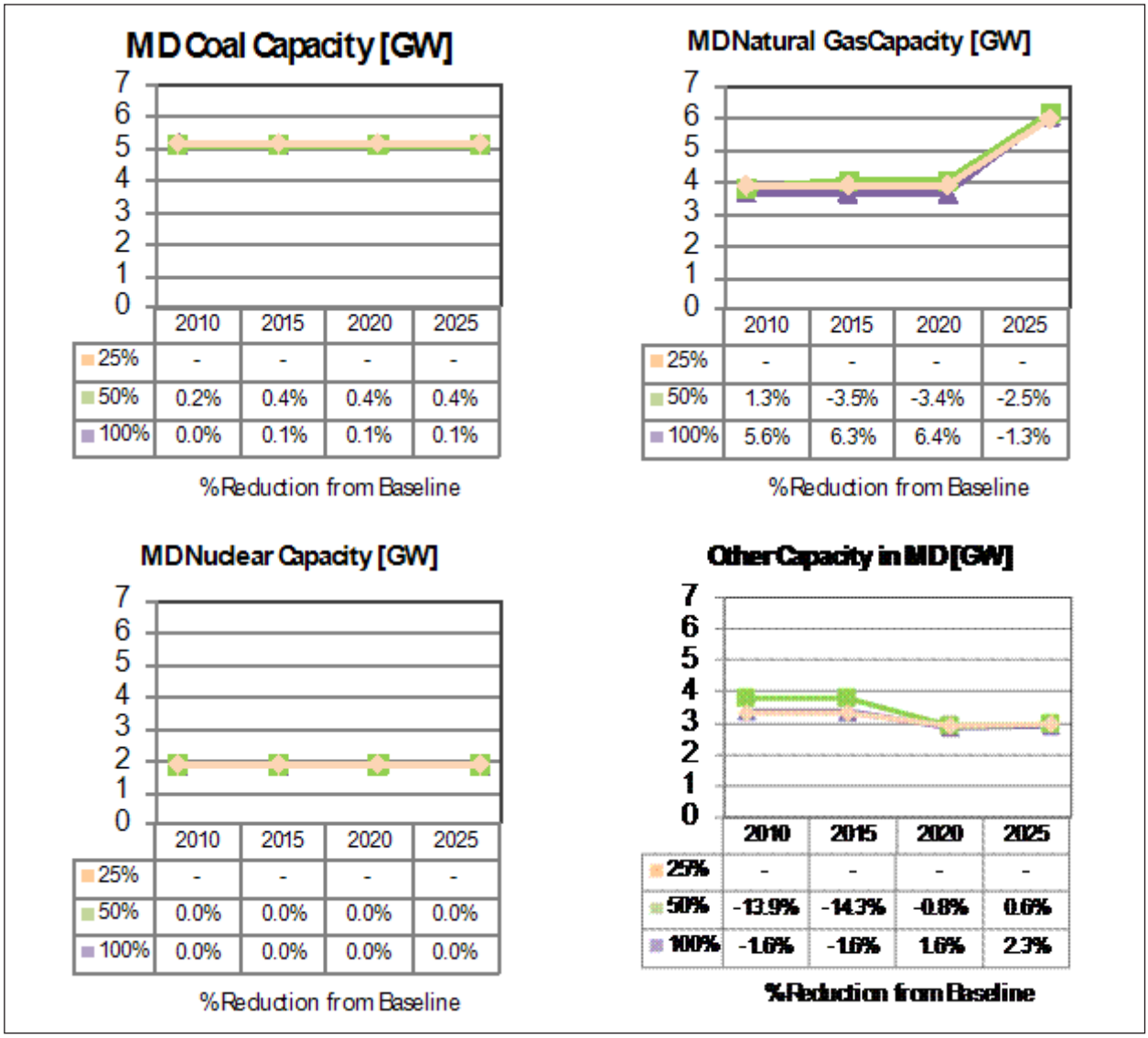
Figure 6.5. RGGI CO_2 Allowance Price



6.2 Generation Capacity and Profits

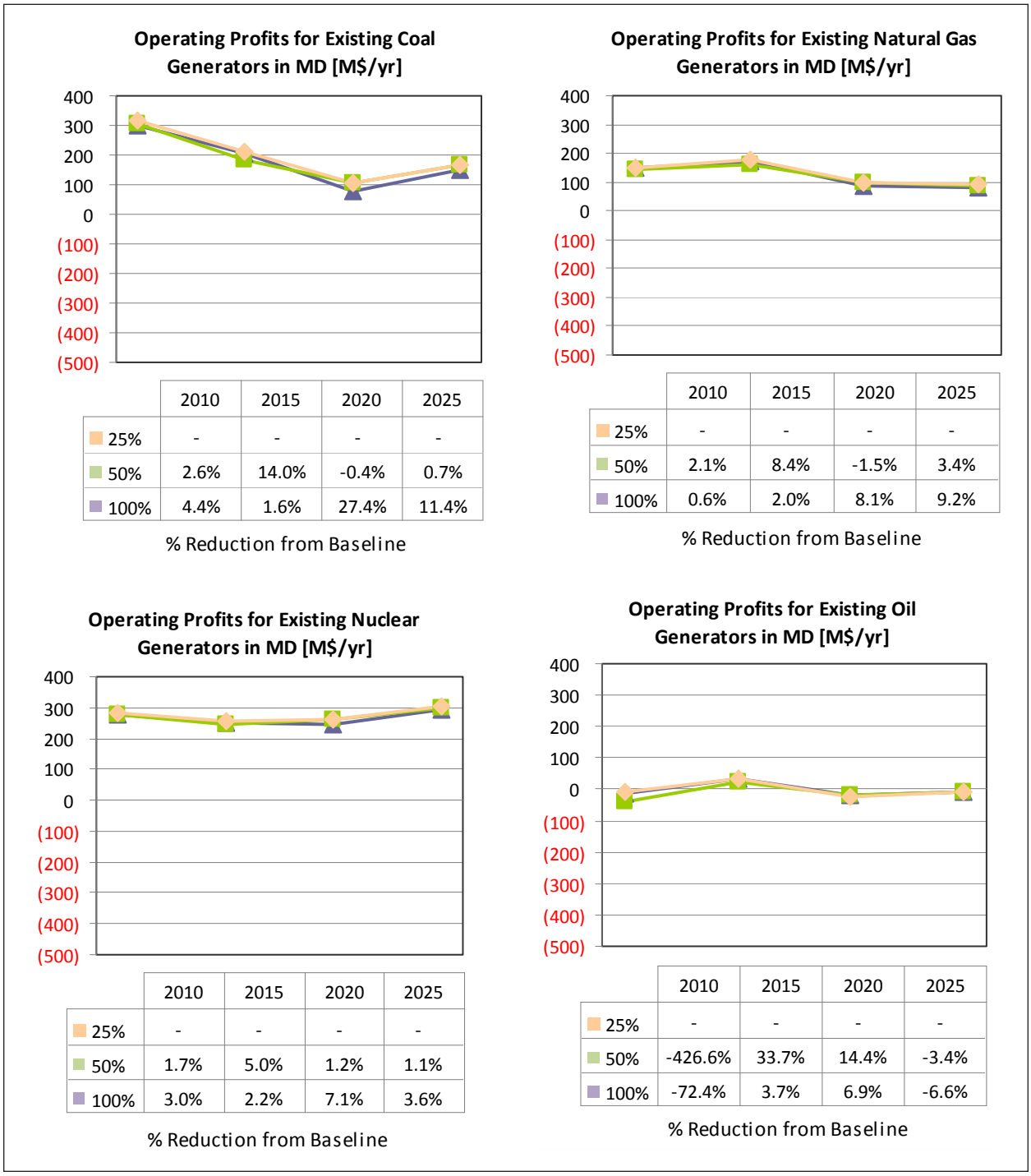
Generation capacity retirement and investment are projected to have little dependence on efficiency spending. Figure 6.6 shows the projected amount of capacity for each of three fuel types and for all other fuel types combined. The small differences between the efficiency spending scenarios are partly attributable to the convergence criterion of the model and should be read as being essentially equivalent for the three main technology types. Coal and nuclear capacity in Maryland are projected to remain unchanged through the modeling horizon with only natural gas increasing, with that increase being delayed until 2025.

Figure 6.6. Total Generating Capacity in Maryland by Fuel Type



The operating profits of the electricity producers are similarly not meaningfully affected by efficiency spending. Figure 6.7 shows projected operating profits separately for coal, natural gas, nuclear, and oil fired generators in Maryland for each of the three scenarios of efficiency funding. The years after 2015 show almost no decline in profitably under the 50 percent scenario from the 25 percent scenario. The 100 percent scenario shows a small decline compared with the scenarios of lower efficiency funding for all types except oil generators. This corresponds to the larger reduction in electricity demand and generation projected in Maryland under the 100 percent scenario in the more distant future.

Figure 6.7. Operating Profits for Maryland Generators by Fuel Type



	2010	2015	2020	2025
25%	-	-	-	-
50%	2.6%	14.0%	-0.4%	0.7%
100%	4.4%	1.6%	27.4%	11.4%

	2010	2015	2020	2025
25%	-	-	-	-
50%	2.1%	8.4%	-1.5%	3.4%
100%	0.6%	2.0%	8.1%	9.2%

	2010	2015	2020	2025
25%	-	-	-	-
50%	1.7%	5.0%	1.2%	1.1%
100%	3.0%	2.2%	7.1%	3.6%

	2010	2015	2020	2025
25%	-	-	-	-
50%	-426.6%	33.7%	14.4%	-3.4%
100%	-72.4%	3.7%	6.9%	-6.6%

7 Generator Competitiveness

This section addresses the following two basic questions:

1. *Are the conclusions concerning the impact of increased investment in energy efficiency robust to energy market modeling assumptions, including transmission grid dynamics?*

This question is addressed by comparing the Haiku and JHU-OUTEC results. These models differ in several important respects. JHU-OUTEC divides Maryland into four zones (as opposed to the one zone considered in Haiku) and uses a linearized "dc" load flow model (Schweppe et al., 1988) to represent power flows (rather than the path-based flow model used by Haiku). In general, a finer spatial disaggregation can place greater restrictions on interregional trade and the ability of a system to redispatch in response to policy, technology, or economic changes. As a result, it is possible that the estimated cost of a new environmental policy could be higher than with a less aggregated model. This analysis examines whether spatial aggregation could affect the comparison of different levels of investment in energy efficiency by Maryland, as represented by the three scenarios described in Section 4.2 above (assuming full devotion of RGGI allowance revenues to energy efficiency programs in the remainder of RGGI).[9]

2. *Could the conclusions concerning the impact of Maryland joining RGGI appreciably change if the possibility of the exercise of market power by large electric generating companies is considered?*

To address this question, an extremely hypothetical case is considered in which (1) all utilities in the eastern PJM region are broken up vertically into separate generation, transmission and distribution companies, and (2) generation companies compete to sell power to "load serving entities." Transmission costs are represented as congestion costs between generators and points of consumption using the "locational marginal pricing" system adopted by PJM.

7.1 Comparing and Integrating Haiku and JHU-OUTEC Models

The model used to simulate both competitive and oligopolistic market scenarios under a more detailed transmission network is the JHU-OUTEC model. As explained in detail in Appendix D.2 (see also Chen and Hobbs, 2005), the JHU-OUTEC model is a computational game-theoretical economic-engineering model that is formulated as a linear complementarity problem. The model was previously used to assess the ability of generators in the PJM regional electricity market to manipulate power prices through the NOx allowances market (Chen and Hobbs, 2005). In this analysis, the model is used to analyze the effects of network constraints and the possible exercise of market power on the comparison among three scenarios. These three scenarios are differentiated by the percent of allowances that is devoted to energy efficiency programs, as described in Section 4.2. This is done by taking the specific results in the Haiku solutions (generation capacity, emissions rates, fuel costs, and spatial load distribution for the JHU-OUTEC region, as well as interregional power flows between the JHU-OUTEC region and other regions), and then treating them as boundary conditions for the more geographically disaggregated simulations by JHU-OUTEC. JHU-OUTEC is run for four future years (i.e., 2010, 2015, 2020 and 2025) with 12 periods per year. The definition of periods is consistent with assumptions used in Haiku. The additional detail includes a simplified transmission network connecting 17 regions in the eastern region of the PJM market (including four zones in Maryland, as mentioned), and alternative assumptions about the pricing behavior of large generating firms.

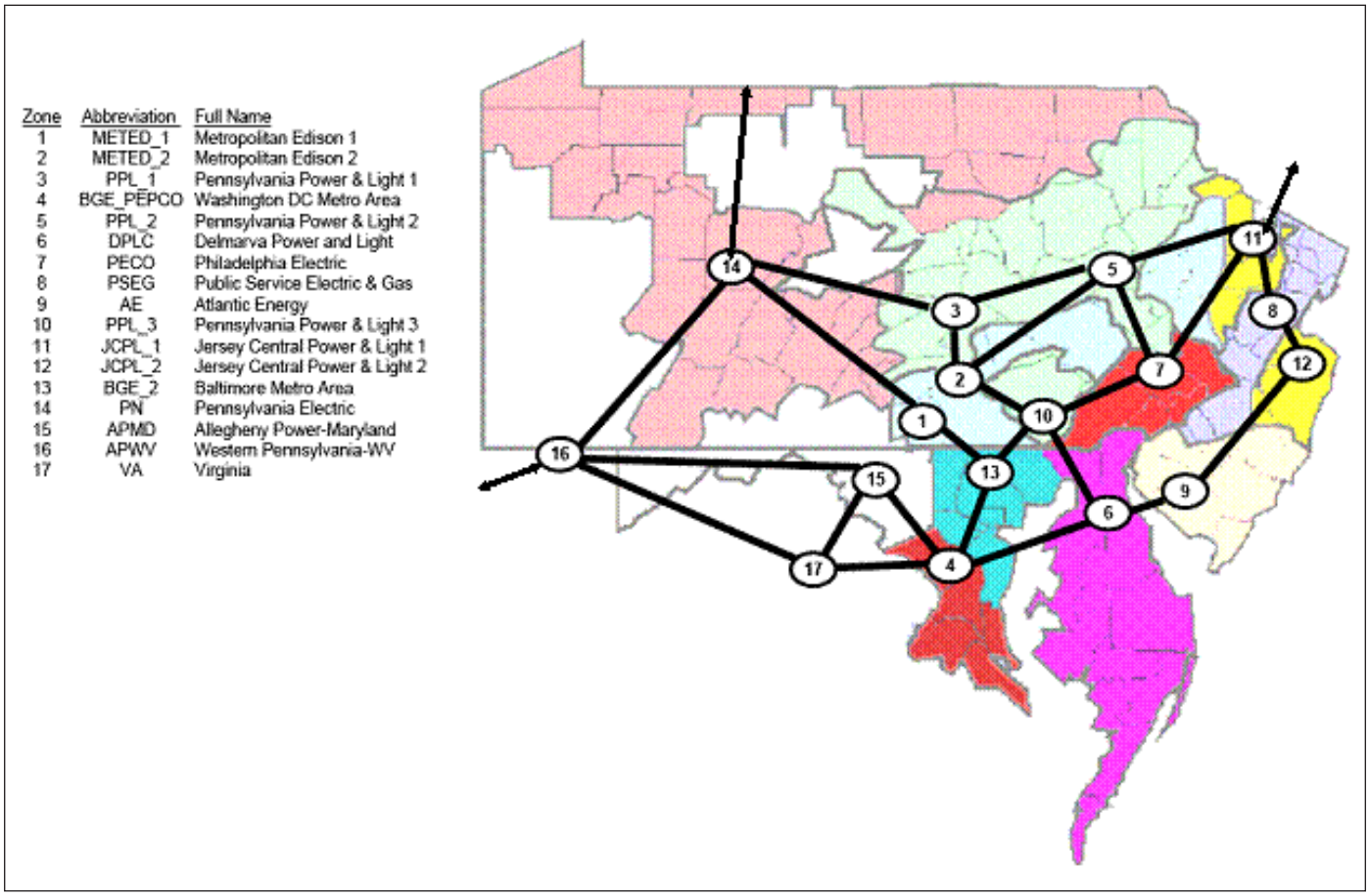
Figure 7.1, below, shows the network and the six state region (plus the District of Columbia) whose power market is studied in the JHU-OUTEC analysis. These six states include:

[9] Thus, only three of the five scenarios simulated by Haiku were considered. None of the scenarios in which the proportion of RGGI allowance revenues devoted to energy efficiency in the non-Maryland region of RGGI is less than 100 percent were considered.

• Maryland (four zones, one of which one – the Delmarva peninsula – is shared with Delaware)
• Delaware
• New Jersey (five zones, including one shared with Pennsylvania)
• Pennsylvania (eight zones, including one shared with West Virginia and Kentucky and one shared with New Jersey)
• West Virginia and Kentucky (combined with the Allegheny Power System portion of Western Pennsylvania)
• Virginia and North Carolina.

The JHU-OUTEC study area in the present analysis is somewhat larger than assumed in the previous report (CIER 2007). The West Virginia area has been combined with Kentucky while the North and South Carolina areas have been combined with Virginia so that the boundaries of those two regions conform to the Haiku regional boundaries for those areas. This simplified the calculation of net imports from the rest of the Eastern US market, as then Haiku flows between the PJM region and the rest of the market could be used directly.

Figure 7.1. Transmission Network Approximation in JHU-OUTEC in RGGI Analysis (Double arrows indicate exchanges with neighboring regions; lines without arrow heads are transmission corridors within the network model).



Seventeen nodes and twenty-four (in 2010) or twenty-five (in 2015) transmission corridors compose the simulated transmission network, representing the 500 kV backbone of the eastern PJM system. Ten large power companies are represented as potentially oligopolistic firms in the market power analyses:

- Allegheny Electric System
- American Electric Power
- Connectiv
- Dominion
- Constellation
- Mirant
- PECO
- PPL
- PSE&G
- Reliant

There are other large companies in Kentucky, South Carolina and North Carolina. However, these are modeled as pricing competitively due to the size of their zones.

Six basic runs of JHU-OUTEC were executed. Unlike the previous analysis (see CIER 2007), all assume that Maryland has joined RGGI; they differ only in whether competitive or oligopolistic markets are assumed, and the extent to which Maryland RGGI allowance revenues are devoted to energy efficiency programs:

1. *Competitive JHU-OUTEC.* Here, the 17 zone model is executed assuming that all generating companies behave as "price takers" (e.g., they do not attempt to manipulate price to their advantage).
   - 1a. *Competitive 25 percent Energy Efficiency ("CompMd25%").* Only 25 percent of Maryland RGGI allowance revenues are spent on energy efficiency programs. (The energy savings in this and the other scenarios are consistent with those calculated by Haiku for their analogous scenarios.[10])
   - 1b. *Competitive 50 percent Energy Efficiency ("CompMd50%f").* The portion of RGGI allowance revenues that Maryland spends on energy efficiency is 50 percent.
   - 1c. *Competitive 100 percent Energy Efficiency ("CompMd100%").* All of the RGGI allowance revenues that Maryland obtains support energy efficiency programs.

2 *Oligopolistic JHU-OUTEC.* Here, the 17 zone model is executed instead assuming that the generation market is oligopolistic, and that the market equilibrium is of the Nash-Cournot type. In a Nash-Cournot market, each of the larger companies believes that it has chosen its best output and sales, given the sales of all other firms. (Smaller "fringe" companies are instead assumed to behave competitively; i.e., they are price-takers, believing that they cannot affect market prices.) The JHU-OUTEC formulation accounts for transmission limitations in its formulation, so that transmission-constrained regions with dominant companies can experience higher price mark-ups due to market power than other regions. As explained further below, the model represents what is believed to be the worse oligopolistic case; actual market power exercised is very likely to be much less than described here for several reasons. Thus, it is reasonable to conclude that if the differences in the results among the three levels of energy efficiency expenditures are similar under the oligopolistic case to the competitive case, then those differences are likely to be similar under the actual market power conditions in the PJM market.

   - 2a. *Oligopolistic 25 percent Energy Efficiency ("OligMd25%").* Analogous to CompMdMin case.
   - 2b. *Oligopolistic 50 percent Energy Efficiency ("OligMd50%").* Analogous to CompMdHalf case.

[10] This is accomplished as follows. For each period in each year in each scenario, a least-cost model based on linear program formulation is used to dispatch power generation against the equilibrium quantity from the Haiku analysis. The resulting equilibrium prices are used to construct linear demand curves of each node and each period with assumed own-price elasticity of demand (0.2) that are then implemented in JHU-OUTEC. For Maryland, New Jersey, and Pennsylvania (which each have multiple zones in JHU-OUTEC, whereas Haiku only has a single zone in each case), the demand curves are disaggregated in proportion to the relative sizes of the loads in each of those regions. The location of these demand curves reflects the impact of the investments in energy efficiency. Thus, the demand curves for the 100 percent (100 percent of RGGI allowance revenues) efficiency investment scenarios will lie to the left (i.e., have lower quantities) compared to the demand curves for the 50 percent and 25 percent scenarios.

2c. *Competitive 100 percent Energy Efficiency ("CompMd100%").* Analogous to CompMdFull case.

In the JHU-OUTEC analysis, the price of RGGI allowances and the load effects of the demand-side programs are taken as fixed (exogenous) to the model, as opposed to the Haiku analysis, in which the equilibrium price of RGGI allowances is solved for. This is because most of the RGGI region is outside the region considered in the JHU-OUTEC analysis.

It should be noted that all JHU-OUTEC solutions take for granted the plant capacities and emissions allowance prices solved for by Haiku. The capacities are distributed among zones and owners within Haiku regions using technology-specific historical distributions. However, it is possible that network constraints and strategic behavior would result in changes in the types and locations of new generating capacity, as well as in the cost of RGGI allowances.[11] On the other hand, the amount of capacity added in the Haiku scenarios to Maryland is small, so any distortion resulting from using the Haiku capacities is likely to be minor, especially in the earlier years considered.

7.2 Analysis of Robustness of Consumer Price, Market Power and Price Mark-ups, and Transmission Grid Representation

The detailed JHU-OUTEC results are shown in the Appendix E. Below the main conclusions of the analyses are summarized. The conclusions are divided into three parts:

1. The effect of model choice (Haiku vs. JHU-OUTEC; competitive behavior vs. oligopoly) upon the economic benefits to Maryland consumers of the 100 percent and 50 percent energy efficiency programs
2. The effect of expanding Maryland's energy efficiency programs upon market power in the bulk energy market, as measured by price mark-ups (comparing the results of the JHU-OUTEC model under competitive and oligopolistic assumptions
3. The effect of changes in transmission capacity upon the market outcomes and the benefits of energy efficiency (using JHU-OUTEC with and without planned transmission additions).

7.2.1 Comparision of Results of Haiku and JHU-OUTEC: Robustness of Consumer Price and Total Bill Effects

The treatment of the mid-Atlantic power market by Haiku and JHU-OUTEC differ in at least five important respects. A comparison of the results of these two models provides an indication of how robust any conclusions about the impact of larger energy efficiency programs in Maryland might be. The two major differences between the models include:

- *Transmission representation.* JHU-OUTEC includes a more detailed linearized dc load-flow representation of power flows, approximating the extra high voltage grid in the east PJM region. Consistent with Kirchhoff's laws, power flow between two points is split among all parallel paths, and cannot be directed one way or another on the network. Haiku instead has a "transportation" or "path" formulation, in that power flows can be routed, and the grid itself is not modeled. JHU-OUTEC also has a more detailed representation of the locations of loads and power plants. The result is that JHU-OUTEC is likely to more realistically represent the effect of transmission congestion upon power trade and costs, at least in the eastern PJM region.
- *Generator competitiveness.* The oligopoly version of JHU-OUTEC uses a Nash-Cournot market formulation to represent the possible effect of large generators who might exercise market power. In contrast, Haiku (as well as the competitive version of JHU-OUTEC) assume price-taking behavior among all generators.

[11] For instance, the higher Nash-Cournot prices might encourage more plant construction by small companies in the competitive fringe compared to the competitive cases. On the other hand, it can be plausibly argued that existing large companies own the most favorable sites for new plants, and would choose not to expand capacity as much as competitive firms in order to keep prices higher. Furthermore, it might be argued that the threat of predatory pricing by large incumbent firms might also discourage entry by the competitive fringe. Therefore, the middle ground was chosen, using the capacity amounts that Haiku calculates, and furthermore assuming that any new plants are built by the competitive fringe. Alternative assumptions could change prices.

However, there are three other sources of differences between the Haiku and JHU-OUTEC models:

- *Demand representation.* Haiku uses a habit-forming demand curve representation that results in prices in a given year affecting loads not only in that year, but also in following years. In contrast, in JHU-OUTEC, price in a given period and year affects quantity demanded only in that year. However, the long-run impact of price increases is indirectly captured in JHU-OUTEC by a shifting of the demand curve resulting from the quantity equilibria calculated by Haiku.[12]
- *Reserve Pricing.* JHU-OUTEC simultaneously considers operating reserve and energy markets. A requirement of 7 percent is assumed to be the amount of spinning reserve provided by unloaded generating plants. The need for some generating plants to be devoted to reserves means, in general, less capacity available for producing energy and possibly higher energy prices. In contrast, in Haiku, there is no such requirement, so energy prices could be lower for just that reason. Haiku instead calculates reserve prices after solving for the energy market equilibrium, and those reserve prices are more reflective of capacity market prices than of pure operating reserves prices.
- *Calibration.* Haiku results are calibrated to historical (2004) energy outputs and prices through several calibration steps, including adjustments in the variable costs of generation types that are either over- or under-dispatched. For instance, if there is too little generation from generation type X, its variable cost is decreased until the output of the generation plants increases to levels closer to historical levels. In contrast, no calibration process is used to obtain JHU-OUTEC solutions.

These reasons can contribute as much or more to divergences between Haiku and JHU-OUTEC output as transmission representation differences. Thus, a comparison of Haiku and JHU-OUTEC competitive results should be more appropriately interpreted as a general robustness check. Therefore, it is logical to ask do the conclusions of the analysis depend on the modeling framework?

Figures 7.2.1A and 7.2.1B show the results for three economic indices of high concern to Maryland consumers. The first figure shows the total bulk energy bill for consumers (price times energy demand), while the second figure shows its two components: average bulk power prices in the state and total energy demand by consumers. The three models show surprising consistency concerning their most important conclusion: the effect of increasing the size of spending on the energy efficiency program from the minimum of 25 percent to 50 percent and then to a full 100 percent of the Maryland RGGI allowance revenues. The Haiku and JHU-OUTEC competitive results are particularly consistent. The short-run (2010 results) cost savings are less than those in the long run, with the benefits accumulating to $250M/year for consumers in 2020 and 2025 under the 100 percent program, and somewhat less than half that for the 50 percent program. In percentage terms, the 2010 bill reduction for the 100 percent funding case versus the 25 percent case is approximately 2.5 percent, while being about 5 percent, 7 percent, and 7.5 percent in 2015, 2020, and 2025 respectively. The similarity of the Haiku and JHU-OUTEC competitive results is strong in spite of somewhat different mixes of fuel sources for Maryland generation, among other variables (see the detailed JHU-OUTEC case results in Appendix E).

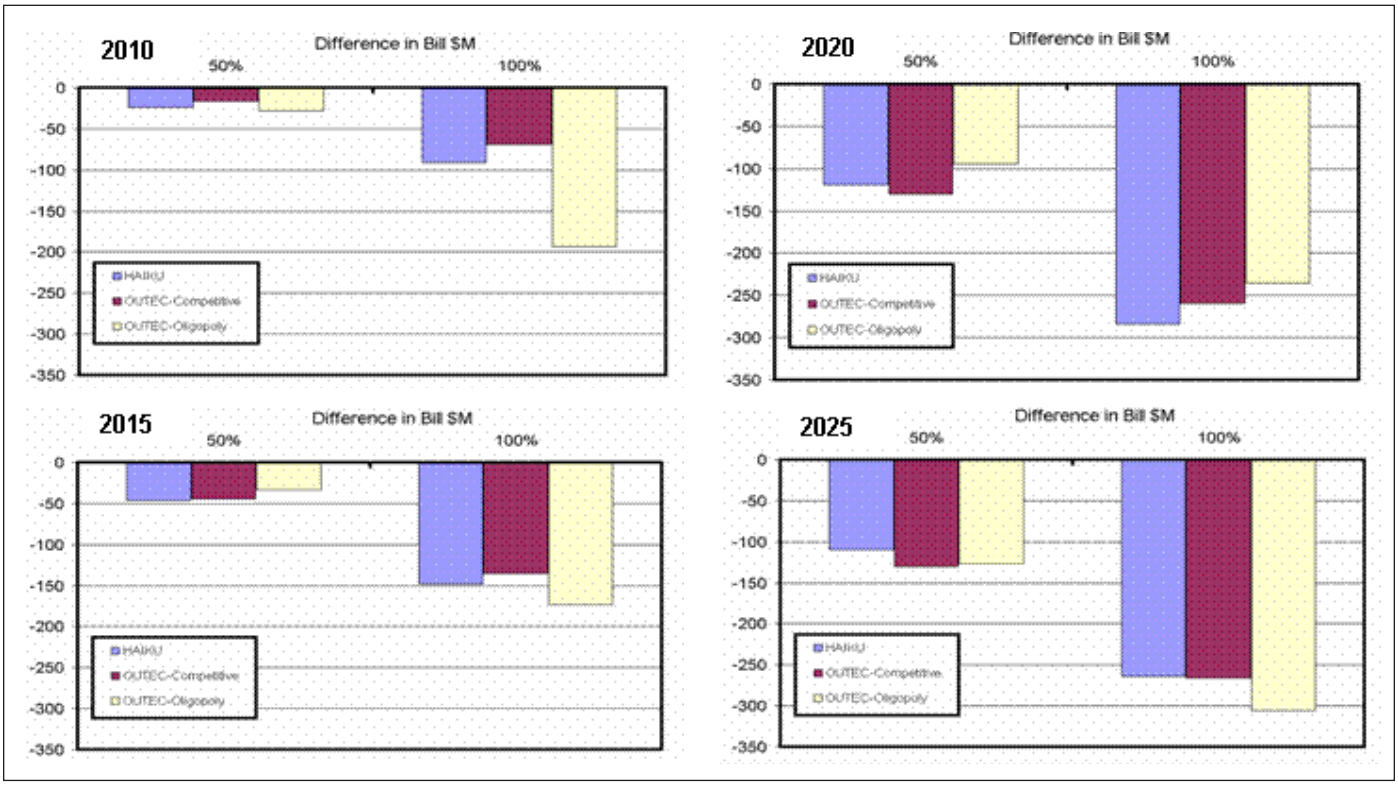
Meanwhile, the JHU-OUTEC oligopoly results differ more from the Haiku results than the JHU-OUTEC competitive results do, which should not be surprising, the greatest difference being in 2010. The divergence of the oligopoly results is much smaller in the other years. However, the bill savings under the JHU-OUTEC oligopoly model are neither consistently larger nor smaller than the competitive results, and so no conclusions can be made about whether energy efficiency programs are more beneficial under more oligopolistic conditions.

Figure 7.2.1B indicates that the similar reductions in total bulk energy costs to consumers from the different models in Figure 7.2.1A are not because the price reductions are similar. The price reductions vary predictably. For instance, the greatest Haiku price reductions are in 2020, with the 2025 price changes being similar to 2010 and 2015. (Note that the vertical scales of the price charts are not the same across years.) Meanwhile, the JHU-OUTEC competitive model shows price decreases that build from 2010 to what appears to be a steady state in 2020. Both competitive models show greater price decreases for the case in which all allowance revenue is allocated to efficiency spending than when only 50 percent of allowance revenue is allocated to efficiency spending. On the other hand, the JHU-OUTEC oligopoly results are more

[12] For instance, if high prices are experienced in 2010, the demand Haiku shifts short-run demand curves in later years to the left, resulting in smaller quantities for a given price. As a result, the calibrated JHU-OUTEC curves will also be shifted to the left.threat of predatory pricing by large incumbent firms might also discourage entry by the competitive fringe. Therefore, the middle ground was chosen, using the capacity amounts that Haiku calculates, and furthermore assuming that any new plants are built by the competitive fringe. Alternative assumptions could change prices.

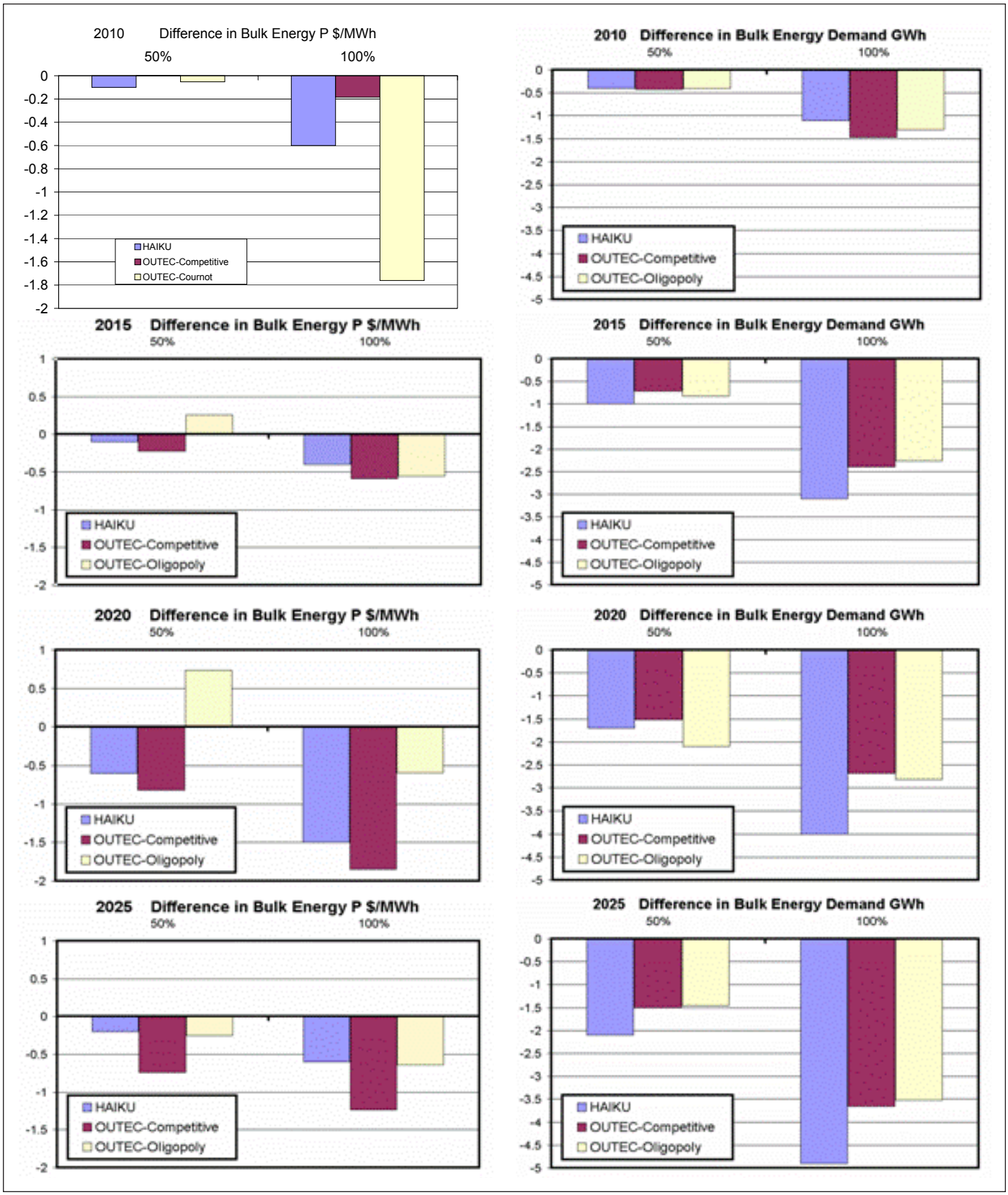
inconsistent, with some of the 50 percent scenarios actually resulting in price increases. Despite this variation in price results, the changes in quantities demanded are fairly consistent—and large—ranging from about 1.5 percent-2 percent of demand in 2010 to 3-4 percent in 2015 and 3.5-6 percent in 2020 and 2025. It is the fairly consistent decreases in load that mainly account for the consistent decreases in total consumer bills for bulk energy.[13]

Figure 7.2.1A. Changes in Maryland Total Bulk Energy Costs to Consumers ($M/yr) Compared to 25% Energy Efficiency Case Size for the Three Market Models: Haiku, JHU-OUTEC Competitive, and JHU-OUTEC Oligopoly, 2010-2025



[13] Note again that these percentage changes are for bulk energy only, and do not include charges for electric power capacity, transmission, distribution, and miscellaneous charges, which approximately double the cost of power for consumers. Thus, if expressed as a percentage of total retail power costs, the percentage reductions in prices and total payments would be about half of the values stated here. The Haiku results indicate that these other components of power costs are relatively constant, so that most of the bill changes consumers would experience are due to the decreases in bulk energy costs analyzed here.

Figure 7.2.1B. Changes in Maryland Bulk Energy Prices ($/MWh) and Bulk Energy Demand (GWh/yr) Compared to 25% Energy Efficiency Case Size for the Three Market Models: Haiku, JHU-OUTEC Competitive, and JHU-OUTEC Oligopoly, 2010-2025



7.2.2 Possible Effect of Expanded Energy Efficiency Program on Oligopolistic Price Mark-Ups

It might be conjectured that energy efficiency programs could lower the ability of generators to exercise market power. This indeed would be true for "demand response" programs in which load responds adaptively to higher prices in real time; demand would then be more elastic, which would mitigate market power. However, traditional energy efficiency programs might not affect elasticity, and so might not impact the degree to which oligopolistic generators might be able to mark up prices. Appendix E summarizes price results for the JHU-OUTEC competitive and oligopolistic (Nash-Cournot) solutions.

Readers are cautioned that the results represent much higher prices than would be actually experienced in PJM, and are an extreme case of oligopoly. The reason for these higher prices lies in the assumption that there is no forward contracting or vertical integration in the PJM market. Analyses elsewhere (e.g., Chen and Hobbs, 2005; Bushnell et al. 2008) indicate that such contracting can greatly dampen the ability of generators to exercise market power, thus, the results represent a bounding case. In reality, market power is less extreme, and so any effects of energy efficiency on that market power are likely to be more modest than indicated. Indeed, as shown below, the effect of energy efficiency upon mark-ups is negligible; the main effect of energy efficiency in the oligopoly cases is to lower total bills by lowering quantities demanded, not by lowering mark-ups.

The mark-up is defined as the difference between the oligopolistic price in Maryland and the competitive price (as calculated by the JHU-OUTEC models). To show the impact of a 100 percent energy efficiency program, the following ratio is calculated:

$$[(POlig,100\% - PComp,100\%) / (POlig,25\% - PComp,25\%)] \times 100\%$$

where:

POlig,100% = Oligopoly Price, given 100% spending on energy efficiency programs

PComp,100% = Competitive Price, given 100% spending on energy efficiency programs

POlig,25% = Oligopoly Price, given 25% spending on energy efficiency programs

PComp,25% = Competitive Price, given 25% spending on energy efficiency programs

The numerator is the mark-up in the 100 percent scenario (for instance, if it were $15/MWh, then simulated oligopolistic bulk power prices were found to be $15/MWh higher than simulated competitive prices, given that Maryland devotes 100 percent of its RGGI allowance revenue to energy efficiency). The denominator is the mark-up if Maryland only spends 25 percent of that income on energy efficiency programs. If this ratio is appreciably different from 100 percent, then expanding the size of the energy efficiency program could be interpreted as significantly affecting the exercise of market power and the resulting mark-ups. Otherwise, it would be concluded that there is no evidence from these simulations that market power would be worsened or mitigated.

Table 7.2.2A shows these ratios for each of the scenario years. In every case, the ratio is close to 100 percent (ranging from 90 percent to 108 percent). This implies that market power (as measured by price mark-ups) is not projected by these simulations to be greatly affected by the scale of Maryland's energy efficiency programs. Furthermore, the direction of change is inconsistent, which leads to the conclusion that it is not possible to predict even a small change in a particular direction.

Table 7.2.2A. Impact of Expanding Energy Efficiency Cases From 25% to 100% in Maryland Upon Maryland Oligopolistic Price Mark-ups (As a Percentage of Mark-Ups in the 25% Case), Given 100% Spending in Other RGGI States

	2010	2015	2020	2025
Maryland	90%	98%	108%	101%

The same comparison was made, using the 50 percent spending case and the 25 percent base case, substituting POlig,50% and PComp,50% for POlig,100% and PComp,100% in the above calculations. The results are shown in Table 7.2.2B. Again, the changes in mark-ups due to expanding the program are not large, and are inconsistent in sign.

Table 7.2.2B. Impact of Expanding Energy Efficiency Cases From 25% to 50% in Maryland Upon Maryland Oligopolistic Price Mark-ups (As a Percentage of Mark-Ups in the 25% Case), Given 100% Spending in Other RGGI States

	2010	2015	2020	2025
Maryland	104%	106%	99.7%	102%

7.2.3 Effect of Transmission Grid Representation

The effect of transmission representation is considered by comparing sets of runs of JHU-OUTEC for the year 2015 under the 100 percent and 25 percent energy efficiency spending scenario. The first set uses the 2015 network, in which two major east-west transmission reinforcements are anticipated to increase Maryland import capacity by approximately 50 percent (see Appendix D.2 for a description of these assumptions). The second set uses the 2010 network, under the alternative assumption that those new lines are not built. Each set includes four runs (100 percent and 25 percent efficiency programs under both perfect competition and Cournot oligopoly). Both the 25 and 100 percent results are shown in the following table.

Table 7.2.3C. Comparison of JHU-OUTEC Maryland Results for 2015 Under 2010 and 2015 Transmission Grids under 100% and 25% Energy Efficiency Programs for Maryland

Energy Efficiency Program	100% Spending				25% Spending			
Type of Competition	Competitive		Cournot		Competitive		Cournot	
Grid Specification	2010	2015	2010	2015	2010	2015	2010	2015
Energy Revenue Generators (M$)	1994	1886	3130	3155	2032	1940	3168	3196
Variable Generation Cost (M$)	1126	1103	1209	1203	1155	1127	1224	1222
Consumer Bulk Energy Costs (M$)	2879	2789	3943	3960	2996	2924	4115	4134
Energy Demanded MD (BkWh)	73.7	74.0	65.8	65.6	76.1	76.4	68.0	67.9
Maryland Generation (BkWh)								
Coal	31.2	31.5	32.5	32.5	30.9	31.5	32.5	32.5
Natural Gas	1.5	1.0	1.5	1.4	2.0	1.2	1.5	1.5
Oil	0.1	0.0	0.4	0.4	0.0	0.0	0.4	0.4
Nuclear	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
Hydro	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Wind	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Biomass	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1
Landfill Gas	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Total Maryland Generation	51.2	51.0	52.9	52.7	51.5	51.3	53.0	52.9
Imported Energy	22.5	23.1	12.9	12.9	24.6	25.1	15.0	14.9
% of Load	30.5	31.2	19.7	19.6	32.3	32.9	22.1	22.0
MD Sale-weighted price ($/MWh)	39.1	37.7	59.9	60.4	39.4	38.3	60.5	60.9
PA Sale-weighted price ($/MWh)	39.7	38.1	59.0	59.8	39.6	37.7	59.2	60.1
NJ, DE Sale-weighted price ($/MWh)	45.0	43.9	63.0	62.9	44.9	44.0	63.5	63.5

The first two columns show the effect of the additional lines (comparing the 2015 grid with the 2010 grid results) under the competitive scenario assuming 100 percent spending on energy efficiency. These results show a surprisingly small effect; increasing import capacity by about 50 percent only increases energy imports by 0.7 percent of the load (31.2 percent of load vs. 30.5 percent of load). The only discernable effects are the displacement of natural gas generation by an amount approximately equal to the imports, and a slight increase in coal-fired generation equal to the increase in Maryland energy

demand. The higher loads result from the 3.5 percent lower bulk power price (37.7 $/MWh versus 39.1 $/MWh) under the 2010 grid configuration.

In contrast, under oligopoly and the 100 percent efficiency program (the third and fourth column of numbers), the transmission reinforcement has a smaller and opposite effect on prices and load, with prices increasingly slightly (by less than 1 percent) rather than decreasing, and gas-fired generation changing slightly. This shows that the interaction of the grid with the strategic behavior by producers can be surprising. The opposite directions of the effects under oligopoly compared to competition are consistent with the results obtained in the previous report (CIER 2007). The incremental impacts of the 2015 reinforcement are almost exactly the same under the 25 percent efficiency program.

The effect of the reinforcement upon the economic implications of the energy efficiency program can also be evaluated. To do this, from the table above the 25 percent scenario results were subtracted from the 100 percent results, yielding Table 7.2.3D below. For instance, by subtracting the fifth from the first column of numbers in Table 7.2.3C, the first column of numbers in Table 7.2.3D is generated, which is the incremental effect on the results of the energy efficiency program for the 2010 grid configuration under a competitive market simulation.

Table 7.2.3D. Incremental Effect of 100% Energy Efficiency Program in 2015 Relative to 25% Energy Efficiency Program Under 2010 and 2015 Transmission Grids (Competitive and Cournot JHU-OUTEC Runs)

Energy Efficiency Program	100% Spending		25% Spending	
Type of Competition	Competitive		Cournot	
Grid Specification	2010	2015	2010	2015
Energy Revenue to Generators (M$)	-38.2	-53.8	-37.9	-40.9
Fuel and Other Variable Generation Cost (M$)	-29.5	-23.3	-15.1	-18.6
Consumers Bulk Energy Costs (M$)	-117.5	-135.0	-171.2	-173.7
Energy Demanded Maryland Consumers (BkWh)	-2.5	-2.4	-2.2	-2.3
Maryland Generation (BkWh)				
Coal	0.3	0.0	0.0	0.0
Natural Gas	-0.5	-0.2	0.0	-0.1
Oil	0.1	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0	0.0
Hydro	0.0	0.0	0.0	0.0
Wind	0.0	0.0	0.0	0.0
Biomass	-0.1	-0.1	-0.1	-0.1
Landfill Gas	0.0	0.0	0.0	0.0
Total Maryland Generation	-0.3	-0.3	-0.1	-0.2
Imported Energy	-2.1	-2.1	-2.1	-2.1
% of Load	-1.8	-1.7	-2.4	-2.4
MD Sale-weighted price ($/MWh)	-0.3	-0.6	-0.6	-0.6
PA Sale-weighted price ($/MWh)	0.1	0.4	-0.2	-0.3
NJ and DE Sale-weighted price ($/MWh)	0.0	-0.1	-0.5	-0.6

The table shows that under competition, going from 25 percent to 100 percent energy efficiency programs saves consumers about the same amount under the 2010 and 2015 grid configurations (with about 15 percent more benefits under the 2015 grid - 135 $M/yr versus $118M/yr). Due to the energy efficiency program, prices fall somewhat more under the 2015 grid as do Maryland generator revenues. In contrast, under Cournot oligopoly, the choice of grid makes almost no difference in the net results of expanding the energy efficiency programs. In all cases, consumers appear to benefit significantly from expanding the energy efficiency programs, while Maryland generator net revenue decreases. Thus, the conclusions of this study appear robust relative to whether or not the anticipated reinforcements of Maryland's transmission links with neighboring states materialize.

8 Electricity Reliability

Reliability in the context of electricity markets can mean many things. In this report, reliability is focused on generation adequacy rather than generation investment and sufficiency. In other words, in this report reliability means the ability of installed generation to meet anticipated demand in the face of uncertainties of weather, economic growth, and forced generator outages. The standard adopted, no more than one involuntary load curtailment day in ten years ("1 day in 10 years"), is projected to be met with a target installed capacity of 15 percent (excess of capacity over peak). PJM intends to achieve this availability standard for constrained "LDAs" (local demand areas) as well.[14]

8.1 Reliability Pricing Model (RPM)

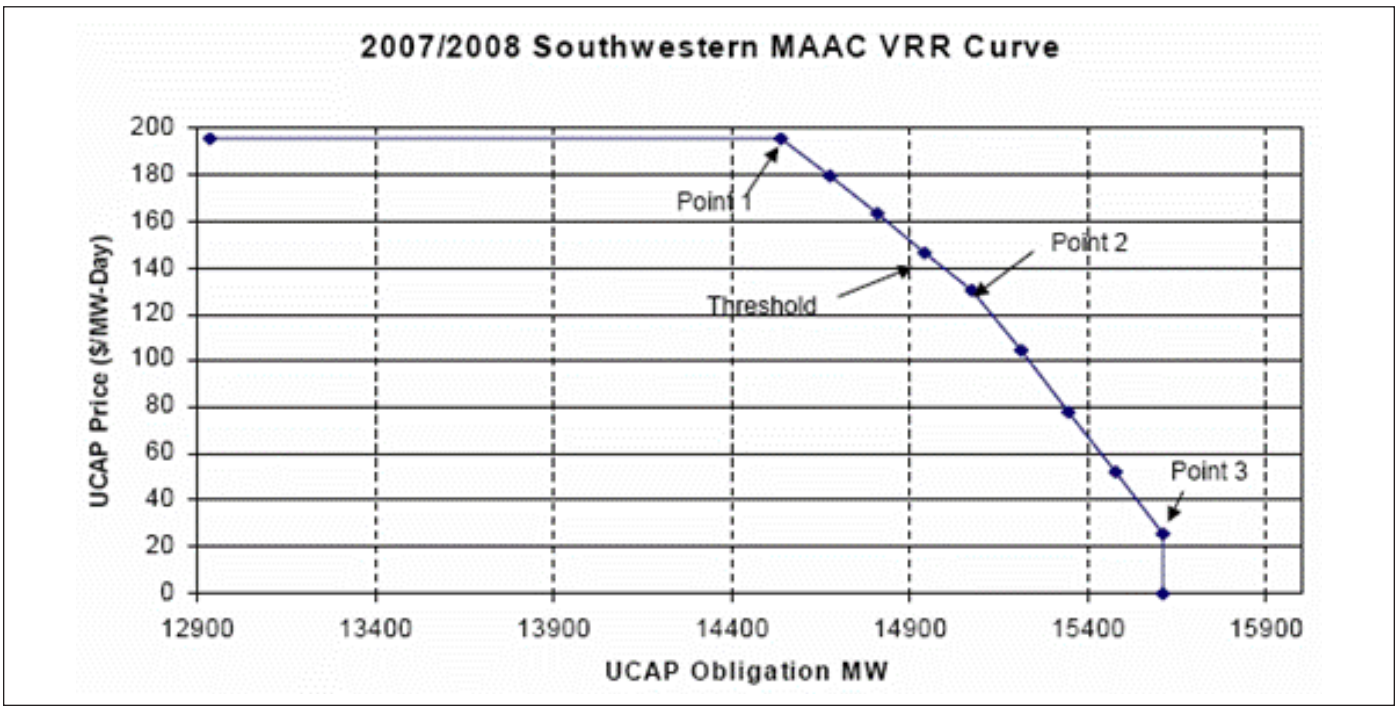
Several mechanisms will be used to ensure adequate generation and transmission capacity. One is the Reliability Pricing Model, which has just been implemented by PJM, provides payments for generating capacity in order to encourage investment. Meanwhile, the PJM Regional Transmission Expansion Planning Process (RTEP) is a commitment to deliver capability to local delivery areas (LDAs). It is assumed that if joining RGGI would result in a decrease in generation capacity relative to loads in Maryland, the RPM and RTEP would provide sufficient incentives to additional investment in generation and transmission to maintain reliability.

Because these incentives could be costly to Maryland ratepayers, it was assessed whether implementation of the 100 percent energy efficiency program would increase or decrease payments through the PJM RPM mechanisms.

As the previous report on the Economic and Energy Impacts from Maryland's Potential Participation in the Regional Greenhouse Gas Initiative (CIER 2007) explained, the price of RPM capacity in the SW MAAC region is determined by the intersection of capacity supply with an administrative demand curve determined by PJM for that region. Supply is determined by the sum of "imported" capacity and within-SW MAAC capacity, both measured in "unforced" terms (derated for outages). An example of such a curve used by PJM is shown in Figure 8.1. The capacity payments by consumers equal the product of the price (as read off of the curve) and the amount of peak load in the region. The amount of decrease in payments depends on where on the PJM RPM demand curve the intersection of supply and demand in SW MAAC takes place. If the intersection is on the horizontal part of the curve (either on the far left or right in Figure 8.1) then the change in payments will be proportional to the change in supply of capacity, as the price of capacity will be unaffected. In contrast, if the intersection is on the sloped portion, then the change of payments is more complicated, as the price of capacity will also change if the net reserves changes.

[14] In this analysis, as well as in the Haiku – JHU-OUTEC analyses, it is assumed that demand growth is consistent with the values assumed in the US Energy Information Agency Annual Energy Outlook (see Section 4.2.1.6, *infra*). Among other assumptions, those scenarios assume climate stationarity – no changes in average annual cooling- and heating-degree-days.

Figure 8.1. Sample Demand Curve for a Local Demand Area (SW MAAC) (Source: www.pjm.com)[15]



The question addressed in this section is whether implementation of the 100 percent energy efficiency program in Maryland (relative to the 25 percent program) would increase or decrease capacity payments by SW MAAC consumers to generators under the RPM system. These payments can change for two reasons:

- The quantity of credits that Maryland consumers have to buy will fall in those years in which the supply of capacity decreases. If the price for capacity does not change (which is possible if the capacity demand-supply equilibrium falls on a horizontal portion of the demand curve in Figure 8.1), payments would then fall. This is because the price will be determined by the intersection of the supply of capacity (including imports of capacity from elsewhere in PJM, which will be at the maximum value if SW MAAC RPM prices exceed PJM prices, as they did by a large margin in 2007) with the demand curve; if this occurs at the highest part of the demand curve, then RPM payments will decrease by the product of the decrease in local capacity and the price cap (about $190/MW-day in Figure 8.1).
- The price of capacity credits can change, depending on how the net reserves (capacity minus peak load) changes in Maryland, and where on the demand curve the supply-demand intersection falls, as explained above. If the price falls, then consumer payments will fall for a given level of peak load.

To gauge whether implementation of a 100 percent energy efficiency program in Maryland will increase or decrease capacity payments, data on the peak load in Maryland (from the Haiku results) was assembled and compared to the installed capacity in each of the years (2010-2025) (see Table 8.1).

[15] "UCAP" is "unforced capacity" (installed capacity derated by the expected forced outage rate), and represents the expected available capacity. The demand curves beyond 2010 are not yet determined by PJM, as the curve will be adjusted based on realized RPM auction outcomes and estimated "Cost of New Entry" (the fixed costs of a standard combustion turbine, minus gross margins from the energy and ancillary services markets).

Table 8.1. Changes (MW) in Peak Load and Capacity Supply in Maryland as a Result of Implementation of a 100% Energy Efficiency Program for Maryland (Haiku Results)

	2010	2015	2020	2025
Change in Peak Load (Comparing 100% with 25% Maryland Program)	-224	-559	-725	-871
Change in Installed Capacity (Comparing 100% with 25% Maryland Program)	-30	-30	5	-11
Net Change in Capacity Balance	+194	+529	+730	+860

Table 8.1 shows that 100 percent implementation lowers peak loads in Maryland by 224 to 871 MW (2010 to 2025, respectively). However, the amount of installed generation capacity decreases by much less (and is actually projected to increase insignificantly in 2020). As a result, the net change in capacity reserves is positive as a result of implementing the program. Thus, the effect of full implementation of the energy efficiency programs will improve the adequacy of generation in Maryland. Further, costs to Maryland consumers might fall if RPM prices fall, although this would also be accompanied by lower capacity revenues to generators.

To make the capacity and peak load changes in Table 8.1 comparable, two adjustments are needed:

1. The peak load from Haiku needs to be adjusted upwards, because it is the average load for the highest 36 hours, not the peak hour itself, and also adjusted downwards, since not all of Maryland's load is in SW MAAC. Consistent with the ratio of the BGE/PEPCO's load to Maryland's load (about 75 percent), three quarters of the peak load reduction to SW MAAC is allocated, and then adjusted upwards by the average ratio for 2003-2006 for the PJM-East region between the peak annual load and the average of the 36 highest summer loads (1.035, which adjusts for the fact that the Haiku summer period represents the 36 highest summer load hours). By using this procedure, the peak load changes for Maryland from Haiku are multiplied by 0.75*1.035.
2. To obtain the RPM obligation in terms of unforced capacity associated with that load, the value in Step 1 is multiplied by 1.15*(1-0.0635). Fifteen percent is the target installed reserve margin in the PJM RPM system (CIER 2007), and 6.35 percent is the average derating of generation capacity due to forced outages assumed in the RPM calculations by PJM.[16] This yields the estimate of the change in unforced capacity obligation in SW MAAC due to implementation of the 100 percent energy efficiency program in Maryland (compared to the 25 percent program), shown in the first row Table 8.2. That table also shows the reduction as a percentage of the total peak load (again, estimated from Haiku's Maryland load using the above ratios.)
3. To obtain the change in unforced capacity in SW MAAC, it is assumed, consistent with the ratio of BGE/PEPCO load to Maryland load, that 75 percent of the change in Maryland capacity occurs in SW MAAC. This value is then multiplied by (1-0.0635) to convert installed to unforced capacity. The resulting estimate of the change in unforced capacity in SW MAAC due to implementation of the 100 percent energy efficiency program is shown in the third row of Table 8.1.

Table 8.2. Changes (MW) in Gross Capacity Obligation (Based on Load), Unforced Capacity Supply, and Net Obligation (Gross minus Supply) in SW MAAC as a Result of Implementation of a 100% Energy Efficiency Spending Program for Maryland (Based on Haiku Results)

	2010	2015	2020	2025
ΔObligation (Load Alone)	-181	-452	-586	-704
(% decrease)	-1.6%	-3.9%	-4.9%	-5.8%
ΔUnforced Capacity	-21	-21	4	-8
ΔNet Obligation	-160	-430	-589	-696

[16] See Appendix F of prior report (CIER 2007) for a full discussion of these assumptions.

Considering the two possible ways that RPM costs to Maryland consumers can be decreased by the 100 percent efficiency spending program relative to the 25 percent spending program, the following was concluded:

1. Based on the decrease in Maryland capacity itself, if the RPM prices are at their maximum levels (which they have been at or close to in the initial RPM markets in Maryland) of about $190/MW/day of unforced capacity obligation (Figure 8.1), the decrease in RPM payments by Maryland rate payers in SW MAAC could be as much as $1.5M, based on the decrease in unforced capacity (Table 8.1) times the $190/MW-day * 8760 hours/year. This number is highly uncertain because Haiku's modeling of peak load changes due to energy efficiency programs and energy price shifts is highly approximate, and also because the maximum RPM price will adjust in the future.
2. A change in the net unforced capacity balance in SW MAAC could cause a change in the price of capacity in the RPM mechanism if the supply-demand equilibrium occurs on the slanted portion of the demand curve in Figure 8.1. (There would be no change if the equilibrium is on one of the flat portions.) If it is further assumed that imports of capacity to SW MAAC under the RPM mechanism are at their upper limit in all cases (as they were in the recent auctions, and are anticipated to continue to be), then the change in net obligation within SW MAAC equals the overall change in the net supply/demand balance. Multiplying that change by the average slope of the curve in Figure 8.1 (about -0.19 $/MW-day, or -$68/MW/year) yields the maximum possible change in the RPM SW MAAC price. The result is a maximum decrease of $163M to $703M per year in RPM costs charged to SW MAAC load. However, this number is likely to be much higher than the actual decrease, if any, because it is not likely that both the 100 percent and 25 percent scenarios would result in supply/demand balances on the sloped portions of the curve. Furthermore, the Haiku capacity calculations did not consider RPM payments in this manner, and so the response of generation investment in Maryland to these incentives might be very different than what the Haiku model calculates.

Although it is believed that these decreases in RPM costs cannot be considered to be accurate predictions, they indicate that efficiency program-induced decreases in peak demands in Maryland, especially if they are greater in magnitude than program-induced plant retirements, have the potential to lower RPM payments by Maryland consumers by tens or even hundreds of millions of dollars.

9 Economic Welfare

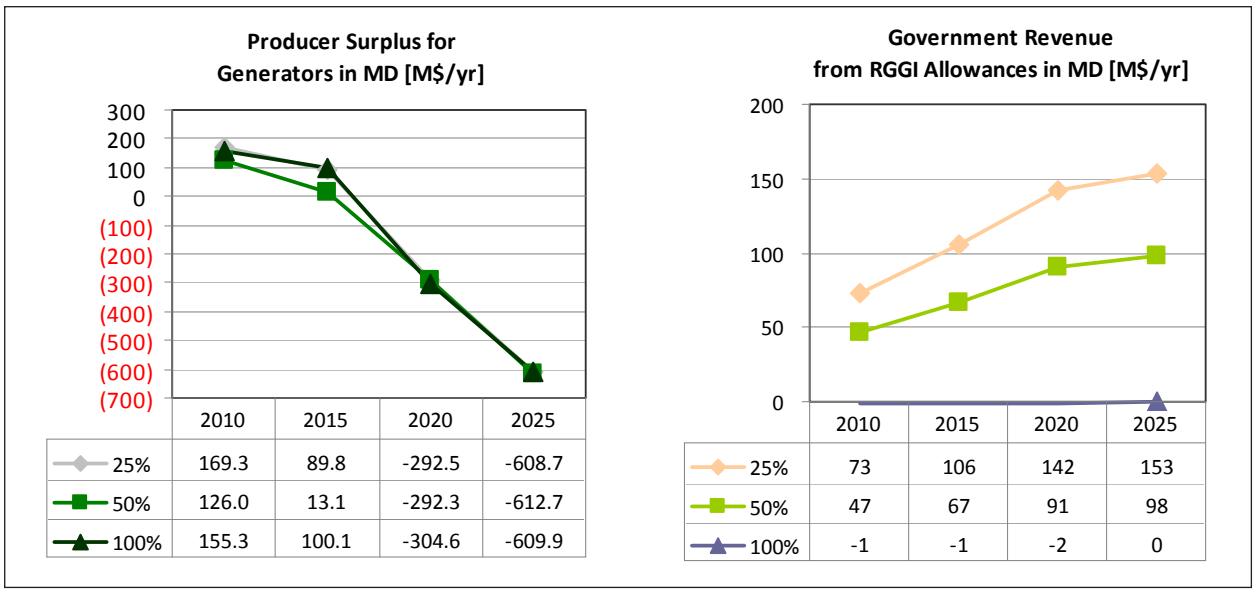
9.1 Economic Impacts of Different Allocations of RGGI Auction Revenue to Energy Efficiency Programs

As was described above, the Haiku and JHU-OUTEC models offer largely consistent perspectives on the implications of applying different shares of auction revenue to energy efficiency programs. While Haiku captures the broader national and regional context within which electricity generation and use are determined under assumptions of perfect competition, JHU-OUTEC offers a more detailed view of market power and higher resolution on regional transmission capacity and choice.

In this section, economic implications of alternative allocations of RGGI auction revenue to energy efficiency programs are examined. To do so, analyses conducted with the Haiku model, which generates information on producer and government surplus, are revisited. Additional outputs from Haiku are then used for a state-wide economic multiplier analysis that is carried out with the IMPLAN model.

The two graphs in Figure 9.1 show, respectively, the levels of producer surplus under each scenario and government revenue associated with RGGI allowance auctions that is available above and beyond the money spent on energy efficiency. These two graphs were generated by the Haiku model.

Figure 9.1. Effects of Expenditure in End-Use Energy Efficiency on Producers and Government



	2010	2015	2020	2025
25%	169.3	89.8	-292.5	-608.7
50%	126.0	13.1	-292.3	-612.7
100%	155.3	100.1	-304.6	-609.9

	2010	2015	2020	2025
25%	73	106	142	153
50%	47	67	91	98
100%	-1	-1	-2	0

9.1.1 Economic Impact Analysis Defined

This section of the report estimates the economic impacts accruing to Maryland from allocating different shares of RGGI allowance auction revenues to energy efficiency. The 25 percent energy efficiency spending level is the baseline, and the 50 percent and 100 percent energy efficiency spending levels represent changes from this baseline. To accomplish this task, the input-output model IMPLAN was used to enumerate the impacts of the different scenarios. The direct impacts of the scenarios were calculated from the results of the RFF Haiku model focusing on electricity prices, net demand, changes to net investment in electricity generating capacity, spending on energy demand conservation initiatives and any allowance revenue accruing to the state that is not allocated to energy efficiency initiatives. From these inputs, the IMPLAN model calculates direct, indirect and induced changes to employment, gross state product, wages, and state tax revenues as a result of Maryland joining RGGI.

Input/output models are the primary tool used by economists to measure the total economic impact of a policy, business or event. For example, input/output models are used to measure the total economic impacts associated with the relocation of a firm to an area. The theory behind economic impact analysis is that the total economic impact of a new firm entering a region is not merely limited to the number of employees the firm hires or to the payroll associated with these employees. Rather, the total economic impact includes these impacts as well as additional, multiplicative impacts. Multiplicative impacts which occur as the new firm spends money in the region on goods and services and as the wages of employees trickle through the local economy.

Specifically, there are three types of impacts captured by input/output models:

- *Direct impacts:* these impacts are generated when the new business creates new jobs and hires workers to fill those jobs.
- *Indirect impacts:* these impacts accrue as the new firm purchases goods and services from other locally situated businesses.
- *Induced impacts:* both the direct and indirect impacts result in an increase in area household income. This increase allows local households to ramp up their spending at local area businesses. The increase in local spending is referred to as the induced impacts.

For the purpose of this analysis, the direct impacts are considered to be equal to the value of electricity savings as they accrue to existing businesses and households (as savings are recycled through the economy), the investment in energy efficiency improvements, impacts on the electricity generating sector including changes to capacity and profits, and new public sector activities funded with RGGI allowance auction revenue. The indirect impacts accrue to additional supporting businesses through purchases of goods and services by businesses and consumers that receive the direct impacts. The induced impacts result from increased household income and related spending which is driven by the direct and indirect impacts.

9.1.2 Electricity Expenditure Changes

In comparing the base case to higher levels of energy efficiency spending, the Haiku model predicts an overall decrease in electricity costs for all customer classes. The expenditure changes were generated by comparing the difference in electricity usage by customer class and multiplying that change by the new estimated electricity rates as generated by the Haiku model. To undertake the analysis, some of the data had to be transformed for the input-output model. The data in Table 9.1 were allocated to households by income level and to industry on the basis of the North American Industrial Classification system (NAICS). To accurately measure the economic impact that results from the change in residential electricity bills, it was necessary to allocate those changes on the basis of household income as there are differences in electricity consumption and expenditure patterns across income groupings that need to be captured by the model. The change in residential expenditures was allocated to income levels on the basis of the Consumer Expenditure Survey conducted by the Bureau of Labor Statistics (BLS) and income levels.

Table 9.1. Reduction in Household Electricity Expenditures Resulting From Increased Energy Efficiency Expenditures

Residential Income Level	50% Efficiency Spending vs. 25% Base Case Spending, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
Less than $10,000	$2,310	$4,930	$3,506	$4,685
$10-15,000	$1,577	$3,366	$2,394	$3,198
$15-25,000	$3,292	$7,026	$4,997	$6,677
$25-35,000	$3,553	$7,585	$5,394	$7,208
$35-50,000	$5,192	$11,083	$7,882	$10,532
$50-75,000	$7,131	$15,223	$10,826	$14,467
$75-100,000	$5,125	$10,941	$7,781	$10,397
$100-150,000	$5,317	$11,350	$8,072	$10,786
Greater than $150,000	$3,138	$6,698	$4,763	$6,365
TOTAL	**$36,636**	**$78,203**	**$55,617**	**$74,318**

Residential Income Level	100% Efficiency Spending vs. 25% Base Case Spending, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
Less than $10,000	$4,647	$8,066	$11,318	$11,779
$10-15,000	$3,172	$5,507	$7,726	$8,041
$15-25,000	$6,623	$11,496	$16,130	$16,786
$25-35,000	$7,149	$12,410	$17,412	$18,121
$35-50,000	$10,446	$18,133	$25,442	$26,478
$50-75,000	$14,349	$24,906	$34,946	$36,368
$75-100,000	$10,312	$17,900	$25,116	$26,138
$100-150,000	$10,698	$18,570	$26,055	$27,115
Greater than $150,000	$6,313	$10,959	$15,376	$16,002
TOTAL	**$73,712**	**$127,949**	**$179,522**	**$186,829**

Overall, Maryland households will save approximately between $36 million in 2010 and $74 million in 2025 on their electricity bills if energy efficiency efforts are increased from the base case of 25 percent spending level to the 50 percent level. Dedicating 100 percent of RGGI allowances to energy efficiency spending efforts increases electricity savings by $73 million in 2010 to $186 million in 2025 when compared to the base case scenario. For a typical household, the 50 percent efficiency scenario yields an additional $15 in annual electricity bill savings in 2010, whereas increasing to the 100 percent efficiency scenario boosts electricity savings to approximately $32 per household annually in 2010 compared to the base case level of spending of RGGI funds on energy efficiency.

The change in non-residential electricity expenditures are allocated to industry on a NAICS basis. Here again, to accurately portray the economic impact associated with the change in non-residential electricity bills as there are distinct differences in how firms in each NAICS category would use those decreases, it was necessary to allocate these changes within commercial and industrial customer classes. The allocation across sectors was based on relative employment levels. This allocation is detailed in Table 9.2 below. Total savings to non-industrial customers exceeds that of residential users.

Table 9.2. Reduction in Non-Residential Electricity Expenditures Resulting from Increased Energy Efficiency Expenditures

	50% Efficiency Spending vs. 25% Base Case Spending, in thousands (due to rounding, totals may not coincide with data)			
Non Residential Sector	2010	2015	2020	2025
Agriculture/Mining	$557	$1,321	$1,123	$1,243
Construction	$8,875	$21,062	$17,907	$19,828
Manufacturing	$7,921	$18,799	$15,983	$17,697
Wholesale Trade	$651	$1,652	$1,409	$1,836
Retail Trade	$2,396	$6,081	$5,185	$6,757
Transportation	$1,156	$2,933	$2,501	$3,259
Information	$670	$1,700	$1,449	$1,889
Finance	$1,580	$4,011	$3,420	$4,456
Professional	$3,270	$8,298	$7,076	$9,220
Education	$5,047	$12,808	$10,922	$14,232
Arts/Hotels/Eating	$1,656	$4,202	$3,584	$4,670
Other Services	$1,323	$3,356	$2,862	$3,729
Total	$35,101	$86,222	$73,420	$88,815

	100% Efficiency Spending vs. 25% Base Case Spending, in thousands (due to rounding, totals may not coincide with data)			
Non Residential Sector	2010	2015	2020	2025
Agriculture/Mining	$1,151	$2,160	$3,278	$3,162
Construction	$18,348	$34,439	$52,276	$50,414
Manufacturing	$16,376	$30,738	$46,659	$44,996
Wholesale Trade	$1,303	$2,700	$4,254	$4,645
Retail Trade	$4,796	$9,936	$15,654	$17,095
Transportation	$2,313	$4,793	$7,551	$8,245
Information	$1,340	$2,777	$4,376	$4,778
Finance	$3,163	$6,554	$10,325	$11,275
Professional	$6,544	$13,559	$21,362	$23,328
Education	$10,102	$20,930	$32,974	$36,009
Arts/Hotels/Eating	$3,314	$6,867	$10,819	$11,815
Other Services	$2,647	$5,485	$8,641	$9,436
Total	$71,397	$140,939	$218,169	$225,199

9.1.3 Energy Efficiency Investments

The energy efficiency investments funded by RGGI auction allowances will generate economic activity and jobs within the state. As the portion of RGGI auction revenues allocated to these functions increase in each scenario, the associated economic impact will increase. Table 9.3 shows the additional revenue dedicated to energy efficiency spending under each scenario.

Table 9.3. Additional Auction Revenues Dedicated to Energy Efficiency Spending

	2010	2015	2020	2025
50% vs. 25% Basecase Levels, in thousands	$22,471	$32,370	$43,673	$47,059
100% vs. 25% Levels, in thousands	$64,425	$92,781	$125,273	$145,907

To determine the economic impact of energy efficiency spending in the electricity end-user market, these funds must be allocated to different sectors. Following the assumptions used in the Haiku model, it was assumed that 40 percent of these funds would be required for government administration of various energy efficiency programs, and the remaining 60 percent would go directly to supporting energy efficiency investments in the private sector. Again, following the Haiku assumptions based on the experience of other energy efficiency programs, it was estimated that 20 percent of these remaining funds or 12 percent of the total funds would go to "free-riders." In this setting, the term free-riders refers to subsidies going to energy efficiency investments that would have also been made in the absence of the new spending on energy efficiency programs. These funds were treated as an income transfer, and assumed to be spent in a manner similar to electricity bill savings described in the previous section The remaining dollars were assumed to stimulate the construction of new energy efficiency investments and were allocated to wholesale trade (e.g. building materials and supplies), construction sectors (e.g. electricians, builders), and professional areas (architects and engineers) according to breakdowns for residential, commercial and industrial construction as specified in the Architects, Contractors, and Engineers Guide to Construction Costs, 2008 Edition. In the economic impacts sections that follow, the "free rider" and public administration spending is grouped with the income enhancements from reduced energy bills and government sector respectively. Thus, the energy efficiency spending impacts focus specifically on the new efficiency investment directly stimulated by the additional funds from participation in RGGI (Table 9.4).

Table 9.4. Breakdown of Energy Efficiency Spending

	50 percent Spending Level vs. 25 percent Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
"Free Riders"	$2,690	$3,874	$5,228	$5,639
Construction	$7,150	$10,297	$13,892	$14,950
Wholesale trade	$2,606	$3,725	$5,031	$5,411
Professional	$2,191	$3,154	$4,256	$4,580
Public Administration	$8,968	$12,914	$17,425	$18,797
	100% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
"Free Riders"	$7,690	$11,074	$14,942	$17,508
Construction	$20,565	$29,601	$40,002	$46,288
Wholesale trade	$7,493	$10,707	$14,504	$16,773
Professional	$6,301	$9,068	$12,255	$14,181
Public Administration	$25,634	$36,912	$49,808	$58,361

9.1.4 Power Generating Sector

Increasing energy efficiency spending in Maryland has the potential to impact electric power generators. These include changes to profits driven by changes to electricity prices and consumption, as estimated in the Haiku model. In addition, there are some estimated changes to generating capacity as the programs change electricity consumption and power imports to the state. In certain years, Maryland generating capacity is predicted to increase even as consumption declines as a result of reduced electricity imports. Most of the capacity adjustments occur at gas fired power plants. Table 9.5 details the value of estimated net changes to investment in new power plants and the profits of existing units.

Table 9.5. Changes to Power Plant Investment and Profits

	50% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
Investment in New Generating Capacity	$(44,965)	$58,380	$68,044	$73,818
Profits at Power Generating Units	$(43,249)	$(76,695)	$173	$(3,970)
	100% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
Investment in New Generating Capacity	$(130,610)	$(145,584)	$(139,976)	$26,034
Profits at Power Generating Units	$(14,022)	$10,265	$(12,116)	$(1,212)

9.1.5 Government Sector

The auction of RGGI allowances will generate significant revenues for the state. As more of these revenues are dedicated to energy efficiency spending as described in section 9.1.3, fewer revenues are available to other state government purposes which may or may not be related to energy and environmental concerns. For the purposes of this analysis, no specific assumptions are made regarding the exact disposition of the allowance funds that are not dedicated to energy efficiency spending. In the economic impact model, these funds are treated as decreases to general state government spending as more auction revenue is dedicated to energy efficiency spending in the various scenarios. As detailed in section 4.3.2, a significant portion of the RGGI allowance will remain in the state government sector for program administration. Table 9.6 outlines the estimated impacts on state government activities.

Table 9.6. Changes to State Government Activities

	50% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
Administration of Efficiency Programs	$8,968	$12,914	$17,425	$18,797
General State Government	$(26,558)	$(38,267)	$(51,624)	$(55,557)
	100% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	2015	2020	2025
Administration of Efficiency Programs	$25,634	$36,912	$49,808	$58,361
General State Government	$(74,018)	$(106,603)	$(144,008)	$(153,623)

9.1.6 Impact on Gross State Product

Increasing the share of RGGI funds to energy efficiency is estimated to have a net positive impact on economic activity in Maryland. Gains in the private sector through reduced energy bills and the direct impacts of energy efficiency programs should exceed any losses to power generators and other parts of the government through the diversion of RGGI funds. The boost to the economy is very small in 2010, but the GSP impact increases rapidly in 2015 and in subsequent years. This is primarily due to two effects. First, energy efficiency improvements yield benefits over a number of years, so energy savings are initially low relative to investment but increase over time as years of energy conservation investment accumulate. In addition, initial negative impacts in the power generating sector are forecast to dissipate over time. Although the estimated impact is positive in all periods, it should be noted that the boost to gross state product is small relative to a state economy that will likely exceed $300 billion by 2010. In most periods in both scenarios, the estimated boost to economic growth is less than 0.1 percent (see Table 9.7).

Table 9.7. Change to Gross State Product by Impact Category

	50% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
Residential Energy	$41,046	$87,619	$62,313	$83,266
Non-Residential Energy	$64,456	$158,694	$135,145	$164,388
Demand Conservation	$20,338	$29,243	$39,462	$42,461
Power Plants	($73,598)	($88,355)	$21,008	$17,036
Government	($29,005)	($30,582)	($41,252)	($44,342)
Total	**$23,238**	**$156,618**	**$216,677**	**$262,810**
	100% Spending Level vs. 25% Basecase Level in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
Residential Energy	$82,587	$142,187	$199,501	$207,621
Non-Residential Energy	$130,961	$259,397	$402,048	$416,751
Demand Conservation	$58,498	$84,062	$113,660	$131,505
Power Plants	($59,278)	($30,226)	($59,498)	$6,269
Government	($58,364)	($84,064)	($113,629)	($114,910)
Total	**$154,404**	**$371,356**	**$542,083**	**$647,236**

9.1.7 Impact on Employment and Wages

Increasing the share of RGGI funds directed to energy efficiency is expected to have a small positive impact on Maryland employment. Jobs created by electricity bill savings to residential and non-residential customers are the largest contributor and grow the fastest over time as energy efficiencies accumulate with sustained investment over time. In the power plant sector, employment impacts are initially negative, but decrease over time and eventually turn slightly positive. Job losses related to reduced general government spending reflect the diversion of funds away from general state government expenditures to energy efficiency spending and show the net job impact of these programs. In the aggregate, the employment impact is quite small compared to the 2.65 million non-farm payroll jobs in the state in 2007 (see Table 9.8).

Table 9.8. Change to State Employment by Impact Category (Number of Changes in Jobs)

	50% Spending Level vs. 25% Basecase Level			
	2010	**2015**	**2020**	**2025**
Residential Energy	408	871	620	828
Non-Residential Energy	567	1408	1199	1489
Demand Conservation	163	234	315	339
Power Plants	(313)	(186)	183	180
Government	(396)	(458)	(617)	(663)
Total	**428**	**1869**	**1700**	**2172**
	100% Spending Level vs. 25% Basecase Level			
	2010	**2015**	**2020**	**2025**
Residential Energy	821	1414	1983	2064
Non-Residential Energy	1146	2301	3583	3773
Demand Conservation	467	672	908	1051
Power Plants	(412)	(344)	(429)	64
Government	(873)	(1258)	(1700)	(1719)
Total	**1149**	**2785**	**4345**	**5233**

Figure 9.2. Top Employment Gaining Industries with 50 Percent Revenue Spending Scenario

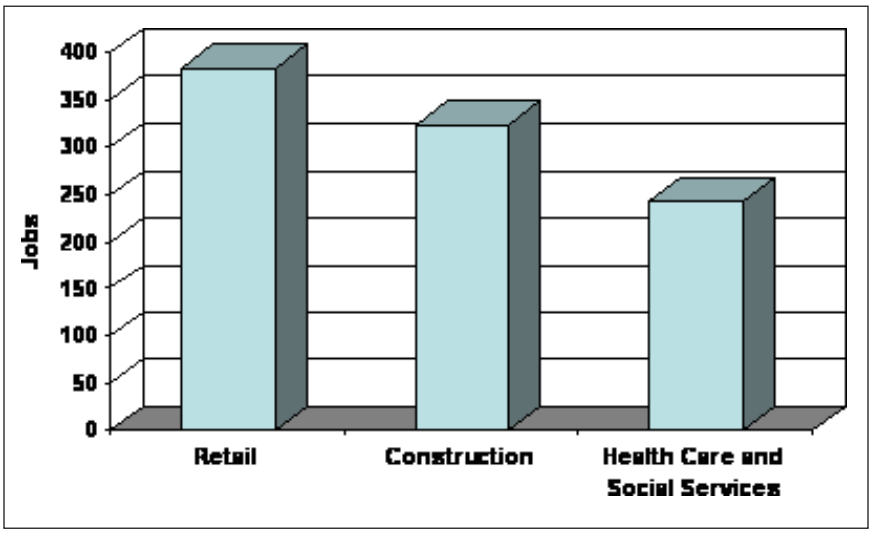
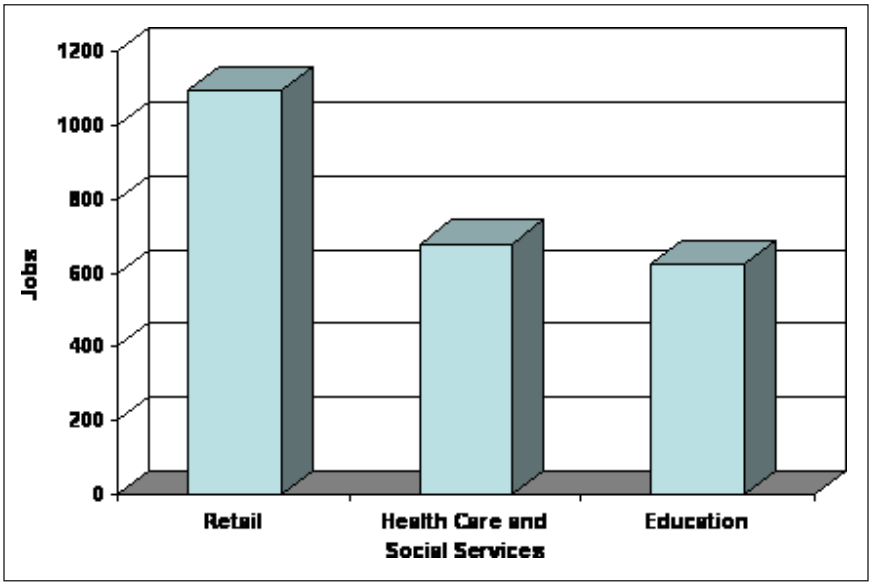


Figure 9.3. Top Employment Gaining Industries with 100 Percent Revenue Spending Scenario



Wage changes are positive but are proportionally smaller in magnitude than employment changes. This result is because the sectors with the greatest job losses (e.g. power generating sector, state government) typically have higher wages than those sectors showing the greatest gains. Although the jobs created by the energy efficiency programs tend to have higher wages, the largest job gains are through spending stimulated by lower electricity bills that create proportionally more jobs in lower paying retail and service sectors (see Table 9.9).

Table 9.9. Change to Employee Wages by Impact Category

	50% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
Residential Energy	$12,860	$27,452	$19,523	$26,088
Non-Residential Energy	$21,004	$52,061	$44,349	$54,806
Demand Conservation	$6,736	$9,682	$13,066	$14,059
Power Plants	($13,755)	($9,547)	$7,349	$7,115
Government	($18,288)	($22,814)	($30,773)	($33,078)
Total	**$8,557**	**$56,834**	**$53,514**	**$68,990**
	100% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
Residential Energy	$25,875	$44,548	$62,505	$65,049
Non-Residential Energy	$42,537	$85,093	$132,373	$138,877
Demand Conservation	$19,373	$27,832	$37,635	$43,543
Power Plants	($16,930)	($13,529)	($17,543)	$2,548
Government	($43,538)	($62,710)	($84,764)	($85,720)
Total	**$27,317**	**$81,234**	**$130,206**	**$164,297**

9.1.8 Fiscal Impacts

The economic activity described in the previous sections may generate tax revenue for the state. The fiscal impacts are initially small, and are in fact predicted to be slightly negative for the 50 percent energy efficiency spending scenario in 2010. In this scenario, fiscal impacts are nearly zero for the first decade of the simulation and increase to about $15 million in revenue in 2020 and beyond. As expected, the fiscal impacts of the 100 percent energy efficiency spending are larger, beginning at about $8 million in 2010 and increasing to $40 million in 2025. When interpreting these charts, it is important to keep in mind that it is assumed that RGGI revenues that were not directed to efficiency programs were used for general state government spending to match historical general spending patterns. (see Table 9.10).

Table 9.10. New State Tax Revenues by Impact Category

	50% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
Residential Energy	$2,990	$6,382	$4,539	$6,065
Non-Residential Energy	$3,498	$3,498	$8,613	$8,922
Demand Conservation	$1,195	$1,718	$2,318	$2,494
Power Plants	($6,377)	($7,655)	$1,820	$1,476
Government	($1,445)	($1,523)	($2,054)	($2,208)
Total	**($138)**	**$2,420**	**$15,236**	**$16,750**
	100% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
Residential Energy	$6,016	$10,357	$14,532	$15,124
Non-Residential Energy	$7,108	$14,079	$21,822	$22,620
Demand Conservation	$3,437	$4,938	$6,677	$7,726
Power Plants	($5,136)	($2,619)	($5,155)	$543
Government	($2,907)	($4,187)	($5,659)	($5,723)
Total	**$8,518**	**$22,569**	**$32,217**	**$40,289**

The fiscal impact of the enhanced energy efficiency scenarios can be compared to RGGI funds that flowed from general use. If the energy efficiency programs stimulate the Maryland economy, they could generate tax revenues to partially offset the dollars allocated to energy efficiency. As shown in Table 9.11, the fiscal impacts are small relative to the dollars allocated to energy efficiency programs, especially during the early years of the program. Once the energy efficiency programs have had time to become established, it is estimated that positive fiscal impacts will be roughly 25 percent of the additional RGGI auction revenues dedicated to enhanced energy efficiency.

Table 9.11. Comparison of Tax Revenue Generated by Energy Efficiency Initiatives to RGGI Funds Directed to Energy Efficiency

	50% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
State revenue generated by new efficiency investments	($138)	$2,420	$15,236	$16,750
RGGI revenue available for non-efficiency purposes	$(26,558)	$(38,267)	$(51,624)	$(55,557)
	100% Spending Level vs. 25% Basecase Level, in thousands (due to rounding, totals may not coincide with data)			
	2010	**2015**	**2020**	**2025**
State revenue generated by new efficiency investments	$8,518	$22,569	$32,217	$40,289
RGGI revenue available for non-efficiency purposes	$(74,018)	$(106,603)	$(144,008)	$(153,623)

10 Analysis of Statewide Energy Efficiency Programs in Three Northeast States

By Joanna Mauer, Iván Darío Valencia, Nate Hultman, Kim Ross, Matthias Ruth, Nicolai Herrmann

In assessing possible approaches for Maryland's investment in energy efficiency, it is useful to examine lessons and results from other states. For this report, efficiency programs in New York, Vermont, and Maine, three states that are also part of RGGI, were analyzed. This section will present a comparison of efficiency spending among these states, a summary of the administering organizations in each of the three states and the cost-effectiveness of their efficiency programs, an analysis of program costs, and a comparison of program cost-effectiveness among the states. With this focus on spending levels and cost-effectiveness, the analysis complements the modeling of different levels of spending for energy efficiency in Maryland (specifically from RGGI allowance revenue).

It is not the purpose of this study to provide a complete, formal evaluation of these statewide energy efficiency programs. The research team recognizes that the program annual reports as well as formal evaluations may contain biases or other limitations that complicate a comprehensive assessment.

This study was conducted prior to the first RGGI auction and, therefore, revenues for all existing energy efficiency programs are from other sources. Yet the experiences and design of these existing statewide programs can help reveal opportunities for achieving Maryland's new goals.

10.1 Statewide Programs Analyzed

The three case study states were chosen because of specific similarities to Maryland's situation and thus are useful for evaluating possible Maryland state policies. New York's efficiency programs are administered by a state agency, the New York State Energy Research and Development Authority (NYSERDA), and New York's urban-rural population divide is similar to that of Maryland. New York's rural population is 13 percent of its total population while the figure for Maryland is 14 percent (Northeast Midwest Institute, 2002). In both Vermont and Maine, efficiency programs are administered by independent entities: Efficiency Vermont and Efficiency Maine. Both states also have large rural populations of about 60 percent of the total population, which demonstrates how Maryland might approach efficiency improvements not just in its urban population centers, but in rural parts of the state as well. According to the American Council for an Energy-Efficient Economy (ACEEE), in 2004 Vermont ranked first in the country in per capita efficiency spending (Eldridge et al., 2007). Maine's program was established more recently, but is realizing significant growth in reported energy savings. The range of past experiences with efficiency programs, the different levels of funding and political commitment to them, and the different priorities they place on various policy goals – from improvements in efficiency to social equity concerns – offer a range of insights that may be relevant to Maryland, as it expands its own activities in this area.

10.1.1 Program Design & Evaluation: Differences Among States

In comparing statewide energy efficiency programs, it is important to consider differences in program design and evaluation. For example, the three states analyzed all target low-income residents either through specific low-income programs or through low-income components of comprehensive programs. However, the definition of low-income varies among the states.

In estimating electricity savings, important considerations to take into account include assumptions of measure lifetimes, defined as the estimated number of years that efficiency measures will remain installed and functioning, as well as free rider and spillover effects. Among the three states analyzed, the range of measure lifetimes varies, and some programs include free rider and spillover effects while others do not as described in more detail below.

10.1.1.1 Defining Targeted Low-Income Customers

Efficiency programs in the three states are grouped into two sectors: commercial/industrial and residential/low-income. In New York, residents with an income less than 60 percent of the state median income, based on household size, are eligible for specific low-income programs (NYSERDA 2008a). In Vermont, eligibility for targeted low-income initiatives is determined by the resident's local Weatherization Agency (Efficiency Vermont, 2008). Low-income programs in Maine are available to residents determined eligible under the Low Income Home Energy Assistance Program (LIHEAP); households with incomes at or below 150 percent or 170 percent of the federal poverty level, depending on household characteristics, are generally eligible (Efficiency Maine, 2008).

10.1.1.2 Calculations of Measure Lifetimes

The calculation of lifetime electricity savings depends on the lifetimes assumed for each of the efficiency programs, and it is difficult to estimate lifetimes accurately. The estimated number of years that efficiency measures will remain installed and functioning is defined as the measure lifetime. Since different measures contribute unequally to total conservation, individual measures are weighted by their expected savings to calculate measure-weighted lifetimes. Longer lifetime estimates for a given measure result in lower values of costs per kWh saved. Measure-weighted lifetimes for particular programs range from 10-26 years for New York; 6-21 years for Vermont; and 5-14 years for Maine. Lifetime estimates for programs focusing on lighting and appliance replacement are lower than for programs targeting whole-building efficiency measures.

10.1.1.3 Free rider and Spillover Effects

Efficiency measures are individual technological efficiency improvements such as installing compact fluorescent light bulbs (CFLs), replacing a refrigerator with a more efficient model, or weatherizing a building. Efficiency programs sometimes focus on a single measure such as promoting CFLs but more often encompass a wide range of measures. For example, the national program Home Performance with ENERGY STAR offers a whole-house approach to improving energy efficiency including sealing air leaks, improving heating and cooling systems, and upgrading lighting and appliances (ENERGY STAR 2008).

Free rider effects refer to energy savings that would have occurred in the absence of the program and without program incentives. Free riders are customers who take advantage of incentive payments for efficiency measures even though they would have made the same investment without the incentive. Spillover effects are energy savings that occur as a result of the program but without program incentives. Spillover includes customers who purchase efficiency measures due to marketing of an efficiency program without taking advantage of incentives and customers who have received incentives through an efficiency program and then invest in additional efficiency measures without further incentives. Spillover effects can also take the form of market transformation in which the underlying market structure is altered by the presence of the program. On the supply side this could be because efficient goods achieve a market share sufficient to gain economies of scale. On the demand side, the preferences of consumers may be altered if they see more efficient goods at the market, see their friends using efficiency goods, become educated about efficient goods, etc. Quantification of spillover effects is hampered by lack of empirical or experimental data, yet they can play an important role in achieving efficiency goals.

In addition to free rider and spillover effects, a realization rate can be used to adjust for the difference between energy savings claimed by the administering organization and measured and verified savings. A rate of 1.0 means that the savings measured and verified align exactly with the savings claimed. Net savings are the amount of energy savings attributable to a program after adjustments are made for free rider and spillover effects and realization rate. The savings data from New York and Vermont take into account both free rider and spillover effects, and the data from New York also takes into account realization rates. The savings data from Maine represents gross savings without taking into account free rider or spillover effects or realization rates.

For NYSERDA's programs, the estimated spillover for many programs outweighs the free rider effect. The average free ridership, spillover, and net-to-gross ratios for NYSERDA's commercial/industrial and residential programs are shown in Table 10.1 (NYSERDA 2007a).

Table 10.1. Average Free Ridership, Spillover, and Net-to-gross Ratios for NYSERDA's Commercial/Industrial and Residential Program Sectors

Sector	Average Free ridership	Average Spillover	Average Net-to-Gross Ratio*
Commercial/Industrial	0.31	0.52	1.05
Residential	0.18	0.20	1.03

net-to-gross ratio = (1-freeridership)(1+spillover)

10.1.2 Elements of Statewide Program Costs

The following describes the cost elements of the statewide programs examined in this analysis, as well as key issues considered and calculations used. These could also be useful considerations for the State of Maryland in designing an overall program, as well as in selecting specific energy efficiency measures or combinations of measures.

Analyzing program cost-effectiveness is one method of evaluating efficiency programs, and it provides a measure for comparing individual efficiency programs within states as well as between states. In calculating cost-effectiveness, it is important to distinguish between program costs and customer costs. Within program costs, it is useful to differentiate between program administration costs and funds dedicated to financial incentives. Another consideration is the selection of a discount rate for the lifetime electricity savings to account for the time value of money.

The cost-effectiveness of programs was assessed based on a calculated cost per kWh of electricity saved ($/kWh). The adjusted cost-effectiveness was calculated for program costs and customer costs. Adjusted cost-effectiveness takes into account the time value of money to discount electricity savings over the expected lifetime of each investment. For these calculations, a discount rate of 5 percent was used, which is consistent with the work of the Maryland Commission on Climate Change (MCCC 2008).

It is important to note that cost-effectiveness is only one measure of program effectiveness and that states are generally balancing several goals including environmental impacts, equity, job creation, and grid reliability. The research team also recognizes that the data used for the cost-effectiveness calculations may contain biases or other limitations due to the difficulty of measuring energy savings from efficiency programs. Gillingham et al. point out that measuring energy savings can be problematic for many reasons including difficulties in defining the right baseline and double counting of energy savings (2004).

10.1.2.1 Program and Customer Costs

Program costs include all the costs of the administering organization in the design, implementation, and evaluation of efficiency programs. However, customers also often incur costs, which are generally the customer's contribution to the purchase of efficiency measures such as appliances or equipment. Efficiency Vermont and Efficiency Maine both reported customer costs for 2006. For New York, estimated customer costs for 2006 were calculated using data from a program cost-effectiveness assessment released in 2005 (Heschong Mahone Group), assuming the same ratio of customer to program costs.[1]

10.1.2.2 Program Administration and Incentive Costs

Incentive payments represent a contribution to the capital cost of efficiency measures while program administration costs include all costs other than incentive payments. Two of the states analyzed also further separate program administration costs. Efficiency Vermont reports operating and technical assistance costs, and Maine reports program delivery and administration costs. No data were available for New York.

[1] The EmPOWER New York program, which provides energy efficiency services to low-income customers, did not exist at the time the quarterly report was released. Customer costs for EmPOWER are based on costs for the Low-Income Direct Installation program.

10.1.3 Spending on Efficiency Programs

To compare spending on efficiency programs across states, Table 10.2 shows data on population, GDP by state, electricity consumption, and energy efficiency expenditures for New York, Vermont, and Maine. Spending per person, spending per GDP, and spending per million kWh consumed were calculated for each state to compare spending among states. Vermont has the highest spending ratios--$22.44 spent on efficiency per capita, for example, compared with $5.65 for New York and $6.96 for Maine. In comparison, Maryland spent only $0.45 per capita on energy efficiency in 2006.

Table 10.2. Comparison of 2006 Efficiency Spending Across States

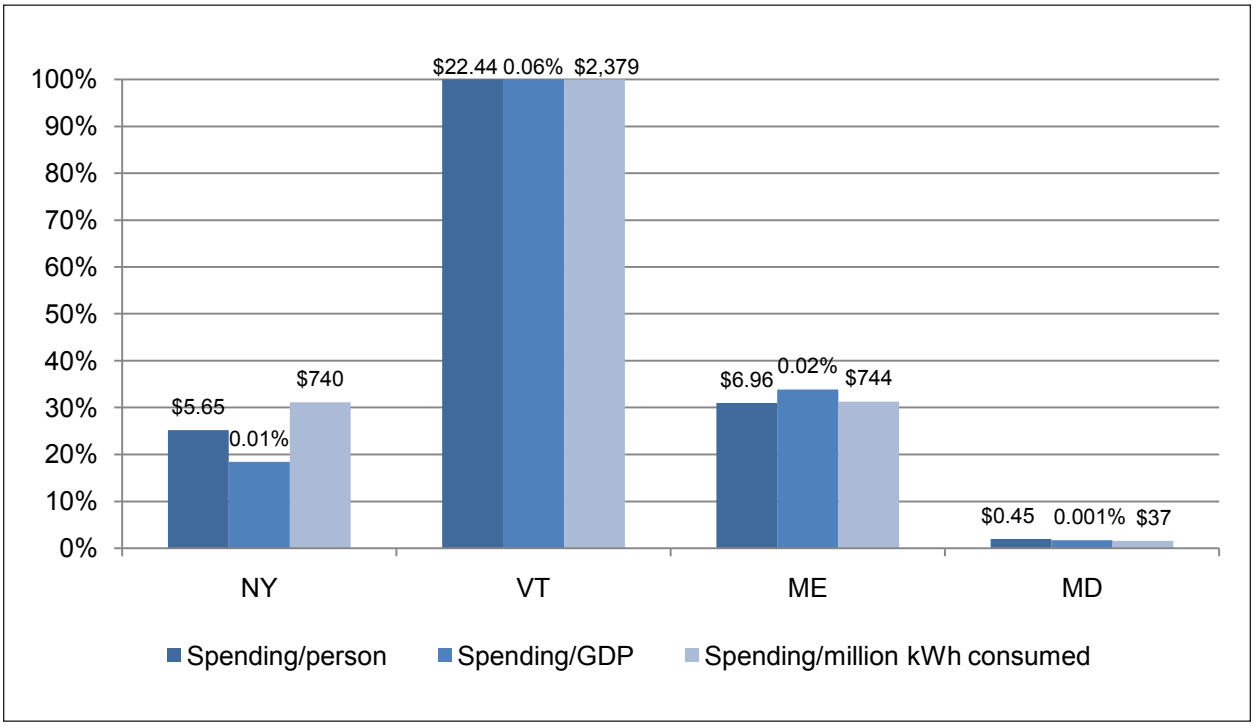
	New York	Vermont	Maine	Maryland
Population[1]	19,306,183	623,908	1,321,574	5,615,727
GDP by state (billion)[2]	$1,021.9	$24.2	$47.0	$257.8
Total Electricity Consumption (million kWh)[3]*	147,302	5,884	12,362	67,889
Residential	50,533	2,189	4,503	28,440
Commercial	76,822	2,051	4,157	17,932
Industrial	19,947	1,644	3,702	21,517
Energy Efficiency Spending ($million)**	109.0[4]	14.0[5]	9.2[6]	2.5[7]
Spending/capita	$5.65	$22.44	$6.96	$0.45
Spending/GDP	0.01%	0.06%	0.02%	0.001%
Spending/million kWh consumed	$740	$2,379	$744	$37

*electricity consumption data is for 2005
** data for New York is excluding R&D spending

Figure 10.1 shows a comparison of the spending measures across the four states. To reach a level of efficiency spending comparable to current spending in New York and Maine, Maryland would need to spend $42 million annually. To reach a spending level comparable to that of Vermont, Maryland would spend approximately $146 million annually (for calculations see Appendix F).

[1] U.S. Census Bureau, 2008.
[2] EIA, 2008b.
[3] EIA, 2008a.
[4] NYSERDA, 2007a.
[5] Efficiency Vermont, 2007.
[6] Efficiency Maine, 2006a.
[7] Maryland General Assembly, 2006.

Figure 10.1. Comparison of 2006 Efficiency Spending Across States Where VT=100



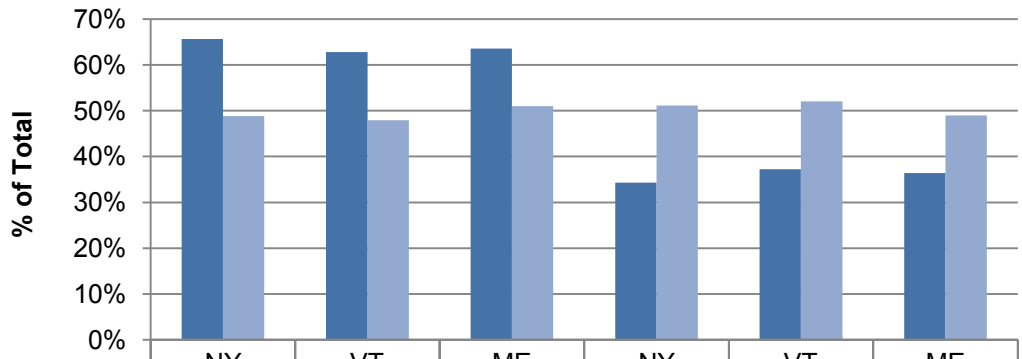
Sources: U.S. Census Bureau, EIA, NYSERDA, Efficiency Vermont, Efficiency Maine, Maryland General Assembly.

10.1.4 Sector Efficiency Budgets vs. Electricity Usage

Decisions about the allocation of funds for efficiency improvements ideally are guided by the cost-effectiveness with which these funds generate desired outcomes. One of the desired outcomes is an actual improvement in energy efficiency, another is the reduction of financial burdens of energy users, as energy prices increase, while yet another is a redistribution of assets among members of the economy and society. While other parts of this report address issues of efficiency gains, cost effectiveness and economic burdens on consumers, this brief section attends to the allocation of funds among the residential, commercial, and industrial sectors.

Figure 10.2 shows the electricity usage of the residential and commercial/industrial sectors in New York, Vermont, and Maine as a percentage of total usage compared to the share of energy efficiency funds allotted to the respective sectors. Electricity usage is based on the 2005 data in Table 10.2 and the efficiency spending is based on data from the 2006 annual reports for the efficiency programs from each of the three states. In each of the three states, while commercial/industrial electricity usage makes up more than 60 percent of the total electricity usage, only about 50 percent of total funds are spent on commercial/industrial efficiency programs. Similarly, while residential electricity usage makes up less than 40 percent of the total in each of the three states, between 49 percent and 52 percent of the funds are spent on residential and low-income programs.

Figure 10.2. Electricity Usage Compared to Efficiency Spending by Sector



	Commercial/Industrial			Residential/Low-Income		
	NY	VT	ME	NY	VT	ME
Electricity Usage	65.7%	62.8%	63.6%	34.3%	37.2%	36.4%
Efficiency Spending	48.9%	47.9%	51.0%	51.1%	52.1%	49.0%

Sources: EIA 2008a; NYSERDA 2008; Efficiency Vermont 2007; Efficiency Maine 2006a.

10.1.5 New York

10.1.5.1 Overview

NYSERDA operates based on an inter-agency Memorandum of Understanding (MOU) with the New York Public Service Commission (NYPSC). NYSERDA's programs are funded through a systems benefit charge. Each year from 2006-2011, each utility must collect and remit to NYSERDA a sum equal to 1.42 percent of the utility's 2004 revenue (NCSU, 2007). The public benefits program to promote efficiency is called New York Energy $mart and has four broad public policy goals: improve New York's energy system reliability and security; reduce the energy cost burden of New Yorkers; mitigate the environmental and health impacts of energy use; and create economic opportunity and promote economic well-being (NYSERDA 2007a).

Individual New York Energy $mart programs are implemented by contractors while NYSERDA oversees program evaluation conducted by a team of independent evaluation contractors. NYSERDA has seven energy efficiency programs targeting the commercial/industrial sector and six programs targeting the residential and low-income sectors. Brief descriptions of the programs are provided in Appendix F.

10.1.5.2 Data Analysis Methods

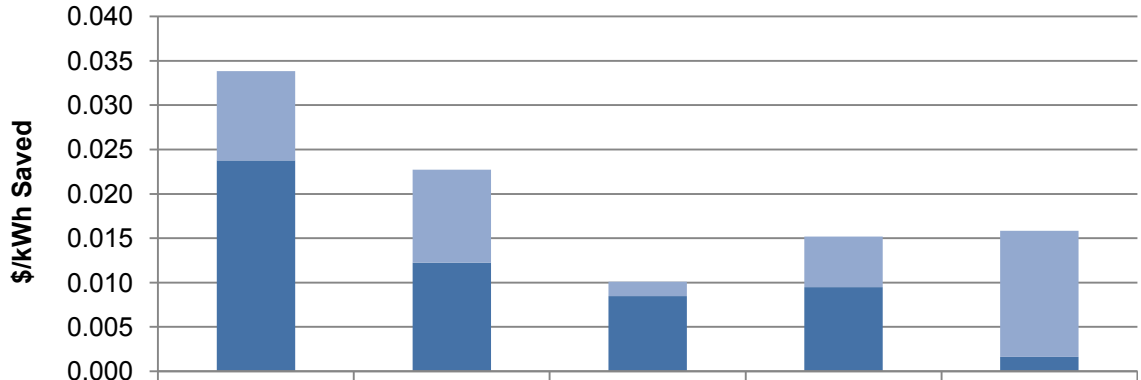
In each year, NYSERDA reports cumulative funds spent and cumulative annual energy savings from all measures implemented since the start of the program in 1998.[8] Lifetime energy savings were calculated by multiplying the annual savings in 2006 by the measure-weighted program lifetimes, which also came from the quarterly report. Several of the New York Energy $mart programs contribute to natural gas savings in addition to electricity savings. NYSERDA estimates that 15 percent of total costs are associated with natural gas savings (NYSERDA 2008b). However, spending data was not adjusted to account for these non-electricity costs due to a lack of information about the contributions to natural gas savings among individual programs.

[8] Funds spent in 2006 were calculated by subtracting the cumulative funds spent as of 2005 from the cumulative funds spent as of 2006, which came from the 2005 and 2006 New York Energy $mart annual reports (NYSERDA 2006, NYSERDA 2007a), respectively. Similarly, annualized energy savings from measures installed in 2006 were calculated by using the cumulative annual energy savings in 2005 and 2006, obtained from a New York Energy $mart Quarterly Report (NYSERDA 2007b).

10.1.5.3 Cost-Effectiveness

NYSERDA spent a total of $109 million on energy-efficiency in 2006, excluding Research and Development (R&D) (NYSERDA 2008b). Figure 10.3 shows adjusted program and customer costs per kWh saved for the New York Energy $mart commercial/industrial programs for which estimated energy savings are calculated.[10] The height of each bar represents the total adjusted cost (sum of program and customer costs) divided into program costs and customer costs. For the commercial/industrial programs, adjusted program costs range from $0.002/kWh saved for the FlexTech program to $0.024/kWh saved for Peak Load Management. Adjusted customer costs range from $0.002/kWh saved for Business Partners to $0.014 for FlexTech.

Figure 10.3. New York Energy $mart 2006 Adjusted Program and Customer Costs per kWh Saved for Commercial/Industrial Programs. The Sum of Program and Customer Costs (total height of bars) Indicates Total Out of Pocket Costs Attributable to the Programs



	Peak Load Management	Enhanced C/I Performance	Business Partners	High Performance New Buildings	FlexTech Technical Assistance
Customer Costs*	0.010	0.011	0.002	0.006	0.014
Program Costs*	0.024	0.012	0.008	0.009	0.002

*adjusted for the present value of the lifetime energy savings

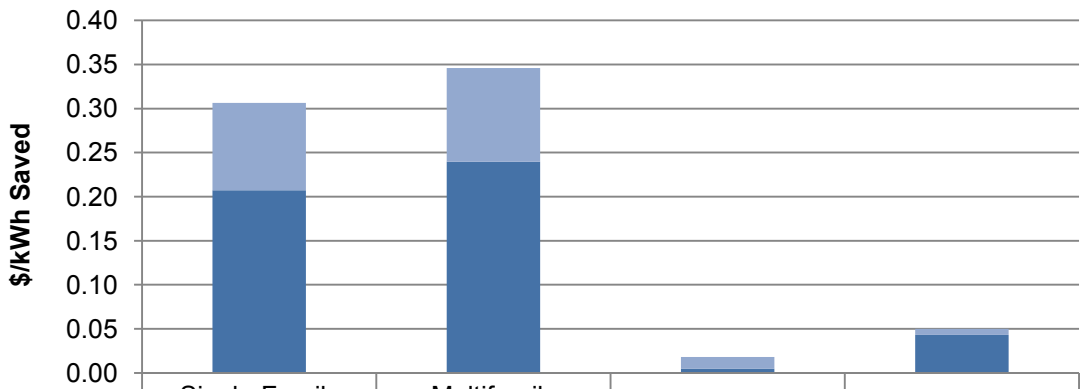
Sources: NYSERDA 2006; NYSERDA 2007a; NYSERDA 2007b

The example of the FlexTech program demonstrates the importance of examining total costs (sum of program and customer costs) in addition to costs solely attributed to the administering agency. While the FlexTech program is by far the most cost-effective of NYSERDA's commercial/industrial programs based on adjusted program costs, the Business Partners and High Performance New Buildings programs are more cost-effective when customer costs are included. In addition, it is useful to note that while the Peak Load Management program has the highest adjusted cost per kWh saved (on both a program cost and total cost basis), reducing peak load can produce substantial benefits in terms of lower electricity costs.

Figure 10.4 shows adjusted program and customer costs per kWh saved for the New York Energy $mart residential/low-income programs for which estimated energy savings are calculated. Adjusted program costs range from $0.005/kWh saved for the Market Support program to $0.24/kWh saved for Multifamily Building Performance. Adjusted customer costs range from $0.007/kWh saved for EmPower New York to $0.106 for Multifamily Building Performance.

[10] For the Peak Load Management program, the reported savings only include permanent demand reductions.

Figure 10.4. New York Energy $mart 2006 Adjusted Program and Customer Costs per kWh Saved for Residential/low-income Programs



	Single Family Home Performance	Multifamily Building Performance	Market Support Residential	EmPower New York
Customer Costs*	0.099	0.106	0.013	0.007
Program Costs*	0.207	0.240	0.005	0.043

*adjusted for the present value of the lifetime energy savings

Sources: NYSERDA 2006; NYSERDA 2007a; NYSERDA 2007b

The Market Support Residential program is likely the most cost-effective of NYSERDA's residential programs because of its focus on increasing the supply of ENERGY STAR products rather than on efficiency improvements in individual homes or multifamily buildings, which require a great amount of technical assistance. Because they are driven by policy considerations other than cost, low-income programs are often not as cost-effective as other residential programs. NYSERDA's EmPOWER New York program tries to achieve greater cost-effectiveness by focusing efforts on lighting and refrigerator replacement and prioritizing projects based on the potential for cost-effective energy usage reduction (NYSERDA 2008a).

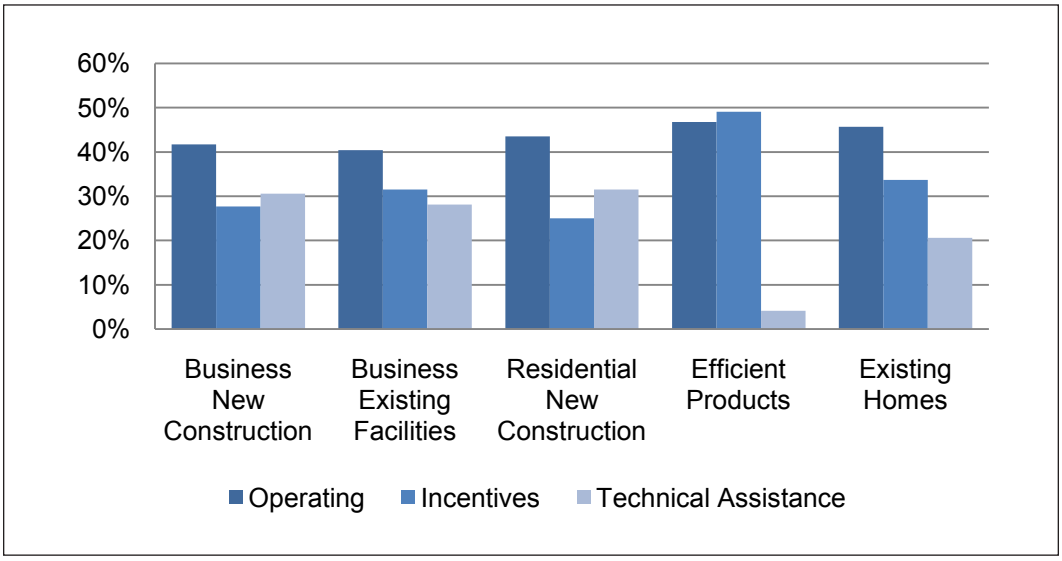
10.1.6 Vermont

10.1.6.1 Overview

Efficiency Vermont is a non-profit corporation that acts as an "Energy Efficiency Utility" and is responsible for program administration, design, and implementation. Efficiency Vermont is funded by a systems benefit charge of about $0.005/kWh (U.S. DOE, 2007). Efficiency Vermont has five general program areas: business new construction, business existing facilities, residential new construction, efficient products, and existing homes. A brief description of these programs is provided in Appendix F.

Figure 10.5 shows Efficiency Vermont's budget divided into operating, incentive, and technical assistance costs for each of the five programs. Operating costs are between 40-47 percent of total costs for all programs and represent the largest portion of costs for all programs except Efficient Products. Incentive costs range from 25 percent for Residential New Construction to 49 percent for Efficient Products, and technical assistance costs range from 4 percent for Efficient Products to 32 percent for Residential New Construction. In comparing new construction to existing buildings, in both the commercial/industrial and residential programs, the new construction programs allocate a greater portion of funds to technical assistance and less to incentives.

Figure 10.5. Efficiency Vermont 2006 Operating, Incentive, and Technical Assistance Costs for Each Program Area

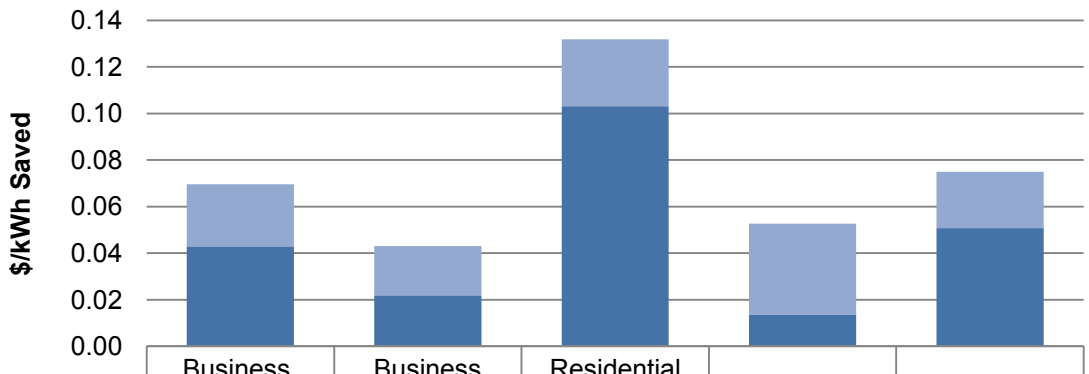


Source: Efficiency Vermont, 2007.

These data show that programs can vary widely in terms of the relative amounts of administrative and technical labor involved as well as incentive payments. For example, less than 5 percent of total program costs for the Efficient Products program are allocated to technical assistance while for the other four Efficiency Vermont programs, technical assistance contributes at least 20 percent of total program costs. This suggests that for some programs such as those that encourage the purchase of CFLs, efforts are best targeted towards marketing and reducing the capital cost for customers, while for other programs such as new construction, a large share of costs may need to be directed towards quality technical assistance.

Figure 10.6 shows adjusted program and customer costs per kWh saved for all five Efficiency Vermont programs. Data on costs and energy savings came from Efficiency Vermont's 2006 annual report. Adjusted program costs range from $0.013/kWh saved for Efficient Products to $0.103 for Residential New Construction. Adjusted customer costs range from $0.021/kWh of electricity saved for Business Existing Facilities to $0.039 for Efficient Products.

Figure 10.6. Efficiency Vermont 2006 Adjusted Program and Customer Costs per kWh Saved



	Business New Construction	Business Existing Facilities	Residential New Construction	Efficient Products	Existing Homes
Customer Costs*	0.027	0.021	0.029	0.039	0.024
Program Costs*	0.043	0.022	0.103	0.013	0.051

*adjusted for the present value of the lifetime energy savings

Source: Efficiency Vermont, 2007.

It is generally assumed that installing efficiency measures during construction is more cost-effective than making efficiency improvements once a home or building is already built. However, in the case of Efficiency Vermont's programs, for both the residential and commercial/industrial sectors, the programs for existing buildings are actually more cost-effective than the new construction programs. There are several contributing factors to this counterintuitive data. According to Efficiency Vermont, a downturn in the new construction industry contributed to a greater number of small projects in the Business New Construction program resulting in lowered savings per project. In the residential sector, Efficiency Vermont noted changes to the ENERGY STAR Home specifications and the Residential Energy Services Network (RESNET) that increased implementation challenges and likely contributed to increased costs for new construction projects. In addition, in the existing home market, Efficiency Vermont is increasingly focusing on supporting other energy service and product providers such as Home Performance with ENERGY STAR contractors rather than providing direct services (Efficiency Vermont, 2007). Given these recent experiences in Vermont, program managers and policy makers in Maryland may wish to consider similar approaches when targeting new constructions and existing homes.

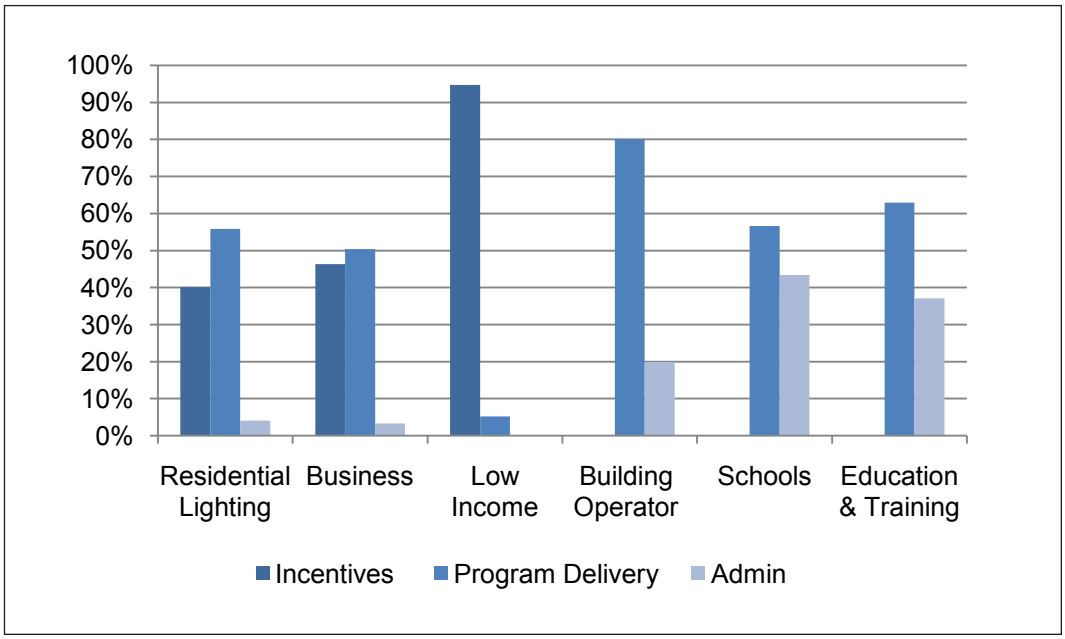
10.1.7 Maine

10.1.7.1 Overview

Efficiency Maine, established in 2002, is funded by electricity customers and administered by the Maine Public Utilities Commission. The self-stated objectives of Efficiency Maine include increasing consumer awareness of cost-effective options for conserving energy, creating more favorable market conditions for the increased use of efficient products and services, promoting sustainable economic development and reduced environmental damage, and reducing the price of electricity over time for all consumers (Efficiency Maine, 2006a). Efficiency Maine has six program areas: residential lighting, business, low income, building operator certification, high performance schools, and education and training. A brief description of these programs is provided in Appendix F.

Figure 10.7 shows Efficiency Maine incentives, program delivery, and administration costs as a percentage of total costs for each of the six programs. Incentive costs only contribute to the budget for the Residential Lighting, Business, and Low Income programs and range from 40 percent for Residential Lighting to 95 percent for Low Income. Program delivery costs range from 5 percent for Low Income to 80 percent for Building Operator Certification. Administrative costs make up only 0.2 percent of the budget for the Low Income program and are highest for the High Performing Schools and Education & Training programs at 43 percent and 37 percent, respectively.

Figure 10.7. Efficiency Maine Incentives, Program Delivery, and Administrative Costs for Each Program Area for 2006

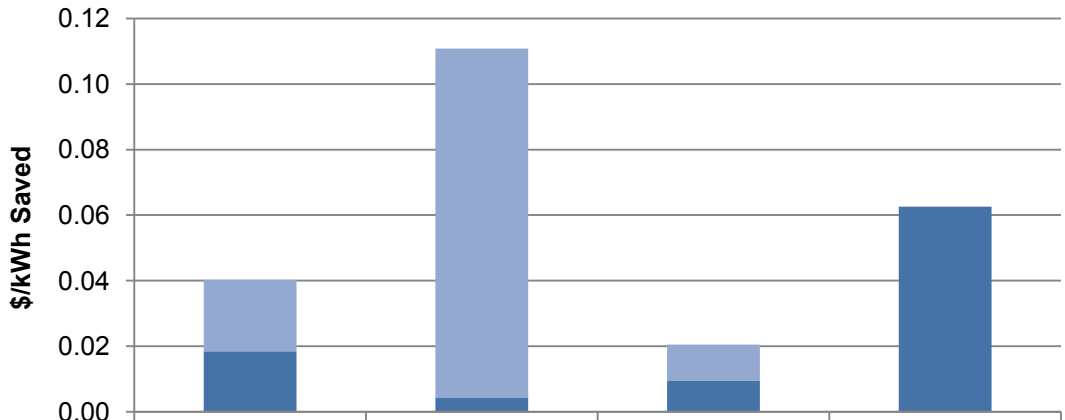


Source: Efficiency Maine, 2006b.

These data show that the goals of different efficiency programs result in varying cost allocation. For example, programs that focus on market transformation through education and training to create demand for efficiency products and services generally do not require incentives for capital, but often involve substantial administrative, marketing, and advertising costs.

Figure 10.8 shows adjusted program and customer costs per kWh saved for Efficiency Maine's programs for which data on energy savings is available. Data on costs and energy savings came from Efficiency Maine's 2006 annual report. Adjusted program costs range from $0.004/kWh saved for Building Operator Certification to $0.063 for Low Income. Adjusted customer costs range from zero for Low Income to $0.106 for Building Operator Certification.

Figure 10.8. Efficiency Maine Adjusted Program and Customer Costs per kWh Saved for 2006



	Business	Building Operator	Residential Lighting	Low Income
Customer Costs*	0.022	0.106	0.011	0.000
Program Costs*	0.018	0.004	0.010	0.063

*adjusted for the present value of the lifetime energy savings

Source: Efficiency Maine, 2006b.

From the perspective of Efficiency Maine, the cost of the Building Operator program is very low compared to the estimated energy savings. However, because the participants in the training pay the majority of the cost, the total cost per kWh saved is greater than for the other Efficiency Maine programs. Therefore, the Building Operator program demonstrates a program that is very cost-effective for the administering organization, but that is not cost-effective compared to other programs from a more general societal perspective.

The program cost per kWh saved is the greatest for the Low Income program since customers do not pay any of the cost. However, as mentioned previously, cost-effectiveness is only one measure of program effectiveness, and an important goal of State governments is often to specifically target assistance to low-income residents, which can justify a higher program cost compared to energy saved.

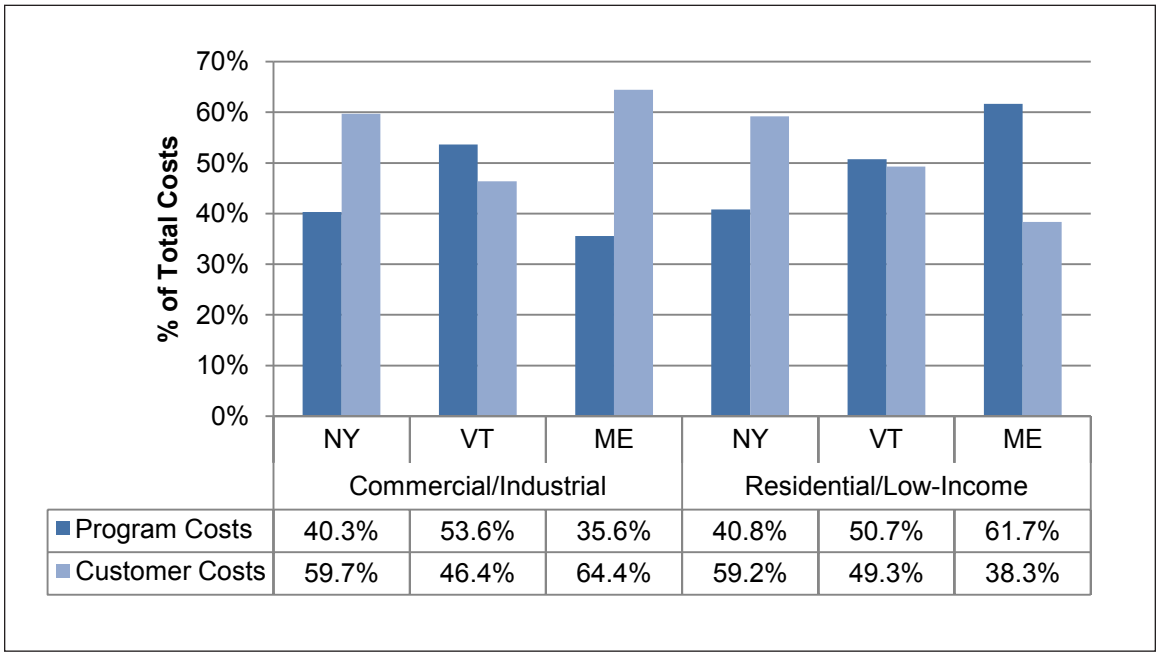
10.1.8 Analysis of Program Costs

10.1.8.1 Program vs. Customer Costs

Figure 10.9 shows a comparison of program and customer costs as a percentage of total costs for each of the three states by sector.[11] In the commercial/industrial sector, in New York and Maine, customers pay between 60-64 percent of the total costs while in Vermont customers pay less than 50 percent of the total costs. In the residential/low-income sector, New York is the only state in which customers pay a larger percentage of the total costs (59 percent). In Vermont, Efficiency Vermont and customers pay almost equal portions of the total costs whereas in Maine, customers only pay 38 percent of the total cost. The low portion of total costs paid by residential customers in Maine is likely due to the Low Income program where there is no customer contribution. The only other residential program in Maine is the Residential Lighting program.

[11] Data for Vermont and Maine is from 2006 while data from New York is from a report (Heschong Mahone Group) released in 2005.

Figure 10.9. Program and Customer Costs as a Percentage of Total Costs



Sources: Heschong Mahone Group, 2005; Efficiency Vermont, 2007; Efficiency Maine, 2006b.

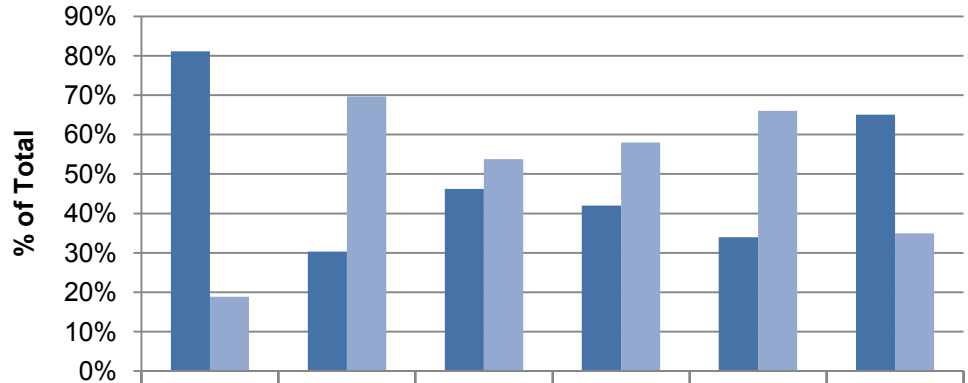
These data again address the issue of cost-effectiveness from the perspective of the administering organization versus that of the society. Customers will likely perceive the costs of programs very differently depending on their relative contribution to the cost even if the total cost per kWh saved is identical. At the same time, in designing efficiency programs, an important consideration is the level of incentives necessary to attract a large number of customers without giving financial incentives that are unnecessarily high, which could instead be allocated to a program component that would yield greater energy savings.

10.1.8.2 Program Administration Costs vs. Incentive Costs

Figure 10.10 shows incentives and program administration costs as a percentage of total costs of the administering organizations in the three states by sector.[12] In the commercial/industrial sector, more than 80 percent of the funds in New York go towards incentive payments while in Vermont and Maine, only 30 percent and 46 percent of total funds are allotted to incentives. In the residential sector, more than 50 percent of total funds in New York and Vermont are dedicated to program administration while in Maine more than 60 percent of funds go towards incentive payments.

[12] Data from Vermont and Maine is from 2006 while data from New York is from a report (Heschong Mahone Group) released in 2005.

Figure 10.10. Program Administration and Incentive Costs as a Percentage of Total Costs



	Commercial/Industrial			Residential/Low-Income		
	NY	VT	ME	NY	VT	ME
Incentives	81.1%	30.3%	46.3%	42.0%	34.0%	65.1%
Program Administration	18.9%	69.7%	53.7%	58.0%	66.0%	34.9%

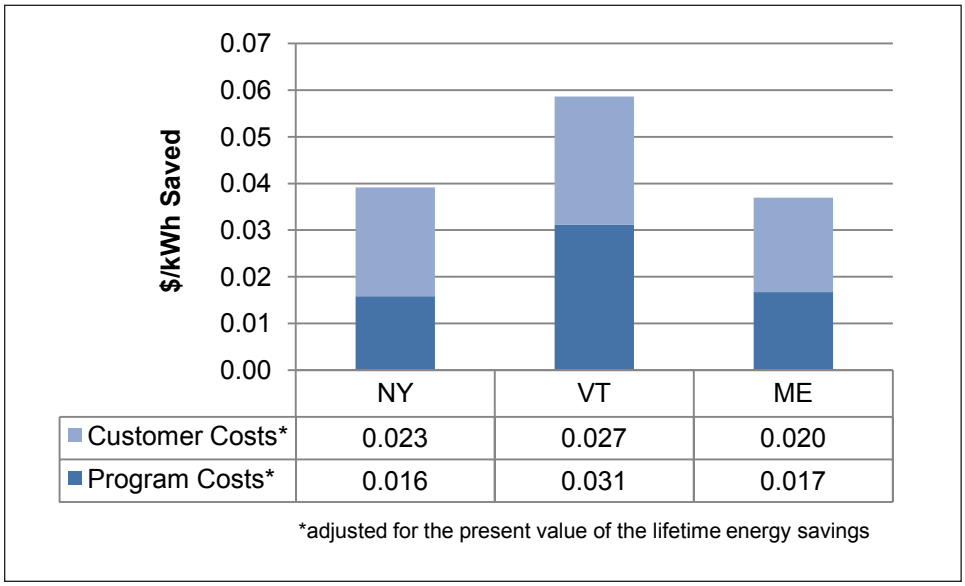
Sources: Heschong Mahone Group, 2005; Efficiency Vermont, 2007; Efficiency Maine, 2006b.

These data show that the percentage of program costs allocated to program administration and incentives vary widely among the three State programs. This is likely due in part to the different portfolios of programs, some of which are more focused on prescriptive incentives while others concentrate more on customized projects and technical assistance. This suggests that in developing a set of efficiency programs for Maryland, the relative portion of funds allocated to program administration compared to incentives will depend heavily on the suite of programs selected.

10.1.8.3 Comparison of Cost Effectiveness of the Three State Programs

Figure 10.11 shows overall adjusted program and customer costs for the three states. Adjusted program costs for New York and Maine are almost identical at $0.016 and $0.017 per kWh saved, respectively, while Vermont's program costs are $0.031/kWh. Customer costs are similar for all three states, ranging from $0.02/kWh for Maine to $0.027/kWh for Vermont.

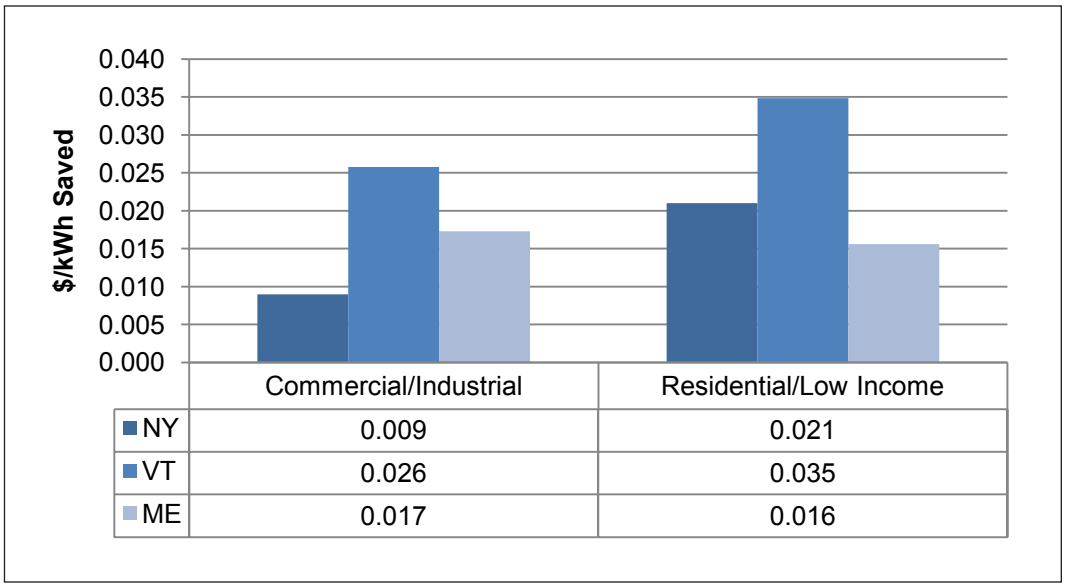
Figure 10.11. Comparison of Cost-effectiveness of the Three State Programs



Sources: NYSERDA 2006; NYSERDA 2007a; NYSERDA 2007b; Efficiency Vermont, 2007; Efficiency Maine, 2006b.

In general, commercial/industrial programs are more cost-effective than residential/low-income programs. Figure 10.12 shows the adjusted program cost per kWh to be lower in the commercial/industrial sector for New York and Vermont, and almost equal for Maine. The explanation for the low program cost per kWh saved of Maine's residential/low-income programs is likely that the residential sector of Efficiency Maine only includes lighting programs and appliance replacements. In contrast, the residential programs in New York and Vermont include programs targeting the new construction sector and comprehensive improvements for existing homes, which require technical assistance and in many cases larger incentive payments.

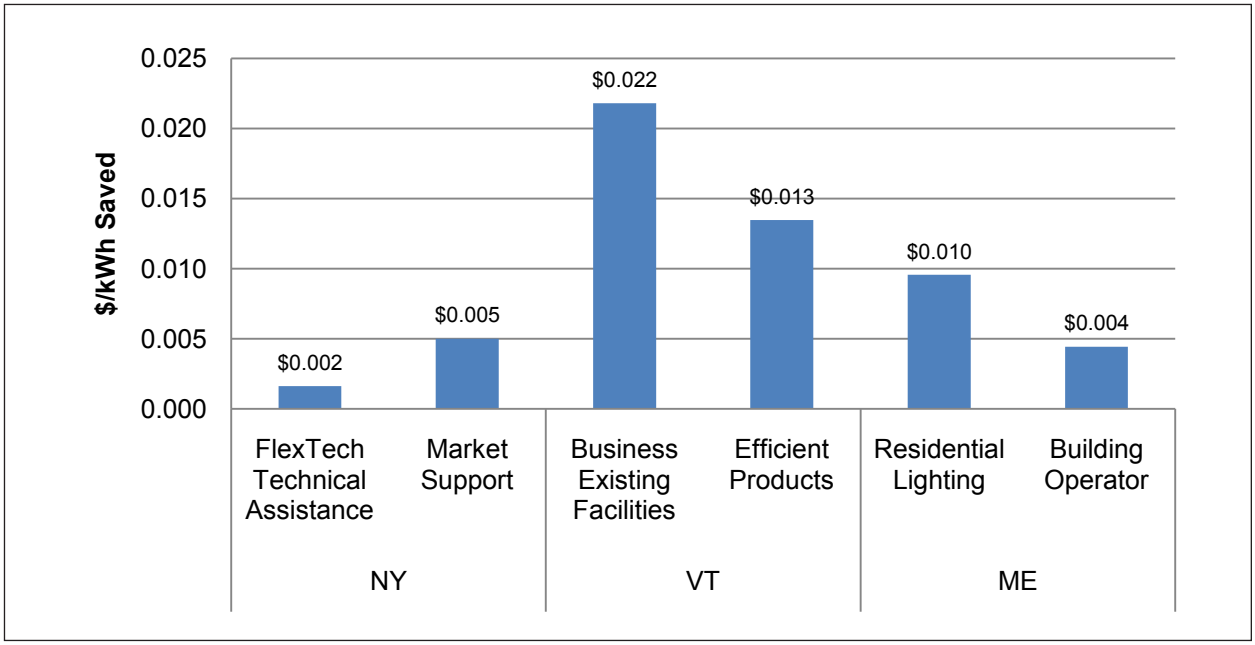
Figure 10.12. Comparison of Adjusted Program Costs Among Sectors



Sources: NYSERDA 2006; NYSERDA 2007a; NYSERDA 2007b; Efficiency Vermont, 2007; Efficiency Maine, 2006b.

Figure 10.13 shows the adjusted program cost per kWh saved of the two most cost-effective programs in each of the three states. The costs of these six programs range from $0.002/kWh saved for NYSERDA's FlexTech Technical Assistance program to $0.022/kWh saved for Efficiency Vermont's Business Existing Facilities program. These programs include three commercial/industrial programs (FlexTech Technical Assistance, Business Existing Facilities, and Building Operator Certification) and three residential programs (Market Support, Efficient Products, and Residential Lighting).

Figure 10.13. The Two Most Cost-Effective Programs in Each of the Three States for 2006 Based on Adjusted Program Cost/kWh Saved



Sources: NYSERDA 2006; NYSERDA 2007a; NYSERDA 2007b; Efficiency Vermont, 2007; Efficiency Maine, 2006b.

These programs show that while commercial/industrial programs in general are usually more cost-effective than residential programs, this does not always apply when analyzing individual programs. Several of the residential programs in the states analyzed have very low program costs compared to the electricity saved. It is also important to note that these programs are not the most cost-effective when examining total costs (including customer costs). For example, the Building Operator program is actually the least cost-effective of Efficiency Maine's programs when customer costs are included.

The data on costs and savings from New York, Vermont, and Maine show that cost-effectiveness varies significantly among individual programs and often varies substantially among sectors. The data also show that it is important to examine not only the cost-effectiveness of individual programs, but also of the portfolio of programs. For example, while NYSERDA's Multifamily Building Performance program ($0.24/kWh) and Single Family Performance Program ($0.21/kWh) have relatively high adjusted program costs per kWh saved compared to other New York Energy $mart programs, the overall portfolio of programs still has a low adjusted program cost of $0.016/kWh saved.

The three states analyzed for this report have demonstrated that efficiency programs can be designed to target all sectors (residential, commercial, and industrial) as well as a wide range of income levels and customer sizes while maintaining relatively low overall program costs compared to estimated electricity savings. These statewide efficiency programs can inform Maryland as the State makes decisions regarding program design and budget allocation.

11 Policy and Implementation Considerations in Developing Energy Efficiency Programs in Maryland

By Iván Darío Valencia, Joanna Mauer, Nate Hultman, Kim Ross, Matthias Ruth, Nicolai Herrmann

This section discusses various factors that should be considered as Maryland develops and implements energy efficiency programs. These factors include the potential public good benefits, financial and administrative considerations and mechanisms, components of comprehensive efficiency programs, and sector specific considerations. These factors, while qualitative and therefore may only be highlighted in an exemplary way, are considered as important as the quantitative results the economic models yielded. Taking into consideration these other factors when shaping policy and implementation decisions surrounding an energy efficiency spending program will only add to the positive impact of the outlined measures.

11.1 Potential Public Good Impacts of Efficiency Programs

Energy efficiency programs are usually designed to achieve public policy goals across several dimensions; nevertheless a significant focus is often on cost effectiveness based on how much electricity is saved per unit of investment (or "the bang for the buck"). Cost-minimization is also a core function for the modeling, described earlier in this report, of a potential energy efficiency program in Maryland. However, other important considerations include potential impacts on electricity bills, greenhouse gas emissions, equity, jobs, energy security and grid reliability, and public health and the environment.

11.1.1 Electricity Bills

The most direct savings induced by increased energy efficiency to individual consumers arise from savings on electricity bills as, obviously, the consumer does not have to pay for electricity that is not used. Retrofitting homes with state-of-the-art efficient appliances, efficient lighting, increased weatherization, and other routine targets of residential and commercial efficiency programs will lead to instant and often substantial reductions in monthly electricity bills. Such reductions (when not charged to the consumer in some way) can be a form of economic stimulus as a reduction in electricity bills increases household purchasing power. (See Table 9.1)

11.1.2 Greenhouse Gas Emissions

Improved efficiency in electricity consumption reduces demand for electricity, but will not reduce greenhouse gas emissions because of the effect of the cap. Unless the RGGI program is not implemented as planned, emissions will not change except for some potential effect from offsets and banking. Since emissions from the combustion of other energy sources are not capped, then end-use efficiency improvements will reduce consumption of those types of energy and will reduce emissions of greenhouse gasses from those sources.

Energy efficiency programs targeting electricity use would not deliver additional CO_2 emission reductions from power generators within the RGGI region beyond the cap because generators can achieve compliance with the cap partly through these measures while avoiding or delaying alternative measures such as fuel-switching, retirement of carbon-intensive power plants, or efficiency improvements in their generating facilities. The results of this report suggest that in all scenarios of investments in energy efficiency, overall CO_2 emissions for the generators under the RGGI cap would remain similar for the RGGI region as a whole. Increasing the level of efficiency investment would reduce CO_2 emissions from generators within Maryland, with these reductions offset by increases in other parts of the RGGI region.

However, some efficiency investments can achieve additional emission reductions by targeting both electricity and other fuels. For example, building weatherization generates electricity savings from air conditioning and natural gas savings from heating. The latter is outside of the purview of RGGI and thus generates additional carbon emission reductions outside the RGGI cap. In this study, the additional emission reduction potential in Maryland from natural gas savings via building weatherization was not quantified, but it could be significant. Emissions reductions achieved through investment in end-use natural gas efficiency can be used as offsets according to the RGGI model rule, and in that case they would be already be counted under the RGGI cap.

If the State wishes to use the RGGI allowance money to achieve further greenhouse gas emission reductions beyond and outside the RGGI cap, investments would need to be made outside of the electricity sector. The transportation sector is one such candidate for consideration because it is not faced with a cap under RGGI, and its emissions comprised 30 percent of Maryland's emissions in 2005 (CCS 2008). Other possibilities include agriculture and energy-intensive industries whose emissions are excluded from RGGI. However, avoided methane emissions from agricultural manure management operations can also be used as an offset.

The analysis of the emission reduction potential or cost-effectiveness of emissions reductions outside of the electricity sector falls outside of the realm of this report, but the State could nonetheless contemplate these as alternative investments for the RGGI revenue.

11.1.3 Equity

One of the main hurdles for the implementation of energy efficiency measures is their upfront cost. As a proportion of income, these costs are generally much higher for low income households and small businesses. Therefore, incentives or subsidies needed for participation of low income groups in these programs are higher. Tiered requirements for programs may be necessary to encourage participation among all income levels and customer sizes. Variation in the mechanisms (rebates, loans, grants, tax incentives, etc.) is also important because not all of them are equally favorable to different customers, and under some circumstances, perverse outcomes may result. For example, if support to low-income households for efficiency programs is not strong enough, they may not take advantage of the programs and inadvertently help efficiency gains and cost savings among higher income households who are more likely to take advantage of efficiency programs (Ruth, Bernier, Meier, Laitner 2007).

Equity considerations also include program funding availability across customer classes. According to Eto et al., equity ensures that efficiency programs are available to all customer classes (residential, small commercial, large commercial, industrial) to allow for equal opportunity to reduce electricity bills. Eto et al. argue that in situations where the private sector is already providing energy efficiency services to certain customer classes, it is appropriate for publicly funded efficiency programs to target market segments that are unlikely to benefit from these private sector activities (1998).

11.1.4 Job Creation

Energy efficiency investments can result in positive macroeconomic impacts including job creation in addition to environmental and ratepayer benefits. A macroeconomic analysis conducted by NYSERDA estimated that the New York Energy $mart programs have created and sustained 3,700 jobs since 1999 (NYSERDA 2007). According to an analysis by ACEEE, expanded energy efficiency in Maryland to meet the EmPOWER goal has the potential to create more than 8,000 jobs by 2015 and more than 12,000 jobs by 2025 (Eldridge et al., 2008). (See Table 9.8 and Figures 9.1 and 9.2)

11.1.5 Energy Security and Grid Reliability

Energy efficiency investments can help improve grid reliability through a decrease in peak load and overall base load. It is important to note that peak load management is a principal concern of the Public Service Commission and the Maryland utilities. Furthermore, the newly legislated EmPOWER Maryland goal gives utilities full responsibility to achieve the 15 percent reduction in peak load per capita by 2015 (MD General Assembly 2008).

11.1.6 Public Health and Secondary Environmental Impacts

There are some potential negative environmental consequences of energy efficiency programs that should not be ignored. For example, CFLs have small amounts of mercury that can be hazardous if CFLs are broken and not remediated properly. New York, California, Florida and Minnesota, plus five New England states require that all CFLs be recycled. In Maryland, there are CFL recycling programs for only 10 of Maryland's 24 local jurisdictions (Roylance 2008). Contractors, retailers and ESCOs are possible partners in this effort of channeling the CFL and appliance waste stream into recycling instead of landfills. The state could also accompany energy efficiency education with public information about recycling of old appliances and CFLs. Furthermore, given that disposed appliances and electronics sometimes end up being exported for recycling abroad, potential impacts on developing countries could be examined.

11.2 Financial and Administrative Considerations

11.2.1 Allocation of Revenue

One of the directives of the Maryland Energy Strategic Investment Fund is to directly mitigate the impact of higher electricity prices on ratepayers, which are present due to increased demand, increased transmission congestion, higher generation costs and the introduction of emission certificates as a new production factor to generators. Although rebates benefit customers immediately and are sometimes necessary, particularly in the event of sudden price hikes, they also can act as a disincentive to energy conservation. If rebates are implemented as an electricity consumption subsidy tied to the level of consumption, then they could actually lead to an increase in overall consumption. Rebates on electricity bills to reduce short-term impacts on consumers miss opportunities to change behaviors, reduce energy use, and cut costs over long time frames. In order to avoid maintaining and locking in behaviors and equipment choices that keep energy use high, a program could evaluate the energy consumption impact of direct consumer rebates.

11.2.2 Financial Considerations

In order to achieve energy demand reductions in the short run and lay the groundwork for more substantial efficiency gains in the future, it is reasonable to grasp the "low-hanging fruit" of energy efficiency first. Exploiting remaining efficiency opportunities may require the combination of an aggressive marketing campaign with adequate financial incentives.

One approach would be to develop a diversified portfolio of efficiency policies that incorporate activities targeting areas of high risk but high possible return, and other sectors targeting areas of lower risk and more secure returns. There could also be a balance between long-term programs and one time projects, as well as with programs that yield short-term energy savings with those that give a longer-term return (e.g. research and development of renewable energy). Too little is known from existing programs and the scientific literature, however, to help identify the potential mix and balance of portfolio elements. As a consequence, as the state breaks new ground when building its programs, it will be advantageous to carefully monitor and document the experiences and allow for program adjustments as experiences are gained.

Given that the RGGI funds come from auctions, the revenue cannot be exactly forecasted due to fluctuations in allowance price and auction volume. The state might therefore consider mechanisms to stabilize the funding stream. Potential mechanisms to stabilize funding include:

a. Using part of the fund for revolving low-interest loans so that the payments received from loans help compensate for sudden sharp drops in auction revenue.

b. Planning funding appropriations with different scenarios, including a low-end and a high-end scenario. The low-end scenario would have a low auction price.

c. Within the discretionary margin for money allocation of the fund, having a subset of high priority programs guaranteed under all funding scenarios, whereas others would be funded only with the availability of revenue beyond a certain threshold.

11.2.3 Governance Structure

Energy efficiency programs can be administered by utilities, a state agency, or an independent agency, and successful examples exist of all three governance structures. According to an analysis by the Regulatory Assistance Project of the administration and implementation of efficiency programs, the following three criteria are essential for successful energy efficiency programs, regardless of the administrative structure (Harrington and Murray, 2003):

- Clarity of stated purpose at every level.
- Consistency of policy over time.
- Consensus of key stakeholders as to goals and structure as well as program design, measurement metrics, and performance based regulation.

Energy efficiency experts interviewed for this report added that considerations for success in any governance model include:

- Effective oversight to assure accountability such as through an advisory board or overseeing entity.
- Transparency in the administration of funds.
- Comprehensive monitoring and evaluation of programs.

A Lawrence Berkeley National Laboratory analysis evaluated the benefits and challenges of the three administrative structures, a summary of which are presented in Table 11.1 (Blumstein et al., 2005). It was found that utilities often have a trusted position with customers, the benefit of experience and are able to take advantage of economies of scale. However, utility-administered programs can present conflicts of interest since electricity sales are the main source of utilities' revenues and profits. In addition, the incentives required to motivate utility performance are high, and utilities are usually not well positioned to serve hard-to-reach customers. Since utilities in Maryland have not implemented efficiency programs since 1998, Maryland utilities may not have the same benefit of experience as utilities in other states.

State agencies such as NYSERDA do not have the perceived conflicts of interest, as do utilities. A state agency model offers end users and service providers consistent statewide programs and facilitates the ability to respond to short-term generation shortfalls and transmission constraints. Furthermore, state agencies might be able to address equity-related issues such as equity of subsidies among households of varying income levels. However, administrative challenges for a state agency model can include constraints imposed by staffing limitations or bureaucratic procurement requirements as well as a suboptimal allocation of funds due to political pressure.

An independent agency model, like that of Efficiency Vermont, has the benefit of having the delivery of efficiency programs as its sole mission. However, this governance model often involves the creation of a completely new organization and therefore would likely not have the same experience as utilities or a state agency. Since Maryland has comparatively little experience with broad, institutionalized promotion of energy efficiency to start with, the comparative disadvantages, which may have been present elsewhere when establishing an independent agency alongside existing state agencies, may not apply.

Table 11.1. Benefits and Challenges of Program Administration by Utilities, State Agencies, and Independent Agencies

Administering Organization	Benefits	Challenges
Utilities	Trusted position with customers and market entities; economies of scale and scope; experience	Perceived conflicts of interest; incentives required to motivate performance can be high; not well-positioned to serve hard-to-reach customers
State Agency	No perceived conflicts of interest; offers end users and service providers consistent statewide programs; ability to respond to short-term generation shortfalls and transmission constraints	Potential problems of state government administration including difficulties in focusing on a new mission, constraints imposed by staffing limitations or bureaucratic procurement requirements, challenges of providing effective incentives, and the potential for suboptimal allocation of funds or mix of programs due to political pressure
Independent Agency	Sole mission is delivery of energy efficiency programs; alignment of administrator objectives/mission with public policy	Challenge of creating an acceptable governance mechanism and establishing a well-respected, trusted administrator with a significantly expanded scope of activities for existing staff or creating a new organization

Source: Blumstein et al., 2005

Energy efficiency encompasses both resource acquisition and market transformation. Resource acquisition refers to providing technical assistance, information, and financial incentives to individual customers to encourage the adoption of efficiency measures. Because of their access to customers, utilities can serve as effective administrators of efficiency programs. The effectiveness of resource acquisition programs is also relatively easy to measure, allowing for utility accountability.

Market transformation, rather than targeting individual customers, focuses on making lasting changes in markets for energy-consuming goods and services. The goal of market transformation is to remove market barriers including high customer discount rates, split incentives, lack of information, and high upfront costs (Harrington and Murray, 2003). Market transformation includes encouraging retailers, distributors, contractors, and builders to promote energy efficiency and targeting education and training efforts at key consumer and business decision points. Programs emphasizing market

transformation often target suppliers rather than individual customers, and program success is more difficult to measure. Blumstein et al. argue that if resource acquisition and market transformation are viewed as complements, more arrangements may emerge where a single-purpose regional agency administers market transformation programs and utilities or non-utility entities administer resource acquisition programs (2005).

Maryland is adopting a hybrid approach, giving responsibilities for energy efficiency to utilities and MEA, whereas peak load management rests mostly with utilities, and renewable energy programs with MEA. The hybrid approach has the advantage of utilizing current resources and administrative structures, and in that sense the ramp-up period for programs to become operational should be shorter than if a new entity had to be created or the programs reallocated. However, the hybrid model demands sufficient coordination so that utilities' and MEA's efforts complement each other rather than overlap, do not generate confusion among clients, and still leave space for private sector involvement. In addition, energy efficiency experts stressed that in order to have a successful utility-state partnership, it is important to have good communication between the parties, aligned incentives to encourage cooperation rather than competition, clear accountability, and oversight by the same group.

11.3 Financial Mechanisms for Efficiency Programs

Efficiency programs generally involve financial incentives to encourage customer participation. These financial incentives include rebates, retailer buy-downs, loans, and financing schemes through private sector collaboration, which are summarized in Table 11.2.

Table 11.2. Financial Mechanisms for Efficiency Programs

Mechanism	Description	Examples/Lesson
Rebates	Incentives given to customers for the purchase and/or installation of specific efficiency measures	Efficiency Vermont's Efficient Products program offers instant coupons for lighting and ceiling fans and mail-in rebates for certain appliances
Retailer Buy-Downs	Incentives given to retailers to reduce the in-store price of efficiency measures	Efficiency Vermont found that buy-downs were well-received by both retailers and customers and were preferable to coupons
Loans	Funding mechanism to finance energy efficiency improvements through preferential interest rates	Through NYSERDA's Loan Fund and Financing program, lenders and leasing agencies reduce the interest rates on energy-related loans in exchange for a lump sum subsidy
Innovative Financing Schemes	Private sector financing instruments to reduce the upfront costs of energy efficiency improvements, including shared savings contracts	Energy Service Company (ESCO) model where the ESCO recoups their investment via the energy savings generated

11.3.1 Rebates

Rebates are a common mechanism for encouraging the adoption of energy efficiency measures. Rebates are given to customers after the purchase and/or installation of specific efficiency measures. In 2006, Efficiency Vermont's Efficient Products program offered $10 instant coupons for lighting fixtures, ceiling fans, torchieres, and floor lamps. A $50 mail-in rebate was offered for a selected group of ENERGY STAR qualified clothes washing machines, and a $25 rebate was provided for ENERGY STAR qualified air conditioners (Efficiency Vermont, 2007). The effectiveness of rebate programs largely depends on administrative cost, the extent to which it supports free riders, and the resulting overall efficiency

improvements relative to the rebate amounts. No adequate empirical information is available to quantify for specific rebate programs or across programs their overall cost effectiveness.

11.3.2 Retailer Buy-Downs

Retailer buy-downs refer to programs where incentives are given to retailers rather than customers to reduce the in-store price of efficiency measures such as light bulbs and appliances. A component of Efficiency Vermont's Efficient Products program uses negotiated cooperative agreements, or buy-downs, to lower the price of CFLs without the need for customer coupons. Efficiency Vermont reported that this approach was well received by retailers, who indicated that it was easier for both them and their customers and was preferable to coupons. Efficiency Vermont also partners with hardware stores for advertising and store promotions for CFLs (Efficiency Vermont, 2007).

11.3.3 Loans

Revolving loan funds are a common instrument to finance energy efficiency improvements and overcome the upfront costs of auditing and installation. These loans, with preferential interest rates, are convenient for customers that might not qualify for regular commercial loans or whose investment decision require pay-back times that are much shorter than can be realized with current loan programs.

Several other alternatives exist for the state, beyond directly financing loans. For instance, it can provide the collateral for energy efficiency loans taken by an agency or local government, so that these entities can afford commercial loans. This approach was suggested by the Maryland Commission on Climate Change (Maryland Climate Change Advisory Group, 2008) and can be an alternative to the Energy Performance Contracting (EPC), in the cases where it is preferable, such as small facilities where EPC is not functional.

NYSERDA's New York Energy $mart Loan Fund and Financing program aims to increase the availability of low-interest capital for energy efficiency equipment and process improvements. The Loan Fund and Financing program targets lenders and leasing agencies, which enroll in the program by agreeing to reduce the interest rates on energy-related loans in exchange for a lump sum subsidy paid by NYSERDA. The program also involves training activities including developing tools to allow lenders to calculate the monetary savings their customers will receive from making efficiency improvements (NYSERDA 2007).

11.3.4 Innovative Financing Schemes Through the Private Sector

There are various instruments of innovative financing for energy efficiency, aimed at reducing the burden of the upfront costs. One of the most common is the concept of shared savings, where Energy Service Companies (ESCOs) install efficiency measures and recoup their investments via the energy savings generated through the measures. The consumer does not face an upfront cost, but instead pays the ESCO with amounts corresponding to a share of the electricity savings. After a period of time when the ESCO has been paid through the savings, usually around 5 years, these revert completely to the customer. Shared savings contracts, like the Energy Performance Contracting in Maryland, are attractive for the private sector with large consumers, but not very cost-effective with smaller consumers. With partnerships with the private sector, public funds can leverage a larger impact for energy efficiency, filling the financing gaps between what is profitable for business and affordable to consumers.

11.4 Components of Comprehensive Efficiency Programs

Financial mechanisms can reduce upfront costs of efficiency measures. However, comprehensive efficiency programs go beyond mere financial incentives to also include energy audits, technical assistance, education and training, marketing, and monitoring and evaluation. Table 11.3 lists some of these components and examples of their use.

Table 11.3. Features of Comprehensive Efficiency Programs

Program Component	Examples/Lessons
Energy Audits	• Farmers in Maryland reported that energy audits conducted by MEA have been popular • Efficiency Vermont stopped providing home energy audits in 2006 in order to promote work for certified contractors
Technical Assistance	• Efficiency Vermont considers the technical assistance they provide to be the key factor in the success of the Residential New Construction program and the reason why builders continue to participate
Education and Training	• Encouraging behavior changes such as taking shorter showers, turning off unused lights, lowering thermostats, and using cold water for laundry • Efficiency Maine's Building Operator Certification program offers training for facility managers to improve energy efficiency, reduce maintenance costs, and enhance building occupant comfort
Marketing	• NYSERDA's Energy Smart Focus program is a marketing effort targeting specific sectors including industrial manufacturing, municipal water/wastewater, and colleges and universities • California's "Flex Your Power" and New York's "Get Energy Smart" are statewide efficiency "brands" that provide a single portal for customer access to efficiency programs
Monitoring and Evaluation	• The International Performance and Measurement Verification Protocol (IPMVP) is the accepted industry standard used by ESCOs and provides an overview of current best practice techniques available for verifying results of energy efficiency projects • In estimating energy savings, it is important to include free rider, spillover, and rebound effects (See Section 10.1.4.5.4 for more information)

11.4.1 Energy Audits

Energy audits typically are a first step for implementing targeted energy efficiency measures in buildings. An audit assesses how much energy a building or operation consumes and identifies possible measures to improve energy efficiency. Gillingham et al. (2006) reported findings that industries significantly increased their investments in energy efficiency after receiving energy audits. Many ESCOs base their business model on conducting audits and then have customers pay for the audit through the shared savings embedded in the utility bills.

Free or subsidized audits can introduce energy efficiency into new sectors. In Maryland, farmers contacted for this study reported that energy audits conducted by MEA have been welcomed for the perceived or actual value they had in reducing the energy cost of their operations.

An integral component of Efficiency Vermont's Home Performance with ENERGY STAR program is the energy audit, conducted by certified contractors, which includes assistance with prioritizing efficiency improvements and access to discount financing for energy-efficient home improvement loans. The program includes training sessions for contractors as well as free sessions for contractors preparing for their certification exams. Efficiency Vermont has also marketed the program heavily to encourage more homeowners to participate (Efficiency Vermont, 2007).

Although free audits can reach consumers who otherwise might not participate in efficiency programs, they can be very costly, compared to the resulting energy savings if consumers do not implement the efficiency recommendations. In order to minimize wasted free audits, some ESCO's only write-off the cost of the audit if the customer pursues the repairs with the ESCO[1], not by itself or with another ESCO that didn't perform the audit. Another side effect of free government audits

[1] As reported in the Energy Efficiency Global Forum, Washington DC, 2007

may be to drive away private businesses conducting audits because of competition from the State. An energy consultant interviewed for this study explained that NYSERDA was doing such a comprehensive job that private energy consultants had no market in New York. Efficiency Vermont stopped providing home energy audits in 2006 in order to support their overall strategy of promoting work for certified contractors (Efficiency Vermont, 2007).

In contrast, programs that subsidize efficiency measures but not audits face the hurdle of the upfront cost of audits for consumers. Subsidies for energy audits can take various forms such as rebates, inclusion in loan or grant costs, and shared savings through ESCOs. The State could attempt to balance the need to reach customers with the leverage of market transformation without absorbing the market entirely.

11.4.2 Technical Assistance

Lack of technical knowledge can be a significant market barrier to efficiency investments. Technical assistance can therefore be an important mechanism for encouraging adoption of efficiency measures within the residential, commercial, and industrial sectors. Many successful efficiency programs combine technical assistance with financial incentives.

An example of technical assistance in the residential sector is Efficiency Vermont's Residential New Construction program. The program provides one-on-one direct technical assistance to builders, their subcontractors, and trade allies. Technical assistance is initiated early in the planning and construction process and includes assistance in setting project energy objectives; preliminary plan reviews; determining an appropriate energy rating; and preparing detailed energy and economic analyses (York et al. 2008). Efficiency Vermont considers the technical assistance they provide to be the key factor in the success of the Residential New Construction program and the reason why builders continue to participate.

11.4.3 Education and Training

Education and training often comprise an integral part of comprehensive portfolios of efficiency programs. While it is often not possible to measure the energy savings, education and training can encourage awareness of the benefits of energy efficiency and can lead to improved energy management in facilities. Education and training activities often target specific audiences such as schools, facility managers, or contractors.

NYSERDA's Communities and Education program has the expressed goal of creating a more energy-conscious society in New York. The program includes two components: (1) educating teachers, students, homeowners, representatives of community-based organizations, and community leaders on various energy topics including efficiency; and (2) making them aware of New York Energy $mart programs. One focus of the program is targeting K-12 students by providing workshops and an energy curriculum for teachers. The program's community outreach includes recruiting builders, contractors, realtors, code officials, architects, engineers, and others into the residential programs as mid-stream partners (NYSERDA 2007).

Education promoting behavior changes such as taking shorter showers, turning off unused lights, lowering thermostats, and using cold water for laundry can be an important strategy complementing efficiency investments to reduce energy use. In a study in the Netherlands, Poortinga et al. (2003) found that technical measures to reduce energy use were relatively more acceptable to people with higher income and levels of education than those with low or average income and lower levels of education, who found behavioral measures more palatable. One possible reason for this is that technical measures demand an initial investment that represents a greater burden for lower income groups, whereas behavioral measures do not involve any monetary cost and result in immediate energy savings. The study found surprisingly that the level of energy savings achieved by different measures did not influence their acceptability. The study also found that energy-savings measures were more acceptable if it was apparent that they were beneficial for the environment.

Education and public information campaigns can also help encourage social pressures for change. One example is the EnergyHog campaign from the Alliance to Save Energy, which portrays an energy wasteful person pejoratively and issues a checklist of no- and low-cost tips to save energy and money (Alliance to Save Energy, 2007).

Given that buildings represent a large portion of total electricity use, facility managers can be an important target audience for promoting energy efficiency. Efficiency Maine's Building Operator Certification program, provided in cooperation with the Northeast Energy Efficiency Partnerships (NEEP), offers training for facility managers to improve energy efficiency, reduce maintenance costs, and enhance building occupant comfort. The program is an eight-day course offered over a four month

period and focuses on identifying efficiency opportunities through the use of advanced building equipment controls, the installation of efficient equipment, and simple preventive maintenance (Efficiency Maine 2006a).

11.4.4 Marketing

Considerable attention is given to marketing as an essential component of several energy efficiency programs. For example, NYSERDA has dedicated almost 2 percent of its total New York Energy $mart budget to marketing and has allocated $15 million over five years (2006-2011) to marketing efforts (NYSERDA 2007). Efficiency Vermont spent more than $2.5 million or 18 percent of its total budget, on marketing and business development in 2006 (Efficiency Vermont, 2007). Efficiency Maine spent 8 percent of its 2006 budget on marketing, with marketing as a percentage of total costs ranging from 0 percent for its Low-Income, Building Operator Certification, and High Performing Schools program to 16 percent for the Residential Lighting program (Efficiency Maine, 2006b).

NYSERDA's Energy Smart Focus program is a marketing effort targeting specific sectors including institutions, industrial manufacturing, commercial real estate, municipal water/wastewater, hospitality, healthcare, and colleges and universities. The goal of the Energy Smart Focus program is to facilitate and encourage greater energy efficiency awareness and market penetration to the targeted sectors. Program strategies include outreach, targeting marketed materials and messages, training, partnerships with trade associations, and integration with regional and national efforts (NYSERDA 2007).

An important aspect for the successful marketing of programs is for consumers to receive a clear and simple message about how to participate in the programs. One mechanism to improve communication with customers and to provide "one stop shopping" is the creation of a single access portal and brand for energy efficiency programs. Examples of a single portal for energy efficiency include the "Flex Your Power" brand in California and "Get Energy Smart" in New York. The purpose of the portal is to provide a single point of access through a website and toll free number where customers can receive information about the range of efficiency programs, whether they are administered by the state, utilities, or a combination.

11.4.5 Monitoring and Evaluation

Monitoring and evaluation are necessary in order to verify energy savings and analyze program effectiveness. A study conducted by Northeast Energy Efficiency Partnerships (NEEP) found that Northeast states lack a common protocol for measurement, verification, and reporting of energy savings. Specific findings included the following (NEEP 2006):

- Baseline conditions are not always consistently defined
- States use similar algorithms to calculate gross savings, but the calculation of net savings differs
- Most states do not retrospectively adjust their initial savings based on evaluation/verification
- Reported savings data can vary in terms of whether it is annual, lifetime, or cumulative savings
- States have different reporting schedules and different levels of regulatory review, which make benchmarking against other state programs difficult, if not impossible, unless standard reporting is implemented.

11.4.5.1 International Performance and Measurement Verification Protocol

The International Performance and Measurement Verification Protocol (IPMVP) is the accepted industry standard used by ESCOs for performance contracting projects. The IPMVP provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects. First published in 1996, the IPMVP contains methodologies compiled by a technical committee of hundreds of industry experts. The protocol provides a common set of terms to discuss key monitoring and verification (M&V) project-related issues, establishes methods which can be used in performance contracts, defines broad techniques for determining energy savings, and presents procedures for measuring and/or verifying baseline conditions and long-term energy savings (IPMVP Committee, 2002).

11.4.5.2 Overview of NYSERDA's Program Evaluation Approach

NYSERDA allocates almost 2 percent of its total New York Energy $mart budget to metrics and evaluation. The current 5-year budget (2006-2011) includes $17.9 million for metrics and evaluation. NYSERDA program evaluation is conducted by competitively selected contractors. An independent advisory group along with the Department of Public Service helps allocate the evaluation budget, identify evaluation activities to be conducted, and establish timelines for evaluation activities. Program evaluation includes five components:

- Measurement and verification
- Market characterization, assessment and causality
- Process evaluation
- Program theory and logic
- Peer review assessments.

For each efficiency program, surveys are conducted to measure key market indicators and cumulative program progress including awareness and knowledge, availability of services, change in practices, and participant motivations and decision-making criteria. Evaluation activities also contribute to determining realization rates and free ridership and spillover effects in order to accurately report program savings. In addition to program costs and energy savings, NYSERDA also calculates benefit-cost ratios and conducts an analysis of macroeconomic impacts (NYSERDA 2007).

11.4.5.3 Free Rider/Spillover Effects

When evaluating energy efficiency programs, it is necessary to take into account the free rider and spillover effects in order to determine the actual energy savings achieved by specific programs. It is generally preferable to design programs that limit the number of free riders and instead target customers who would not have made efficiency improvements in the absence of the program. At the same time, it is important to recognize the spillover benefits of programs, which contribute to energy savings without increasing program costs.

11.4.5.4 The Rebound Effect

The rebound effect refers to the increase in electricity consumption after energy efficiency measures are installed provoked by the improved performance. For instance, a person might worry less about turning off lights if the bulbs are CFLs, or he might set the air conditioning at a lower temperature than he would if the home was not weatherized. Greening et al. (2000) found that the rebound effect varies considerably for different end uses. It is estimated at 10-40 percent for water heating (by taking longer or hotter showers), 10-30 percent for space heating, 0-50 percent for space cooling, and 5-12 percent for lighting.

11.5 Best Practices and Considerations for Specific Sectors

Best practices to promote energy efficiency in the residential and commercial/industrial sectors came from phone conversations with program managers from Efficiency Vermont, NYSERDA, and Wisconsin's Focus on Energy as well as from 2006 annual reports from NYSERDA, Efficiency Vermont, and Efficiency Maine. This section will present these as well as additional considerations for the residential, commercial/industrial, and government sectors. The best practices here represent current thinking and opinion as presented by the administrators of successful programs and as such, are qualitative in nature.

11.5.1 Residential Sector

ACEEE estimates that the residential sector represents 43 percent of the potential electricity savings in 2025 due to energy efficiency programs and policies (Eldridge et al., 2008). Within existing homes, the largest potential savings can be found in heating, ventilation, and air conditioning (HVAC) (34 percent), lighting (21 percent), and water heating (11 percent), followed by electricity use feedback, plug loads (appliances in standby mode), furnace fans, refrigeration and efficient appliances. The potential for electricity savings from new home construction accounts for 10 percent of the total potential for the residential sector in 2025.

Table 11.4 presents best practices from other states as well as additional considerations for the residential sector.

Table 11.4. Best Practices and Considerations for the Residential Sector

Best Practices	Considerations
• Partner with retailers, manufacturers, contractors, and design professionals • Develop specific strategies to target hard-to-reach customers • Develop education and outreach programs • Take advantage of otherwise "lost opportunities" by targeting new construction • Provide quality technical assistance • Target both builders and consumers for new construction	• HVAC improvements can contribute to savings in heating fuels in addition to electricity savings and can also reduce peak demand • Energy ratings for homes can provide important information about energy efficiency to current owners, renters, and potential buyers • Effective programs to target renters are necessary because of the "landlord-tenant problem," which results when builders, developers, or property owners purchase energy equipment, but tenants pay the electricity bill • Collaboration with state Weatherization Assistance Programs (WAP) can be an effective method for targeting low-income customers

11.5.1.1 Best Practices in Other States

Successful residential efficiency programs require effective partnerships with retailers, manufacturers, contractors, and design professionals. In order to improve effectiveness and acceptability, many residential programs involve specific strategies to target hard-to-reach customers such as the elderly, the low-income population, and the non-English speaking population. Education and outreach programs can raise awareness about energy use and can increase energy savings by changing people's behavior and decisions.

Experience from other states shows that residential new construction is one of the most important markets to target because it takes advantage of otherwise "lost opportunities." Efficiency investments in the original construction result in energy savings for the life of the building. At the same time, most of the potential for residential efficiency investments lies in existing buildings since only a small portion of the housing stock turns over each year.

Furthermore, excellent technical assistance is perceived as essential for encouraging builders to participate in programs. However, it is important to target not just builders but consumers as well. Builders need to be aware of programs when consumers make a request for an ENERGY STAR home, but consumers also need to be aware of programs to create a market pull effect.

In terms of incentives, Efficiency Vermont has found that bundling incentive packages for homes can be very effective, where multiple measures need to be installed to receive the incentives. On the other hand, in some cases bundled incentives can discourage efficiency for customers who wish to make individual efficiency improvement but cannot take advantage of incentives without investing in multiple efficiency measures.

11.5.1.2 Heating, Ventilation and Air Conditioning (HVAC) Efficiency

A major component of HVAC improvements lies in weatherization (improving insulation, sealing ducts, replacing windows), while other components address the efficiency of the systems themselves. HVAC efficiency not only saves electricity, but also heating fuel, mostly natural gas. In the summer, HVAC efficiency improvements result in reduced peak load in the electricity network.

11.5.1.3 Energy Ratings for Homes

The relative efficiency of residential buildings is often unknown to current owners, renters and potential buyers. One option to reduce this informational gap is to mandate energy ratings for new homes and encourage/mandate it for existing homes for further sales or leases, as, for example, was just introduced to the residential housing sector in Germany in the form of an "Energy Passport". Another approach, suggested by the MEA in its strategic plan (MEA 2008) is to mandate the disclosure of the energy consumption history of a property at the time of sale or lease.

11.5.1.4 Renters

A significant market barrier to energy efficiency results from split incentives, or the "landlord-tenant problem." In cases where builders, developers, or property owners purchase energy equipment, but tenants pay the electricity bill, there is no incentive for property owners purchasing the equipment to install efficiency measures as the benefits will be received by the tenant.

The California Statewide Multifamily Energy Efficiency Rebate Program (MEERP) is one example of a program targeting this hard-to-reach sector of multifamily rental housing. Through this program, the four major investor-owned utilities in California provide equipment rebates to owners and tenants of multifamily properties. The program encourages the installation of efficient products in both individual tenant units and common areas, reducing the energy usage of both tenants and property owners. According to ACEEE, one reason for the success of MEERP is the relationships developed by the utilities within the multifamily market sector. In 2006, more than 3000 multifamily properties participated in MEERP (York 2008).

A comprehensive approach to addressing the split incentive problem, developed by the Energy Efficiency Institute, is a program design called Pay-As-You-Save (PAYS). The approach involves packages of one or more cost-effective energy efficiency measures at no upfront cost that are paid for over time through a tariff charge on the customer's monthly electric bill. The tariff charge is assigned to the meter, not to the customer, meaning that when the customer's occupancy ends, the obligation is transferred to the next customer at that location. For rental housing where the renter pays the utility bills, the tenant is the customer in a PAYS system. The building owner must provide approval for the efficiency measures to be installed but has no other obligation (Cillo and Lachman, 1999).

11.5.1.5 Low-Income Customers

Collaboration with state Weatherization Assistance Programs (WAP) can be an effective method for targeting low-income customers. Efficiency Vermont works with Vermont's WAP to provide direct installation of energy- and water-saving products and cost-effective replacement of inefficient refrigerators and electric heat and hot water systems. This allows Vermont's WAP to focus its funds on thermal improvements. In addition to its work in coordination with WAP, Efficiency Vermont engages in additional targeted outreach to low-income households including inserting energy tips and coupons for free CFLs in mailings to low-income residents; distributing CFLs and energy efficiency information at food banks; and installing CFLs and providing information at a mobile home park (Efficiency Vermont, 2007).

11.5.1.6 Energy Monitors for Electricity Consumption

In-home monitors enable people to track their electricity consumption in real time. According to ACEEE, the use of in-home monitors has been documented to result in significant and persistent energy savings even without the aid of educational and instructional materials (Eldridge et al., 2008). Similar results have been observed in other countries where energy consumption monitoring and price information raised awareness for energy consumption and thus lead to a decrease in energy use (Morovic et al. 1997). This concept could be extended to electricity billing, where users can compare their consumption relative to an average household, or state, national or international averages.

11.5.2 Commercial/Industrial Sector

According to the Regional Manufacturing Institute (personal communication), energy use is a significant concern among manufacturers in Maryland, driven by rising energy costs. ACEEE found that lighting represents the highest potential for efficiency improvement in the commercial sector, with 49 percent of potential savings by 2025. This is followed by HVAC (19 percent) and new building performance (17 percent). In the industrial sector, given that the sector is quite heterogeneous, no estimates for the potential of specific measures are available. However, it is estimated that in 2025, chemical manufacturing will account for 41 percent of total industrial electricity use and computer and electronic manufacturing for 23 percent (Eldridge et al., 2007), making these industries potential targets for efficiency improvements.

The potential for spillover in the commercial sector might be less than in other sectors because businesses are less likely to disclose their improvements. At the Regional Economic Studies Institute (RESI) 2008 Economic Outlook Conference (Towson University), SAGE energy, an energy-consulting firm, pointed out that some businesses keep confidential that they have implemented energy savings through energy efficiency because they want to have an edge over their competitors.

Table 11.5 presents best practices from other states as well as additional considerations for the commercial/industrial sector.

Table 11.5. Best Practices and Considerations for the Commercial/Industrial Sector

Best Practices	Considerations
• Cultivate strategic relationships with trade and business associations • Focus on ways to influence upstream market suppliers, contractors, and installers • Market energy efficiency as a way to enhance a company's competitive edge • Provide comprehensive, attractive incentives and financing packages • Encourage the growth of the ESCO community • Meet regularly with stakeholders • Try to continually understand and adapt to the market • Have people who really know specific industries to provide technical assistance • Adopt measurement and verification	• Local governments are very aware of energy conservation, but the upfront cost of measures is the biggest hurdle for implementation • In the agricultural sector, efficiency programs could have the additional objective of increasing the competitiveness of Maryland agriculture in light of rising production costs

11.5.2.1 Best Practices in Other States

Similar to partnerships in the residential sector, in the commercial/industrial sector, the cultivation of strategic relationships with trade and business associations may provide access to markets and help develop an awareness of energy consumption and opportunities to take advantage of efficiency programs. Partnering with utilities has been used to increase utility referrals for energy efficiency projects for their commercial and industrial customers. Cooperation also opens up the potential to influence the upstream market suppliers, contractors, and installers.

Focusing on marketing efficiency as a way to enhance a company's competitive edge is seen as another best practice. Providing customers with comprehensive, attractive incentives and financing packages as well as allowing customers, Energy Service Companies (ESCOs), and contractors access to multiple incentive strategies can greatly encourage program participation. Oftentimes, especially with large companies and industries, customers already have good ideas for how they can reduce their energy demand and they just need an incentive to actually implement their plans. Since commercial and industrial programs target customers of all sizes, programs can contain different tiers for different size customers, as NYSERDA's Enhanced Commercial/Industrial Performance Program does. NYSERDA has also focused on encouraging the growth of the ESCO community.

Experience from other states highlights the importance of meeting regularly with stakeholders to continually understand and adapt to commercial and industrial sector needs. For the industrial sector, it can be useful to break the programs down into separate sub-segments targeting specific industries and to offer in-depth technical assistance. The use of subcontractors can help provide that specialized technical experience. For both commercial and industrial customers, having a checklist of specific energy-saving measures can be an effective way to communicate expectations. Finally, measurement and verification of energy savings for large customers is essential according to best practices available from existing energy efficiency programs.

11.5.2.2 Combined Heat and Power

Combined heat and power (CHP) plants, or cogeneration facilities, are in a stand-alone category between energy efficiency at electricity generation and at consumption. They are generally suitable for large industrial, commercial, and institutional facilities. ACEEE estimates that CHP represents 9 percent of the total energy efficiency resources potential in 2025. ACEEE points out that the State could make CHP projects eligible for Energy Performance Contracting or other financing mechanisms, while modifying the pertinent regulations towards this effect. Clarity over interconnection rules, standby charges, building permits and emission regulations are important for an expansion of CHP (Eldridge et al., 2008). The current legislation in Maryland outlining the allocation of RGGI revenue does not specify any particular incentives for CHP.

11.5.2.3 Targeted Sectoral Programs

Efficiency programs can be designed to target specific markets. These focused efficiency efforts could be useful for areas where neither the private sector nor the utilities are likely to make significant impacts. Programs can also aim to target markets significantly affected by high energy costs. For example, in the agricultural sector, efficiency programs could have the additional objective of increasing the competitiveness of Maryland agriculture in light of rising production costs.

Efficiency Vermont has a number of initiatives targeting specific markets including farms, ski areas, and water and wastewater facilities. For example, in addition to completing efficiency projects at water and wastewater facilities, Efficiency Vermont reported that in 2006 they collaborated with the Vermont Rural Water Association to provide a series of training sessions for water and wastewater operators. Efficiency Vermont also conducted outreach to the water and wastewater sector by contributing articles to water association newsletters and participating in their events (Efficiency Vermont, 2007).

11.5.2.4 Government

Maryland has embraced "leading by example" in the State government. The State Agency Loan Program (SALP), Energy Performance Contracting (EPC), and Community Energy Loan Program (CELP) all have the potential to be scaled up substantially and in the process may generate greater energy savings through efficiency improvements. Local governments, according to a spokesperson from the Maryland Municipal League, are very aware of the potential for energy efficiency improvements, but the upfront cost of measures is the biggest hurdle for implementation.

Although there would be substantial upfront investments, energy savings throughout the lifetime of a public facility can generate important fiscal savings for state and local governments. However, the savings accrue in the long term, not during the short time that elected officials are in office. This makes instruments that spread the costs out over a longer period, such as the SALP and EPC, more attractive. In addition, individual state agencies might not see the energy savings as a big incentive if they would translate into a reduced budget from the state government.

Energy efficiency of public infrastructure is an additional area for state intervention. According to the Maryland Climate Change Commission (Maryland Climate Change Advisory Group, 2008) the Annapolis water supply and sewer pumps together use 23 percent of the city's power. It goes on to say that any water savings measures should revert into energy savings. Street lighting and traffic lights are another sector where efficiency could be demonstrated to the public.

12 CONCLUSIONS

The allocation of RGGI allowances through auctioning will likely generate considerable revenues to the state. Although RGGI states have agreed to use a minimum of 25 percent of total state allowances to promote such consumer benefits as end-use efficiency in electricity consumption, the state may choose to apply larger shares. Benefits may result in the form of energy bill savings for consumers, increased local economic activity and an overall reduction in the cost of the RGGI program. However, it is not clear, a priori, what the comparative benefits are of alternative allocation levels of auction revenue to energy efficiency programs and how those programs may best be structured. This report addresses these issues for the State of Maryland.

The specific questions answered in this report are:

1. What would be the effects of different levels of spending in Maryland on improvements in efficiency in electricity consumption? These impacts are assessed in terms of:
   – Electricity demand
   – Electricity prices and expenditures
   – RGGI CO_2 allowance prices and revenue
   – Electricity supply in Maryland and profits for power generators
   – Generator competitiveness and market power
   – Generation adequacy and transmission import capability
   – Overall economic impacts within Maryland
2. How robust are the conclusions for different modeling assumptions about:
   – energy markets and market power; and
   – transmission capability?
3. What implementation, design, program effectiveness and other lessons are found in existing energy efficiency programs in comparable states?
4. What considerations for implementation of efficiency programs can be identified:
   – from the academic and trade literature; and
   – through a broad range of experts and stakeholders in Maryland?

To answer these questions, three scenarios were developed – a base case scenario in which 25 percent of RGGI auction revenue is allocated to energy efficiency spending, and two alternative scenarios, one with a 50 percent and another with a 100 percent allocation. All three scenarios assume that all emissions allowances are auctioned by the state. In general, the scenario analysis conducted in this study shows that increasing the share of RGGI CO_2 allowance revenue that is devoted to energy efficiency in end-use electricity consumption will result in substantial reductions in electricity demand and expenditures in Maryland, but will have little effect on the retail price of electricity paid by Maryland consumers. Furthermore, energy efficiency spending will reduce electricity imports to Maryland.

On the basis of the existing scientific and trade literature, extensive data and program analysis, as well as energy system, market and economic modeling, the following conclusions were found.

1. Increases in efficiency expenditures have the following effects on:

   Electricity demand
   Electricity demand in Maryland will be substantially reduced by spending on electricity consumption efficiency. The baseline for comparison of alternative efficiency expenditures is 25 percent of auction revenues for efficiency programs. Increasing the share of revenues spent on efficiency from the baseline of 25 percent to 50 percent will reduce demand for electricity by 1.3 percent annually in 2015 and 2.6 percent annually in 2020 compared to baseline levels. If 100 percent of the allowance revenues are spent on efficiency, demand will be 4 percent below baseline levels in 2015 and nearly 6 percent below in 2025.

   These demand reductions would help achieve the goal, set forth under the EmPOWER Maryland plan, of reducing per capita electricity consumption in the state by 15 percent from the 2007 level by 2015 as shown in Figure 1.1. At a

spending level of 25 percent of RGGI allowance revenue, Maryland will reduce per capita electricity consumption by 7.4 percent from the 2007 level, or nearly half of the EmPOWER Maryland goal. Greater spending will reduce per capita consumption further, by 8.7 percent under 50 percent spending and by 11.2 percent if all allowance revenue is spent on electricity consumption efficiency.

Electricity prices and expenditures

Increasing the share of allowance revenues devoted to efficiency will reduce the expenditures on electricity by Maryland consumers. Due to a combination of small effects on electricity prices and reduced electricity demand, total electricity bills in Maryland will be 2 to 3 percent lower in most years after 2010 if 50 percent of the revenue is spent on efficiency, compared to the baseline scenario. Depending on the year, electricity expenditures in Maryland will be between 2 and 7 percent lower than the baseline if 100 percent of the allowance revenue is spent on efficiency.

Spending on energy efficiency may not lower electricity prices, but because of lowered demand will influence consumer bills. Higher efficiency spending by the state will help "lock-in" cost savings, creating both short and long-term beneficial electricity bill impacts for residential, commercial and industrial consumers. The 50 percent efficiency scenario is estimated to save a typical household $15 annually in 2010 and about $25 annually in 2020. The 100 percent efficiency scenario will save an average household $32 annually in 2010 and $72 annually by 2020 compared to the 25 percent baseline efficiency spending.

RGGI CO_2 allowance prices and revenue

Greater spending on efficiency improvement in end-use electricity consumption in Maryland will reduce the RGGI CO_2 allowance price relative to baseline levels. RGGI allowance prices are 4 percent lower than baseline levels when 50 percent of the allowance revenue is spent on energy efficiency and up to 9 percent lower when 100 percent is spent on efficiency. Lower RGGI allowance prices means that the amount of RGGI allowance revenue available to Maryland and other RGGI states declines as the share of that revenue spent on efficiency in Maryland increases.

Electricity supply in Maryland and profits for power generators

The reductions in electricity demand resulting from greater state funding for efficiency improvement in end-use electricity consumption come largely out of reduced electricity imports to Maryland and have a smaller effect on electricity production by generators in the state. Consequently annual producer surplus for Maryland generators changes very little (by substantially less than 1 percent of annual Maryland electricity revenues) as a result of increased efficiency spending.

Generation capacity retirement and investment are projected to have little dependence on efficiency spending. Coal and nuclear capacity in Maryland are projected to remain unchanged through the modeling horizon with only natural gas increasing, with that increase being delayed until 2025. The operating profits of the generators are also not meaningfully affected by efficiency spending, with the exception of coal generators, whose profits are projected to fall in time as RGGI compliance becomes increasingly more expensive.

Generator competitiveness and market power

The 100 percent and 50 percent energy efficiency scenarios do not consistently lower price-cost mark-ups under the JHU-OUTEC scenarios. In order for such effects to occur, it is necessary for energy efficiency programs to include significant elements of "demand response" programs that lower energy use when price is high. If the peak reductions projected by the Haiku analysis are realized, payments to power generators through the PJM Reliability Pricing Model (capacity) mechanism by central Maryland consumers could be decreased by several tens of millions of dollars annually.

Generation adequacy and transmission import capability

Larger allocations of allowance auction revenue to efficiency programs do not adversely impact generation adequacy in the state. At the same time, larger allocations reduce electricity imports.

The effects of the estimated benefits of the 100 percent energy efficiency scenario are not appreciably changed if import capability in 2015 is significantly decreased.

Overall economic impacts of efficiency spending on the State of Maryland

Impacts on Economic Activity
The 100 percent efficiency scenario is estimated to have the greatest positive impact on gross state product, employment and wages. Compared to 25 percent efficiency spending, the 100 percent efficiency spending scenario boosts GSP by $150 million in 2010 and by more than $500 million in 2020. Using only 50 percent of auction revenues for efficiency programs provides less than half the boost, increasing GSP by around $25 million in 2010 and over $250 million in 2020. Although positive, these impacts are small relative to the overall state economy, equaling about 0.1 percent or less of GSP in each period.

Employment Impacts
Both of the higher allocation spending scenarios have a net positive impact on jobs and total wages. The 100 percent spending scenario will create about 4,300 more new jobs in 2020 above the number the baseline level of 25 percent spending would create, whereas the 50 percent spending scenario will result in 1,700 more new jobs than the baseline level. While these employment gains are large, in the context of Maryland's 2.5 million jobs, they are fairly small.

Fiscal Impacts
Committing more allowance revenue to energy efficiency spending reduces the revenue available to other state programs. It also impacts revenue by decreasing pollution allowance prices while increasing energy efficiency in Maryland's economy. The 50 percent energy efficiency spending scenario redirects $26 million in allowance revenue in 2010 increasing to over $50 million in 2020. The 100 percent spending level dedicates an additional $74 million in 2010 and over $140 million in 2020. By 2020, 20-30 percent of these revenues will be offset by new tax revenues generated from growth in the state economy resulting from the energy efficiency investment.

2. Robustness of Results to Model Formulation

Impacts on wholesale electricity costs for the 50 percent and 100 percent allocations of auction revenues to energy efficiency programs are consistent across the two types of models used in this study – Haiku and JHU-OUTEC – which are based on alternative assumptions about market power. The JHU-OUTEC model has a more detailed representation of mid-Atlantic power transmission constraints and allows for market power in the formation of wholesale electricity prices. The similar results obtained in the two models build confidence in the calibrated, aggregate results obtained by the Haiku model.

3. Experience from Statewide Energy Efficiency Programs

Experiences with existing energy efficiency programs in other states show that such programs can be designed to target all sectors (residential, commercial, and industrial) as well as a wide range of income levels and customer sizes while maintaining relatively low overall program costs compared to estimated electricity savings.

4. Considerations for Program Design and Implementation

A survey of the academic and trade literature as well as of experts and stakeholders in Maryland and the three states studied suggests that any governance model for energy efficiency programs -- administered by utilities, a state agency, or an independent agency -- can be successful as long as there is effective oversight, transparency in the administration of funds, and comprehensive monitoring and evaluation. Successful implementation and administration depends on a number of considerations for governance, administration and financing. For example, increasing coordination, information and access to programs (whether state or utility run), has been achieved in some states through one overarching program "brand" and online portal. A related feature is the consistency, dependability and transparency of the program itself. The more easily the various program mechanisms are understood, the more likely these programs will resonate among their target audience. Similarly, the more potential participants can count on the longevity of program features that are of interest to them, the more likely they will become and remain engaged. Essential for that longevity will be the ability of the state to balance investment risks and returns, and thus create financial stability. Increasing the stability of funds, especially if RGGI auction revenues turn out to be volatile, improves participation and program success.

It should be noted, though, that increasing the proportion of RGGI emission allowance revenue that Maryland spends on efficiency improvement in end-use electricity consumption will not affect total CO_2 emissions from electricity suppliers in the RGGI region, but will reduce demand for RGGI CO_2 allowances by Maryland generators. In essence, the market mechanisms of the cap and trade system lead to the achievement of emissions up to the cap, but not lower than that. Going below the cap will require, for example, improvements in the efficiency of natural gas use (beyond the offsets allowed by RGGI), or establishment of an economy-wide emissions trading market. Additional research will be required to assess the energy and economic impacts of such strategies.

Energy use is in part determined by climate conditions. Forward looking energy policy will therefore need to not only explore options for mitigating climate change but also how to best adapt to it. Several strategies may have both mitigation and adaptation benefits. To the extent that some of these benefits remain unaccounted for, strategies that may be overall optimal could be missed. A second pressing area of research lies in quantifying the benefits of various mitigation and adaptation policies and identifying strategies that optimize both.

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APPENDICES

A. Abbreviations and Acronyms

ACEEE	American Council for an Energy-Efficient Economy
ACI	Activated Carbon Injection
AEO	Annual Energy Outlook
AEP	American Electric Power
APS	Appalachian Power System
BLS	Bureau of Labor and Statistics
BGE	Baltimore Gas & Electric
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CDM	Clean Development Mechanism
CELP	Community Energy Loan Program
CES	Constant Elasticity of Substitution
CFL	Compact Fluorescent Lamps
CH4	Methane
CHP	Combined Heat and Power
CIER	Center for Integrative Environmental Research
CO_2	Carbon Dioxide
DCI	Demand Conservation Incentive
DHCD	Department of Housing and Community Development
DOE	Department of Energy
DPLC	Delmarva Power and Light
DSIRE	Database of State Incentives for Renewable Energy
DSM	Demand-Side Management
EESA	Energy Efficiency Standards Act
EIA	Energy Information Administration
EMM	Electricity Market Model
EPA	Environmental Protection Agency
EPC	Energy Performance Contracting
ESCO	Energy Service Company
EU ETS	European Union Emission Trading Scheme
EUSP	Electric Universal Service Program
FGD	Flue Gas Desulfurization
GDP	Gross Domestic Product
GW	Gigawatt
HAA	Healthy Air Act
Hg	Mercury
HMR	Haiku Market Region
HVAC	Heating, Ventilation, and Air Conditioning
IGCC	Integrated Gasification Combined Cycle
IMPLAN	IMpact analysis for PLANning
IPMVP	International Performance and Measurement Verification Protocol
JCPL	Jersey Central Power and Light
JHU	Johns Hopkins University
JHU-OUTEC	Johns Hopkins University Oligopoly Under Transmission and Emission Constraints
kV	Kilovolt
kWh	Kilowatt hour
LCP	Linear Complementarity Problem
LDA	Local Demand Area
LEED	Leadership in Energy and Environmental Design
LIHEAP	Low Income Home Energy Assistance Program

LMP	Local Marginal Price
LSE	Load Serving Entity
MAAC	Mid-Atlantic Area Coordinating council
MACT	Maximum Achievable Control Technology
MAPP	Mid-Atlantic Power Pathway
MDE	Maryland Department of Energy
MEA	Maryland Energy Administration
MEAP	Maryland Energy Assistance Program
MEERP	Multifamily Energy Efficiency Rebate Program
MIG	Minnesota IMPLAN Group
MOU	Memorandum of Understanding
M&V	Monitoring and Verification
MW	Megawatt
MWh	Megawatt Hour
NAICS	North American Industrial Classification System
NEEP	Northeast Energy Efficiency Partnerships
NEMS	National Energy Modeling System
NERC	North American Electric Reliability Council
NOx	Nitrous Oxide
NSPS	New Source Performance Standards
NYPSC	New York Public Service Commission
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
PAYS	Pay-As-You-Save
PJM	Pennsylvania-New Jersey-Maryland
PN	Pennsylvania Electric Company
PSC	Public Service Commission
R&D	Research and Development
REC	Renewable Energy Credit
REPC	Renewable Energy Production Credit
RESI	Regional Economic Studies Institute
RFF	Resources for the Future
RGGI	Regional Greenhouse Gas Initiative
RESNET	Residential Energy Services Network
RPM	Reliability Pricing Model
RPS	Renewable Portfolio Standard
RTEP	Regional Transmission Expansion Planning Process
SALP	State Agency Loan Program
SAM	Social Accounting Matrix
SCR	Selective Catalytic Reduction
SEU	Sustainable Energy Utility
SF6	Sulfur Hexafluoride
SIL	Surge Impedance Loading
SMECO	Southern Maryland Electric Cooperative
SO_2	Sulfur Dioxide
T&D	Transmission and distribution
TWh	Terawatt Hour
UCM	UC-Merced
VP	Virginia Electric Power
WAP	Weatherization Assistance Program
WCI	Western Climate Initiative

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C. Research Team Biographies

C.1 University of Maryland

Nicolai Herrmann holds a degree as industrial engineer from Flensburg University (Germany) where he graduated in Energy and Environmental Management in 2006. Since then he works as a PhD student for MVV Energie AG (a German network of energy utilities) at the corporate department for Technology & Innovation. His PhD thesis is on sustainable development and strategic backcasting in the energy sector. Additionally Nicolai has expertise in emissions trading, smart grids/microgrids, grid integration of renewable and distributed generation and energy storage, and carbon capture storage.

Nathan Hultman, PhD, is Assistant Professor in the School of Public Policy at the University of Maryland, Assistant Director of the Joint Global Change Research Institute of the Pacific Northwest National Laboratory, and Associate Fellow at the James Martin Institute for Science & Civilization, University of Oxford. His research focuses on international climate policy, decisions about climate risks in policy and technology investment, and the emerging markets for carbon and greenhouse gases. He has participated in the UN climate change process since 1997 and has attended and presented at negotiations and advisory sessions. A former Fulbright Fellow and NASA Earth Systems Science Fellow in climate sciences, Dr. Hultman has conducted research at Lawrence Berkeley National Laboratory and NASA Goddard Space Flight Center. He has also held a faculty appointment at Georgetown University in Washington D.C. He holds an MS and PhD from the University of California, Berkeley and BA in Physics.

Joanna Mauer is a Master of Public Policy candidate at the University of Maryland's School of Public Policy with a specialization in environmental policy. She has a BS in Civil and Environmental Engineering from Cornell University. Before coming to Maryland, Joanna spent three and a half years as a Peace Corps volunteer in the Dominican Republic working on rural water supply and sanitation. Her interests include climate change, renewable energy, and sustainability.

Kimberly Ross, MPP, is Executive Director of CIER which addresses complex environmental challenges through research that explores the dynamic interactions among environmental, economic and social forces and stimulates active dialogue with stakeholders, researchers and decision makers. With over sixteen years of management experience, Ross has led the strategic design and implementation of highly-valued information services, partnerships, and research organizations. Throughout her eight years of public service at the national level, Ross served in a variety of roles with the White House Domestic Policy Office, the White House Office of Intergovernmental Affairs, and the US Department of Education in the Office of Intergovernmental, Interagency and International Affairs; and the Division of Community Services and Partnerships. Prior to moving to the nation's capital, she conducted research for Oregon's Department of Land Conservation and Development. Ross holds an MPP in Environmental Policy from the Maryland School of Public Policy.

Matthias Ruth, PhD, is the Roy F. Weston Chair in Natural Economics, Director of CIER at the Division of Research, Professor and Director of the Environmental Policy Program at the School of Public Policy, and Co-Director of the Engineering and Public Policy Program at the University of Maryland. His research focuses on dynamic modeling of natural resource use, industrial and infrastructure systems analysis, and environmental economics and policy. His theoretical work heavily draws on concepts from engineering, economics and ecology, while his applied research utilizes methods of non-linear dynamic modeling as well as adaptive and anticipatory management. In the last decade, Ruth has published 9 books and nearly 100 papers and book chapters in the scientific literature. He collaborates extensively with scientists and policy makers in the USA, Canada, Europe, Oceania, Asia and Africa.

Ruth's recent interdisciplinary research projects include an assessment of impacts of climate change policies on technology choice, resource use and emissions, and an integrated assessment of climate change impacts on urban infrastructure systems and services. The former project is targeted towards an identification of "smart" energy and climate change policies - policies that promote significant efficiency improvements without jeopardizing economic performance. The latter project cuts across social and engineering sciences, computer modeling, and planning and policy making with the goal of generating consensus about mitigation and adaptation strategies to address climate change in an urban context. Ruth teaches national and international courses and seminars on economic geography, microeconomics and policy analysis, ecological economics, industrial ecology and dynamic modeling at the graduate and PhD levels, and on occasion conducts short courses for decision makers in industry and policy.

Iván Darío Valencia, BSc, is a candidate for a dual Masters in Environmental Policy (MPP) and Sustainable Development and Conservation Biology (MSc) at the University of Maryland (UMD). He is a Geographer from the Universidad Nacional de Colombia in Bogotá. Before entering UMD, Iván worked with Geographic Information Systems and biodiversity conservation science and policy at the Instituto Alexander von Humboldt in Colombia, the Ramsar Convention on Wetlands in Switzerland and the Western Hemisphere Shorebird Reserve Network, based in Massachusetts. An amateur ornithologist, he was a contributing author to a guide book to the birds of the Bogotá Plateau and conducted habitat modeling research on the Horned Lark in Colombia. More recently, his attention has focused on climate change adaptation and mitigation policies. He produced a report for the Global Environment Facility on monitoring and evaluation of adaptation projects, and in CIER, he collaborated with the Maryland 2050 initiative, an effort to discuss sustainability in the state in the coming decades.

C.2 John Hopkins University

Benjamin Hobbs, PhD, is the Theodore M. and Kay W. Schad Professor of Environmental Management in the Department of Geography and Environmental Engineering at The Johns Hopkins University, (JHU) Baltimore, MD, where he has been on the faculty since 1995. He also holds a joint appointment in the Department of Applied Mathematics and Statistics. From 1977-79, he was Economics Associate at Brookhaven National Laboratory, National Center for Analysis of Energy Systems. He later joined the Energy Division of Oak Ridge National Laboratory from 1982-1984. Between 1984 and 1995, he was on the faculty of the departments of Systems Engineering and Civil Engineering at Case Western Reserve University, Cleveland, Ohio. He serves on the California ISO Market Surveillance Committee, the Public Interest Advisory Committee of the Gas Technology Institute, and as an Advisor to the Netherlands Energy Research Center (ECN). Hobbs earned a PhD in environmental systems engineering from Cornell University in 1983, where his dissertation concerned deregulated power markets. He has published widely on electric utility regulation, economics and systems analysis and on environmental and water resources systems. He was named a Presidential Young Investigator by the National Science Foundation in 1986 and is a Fellow of the IEEE.

C.3 Resources for the Future

Erica Myers, MS, is a Research Assistant at Resources for the Future. Myers received her MS in Environmental and Natural Resource Economics from the University of Rhode Island in 2007. Her current work focuses on the implementation of carbon reduction policies in the electricity sector. Her most recent projects include auction design for emission allowances, analysis of the effects of allowance prices on electricity markets, and modeling the impacts of energy efficiency spending.

Karen L. Palmer, PhD, is the Darius Gaskins Senior Fellow in the Quality of the Environment Division of Resources for the Future in Washington, D.C. Palmer received her PhD in economics from Boston College in 1990. She specializes in the economics of environmental regulation and of public utility regulation and her research interests include electricity restructuring, environmental regulation of the electricity sector and the cost effectiveness of energy efficiency programs. Her current projects include an analysis of allowance allocation in regional and national CO_2 cap and trade programs, an analysis of the cost-effectiveness of utility-focused energy efficiency and demand-side management policies, and a study of flexible technology standards to promote the use of clean-coal technologies. Her other recent work has focused on the design of cap-and-trade policies to restrict CO_2 emissions from electric generating plants. She is a co-author of the book, Alternating Currents: Electricity Markets and Public Policy, published by RFF Press in 2002. In 1996-97, Palmer spent six months as a visiting economist in the Office of Economic Policy at the Federal Energy Regulatory Commission.

Anthony Paul, MS, is an RFF Program Fellow whose research focuses on the electricity sector in the United States and its associated environmental issues. He is the lead developer of the Haiku Electricity Market Model that is maintained at RFF. Paul's recent work includes projects and modeling on the demand side of electricity markets, the relationship between renewable electricity generation and electricity transmission infrastructure, and efficiency in pollution allowance allocation. He holds an M.S. in economics from University of Wisconsin-Madison.

C.4 Towson University

Daraius Irani, PhD, is the Director of the Applied Economics Group at the Regional Economic Studies Institute (RESI) and is an adjunct faculty member of the Department of Economics at Towson University (TU). Irani serves as project manager on numerous projects at RESI and presents economic outlook presentations to organizations across Maryland. He has been the principal investigator for a number of economic and fiscal impact studies for developers, corporations and government agencies in the State. In these studies he examined the direct, indirect and induced economic and fiscal impacts of the proposed development/project. For many of these projects, a cost/benefit analysis was undertaken. Prior to joining RESI in 1997, Irani was the senior economist at the Santa Barbara Economic Forecasting project where he developed county level economic forecasts for Santa Barbara, San Luis Obispo and Ventura Counties, California. In addition, he co-authored several reports including an analysis of the oil and gas industry and the tourism sector in the Central Coast of California. Irani received his PhD and MA from the University of California, Santa Barbara.

Jeffrey Michael, PhD, is Director of the Business Forecasting Center at the University of the Pacific. Jeff's areas of expertise are environmental and regional economics with a focus on the impacts of regulation and environmental change on land use and property markets, as well as recent work forecasting economy-wide impacts of climate change. He has received numerous grants, published in scholarly journals and his research papers have received press coverage in sources such as the Wall Street Journal, New York Times Magazine, Washington Post, and the on-line magazine Slate. Before coming to Pacific, Dr. Michael spent 8 ½ years at Towson University in Maryland where he was an award-winning teacher while serving as faculty, Associate Dean, and Director of the Center for Applied Business and Economic Research. Jeff received his Ph.D. from North Carolina State University, M.S. from the University of Maine, and B.A. from Hamilton College (NY).

C.5 University of California, Merced

Yihsu Chen, PhD, (formerly at JHU) is an Assistant Professor in the School of Engineering and the School of Social Sciences, Humanities and Arts of the University of California, Merced. He received his BS degree in environmental science from Tunghai University, Taiwan, and his Master's degree from the Harvard School of Public Health, Boston, MA, in 1999. He earned his PhD degree in the area of energy and environmental economics from the Department of Geography and Environmental Engineering, Whiting School of Engineering, JHU. His publications are focused on modeling of combined electric power and emissions markets.

D. MODELING DESCRIPTIONS

Discussed below are the three models used in the analysis of the impacts of Maryland joining RGGI. The primary model was Haiku, a national simulation of the electric power grid and of environmental policies. Outputs from this model were then used by the JHU-OUTEC and IMPLAN models which analyzed more regional level power grid issues as well as economic aspects. Consequently, the description below provides more detail on the Haiku model.

D.1 Haiku Model

The RFF Haiku model is a simulation model of regional electricity markets and interregional electricity trade in the continental United States. The model also simulates compliance with regulations to control emissions of NOx, SO_2, CO_2 and mercury from the electricity sector. Haiku calculates market equilibrium in each of 20 regions of the lower forty-eight states, during three seasons of the year, and during four time blocks within each season. The model uses separate electricity demand curves for each region and time block and for each of three sectors of the economy; residential, commercial, and industrial. Haiku supply curves vary by region and time block and depend on the many fully integrated modules within the model. These modules include algorithms for capacity investment and retirement, compliance with emissions regulations, interregional power trading, and coal and natural gas markets. The supply curves are composed of model plants that are each constructed by aggregating the generating unit inventory according to salient technology characteristics. Haiku has great versatility in simulating pollution abatement policies as well as emerging market structures, yet is designed to be run on a desktop computer and can serve as a laboratory for sophisticated first-order policy analysis of the electricity industry.

This document provides a narrative description of, and documentation for, the Haiku model. The model is constructed using the Analytica modeling software. Each variable, index, or result is illustrated by an object in Analytica that appears as a node within an influence diagram. Hence, the screen views of the model itself provide additional documentation, and each object in the model has a description field that provides detail about how the model is solved.

The development of Haiku has benefited from the contributions of many persons, including primarily Ranjit Bharvirkar, Dallas Burtraw, David Evans, Danny Khan, David Lankton, Erica Myers, Karen Palmer and Anthony Paul.

D.1.1 Overview of Modeling Approach

Haiku uses a parsimonious approach in constructing a model that captures the detail of the national electricity market within a framework that can be used as a laboratory for exploring market economics and public policy. This is achieved by creating reduced form modules for some aspects of electricity related markets, while preserving detail in others. Haiku is an iterative simulation model that solves for equilibria in spatially and temporally linked electricity markets by obtaining simultaneous compliance with a large set of constraints. The solution identifies the minimum cost strategy for investment and operation of the electricity system for meeting demand given a wide set of regulatory institutions. In the absence of market power or other strategic behavior, the minimum cost solution is also the profit maximizing solution. Since the quantity of electricity demand responds to changes in price the solution is also the welfare-maximizing outcome within the electricity sector. This section provides an overview of the level of detail represented in the model, and a broad discussion of the iterative techniques used to find model equilibrium.

D.1.1.1 Features of the Model

The Haiku model includes a representation of supply and demand in geographic regions that are linked by electricity transmission capability. Generation capacity is represented by model plants which optimize over the short run through scheduling and the long run through investment and retirement. Model plants are linked with each other and through time by prices for factors of production.

D.1.1.1.1 Model Plants & Regions

Haiku aggregates generation capacity into model plants that are comprised of constituent generators sharing technical similarities. Each model plant is defined by four fields including: prime mover (the power plant technology), fuel type, vintage, and fuel demand region (coal plants). The capacity of a model plant is calculated by summing the capacity of all constituent generating units meeting the model plant criteria. Other model plant parameters (latitude and longitude, emissions rates, costs,

planned and forced outage rates, heat rate) are calculated from the nameplate capacity-weighted average of the constituent generating units. Over time, the available generation capacity changes as some existing plants retire, some new plants are built, and the availability of plants evolves according to rates that reflect technological improvement. The configuration of model plants can be altered by the user to meet the needs of any policy scenario. An example set of model plants is contained in Table D.1.

Each model plant is located in one of 20 Haiku regions that divide the lower 48 states of the US as illustrated in Figure D.1. In some cases these regions correspond to the NERC subregions or the Electricity Market Model regions as defined in the NEMS model, which is maintained by the Energy Information Administration. In others, especially in the northeast, finer detail is gained by aggregating model plants into smaller regions that correspond to states or small groups of states. Canada is treated in the model as an aggregate entity with which limited power trading is permissible. There is no power trading with Mexico represented in the model. See Section D.1.3 Model Components for more details on the modeling of interregional power trading.

Table D.1. Model Plants

Existing	New
Steam : Coal[1]	Steam : Coal[5]
Steam : Natural Gas[2]	Steam : Geothermal
Steam : Oil	IGCC : Coal
Steam : Nuclear[3]	IGCC : Biomass
Steam : Biomass	Combined Cycle : Natural Gas[6]
Steam : Geothermal	Combustion Turbine : Natural Gas[7]
Combined Cycle : Natural Gas	Wind
Combined Cycle : Oil	Landfill Gas
Combustion Turbine : Natural Gas[4]	
Combustion Turbine : Oil	
Hydro : Conventional	
Hydro : Pumped Storage	
Wind	
Solar	
MSW / Landfill Gas	

1. There are 15 model plants for existing coal-fired boilers. They vary according to the types of pollution control installed and their location in regions used in the coal market module.
2. There are 4 model plants for existing natural gas-fired boilers. They vary according to vintage and the types of pollution control installed.
3. There are 2 model plants for existing nuclear powered boilers which vary according to vintage.
4. There are 2 model plants for existing natural gas-fired combustion turbines which vary according to vintage.
5. There are 3 model plants for new coal-fired boilers which vary according to their location in regions used in the coal market module.
6. There are 2 model plants for new natural gas-fired combined cycle generators. One represents conventional technology and the other advanced technology.
7. There are 2 model plants for new natural gas-fired combustion turbines. One represents conventional technology and the other advanced technology.

The model user has flexibility in defining the configuration of generators into model plants and regions. This flexibility is not an off-the-shelf feature of the model, but the data which underpin Haiku contain detailed geographic information and technical specifications about each generator which can be used to reconfigure the aggregation of generators with moderate effort. This capability allows the model to evolve as the landscape of policy relevant issues evolves. Since the initial version of Haiku was developed in 1998, the configuration of model plants and regions has changed numerous times.

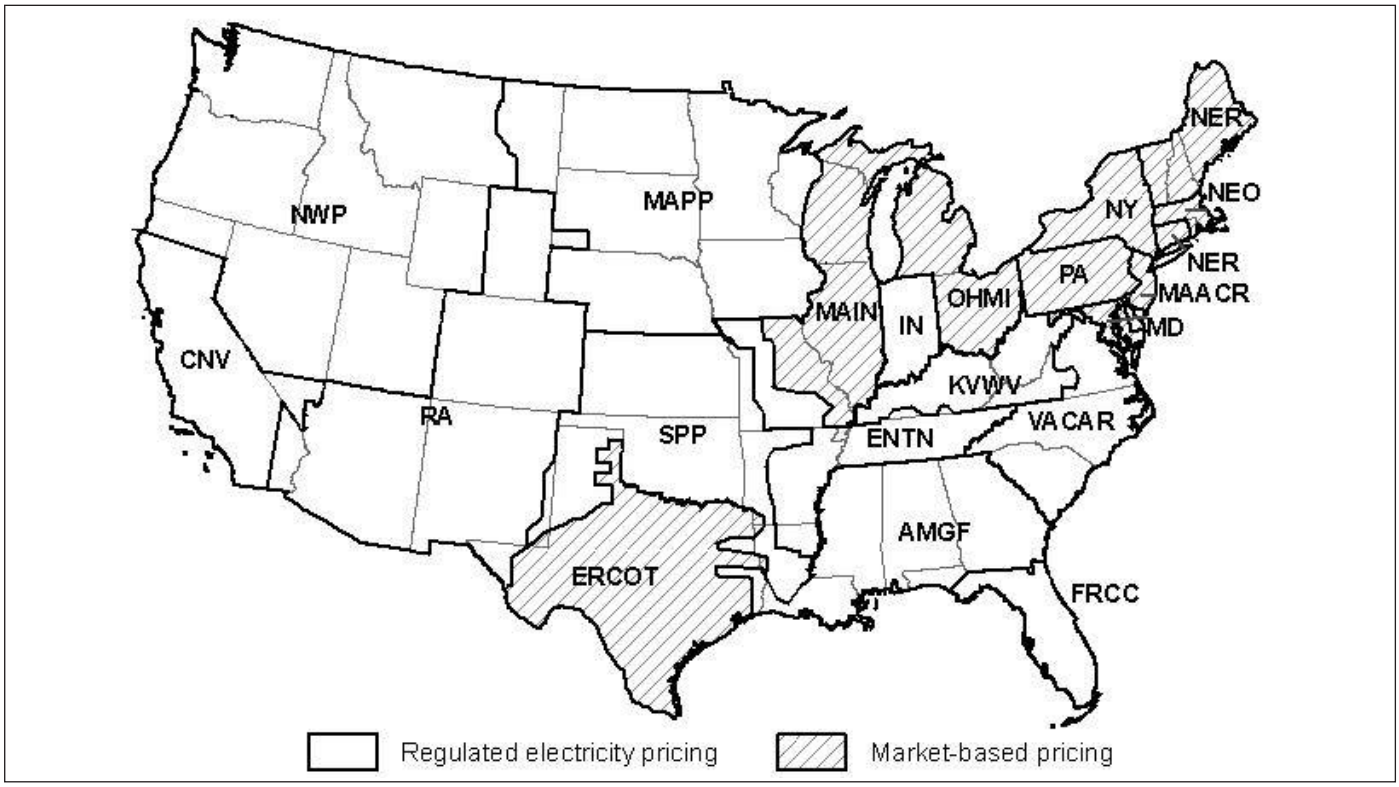
D.1.1.1.2 Seasons, Time Blocks, and Customer Classes

Three seasons are represented in Haiku. Winter is a three-month season including December, January and February. Spring/Fall is a four-month season including March and April, and October and November. Summer is a five-month season from May to September that conforms to the ozone season in the eastern United States.

Within each season, hours are separated into four time blocks that reflect the level of aggregate electricity demand. The time blocks are named baseload, shoulder, peak, and superpeak. The baseload time block includes the 70 percent of hours in the season that have the lowest electricity demand. The shoulder includes the next 25 percent of hours. The peak includes the next 4 percent, and the superpeak includes the final 1 percent of hours in each season.

The total demand for electricity in each region, season and time block is aggregated from demand that is calculated for three customer classes: residential, commercial, and industrial. Each customer class has a unique willingness to pay for electricity and a unique response to changes in electricity price. For details on Haiku demand functions, see Section D.1.3 Model Components.

Figure D.1. Mapping of States and Regions



Note: The pricing regimes indicated are the default settings in Haiku, but can be redefined by the user.

D.1.1.1.3 Simulation Years & Foresight

Haiku finds equilibrium in electricity markets over any set of simulation years. Often the model is run for four or five simulation years between 2010 and 2030 in 5-year increments. Estimates for intervening years are derived by interpolation between the simulation years. Since power plants are long-lived investments, and capacity investment and retirement decisions must account for revenue and cost streams over a long time horizon, the model finds simultaneous equilibria for each simulation year assuming perfect foresight about the future. Perfect foresight is a strong assumption that cannot be relaxed in the Haiku modeling structure, so the model is deterministic. This limitation is addressed through sensitivity analysis in which alternative deterministic solutions are found for input assumptions that vary, or through the use of approximation methods such as the Delta method using finite differences to estimate the nonlinear behavior of the model over a set of random variables.

D.1.1.1.4 Supply, Demand and Interregional Power Trading

A unique equilibrium in electricity markets exists for each simulation year, region, season and time block. The equilibrium is derived from a supply schedule composed of model plants and a demand schedule aggregated from the demand of the three customer classes. The model endogenously determines most of the characteristics of the model plants, including generation capacity and installed pollution abatement technologies, and to some degree the technological characteristics of the model plants. Endogenous factors such as investment in efficiency improvements and conservation also modify the demand schedule in the model. Intraregional line losses and transmission and distribution costs are incurred for each unit of electricity consumed.

In addition to market equilibria within regions, there also exist market equilibria between regions. Haiku represents the national transmission grid as a set of potential bilateral trades between every pair of contiguous regions. For regional pairs that are not contiguous, no direct power trading is allowed. However, power trades between non-contiguous regions may be executed through intervening regions that connect the non-contiguous regions. The model accounts for interregional line losses and transmission costs in a pancake manner, i.e. a power trade which crosses multiple regional boundaries faces losses and costs at each boundary. The power grid is defined for capability, line losses and transmission cost between the thirteen regions comprising the NEMS Electricity Market Model (EMM) regions. Between subregions of the EMM regions, capability is assumed to be infinite with losses and costs assumed to be zero. The limited transmission capabilities between contiguous pairs of regions constrain the interregional equilibrium. Detailed descriptions of intraregional and interregional equilibria are located in D.1.3 Model Components.

D.1.1.2 Control Variables, Iteration and Convergence

The Haiku model uses an iterative convergence algorithm to find an equilibrium involving 17 control variables that contain about 80,000 individual elements. Each element in each control variable has an equilibrium value, depending on the values of all of the other elements in all of the other control variables. Each control variable is adjusted in each iteration in response to the value of the other variables. Equilibrium is defined as the state in which all control variables are simultaneously the best response to the value of all other control variables. Exact equilibrium is never achieved so convergence criteria are applied to determine when adequate precision is achieved. The possibility that the model solution is not unique is mitigated by confirming that equivalent solutions are obtained from different initial conditions.

D.1.1.3 Data Overview

The data in Haiku come from a variety of mostly public sources, which are listed in Table D.1.1. The Energy Information Administration (EIA) is a primary source of data on the performance characteristics of many of the generation technologies represented in the model. In addition the EIA is used for information about fuel supply. The Environmental Protection Agency (EPA) provides important information about pollution control technologies. In some cases this information is supplemented with information from the North American Electricity Reliability Council (NERC), and in other cases firms or individuals have shared proprietary data, including individuals working on this report.

Table D.1.1. Haiku Data Sources

Variables	Source
Existing Generators	
Capacity	EIA
Heat Rate	EIA
Fixed and Variable O&M Cost	FERC\EIA\EPA
Existing Pollution Controls	EPA\EIA\RFF
Planned Pollution Controls	RFF
Baseline Emission Rates	EPA (CEMS/NEEDS)
Scheduled and Unscheduled Outage Rates	NERC GADS data
New Generators	
Capacity	EIA\EPA\Proprietary
Heat Rate	EIA\EPA\Proprietary
Fixed and Variable Operating Cost	EIA\EPA\Proprietary
Capital Cost	EIA\EPA\Proprietary
Outage Rates	EIA\EPA\Proprietary
Fuel Supply	
Wellhead Supply Curve for Natural Gas	Interpolated based on EIA forecasts
Delivery Cost for Natural Gas	EIA (AEO 2007)
Minemouth Supply Curve for Coal	EIA (AEO 2007)
Delivery Cost for Coal	EIA (AEO 2007)
Delivered Oil Price	EIA (AEO 2007)
Pollution Controls	
SO_2 – cost and performance	EPA
NOx – cost and performance	EPA
Hg – cost and performance	EPA
Transmission	
Interregional Transmission Capacity	NERC
Inter and Intraregional Transmission Costs	EMF
Inter and Intraregional Transmission Losses	EMF
Demand	
Demand Level (by season and customer class)	EIA
Load Duration Curve	RFF
Demand Growth (by customer class and region)	EIA (AEO 2007)
Demand Elasticity (by customer class)	Economics literature

D.1.2 Institutions

Haiku is designed to simulate changes in electricity markets. Particular attention is paid to modeling changes in how electricity prices are determined in electricity markets and in the environmental regulations that govern them. Changes in these institutions affect the incentives and the economic behavior of participants in the markets, including producers of electricity and reserve services, transmission grid owners, and electricity consumers. In turn, changes in incentives affect various output measures such as electricity price and environmental performance of the market. This section will detail the capabilities of Haiku for modeling different types of market structures and environmental policies.

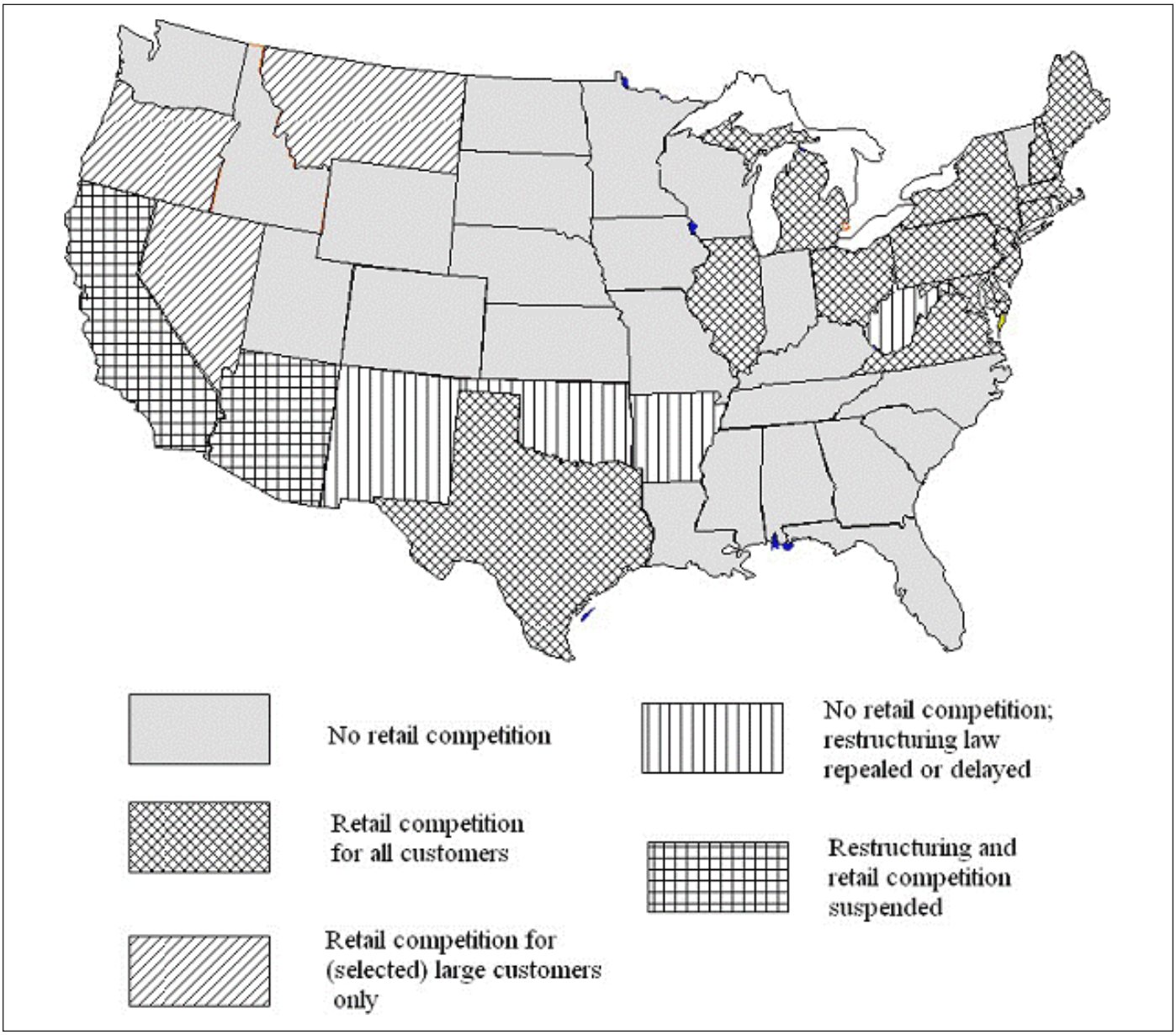
D.1.2.1 Market Structure

The passage of the Energy Policy Act of 1992 unleashed a process that changed the regulatory and market structures of the U.S. electric power industry. The act called on the Federal Energy Regulatory Commission to order all transmission-owning utilities to open access to their transmission systems at nondiscriminatory, cost-based transmission rates to facilitate competitive wholesale power transactions. Many states followed up with legislation and regulations that opened up retail markets to competition as well. Now, almost half of the population in the nation lives in states that have restructured their retail electricity markets and introduced competition. Figure D.1.2 provides a summary of the status of restructuring across the nation as of 2005.

The structural details of electricity markets vary widely across the nation. The model categorizes all markets as either regulated or competitive. In regulated markets, prices have traditionally been set based on average cost of service and this is the approach adopted in the model.[1] In competitive markets, prices are based on the marginal cost of service. Haiku treats each region of the country as either regulated or competitive to find equilibrium electricity prices. In many cases, the states that comprise a region do not all share a single market structure. In such cases, Haiku uses the market structure that characterizes a majority of the population within the region.

The remainder of this discussion of market structure will describe the algorithms for pricing electricity under regulated pricing and competition, the refinements to these general models, and the effects of competition on technical parameters.

Figure D.1.2. Status of Restructuring, 2005



Source: Joskow 2006

[1] Another approach to price regulation that has been used in some states is price cap regulation that essentially sets a cap on prices that regulated firms can charge.

D.1.2.1.1 Regulated Pricing (Average Cost Pricing)

The traditional method employed by state Public Utility Commissions for pricing electricity is to calculate the average cost of providing electricity services to each customer class and set electricity prices accordingly. In the model, this approach is called regulated pricing. Haiku models regulated pricing by breaking electricity services into two primary components. The production component accounts for generation and reserve services and the delivery component accounts for transmission and distribution services (T&D). Each component includes fixed and variable costs which are allocated across sales units (denominated in kWh). Retail electricity prices are adjusted from the sum of these two components to correct for profits garnered in the interregional power trading market.

The average cost of the production component of electricity services varies by time block, but is accounted as identical for all customer classes in each time block. Since each customer class has a unique distribution of demand across time blocks, the annual average production component of costs also varies by customer class. The delivery component of electricity service costs is treated as constant throughout the year, but does explicitly vary by customer class, with industrial customers paying a lower price because they tend to draw power at higher voltages and thus don't rely on the distribution grid.[2] Electricity price is set according to the sum of the annual average costs of electricity production and delivery for each customer class. For a single regulated region (ignoring power imports and exports), the equilibrium electricity price is that which solves Equation (1).

$$P_i = \frac{K + \sum_j V_j}{\sum_{i,j} D_{ij}(P_i)} + T_i \qquad (1)$$

where,

P_i = electricity price for customer class i [$/kWh],

$D_{ij}(P_i)$ = demand for electricity from customer class i in time block j at price Pi [kWh],

K = regional fixed costs of generation capacity, including annualized capital cost [$/yr],

V_j = variable costs incurred for generation and reserve services in time block j [$],

T_i = charge for T&D for customer class i [$/kWh].

The retail electricity prices faced by consumers are adjusted from the prices defined by Equation (1) to correct for the proceeds from interregional power trading. A producer that sells power to a customer outside of the region where the producer is located will collect rents, the difference between revenues and costs. The user of the model must specify how these rents will be divided between the producer and the producer's native consumers. Typically, the majority of these rents are assigned to consumers.

A second adjustment to the retail electricity prices faced by consumers also accounts for model calibration. A discussion of calibration is presented in Section D.1.3 Model Components.

D.1.2.1.2 Competitive Pricing

In regions with competitive electricity markets the retail price of electricity is equal to the sum of three components: generation price, reserve price and a T&D charge. The treatment of T&D in competitive regions is identical to its treatment in regulated regions, i.e. T&D is a fixed charge for each customer class expressed in $/kWh which equals the average cost of T&D services and does not vary throughout a year.

Generation prices in competitive regions are simply equal to the marginal cost of generation in each time block. Marginal cost in a time block consists only of the variable costs that would be avoided by the marginal unit were it to abstain from generating in the time block. The degree to which other costs, such as fixed operation, maintenance and capital costs, are loaded into marginal cost is an empirical matter. Haiku uses a default assumption that no costs other than variable are loaded

[2] Another reason prices might vary by customer class is that state public service commissions, which have authority for setting prices, have discretion in setting prices to promote economic development or attract business. This can lead to prices differentiated by customer class. Since these policies tend to be idiosyncratic, and also to vary among states within Haiku's regions, they are not represented explicitly.

into marginal cost. For a detailed breakdown of the variable cost components of marginal cost, see the section on production, Section D.1.3 Model Components. Generation prices vary by time block, but not by customer class in a time block.

Haiku solves for an equilibrium payment for reserve services, which is termed the reserve price and is analogous to capacity payments that exist in various forms in competitive regions. The reserve price reflects the scarcity value of capacity in each time block. As such, it is like the generation price in that it varies by time block, but not by customer class within a time block. Given an equilibrium set of generation prices and reserve prices, the reserve price in any single time block is set just large enough to prevent the marginal provider of reserve services in the time block from retiring. This calculation accounts for costs incurred and revenues garnered by this marginal unit in all other time blocks. In equilibrium, the reserve prices in base load time blocks typically will be zero, while the reserve prices in other time blocks will vary and the prices in the superpeak time blocks, especially in the summer, will be large. The treatment of reserve prices in producer accounting is addressed in the section on Capacity Investment and Retirement in Section D.1.3 Model Components.

The pricing of retail electricity in competitive regions can vary by the application of time-of-use pricing. Time-of-use pricing allows the retail electricity price to vary in time during a single season or even a single day according to a predetermined schedule that is known to the consumer. Haiku allows time-of-use pricing to be implemented for individual customer classes within any region that is modeled under competitive pricing. Customer classes that do not have time-of-use pricing face the same three components of electricity price as those that do have time-of-use price, but the components are averaged over time blocks within a season for each customer class. This yields prices that vary by season, but not by time block within a season. Ignoring interregional power trades, the equilibrium electricity prices for customer classes that do not face time-of-use pricing are those which solve Equation (2).

$$P_{ik} = \frac{\sum_j D_{ij}\left(P_{ik}\right)\left(G_j + R_j\right)}{\sum_j D_{ij}\left(P_{ik}\right)} + T_i \qquad (2)$$

where,

P_{ik} = electricity price for customer class i in season k [$/kWh],

$D_{ij}(P_{ik})$ = demand for electricity from customer class i in time block j (which falls into season k) at price Pik [kWh],

G_j = generation price in time block j [$/kWh],

R_j = reserve price in time block j [$/kWh],

T_i = charge for T&D for customer class i [$/kWh].

An important distinction exists between wholesale competition and retail competition in electricity markets in the United States. Today there are many customers for whom retail electricity prices are regulated, but the power companies who provide those regulated retail services compete for electricity procurement in a competitive wholesale market. This market structure is simulated in Haiku as a competitive market without time-of-use pricing. The institutional assumption that underlies this modeling approach is that generators will be recompensed on a cost of service basis as if they must procure all of their electricity in a competitive wholesale market that has equilibrium prices set at the marginal cost of generation. The default assumption is that retail electricity prices can vary by season, but not within a season, as it is defined in Equation (2). There are virtually no customers in the US today who face time-of-use pricing under retail competition, but this capability is functional in Haiku and can be used to project the effects of full-blown retail competition in any region of the country.

D.1.2.1.3 Effect of Market Structure on Technical Parameters

Competition in the electricity industry is expected to quicken the pace of technological change. Productivity change that results from restructuring is implemented in the model through changes in four parameters: improvements in availability factor at all generators, reductions in the heat rate at existing fossil fuel and nuclear fired steam boilers, reductions in operation and maintenance costs at all existing generators and reduction in general and administrative costs at all generators. The rates of productivity change resulting from restructuring have two components. First, Haiku assumes that a region that has just moved to competitive pricing will reap rapid improvements for two years. Second, the entire country will observe a

smaller rate of improvement as a function of the proportion of the country that has implemented competitive pricing. As the proportion of the country implementing competitive pricing grows, the rate of improvement in these four parameters grows. This component of productivity improvements reflects the common availability of technology and the common investment climate shared by firms in different regions.

D.1.2.2 Environmental Policies

The Haiku model can simulate a range of different types of environmental policies affecting the emissions of NOx, SO_2, CO_2 and mercury from the electricity industry and the techniques employed by the industry to abate the emissions. Among the environmental regulatory methods that the model is equipped to handle are cap and trade programs for emission allowances, technology standards, post-combustion emission control performance standards, and emissions taxes. Particular flexibility is available for modeling emissions allowance trading programs with capabilities including allowance banking, different methods of allowance allocation, safety valves on allowance prices, allowance caps which rely on circuit breakers and allowance offsets for CO_2 emissions. Haiku is also equipped to model policies specific to renewable technologies including renewable portfolio standards and renewable energy production credits.

This section provides detail on the modeling techniques employed to simulate environmental policies. For details on the algorithms used to simulate emissions and abatement techniques, please see the discussion on pollution controls in Section D.1.3 Model Components.

D.1.2.2.1 Emission Allowance Trading

Cap and trade programs for emission allowances have become the gold standard for emissions regulation in the electricity industry. Typically such a regulatory approach will establish a cap on aggregate emissions. Individual facilities are required to surrender one allowance for every unit (e.g. ton) of emissions. Individual facilities retain flexibility on how to meet their compliance obligation. One option is to reduce their emissions, but if another facility can reduce emissions at less cost, then it is profitable to compensate the other facility for doing so by purchasing an emission allowance that subsequently can be used for compliance. There are numerous variations in these programs, most of which can be represented in the model. These are described below.

Allowance Prices & Banking

The fundamental element in the emissions-trading algorithm is the allowance price. Many other components in the model take the solution to the allowance price algorithm as an input that affects incentives and behavior. These components include the algorithms for generation dispatch and investments in pollution controls. Haiku also is capable of modeling emissions taxes. The model treats an emissions tax as equivalent to an allowance-trading program with an exogenously specified allowance price. Because emissions taxes can be modeled as a special case of an allowance program, no more discussion will be devoted to taxes.

Under the simplest type of allowance trading policy, Haiku simply finds the allowance price that, in equilibrium, yields annual emissions equal to annual allowance allocation. Any combination of the Haiku regions may be aggregated under a single allowance policy and any combination of model plants may be designated as requiring an allowance for each unit of emissions. The model is equipped to handle policies in which the number of allowances required per unit of emissions varies by season. This is managed by multiplying seasonal emissions by a coefficient reflecting the number of allowances required per unit emissions in each season. It is in this manner that Haiku can simulate the NOx SIP Call policy, which applies only to emissions between May and September. The coefficient for the other months is set to zero.

A common feature of allowance trading is the ability to bank allowances for use in a future compliance period. The Haiku allowance-banking algorithm is built on the Hotelling rule from natural resource theory. This rule states that a non-renewable resource, like oil, will be extracted at a rate that causes the price for the resource to rise at a rate equivalent to the discount rate of the producer. The reason that one might expect this to be true is simply that if the price of the resource were to rise at a different rate, the owner of the resource could make money by leaving the oil in the ground, or alternatively extracting it all at once. If the entire industry behaved in this way, then price would adjust until, in equilibrium, the rate of change in price equals the discount rate.

A version of the Hotelling rule is expected to apply to emission allowance banking because allowances can be treated as

the non-renewable resource with a fixed allocation that will be priced according to the allowance consumption rate of the electricity industry. As such, the bank will be built up and then drawn down at a rate that causes allowance prices to rise at the discount rate of the electricity producers. When the quantity of allowances in the bank is zero, the allowance price may rise at a rate slower than the discount rate because the bank is not permitted to have a negative balance. However, the allowance price may not rise at a rate faster than the discount rate.

Haiku applies the Hotelling rule to emission allowances by bounding the solution to an allowance policy that does not allow banking. In equilibrium, the model has solved for the date at which the allowance bank begins to accumulate, the date it is exhausted, and the allowance price at the moment of exhaustion. The allowance price in all years prior to the initiation of the bank must be rising at no more than the discount rate. Between bank initiation and exhaustion, the allowance price must rise at a rate exactly equal to the discount rate. After bank exhaustion, the model permits the bank to be reinitiated. So the period after bank exhaustion is identical to the period before bank initiation and thus the allowance price must rise at a rate no greater than the discount rate.

Allowance Allocation

Haiku is capable of modeling a variety of methods for the initial distribution of emission allowances. These allocation methods include the apportionment of allowances from the federal to the state level and the method by which the allowances are distributed to the electric utilities that will require them. In some policies, like the SO_2 trading program under Title IV of the 1990 Clean Air Act Amendments, the federal government stipulates that the SO_2 allowances will be forever grandfathered to a set of facilities using a formula identified in the statute. In other policies, like the Regional Greenhouse Gas Initiative (RGGI), each state that is a party to the agreement is apportioned a quantity of allowances that they may allocate to electricity generators (or anyone else) at their discretion, subject to guidelines set forth in the model rule. Haiku is capable of modeling either type of policy. For any allowance policy, the model is configured with a set of regions in the domain of the policy, and the allowances to be allocated under the allowance policy are allocated either in aggregate or apportioned to the regional level and then allocated.

The various methods to allocate emission allowances can be classified in three categories: auction, grandfathering (historic-based allocation), and updating- based allocation. For any bundle of allowances, any two of these three methods may be specified in any proportion for each model year. Thus a policy that incorporates a gradual shift from grandfathering to an auction, for example, can be modeled by Haiku.

Under an auction, allowances are sold at a market price to anyone who wishes to buy them. The government that is responsible for determining the allocation, like the federal government or a state government, collects the revenues from the auction and may then recycle them at their discretion. Haiku generally treats these allowance revenues as an unassigned public good, but also has the capability to model investment in efficiency measures to promote electricity conservation as is proposed under RGGI. Further discussion of how investment in conservation is modeled can be found in Section D.1.3 Model Components.

Under grandfathering, allowances are given for free to a set of recipients who are determined according to some historical measure of output. The agent responsible for allocating grandfathered allowances must determine both the set of eligible recipients as well as the basis upon which allowances are allocated, usually generation or emissions. Haiku can simulate a grandfathering type policy using any historical data.

Updating-based allocation is a system in which allowances are given for free to a set of recipients based on a metric that is continually updated. The usual metric that is proposed is each facility's share of recent electricity generation. For example, allowance allocation in year t could be determined based on generation in year t-2. This allocation method introduces an incentive to generate because generation earns an allocation of valuable allowances. Haiku is configured to accommodate any set of model plants for allowance allocation eligibility and for a lag of any duration between the year in which output is measured and the year in which it earns an allocation. One refinement to updating-based allocation available in Haiku is for allowance allocation to be awarded only to incremental changes in output. For example, Haiku can be configured to allocate allowances to generators only on the basis of recent output that is greater than their output in the year 2000. Thus only recent output that is incrementally larger than historic output earns an allocation. Haiku can also simulate a demand conservation incentive in which electricity consumers can earn the value of an allowance allocation by voluntarily reducing

their electricity demand. This modeling is described in Section D.1.3 Model Components.

After allowances are allocated by the issuing agency, they may be traded among electricity generators and, under banking, by a third party investor. Haiku tracks allowance ownership and accounts for the revenues or costs associated with the allowance market. These costs and revenues can affect the capacity investment and retirement decisions made by generators and have a direct effect on electricity prices in regulated regions.

Safety Valve & Circuit Breaker

The presence of uncertainty is a constant for policymakers, especially for those crafting policy with long-term implications. Global climate change policy is one such issue for which uncertainty threatens to incapacitate the policy process. Among the many policy instruments being considered to manage the costs and benefits of reducing greenhouse gas emissions in the United States from the electricity sector are a "safety valve" and a "circuit breaker". Both of these policy instruments are designed as variants to the textbook carbon allowance cap and trade program to bring a prescribed regulatory response to as yet unrealized circumstances in a carbon allowance market.

A safety valve serves as a ceiling on the price of allowances by increasing the provision of allowances when the price of allowances exceeds the safety valve level. A symmetric safety valve in which there is also a floor on the price of allowances that can be managed by retracting some allowances from the market has also been proposed. Haiku models both a safety valve ceiling and floor by finding the equilibrium number of allowances that must be added to or removed from the market to prevent the allowance price from breaching the bounds defined by the safety valve. The model is also capable of simulating a policy in which there is a constraint on the number of allowances which can be issued or retracted under a safety valve. When a constraint on safety valve allowances is binding, the price for allowances may breach the ceiling or floor defined by the safety valve, but will do so by less than it would have in the absence of a safety valve.

A circuit breaker is a policy in which the stream of allowance provisions depends on the realization of allowance prices. Haiku models a circuit breaker as an initial provision of allowances followed by an annual reduction in the allowance provision. The provision reduction is short-circuited if the allowance price exceeds the circuit breaker price. Haiku is not equipped to model a circuit breaker floor that could yield an allowance provision increase.

Allowance Offsets for Carbon

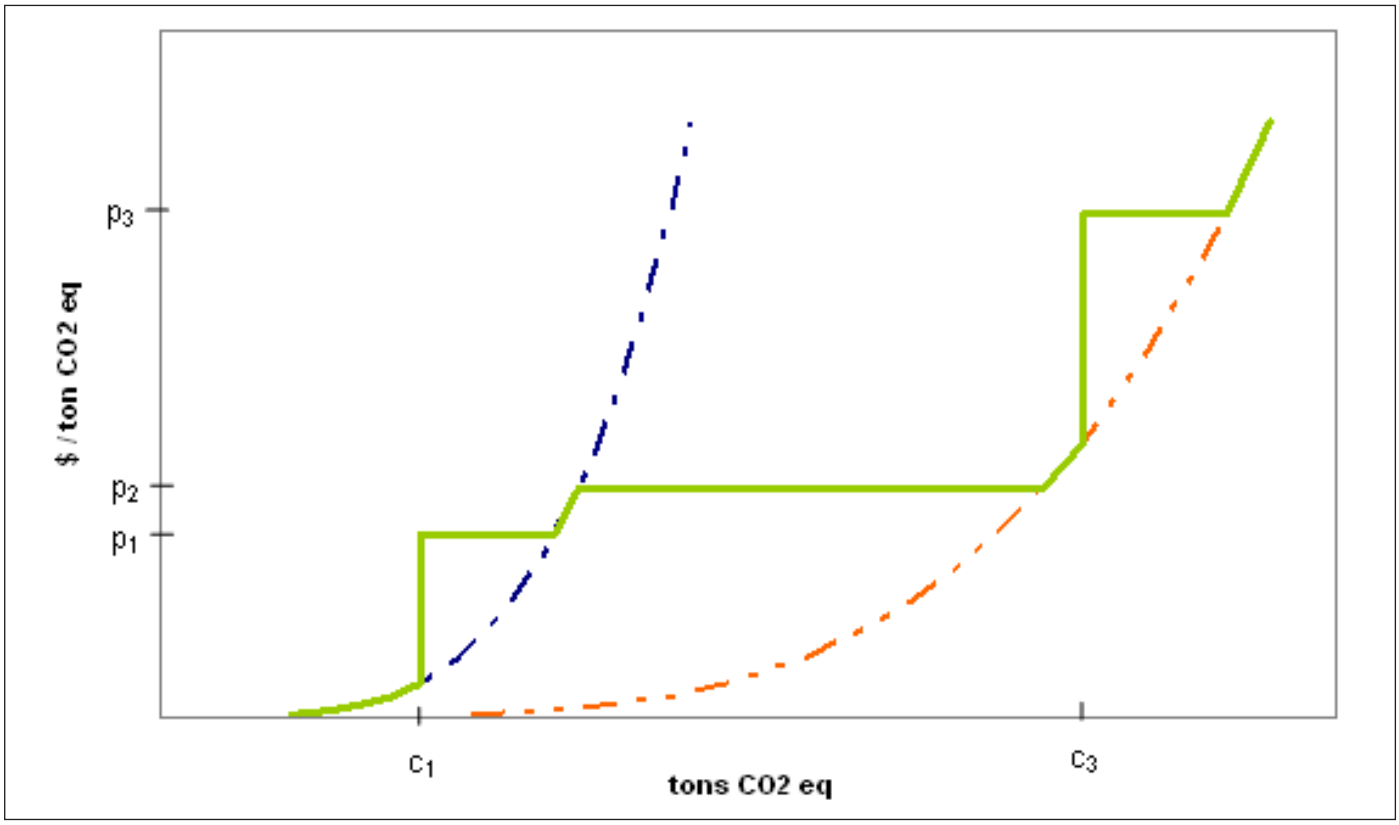
The most important greenhouse gas that is a byproduct of electricity generation is CO_2. CO_2 emissions from electricity generation account for about 40 percent of greenhouse gas emissions in the United States. These emissions have been the focal point of proposed greenhouse gas legislation for near term reductions, but other techniques for greenhouse gas abatement, often involving other greenhouse gases, are available to other industries. Developing legislation for controlling CO_2 emissions from the electricity industry often contains provisions for electricity generators to earn CO_2 reduction credits by paying others to abate greenhouse gas accumulation by these other techniques. These credits are known as allowance offsets.

The September 2005, EPA document called, "Analysis of Carbon Dioxide Offsets Provisions of the Clean Air Planning Act of 2003 (S. 843)" describes EPA's development of marginal abatement cost curves for greenhouse gas mitigation outside of the electricity sector. Haiku incorporates these data, along with adjustments made to them by the RGGI Staff Working Group, as allowance offsets supply curves. These data are expressed as tons of CO_2 equivalent abatement for prices expressed in $ per ton of CO_2 equivalent. Haiku can accommodate regulatory provisions that permit allowance offsets to be used for compliance with an allowance cap and trade program by permitting electricity generators to purchase offsets from the offset supply curves. This provision yields CO_2 emissions that exceed allowance caps by an amount equal to the number of allowance offsets purchased from outside the electricity industry.

Proposed RGGI regulation allows carbon offsets to be used up to limits that increase as the allowance price rises. These limits tend to increase the cost of CO_2 allowance offsets and therefore the overall cost of CO_2 reductions. RGGI also expands the geographic area from which allowance offsets can be purchased as the allowance price rises, thereby expanding the potential supply of offsets. Haiku is capable of modeling both types of provisions. Figure D.1.3 illustrates the effects of these policies on the CO_2 offsets supply curve. The single hashed function to the left represents the supply curve for CO_2 allowance offsets for a single small geographic region. The double hatched function to the right represents the aggregate supply curve for a larger geographic region that contains the original smaller region. The solid function represents the supply of CO_2 allowance offsets

for the smaller region under a regulatory regime in which 1) offsets are capped at c1 until the allowance price reaches p1, 2) the smaller region is permitted to buy offsets from its neighbors only after the allowance price reaches p2, and 3) offsets are capped at c3 until the allowance price reaches p3.

Figure D.1.3. CO_2 Allowance Offsets Supply Curve



D.1.2.2.2 Policies for Renewable Technologies

Many policies are in place to promote renewable technologies. In addition to relatively simple direct mandates for investment in renewables in regulated regions of the country, legislatures have often adopted renewable portfolio standards and tax credits. These can also be modeled in Haiku.

Renewable Portfolio Standard

A renewable portfolio standard (RPS) imposes a requirement that a minimum percentage of annual electricity generation must be provided through using renewable sources. Haiku models an RPS as an allowance trading program in which one Renewable Energy Credit (REC) is equivalent to one MWh of renewable generation, and each generator receives one REC for each MWh generated by a renewable source. A source that is partly renewable (e.g., biomass cofiring) receives allowances commensurate with the percentage of the generator that is powered by a renewable source. The allowances can be traded among facilities and between utilities. At the end of each year every facility must have enough allowances to satisfy the RPS. For example, if the RPS requires that 5 percent of national annual generation be renewable, then a utility that generates 1,000 MWh in a year must have 50 RPS allowances. The RPS can be specified at the national level and at the regional level.

Haiku calculates the value of the RPS allowances such that the prescribed RPS percentage is achieved. The subsidy value (for renewable sources) or cost (for nonrenewable sources) of the allowances is added to the marginal cost at which generators are dispatched. The user is able to cap the value of the RPS allowances using the RPS safety valve. If the allowance price reaches the safety valve price, then the allowance price is not allowed to climb any further, and the RPS percentage specified by the user will not be achieved.

Renewable Energy Production Credit

A renewable energy production credit (REPC) is a program under which electricity generators certified as renewable technologies earn a tax credit for generating power. Such programs are already in existence at the federal level and in some states. Haiku models an REPC by treating it as variable revenue that offsets the variable cost of generation. This moves qualified renewable technologies up in the dispatch ordering of electricity generators and effectively reduces their operating costs. The REPC can be specified at the national level and at the regional level.

Usually REPC programs provide the tax credit only to new facilities and only for a fixed duration. Also, these programs are often enacted for only a few years, after which they expire, and may be renewed. For example, the federal REPC provides a tax credit for renewable generation technologies during their first 10 years of operation, but it has repeatedly lapsed before being quickly renewed. The duration and intermittency of REPC programs presents a modeling challenge in Haiku since model plants representing new generators are not distinguished by vintage. The problem is managed by treating the REPC as an infinite stream of tax credits that is identical for all generator vintages within a model plant and equivalent to the present discounted value of the tax credit stream that would accrue to new vintages over a finite horizon. Equation (3) defines R, the REPC value that is used in Haiku. Note that REPC programs provide a production tax credit, not a production subsidy. An REPC that worked as a production subsidy would omit the (1 – t) term from Equation (3).

$$R = \frac{\overline{R}}{1-t}\left[1-\left(\frac{1}{1+r}\right)^{d}\right]p \qquad (3)$$

where,

R = value of REPC expressed as an infinite stream [$/kWh],

$\overline{R}$ = value of REPC collectible for d years after generator construction [$/kWh],

t = marginal profit tax rate [],

r = discount rate [],

d = duration of REPC eligibility after generator construction [yrs],

p = probability that REPC will be renewed after expiration [].

D.1.2.2.3 Technology Performance Standards (NSPS and MACT)

A technology performance standard for emissions requires that specific emission reduction targets be achieved. New source performance standards (NSPS) for various pollutants are one such example. This standard requires that emissions at newly constructed facilities fall below levels consistent with a maximum emission rate target. In practice, this translates into specific technologies that become the industry standard. In Haiku, all new investments conform to NSPS.

Another type of technology standard applies to existing as well as new facilities. The maximum achievable control technology (MACT) standard that has been adopted in many states for mercury emissions is one such standard. The MACT as modeled in Haiku may require a specific technology or it can be flexible in requiring that all coal-fired model plants either reduce emissions by a specified percentage or achieve a prescribed emission rate, whichever is less expensive. See Section D.1.3 Model Components for details of the implementation of technology performance standards in Haiku.

D.1.3 Model Components

D.1.3.1 Demand

Haiku classifies electricity demand by three customer classes (residential, commercial and industrial), by three seasons (summer, winter, spring/fall), and by four time blocks (baseload, shoulder, peak and superpeak). Demand for each customer class within each time block is represented by a price-sensitive demand function. Haiku is equipped with three different systems for modeling electricity demand: constant own-price elasticity, constant elasticity of substitution (CES), and habit formation. One of the three systems is used for each customer class in each region and they may be combined across different customer classes in different regions. The habit formation and own-price elasticity functions are documented here. The CES system is currently under development and this project made use of the habit formation demand functions.

All three demand systems undergo benchmarking to NEMS (National Energy Modeling System) electricity consumption and retail price projections. The benchmarking is performed such that a Haiku equilibrium that achieves retail prices equivalent to those in the NEMS projections will also achieve electricity consumption equivalent to these in the NEMS projections. This benchmarking defines the level of the demand systems. The demand systems then calculate changes from the benchmark level as a function of retail electricity prices.

D.1.3.1.1 Constant Own-price Elasticity

The constant own-price elasticity demand system finds electricity demand by customer class, season, and time block, where an exogenous elasticity is specified for each customer class, season, and time block. In principle the elasticity values are unique, but in practice data constraints yield many duplicate values. The function is as shown in Equation (4).

$$D = AP^{\varepsilon} \tag{4}$$

where,
D = quantity of demand [kWh],
A = demand function constant [],
P = electricity price [$/kWh],
ε = elasticity of demand with respect to price [].

To solve the demand functions for D and P, Haiku requires that A and ε be known a priori. The elasticity estimate, ε, is derived directly from historical data. The constant A is derived via the benchmarking process. With A and ε known, Haiku can plug any quantity or price into the function to calculate the other.

D.1.3.1.2 Habit Formation

The habit formation demand system finds annual electricity demand by customer class given a sequence of electricity prices. The habit system is dynamic in that the electricity price at any time t0 is one of the determinants of demand at all subsequent times t > t0. The habit formation demand system was originally advanced by Houthakker and Taylor (Houthakker 1970) as an econometric specification for simultaneously measuring the short and long run demand elasticities. In Haiku the model is used to econometrically measure the elasticities and then to project demand using the parameterized functions and endogenous electricity prices. The habit formation demand functions operate on annual data that is specified at the state level and take the form of Equation (5).

$$Q^*_{i,t} = \alpha_{i,t} P_{i,t}{}^{\gamma} X_{i,t}{}^{\beta} \text{ and } \frac{Q_{i,t}}{Q_{i,t-1}} = \left(\frac{Q^*_{i,t}}{Q_{i,t-1}} \right)^{\theta} \tag{5}$$

$$\Leftrightarrow$$

$$\ln Q_{i,t} = \theta \ln \alpha_{i,t} + \theta\gamma \ln P_{i,t} + \theta\beta \ln X_{i,t} + (1-\theta) \ln Q_{i,t-1}$$

where,
$Q_{i,t}$ = electricity consumption in state i at time t [kWh],
$Q^*_{i,t}$ = electricity consumption in the absence of habit in state i at time t [kWh],
$P_{i,t}$ = retail electricity price in state i at time t [$/kWh],
$X_{i,t}$ = covariates in state i at time t for income, population, weather, GDP, natural gas price,
θ = habit parameter,
γ = long run price elasticity,
θγ = short run price elasticity,
α = benchmark parameter.

The parameters θ, γ, and α are estimated using a fixed effects specification on states and time and with the α term omitted. Then the α term is derived using the benchmarking procedure and the estimate values for θ, γ, and α. This provides a parameterized version of Equation (5) that is used in Haiku to project electricity consumption.

D.1.3.1.3 Demand Conservation Incentive (DCI)

An issue in market based approaches to environmental regulation, such as the use of tradable emissions allowances, is how the allowances are allocated to facilities or how the publicly owned auction or tax revenue is allocated. A related issue is whether some portion of the allowances should be allocated to specific purposes to provide special incentives. The Demand Conservation Incentive (DCI) in Haiku provides for the allocation of a portion of allowance revenue to consumers in the form of a subsidy to energy efficient end-use electricity consuming capital investment. The DCI module returns the amount of electricity saved per annum (kWh/yr) based on an annual stream of funding ($/yr) and a set of endogenous variables including retail electricity prices and natural gas prices. In equilibrium, the DCI mechanism lowers electricity consumption and retail electricity price.

The core concept of the DCI algorithm is indifference for the marginal electricity consumer between consumption and non-consumption of the marginal unit of electricity. This marginal consumer is willing to forgo consumption of the marginal unit for only an infinitesimal payment. When a DCI fund administrator has at his disposal a fund to incent consumers to reduce electricity consumption and maximize demand reductions with perfect knowledge of each consumer's demand function, he will optimally start by buying out the marginal consumer for a price of $0. The infra-marginal consumers require payment greater than $0 and demand increasingly greater payment as the regulator moves farther to the left of the margin. This defines a supply curve for demand conservation that is convex and can be used to estimate demand reductions as a function of total funding for the DCI.

The DCI is implemented as a subsidy to end-use electricity consuming capital investment. In this context the marginal electricity consumer is defined in a dynamic framework. The consumer that is willing to forgo electricity consumption via capital replacement, the mechanism of the DCI, must be willing to replace his pre-existing electricity-using capital good. When the DCI program provides an incentive for a capital replacement that is more energy efficient than the alternative investment that would have been made in the absence of the incentive, electricity consumption is reduced. Since capital goods that consume electricity are long lived investments, there are immediate annual demand reductions and a stream of reductions that follow the initial reductions that persist and abate. The DCI algorithm projects initial demand reductions and is implemented in parallel with the habit formation demand specification that projects the persistence of the initial reductions.

Several factors constrain the administrator in implementing a DCI type program. These include the cost of program administration, the efficiency funds that are captured by free riders (those who would have made the efficiency enhancing investment without the program) and the portion of the retail electricity market that is inaccessible to the administrator. These are captured in Haiku according to the series of illustrated descriptions of the DCI algorithm as implemented inside of the habit formation demand model that follows.

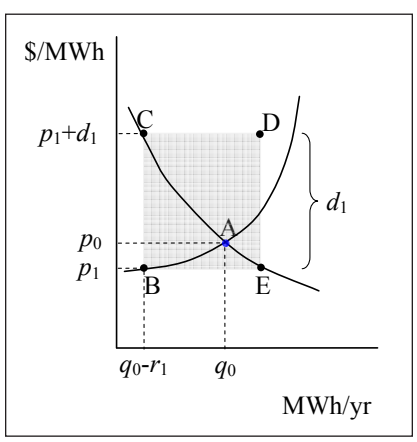


Figure D.1.4.

The inverse demand curve for annual electricity demand is shown in Figure D.1.4 as the line connecting points C, A, and E. The supply curve is shown through points B and A, and is an implicit function in Haiku. In the absence of any DCI fund, the average annual electricity price, p0, will prevail simultaneously with demand level q0. If a DCI program administrator is to maximize demand reductions then he/she must identify and compel the set of consumers that are closest to the margin to take up the investment subsidy. As more consumers take up the DCI payment, demand is reduced and the market equilibrium will move from point A to point B. The new equilibrium price will be p1<p0 and demand will fall from q0 by a quantity r1. The first consumer who takes up the DCI will be located at point E. The last consumer will be located at point C and will require a payment of d1 to make the capital substitution that improves end-use energy efficiency. The amount of money paid to consumers for this program is the area of the shaded rectangle BCDE.

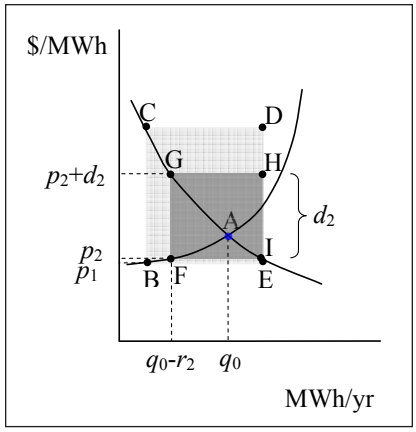


Figure D.1.5.

Suppose the rectangle BCDE represents the entire budget for the DCI program. Not all of these funds will reach consumers for electricity demand reductions and thus the equilibrium demand level depicted in Figure D.1.4, q0-r1, is unattainable under funding level BCDE. The mechanisms that prevent all funds from reaching consumers are captured explicitly by Haiku as program administration costs and free riders. Free riders are those who qualify for and accept the DCI payment for purchasing energy efficiency capital goods, but who would have made the identical capital choice in the absence of the program. Thus free riders are dead-weight on the DCI program in that they consume funds, but yield no demand reductions. In the Haiku DCI algorithm, the funds that are lost to program administration cost and free riders are captured as a proportional decrease in the area of rectangle BCDE to rectangle FGHI (Figure d.1.5). Thus a DCI program that is funded at the level BCDE will make available to consumers who reduce demand, a fund of value FGHI. The demand reductions achieved will amount to r2<r1 at an electricity price of p2, where p1< p2< p0.

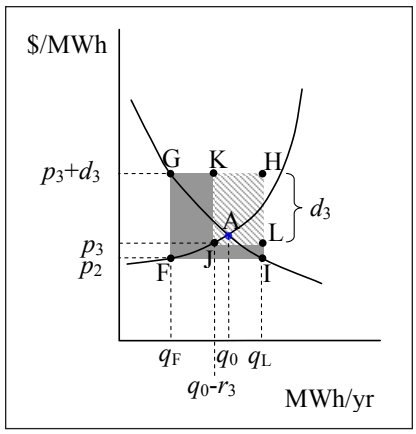


Figure D.1.6.

The DCI program will not be able to reach all of the demand reductions that are closest to the margin for a variety of reasons including consumers who are not aware of the program as well as those who are unwilling to take it up. These inaccessible reductions are modeled as the achievable fraction of economic reductions and reduce the demand reduction level by a fixed proportion. The lost reductions are assumed to be uniformly distributed across all reductions and thus if the opportunity cost of electricity consumption before accounting for inaccessible reductions, p2+d2, is to remain constant then the subsidy to efficient capital will fall from d2 to d3 as the electricity price rises from p2 to p3 in increasing demand. These values are indicated in Figure D.1.6.

As inaccessible reductions do not impose any direct burden on program funds, the cost to administer the program at subsidy level d3, the area of rectangle JKHL, will be insufficient to expend all program funds that reach consumers, the area of rectangle FGHI. The rectangle JKHL is defined such that the achievable fraction of economic reductions is [qL-(q0-r3)]/(qL-qF).

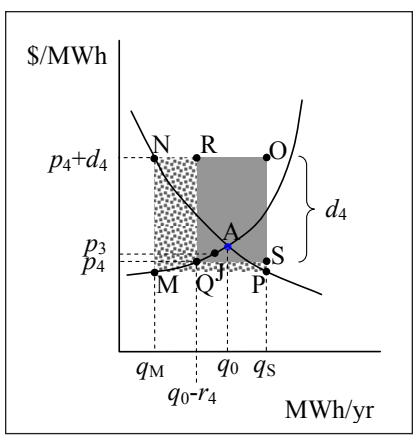


Figure D.1.7.

The DCI program will expand from subsidy level d3 to d4 to bring program expenditures reaching consumers up from JKHL (in Figure D.1.6) to the area of rectangle QROS (in Figure D.1.7). The figures in this document are not drawn to scale, but if they were, then the area of rectangle QROS would be equivalent to that of FGHI in Figure D.1.6. The increase from d3 to d4 will be just large enough to expend all program funds, while maintaining the inaccessible reductions assumption built into Figure D.1.6. So the achievable fraction of economic reductions is [qS-(q0-r4)]/(qS-qM). The electricity market equilibrium, after accounting for administrative costs, free riders, and inaccessible electricity consumption reductions, will support electricity price p4 at consumption level q0-r4.

D.1.3.2 Capacity Investment & Retirement

The generation capacity investment and retirement algorithms in Haiku assume perfect foresight. The model finds simultaneous equilibria that are inter-temporally consistent, with capacity decisions in all years consistent with equilibrium solutions for all control variables in all other years. Inter-temporal consistency for capacity applies both to physical capacity bounds and economic constraints. Since Haiku aggregates generation capacity into model plants, the capacity algorithms work at the marginal MW of each model plant and makes continuous adjustments to capacity. For more discussion of the nature of model plants and for an overview of the convergence techniques employed by Haiku, see Section D.1.1 Overview of Modeling Approach.

D.1.3.2.1 Cost Accounting

The key variable in the capacity algorithm is going-forward profits. Going-forward profits in any year are all revenues earned by a generator less costs that would have been avoided if the generator were retired or not constructed. For new capacity investment, going-forward profits are all revenues less all costs, including variable and fuel costs, fixed costs for maintenance and administration, and capital costs. For retirement of pre-existing capacity, going-forward profits are all revenues less all costs except capital costs. Capital costs are not included in going-forward profits for pre-existing capacity because they are sunk and therefore unavoidable. For investment in new capacity to be economic, it must have positive going-forward profit in the current year and the net present value of all future going-forward profits must also be positive. For pre-existing capacity to retire, it must have negative going-forward profits in the current year and the net present value of all future going-forward profits must also be negative. The components of going-forward profit are detailed in Table D.1.3.

Table D.1.3. Going-Forward Profits: Components and Inclusion Status by Capacity Vintage

	Capacity Vintage	
Revenues	Existing	New
Generation	X	X
Reserve Services	X	X
Stranded Cost Recovery	X	X
Costs		
Variable Costs for Dispatch[1]	X	X
Fixed Operation and Maintenance	X	X
General and Administrative	X	X
Taxes	X	X
Capital Cost for Generation Capacity		X
Capital Cost for Endogenous Pollution Controls	X	X
Cost of Displaced Existing Capital[2]		X
Imported Power	X	X

1. For a detailed accounting of Variable Costs for Dispatch, see the Section D.1.3.4 below on Production.
2. Applies only in regions with regulated electricity pricing.

Revenues from generation and reserve services are calculated based on the generation price and reserve price. Generation price, which is equivalent to the marginal cost of generation, is paid to every MWh of generation. The reserve price reflects the scarcity value of capacity and is set just high enough to retain just enough capacity to cover the required reserve margin in each time block. The reserve price is paid to every MW of reserve service and generation. Generation receives the reserve price because it not only contributes to demand for electricity, but also reduces the scarcity of capacity. If generation did not receive the reserve payment there would be an incentive compatibility problem in the superpeak time blocks, with marginal generators preferring to withhold power from the electricity generation market in order to participate in the capacity market. Paying the reserve price to plants that actually generate removes this incentive incompatibility and properly values the capacity contribution of electricity generation.

Haiku amortizes all capital costs. The capital recovery factor is the coefficient that describes the fraction of up-front capital costs that an electric utility bears annually. The capital recovery factor for investment in pollution controls is exogenous to the model and assumed uniform for all types of pollution control. The capital recovery factor for investments in generation capacity depend on an algorithm that accounts for the time required to construct new generation capacity and the economic lifetime of such investments. These parameters vary across different type of generation capacity. The algorithm also depends on the real cost of capital, which is assumed to be uniform across the electricity industry.

D.1.3.2.2 Capacity Bounds

The generation capacity of each model plant is bounded above and below in each simulation year. For existing generators, the lower bound on capacity is always zero, i.e. any existing capacity may retire at any time if it meets the economic conditions for retirement.[3] The upper bound on existing capacity in the first simulation year is simply the quantity of existing capacity. In subsequent simulation years, the upper bound is equal to the amount of capacity which is not retired in the previous year. Thus existing capacity can retire completely, but may not be rebuilt once it is retired. For new investments, Haiku accounts for both capacity that is under construction or planned for construction in the data year, and for endogenous investment in new capacity. New capacity is never permitted to retire once it is constructed. Therefore, new capacity which is already under construction or planned in the data year defines the lower bound for new capacity in the first simulation year. In subsequent years, the lower bound for new capacity is equal to the amount of new capacity constructed in the previous simulation year. The upper bound for new capacity investments is derived from two constraints: an absolute constraint and a constraint on the rate of new investments. In any simulation year the lesser of the absolute capacity constraint or capacity in the previous year plus the permitted investment rate defines the upper bound for new capacity investments.

Haiku may be configured to simulate a "policy surprise". In this configuration, a baseline model is solved using the constraints described above. Then a policy model is constructed which contains some policy, like new environmental regulation, that was absent in the baseline run and a specified time at which the new policy is announced. To solve the policy model Haiku looks to the solution of the baseline model for capacity retirement and investment in the years prior to the announcement of the new policy. This baseline level of capacity is treated by the policy model as existing capacity in the policy announcement year. From this year forward the standard algorithm described above is used to determine capacity investment and retirement.

D.1.3.2.3 Technological Learning

For new types of electricity generation technology, such as integrated gasification combined cycle (IGCC) plants, it is expected that as more plants are constructed their capital costs will fall. This phenomenon is called learning by doing. Haiku employs the model used by the Energy Information Administration to simulate technological improvement in new electricity generation capacity (EIA, 2006). The essence of the model is that the component parts of any new generation capacity will become cheaper as more are built. The rates at which capital costs fall depend on the maturity of the technology; as the technology matures, the rate of improvement declines. Since different types of generation capacity share mutual components, the construction of any type of capacity will contribute to the improvement of other types of capacity via those mutual components. For example both IGCC plants and combined cycle plants incorporate a heat recovery steam generator. When either type of plant is constructed the learning achieved about the heat recovery steam generator technology will lower the capital cost of future construction of either type of plant.

D.1.3.3 Availability

The fundamental unit of generation capacity in the Haiku model is nameplate capacity. The potential for electricity generation of one MW of nameplate capacity varies through time as ambient conditions change, the plant is taken offline for maintenance, and unscheduled outages occur. Haiku accounts for adjustments to nameplate capacity due to ambient conditions using historical data, from which a ratio between nameplate capacity and operating capacity is calculated for each model plant and season. An endogenous algorithm for determining the timing of scheduled maintenance is described in the next paragraph. Unscheduled outages are assumed to occur with equal frequency during periods for which a generator is scheduled to be in operation. Equation (6) defines the relationship between nameplate capacity and potential electricity generation in each season.

[3] Hydroelectric generation capacity, both conventional and pumped storage, is not permitted to retire or construct new capacity.

Each model plant in Haiku has a specified scheduled outage rate—the fraction of hours the plant is down annually for scheduled maintenance. Because Haiku is a seasonal model, the scheduled outage rate needs to be expressed by season, but the opportunity cost of a scheduled outage (electricity price) is not the same for all seasons. Generators tend to allocate more scheduled outages to low-price seasons and fewer scheduled outages to high-price seasons. Haiku endogenously allocates scheduled outages to the three seasons according to the average seasonal electricity price.

The availability of some types of capacity is not modeled in the manner described above. These include hydroelectric turbines, both conventional and pumped storage turbines, and wind turbines. Seasonal generation by conventional hydroelectric turbines is constrained not by the capacity of the turbines, but by the amount of water available. Haiku looks to historical data for seasonal hydro generation, and then endogenously allocates this generation to the time blocks in which it is most valuable,

$$PG_{ijk} = N_k r_{jk} (1 - s_{jk})(1 - u_k) H_i \qquad (6)$$

where,

PG_{ijk} = potential generation in time block i of season j for model plant k [MWh],
N_k = nameplate capacity of model plant k [MW],
r_{jk} = ratio of operating capacity to nameplate capacity in season j for model plant k [],
s_{jk} = fraction of season j devoted to scheduled maintenance for model plant k [],
u_k = probability of unscheduled outage for model plant k [],
H_i = number of hours in time block i [hrs].

bounded above by the capacity of the turbines and bounded below by the run-of-the-river requirement. Generation by hydroelectric pumped storage capacity is not permitted during base time blocks, as this is the time when water is collected for use in more valuable time blocks. The time block specific capacity factor of wind turbines in Haiku is derived exogenously to the model.

D.1.3.4 Production

Haiku models the requirement for electricity generation and reserve services in each time block depending on electricity demand, the reserve margin requirement, interregional power trading, and losses in interregional and intraregional transmission and distribution. Equations (7) and (8) define these relationships.

Demand for generation and reserve services are satisfied in Haiku for each time block using two separate supply curves. First, electricity generators are dispatched according to their variable costs to meet the requirement for generation. Then the remaining capacity which is not used for generation is dispatched according to unrecovered going-forward fixed costs to meet the requirement for reserve services. The remainder of this section will describe these supply curves.

D.1.3.4.1 Generation

The requirement for electricity generation in Haiku is met using generation supply curves that are distinct for each region and time block. The model plants with available potential generation in each region and time block are dispatched according to their variable costs. Equation (9) shows the components of variable cost that are accounted for generation dispatch. Each

$$G_{ij} = \frac{D_{ij}}{(1-a)} + E_{ij} + \sum_k I_{ijk}\left(1 - e_{jk}\right) \tag{7}$$

$$R_{ij} = \frac{D_{ij} m_j}{H_i} \tag{8}$$

where,
G_{ij} = requirement for generation in time block i in region j [MWh],
D_{ij} = electricity demand in time block i in region j [MWh],
a = coefficient for intraregional transmission and distribution losses [],
E_{ij} = total power exports in time block i from region j to contiguous regions [MWh],
I_{ijk} = power imports in time block I to region j from region k [MWh],
e_{jk} = coefficient for interregional transmission losses between regions j and k [],
R_{ij} = requirement for reserve services in time block i in region j [MW],
m_j = reserve margin requirement in region j [],
H_i = number of hours in time block i [hrs].

model plant has a unique value for Vij.

To facilitate model convergence and better represent the heterogeneity of the constituent generators that comprise a model plant, Haiku dispatches model plants assuming that each has a linear distribution of variable costs around a mean of Vi. The lowest variable cost model plants are dispatched first with each model plant providing generation not exceeding its potential generation. Haiku reads up the supply curve until the generation requirement in each time block is satisfied. This yields the amount of generation performed by each model plant and a marginal cost of generation in each time block. The generation price in each time block, which is a component of electricity price, is set equal to the marginal cost of generation. Figure D.1.8 is an example of a generation supply curve and illustrates the calculation of marginal generation cost and generation price. In the figure, 50 GW is the equilibrium level of supply and demand and the generation price is $70/MWh. Section

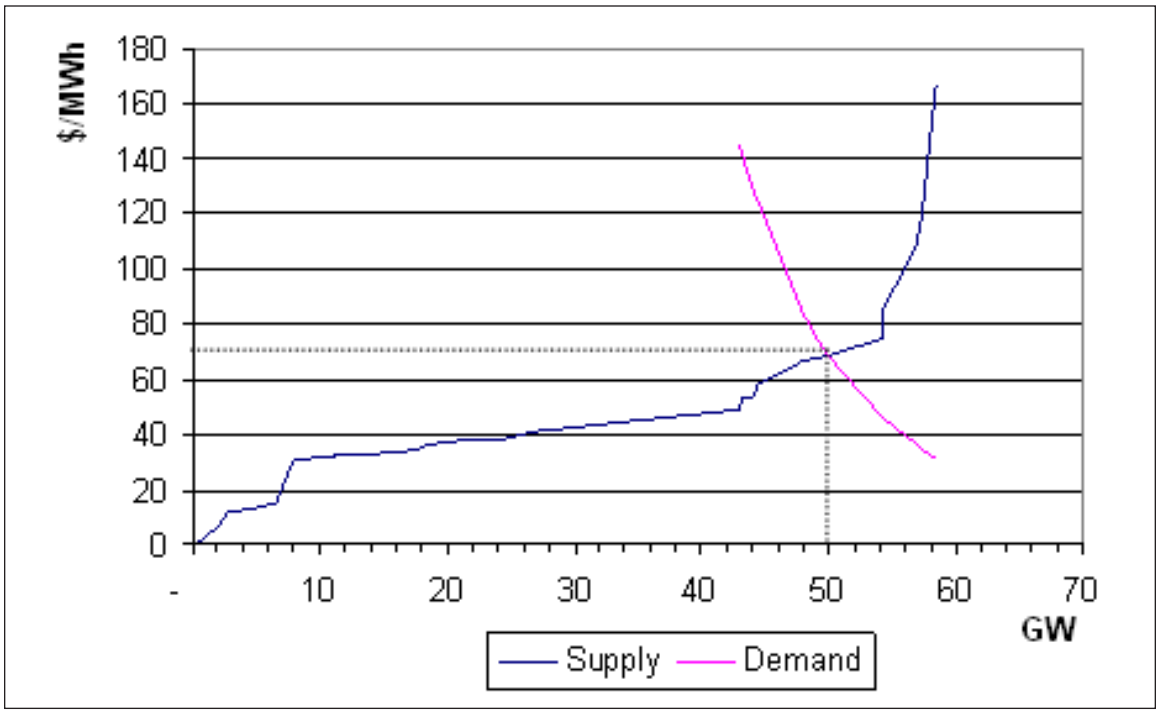
$$V_{ij} = v_j + f_j + \sum_l \left(\theta_{jl} p_{jl} - \alpha_{jl}\right) + \rho_1 + \rho_2 + c \tag{9}$$

where,
V_{ij} = variable cost for generation dispatch in time block i of season j [$/MWh],
v_j = variable cost of operation and maintenance[1] in season j [$/MWh],
f_j = fuel cost in season j [$/MWh],
θ_{jl} = emission rate in season j for pollutant l [tons/MWh],
p_{jl} = aggregate price for allowances or taxes assessed on pollutant l in season j [$/ton],
α_{jl} = allowance subsidy[2] for generation in season j for pollutant l [$/MWh],
P_1 = renewable energy production credit [$/MWh],
P_2 = value of renewable portfolio standard allowance [$/MWh],
c_k = generation calibrator[3] for model plant k [$/MWh].

D.1.2 on Institutions contains a detailed description of the electricity pricing algorithms employed in Haiku.

1. Includes variable cost of operation and maintenance for installed post-combustion pollution controls.
2. This subsidy is realized when allowances are allocated under updating-based allocation.
3. Applies only for steam generators powered by natural gas or oil. See Section D.1.3.8 Calibration below.

Figure D.1.8. Illustration of Generation Supply Curve



Some of the model plants are not dispatched in the manner described above. Biomass cofiring is a generation option chosen by some coal boilers and this portion of the model plant capacity is automatically dispatched with the rest of the coal boiler. The costs of the coal boiler are adjusted for the biomass cofiring portion. Hydroelectric pumped storage capacity is also dispatched in a special way. It is assumed that any generation performed by pumped storage is the result of electricity consumption in the base time block to prepare the water for generation in higher value time blocks. The amount of generation is determined according to the efficiency of the pumps and the time block specific electricity prices relative to the electricity price for industrial customers in the base time block.

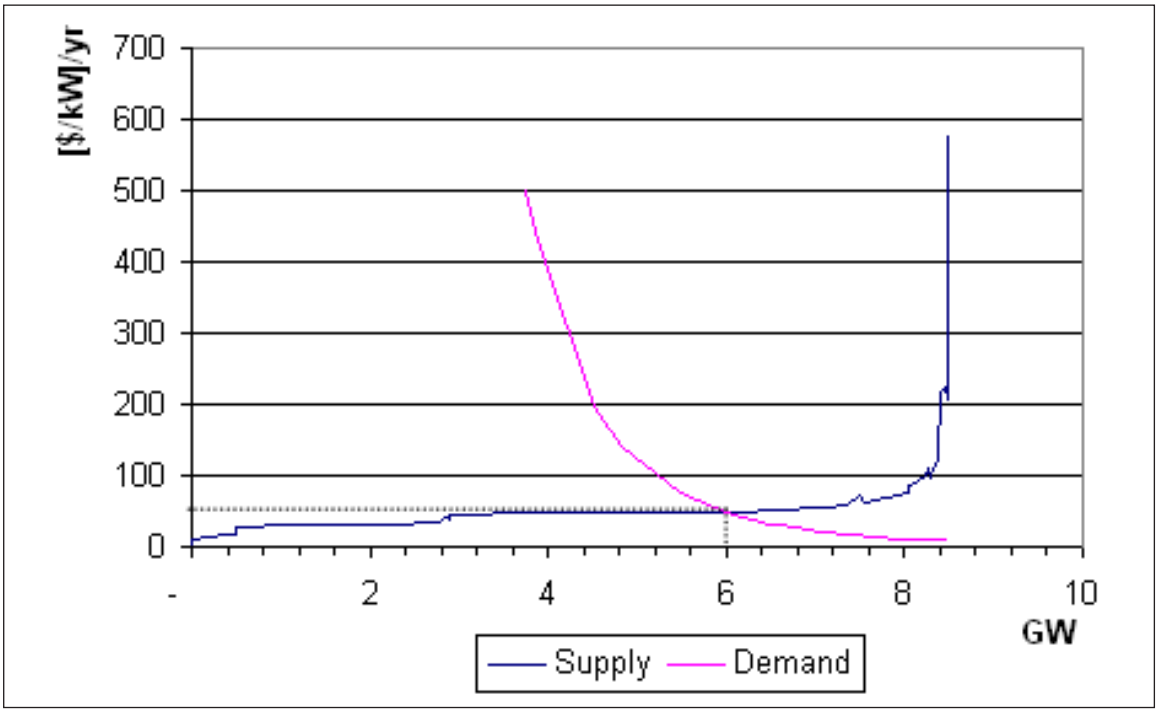
D.1.3.4.2 Reserve Services

The supply curves for reserve services are constructed based on unrecovered going-forward fixed costs that include all fixed costs that would be avoided if the model plant were retired or not constructed less surplus earned in all time blocks in the electricity generation market. Since each component MW of each model plant need not earn identical surplus in the generation markets, the model plants are disaggregated into sets of component MWs with identical unrecovered going-forward fixed costs. Each of these sets of component MW are called sub-MPs and are used only for dispatching capacity to meet reserve requirements.

The potential generation of each sub-MP in each time block is reduced by the amount of generation performed by that sub-MP in the electricity generation markets. The resulting value (in MWh) is divided by the duration of the time block to find the potential for each sub-MP to provide reserve services (in MW). The dispatch ordering for reserve services is determined by the unrecovered going-forward fixed costs of each sub-MP. As discussed in the section above on Capacity Investment & Retirement, the fixed costs that count as going-forward depend on the vintage of the model plant. See Table D.1.3 for an accounting of the going-forward costs.

Haiku does not model separate markets for spinning reserves and capacity reserves. 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. Given this constraint, Haiku constructs supply curves for reserve services using the aforementioned sub-MPs ordering and quantity of potential reserve for each sub-MP. The model reads up the supply curve to the prescribed reserve requirement for each time block to find the quantity of reserve services provided by each sub-MP and model plant. Figure D.1.9 is an example of a supply curve for reserve services.

Figure D.1.9. Illustration of a Supply Curve for Reserve Services



D.1.3.5 Interregional Power Trading

Haiku employs a reduced form interregional power trading model in which the national transmission grid is represented as a set of potential bilateral trades between every pair of contiguous regions. For regional pairs that are not contiguous, no direct power trading is allowed. However, power trades between non-contiguous regions may be executed through intervening regions that connect the non-contiguous regions. The model accounts for differences in regional electricity prices, interregional line losses and transmission costs in a pancake manner to find equilibria subject to constraints on interregional transmission capability. Pancaking means that fees and losses for interregional power trades are assessed at each regional boundary such that they accumulate for power that is traded between non-contiguous regions. Each time block has a unique equilibrium.

The heart of the interregional power trading algorithm in Haiku is the equilibration across regional boundaries of willingness to pay for power, subject to the assumed level of available interregional transmission capability. The equilibration is net of interregional transmission losses and fees. In practice the transmission capability constraints are often binding, leaving sometimes significant differences between willingness to pay in contiguous regions.

Two types of trades are modeled. Economy trades are the type described above. Firm trades represent prearranged commitments to provide power over the interregional transmission system. Exogenous estimates of firm trades come from historical data and EIA projections. These include both estimates and trading quantity and price.

Economy trades are calculated based on the willingness to pay for interregionally traded power. Willingness to pay is defined as the sum of generation price and reserve price (see Section D.1.2.1.2 Competitive Pricing in Section D.1.2 Institutions for a discussion of these prices). Reserve price is a component of willingness to pay because imported power reduces demand not just for electricity generation, but also for scarce capacity as generators displaced from the generation market are able to contribute capacity to the reserve margin and lower the scarcity value of capacity. Economy trades are priced at the mean of the willingness to pay – net of interregional losses and fees – in the two regions trading. When the capability for transmitting power is not binding, these two values are equal. Equation (10) defines the price for an economy trade between any importing region I and contiguous exporting region E.

Canada is treated in the model as an aggregate entity with which limited power trading is permissible. Potential trades with Canada exist for many of the northern regions in Haiku. Since the model does not include a representation of the Canadian electricity system, exogenous projections of international power trading quantities and prices are used to constrain such trades. Given these quantity constraints and prices, Haiku endogenously determines these trades. There is no power trading with Mexico represented in the model.

D.1.3.6 Pollution Controls

Haiku models post-combustion pollution abatement technologies for three different pollutants: NOx, SO_2 and mercury (Hg). The model chooses a set of abatement technologies for each relevant model plant and the variety of coal that is burned at coal-fired steam model plants. Since coal choice and some types of abatement technologies have effects on the emission rates of multiple pollutants, the Haiku pollution control algorithm is integrated to consider all pollutants, including CO_2, simultaneously. The algorithm is also integrated over all simulation years to yield a solution that is inter-temporally consistent

$$P_{IE} = \frac{1}{2}\left(W_I + \frac{W_E + c_{IE}}{l_{IE}} \right) \tag{10}$$

where,

P_{IE} = price for interregional economy trades between importing region I and exporting region E [$/MWh],

W_I = willingness to pay for power in region I [$/MWh],

W_E = willingness to pay for power in region E [$/MWh],

c_{IE} = interregional transmission cost between regions I and E [$/MWh],

l_{IE} = interregional transmission losses between regions I and E [$/MWh],

and optimal over the modeling horizon.

The types of pollution abatement technologies considered by the model are selective catalytic reduction (SCR), flue gas desulfurization (FGD) in both wet and dry configurations, and activated carbon injection (ACI). These technologies may be installed in combinations for which the economics depend on the cost of emissions of each type of pollutant and the capacity factor of the model plant on which they are to be installed. The combinations of pollution abatement technologies considered in Haiku are enumerated in Table D.1.4. Not all combinations of pollution abatement technologies are practical or legal for all model plants. For example, investment in new coal boilers is assumed to include construction of SCR and Wet FGD. Other abatement technologies are forbidden. Columns 2-5 in Table D.1.4 detail which combinations of pollution abatement technology are permissible for each type of model plant.

Table D.1.4. Pollution Abatement Technologies and Their Applicability to Model Plants

Abatement Technology	New Steam Coal	Existing Steam Coal[1]	New IGCC Coal	Existing Steam Gas / Oil
None		X		X
SCR		X	X	X
Wet FGD		X		
Dry FGD		X		
ACI		X		
Wet FGD & ACI		X		
Dry FGD & ACI		X		
SCR & Wet FGD	X	X		
SCR & Dry FGD		X		
SCR & ACI		X	X	
SCR & Wet FGD & ACI		X		

1. Most existing coal-fired steam boilers already have some combination of pollution abatement technologies. Haiku assumes that these will not be replaced, thus shortening the list of technologies that may be endogenously constructed.

Each combination of pollution abatement technologies has a unique set of abatement coefficients for each pollutant. The cost parameters for each technology are also unique, including estimates of variable operation and maintenance (O&M), fixed O&M and capital cost. Haiku permits coal-fired steam boilers to select a coal type from a set of fourteen types that are derived from data compiled by the EIA. These fourteen coal types each have unique values for heat content and pollutant contents for SO_2, CO_2 and Hg. Each coal type also has a unique price for each model plant that is derived from the coal supply curves described in Section D.1.3.7 Fuel Market Modules. Haiku assumes that coal boilers may switch coal types costlessly.

The Haiku pollution control algorithm minimizes the present discounted value of compliance costs over the modeling horizon assuming that any pollution abatement technology that is constructed will never be removed. To achieve this inter-temporally consistent solution, the set of abatement technologies given in Table D.1.4 is concatenated over model simulation years to yield one superset of competing compliance strategies that consists of the timing of abatement technology investments and, for coal burning model plants, a coal choice in each year. For each model plant, the optimal strategy from this superset is selected. Given an equilibrium pattern of electricity generation over time, equilibrium allowance prices or pollutant taxes, and the cost and performance parameters of each combination of pollution abatement technology and coal type, Haiku chooses the set of compliance measures that satisfy Equation (11). For model plants that burn natural gas or oil, the coal choice component of Equation (11) is omitted.

$$\underset{i \in I,\, j \in J}{\arg\min} \sum_{t} \left(\frac{1}{1+r} \right)^{t} \left[K_{it} + F_{it} + g_t \left(V_i + C_{jt} h_t + \sum_{k} P_{kt} e_{ijkt} \right) \right] \tag{11}$$

where,

I = set of pollution abatement investment strategies including investment timing,
J = set of coal types,
r = discount rate [],
t = Time [yrs],
K_{it} = annualized capital cost for strategy i at time t [$/yr],
F_{it} = Fixed O&M for strategy i at time t [$/yr],
g_t = electricity generation at time t [MWh/yr],
V_i = variable O&M for strategy i [$/MWh],
C_{jt} = Price coal type j at time t [$/kBtu],
h_t = heatrate at time t [Btu/kWh],
P_{kt} = allowance price or tax rate for pollutant k at time t [$/ton],
e_{ijkt} = emission rate of pollutant k at time t using strategy i and coal type j [tons/MWh],

To model technology performance standards, like NSPS and MACT, Haiku simply omits combinations of abatement technology and coal type which do not comply. Then the standard algorithm for pollution control choice, as described in Equation (11), is implemented. For more on the nature of technology performance standards, see Section D.1.2 Institutions.

D.1.3.7 Fuel Market Modules

Haiku has separate fuel market modules that endogenously determine prices for coal, natural gas and biomass. All other fuel prices are specified exogenously and change over time. The coal and natural gas modules are derived entirely from Energy Information Administration (EIA) data. The biomass module is derived from a database compiled by Oak Ridge National Laboratory.

D.1.3.7.1 Coal

EIA reports projections of coal consumption by electric utilities and mine mouth coal prices for a set of coal types from a set of coal supply regions. Haiku takes those data and aggregates them to a more manageable list of fourteen coal supply categories, each with a known heat content and pollutant contents for SO_2, CO_2 and Hg. EIA reports that a 10 percent deviation from the projected coal production will result in a 1 percent change in projected coal price. EIA also reports a markup (transportation fee) for each combination of coal demand region and coal supply region. With all of this information Haiku calculates coal supply curves that describe the delivered prices of the fourteen coal types in the thirteen coal demand regions as a function of electric utility demand for each coal type.

D.1.3.7.2 Natural Gas

EIA reports projections of natural gas consumption and national average wellhead price for the entire US economy for three cases: low economic growth, reference, and high economic growth. Haiku uses these three data points to derive a linear natural gas supply curve for the entire US economy. EIA also reports the projected natural gas consumption by all sectors of the economy except electric utilities. Using these data, Haiku calculates the national average wellhead price for natural gas based on endogenous natural gas consumption by the electric utility sector and exogenous consumption by all other sectors. Also from EIA data, a natural gas markup (transportation fee) is calculated for each region of the country, allowing Haiku to express the delivered natural gas price as a function of electric utility demand for natural gas.

D.1.3.7.3 Biomass

The biomass supply function in Haiku is constructed from projections of switchgrass and poplar consumption and prices for each. There are two projections — one for a low case and one for a high case — that are the two points used to define a linear biomass supply function that includes transportation cost. There is an absolute annual regional constraint on the quantity of biomass available. The equilibrium biomass price may fall above the biomass supply function if the absolute quantity constraint is binding.

D.1.3.8 Calibration

There are countless factors that affect the operation of the electricity system that are not explicitly captured by the Haiku model. These include intraregional transmission constraints, out-of-merit order dispatch, electricity market price controls, market power, general equilibrium capital market effects, etc. Two calibration factors in Haiku serve as aggregate correction terms. They are the Electricity Price Calibrator and the Variable O&M cost Calibrator. These values are such that the model solution for a historic year with verifiable data matches the data for regional average annual retail electricity price and regional annual generation by fuel & technology type (in MWh) for natural gas and oil fired steam boilers and combustion turbines.

D.2 Oligopolistic Power Market Model

The Johns Hopkins University Oligopoly Under Transmission and Emissions Constraints model (JHU-OUTEC) is a computational game-theoretical economic-engineering model. The model was previously used to assess the ability of generators in the PJM regional electricity market to manipulate power prices through the NOx allowances market (Chen and Hobbs, 2005). The model is formulated as a linear complementarity problem (LCP).

D.2.1 Background

This subsection provides background information on JHU-OUTEC and includes geographic coverage, the transmission network, loads, and imports and exports.

The geographic scope of the original application of JHU-OUTEC was based on the 2000 PJM footprint, including Maryland, Delaware, New Jersey, and eastern Pennsylvania.[4] In order to account for the bulk electricity flow from the neighboring states, JHU-OUTEC is expanded here to include the following neighboring regions: West Virginia, Virginia, western Pennsylvania, Kentucky, North Carolina and South Carolina, where Kentucky is grouped into APS (Appalachian Power System) system, and the last two states are grouped into VP (Virginia Electric Power) system.

Haiku approximates the electric power network as a transshipment, or "path-based", network in which power can flow along the least expensive path between source and sink. This approximation simplifies calculations, but disregards the parallel flow nature of networks-- in which power flows along all parallel paths between source and sink, satisfying Kirchhoff's Voltage and Current Laws. It is impractical to use a full ac load flow model to calculate average costs and prices over a long term horizon. A practical compromise is the so-called "linearized dc load flow" model, in which real power flows satisfy analogues of Kirchhoff's laws (Schweppe et al., 1988), but reactive power flows and resistance losses are disregarded, and voltage magnitudes are assumed to be constant. This approximation is now used widely in detailed models of competitive and oligopolistic power markets (Ventosa et al., 2005).

In this application of JHU-OUTEC, the simulated region includes seventeen zones (or nodes) and 24 or 25 transmission corridors (or arcs) (Figure D.2.1). The number of arcs depends on the scenario year, with the 25th representing a new connection between the western and eastern shores of the Chesapeake Bay that is assumed to be constructed by 2015.

In contrast to Haiku's representation of Maryland as a single node, in JHU-OUTEC Maryland is separated into four nodes based on flow patterns and network constraints. One zone (DPLC) is the Delmarva Power and Light, which includes Delaware and is recognized by PJM as a separate constrained zone (or Local Demand Area, LDA) in its future capacity market. PJM's RPM also recognizes central Maryland and the District of Columbia (the PEPCO and BGE service territories) as a separate LDA within RPM. This zone is further divided into northern and southern halves (designated BGE_2 and BGE_PEPCO, respectively). Finally, western Maryland is separated out (designated here as APMD, the Allegheny Power service territory within Maryland). Justifying this is an analysis of PJM LMPs (Locational Marginal Prices) from selected buses in APMD and PEPCO, which shows that PEPCO's hourly prices are statistically higher than APMD (Figure D.2.2).

[4] The geographic coverage of PJM Interconnection was the same as MAAC (the Mid-Atlantic Area Coordinating council, a subdivision of the National Electric Reliability Council) in 1998. But over the past few years, PJM has grown substantially. In 1998, it only included four states and Washington, DC in the Mid-Atlantic region. Now its coverage has expanded to comprise 13 states plus Washington, DC. As a result, besides the original territory, it now serves a total of 51 million customers with a peak-load of 131,330 MW-- approximately two and a half times as much load as in 2000.

Figure D.2.1. Transmission Network Approximation in JHU-OUTEC in the RGGI Analysis (Double arrows indicate exchanges with neighboring regions; lines without arrow heads are transmission corridors within the network model)

Zone	Abbreviation	Full Name
1	METED_1	Metropolitan Edison 1
2	METED_2	Metropolitan Edison 2
3	PPL_1	Pennsylvania Power & Light 1
4	BGE_PEPCO	Washington DC Metro Area
5	PPL_2	Pennsylvania Power & Light 2
6	DPLC	Delmarva Power and Light
7	PECO	Philadelphia Electric
8	PSEG	Public Service Electric & Gas
9	AE	Atlantic Energy
10	PPL_3	Pennsylvania Power & Light 3
11	JCPL_1	Jersey Central Power & Light 1
12	JCPL_2	Jersey Central Power & Light 2
13	BGE_2	Baltimore Metro Area
14	PN	Pennsylvania Electric
15	APMD	Allegheny Power-Maryland
16	APWV	Western Pennsylvania-WV
17	VA	Virginia

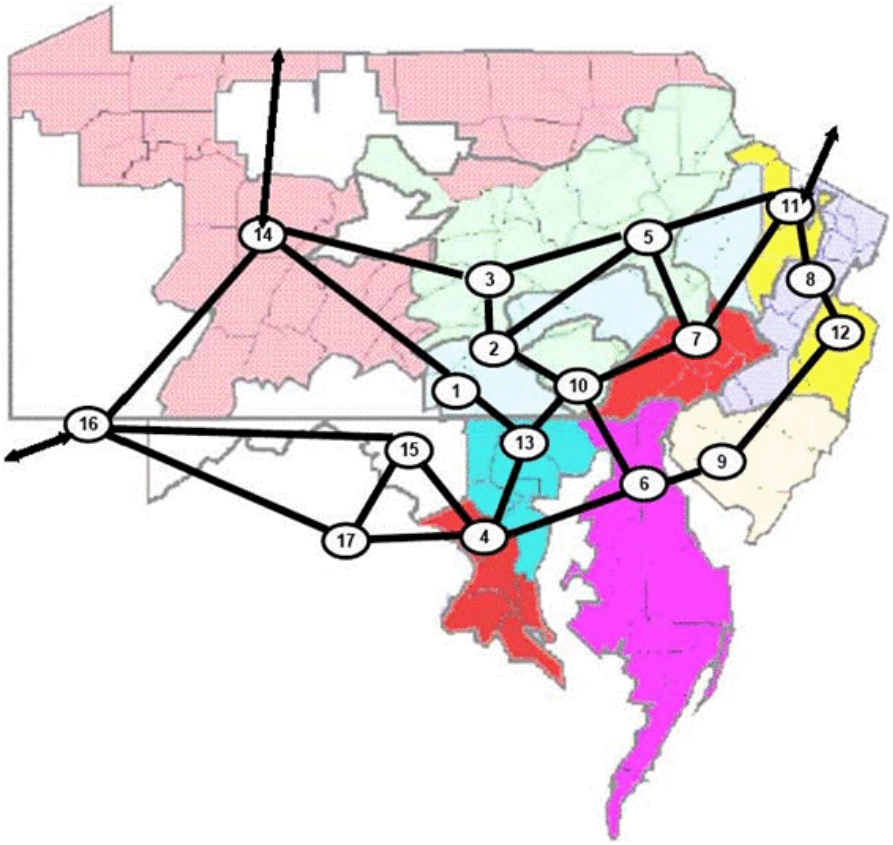
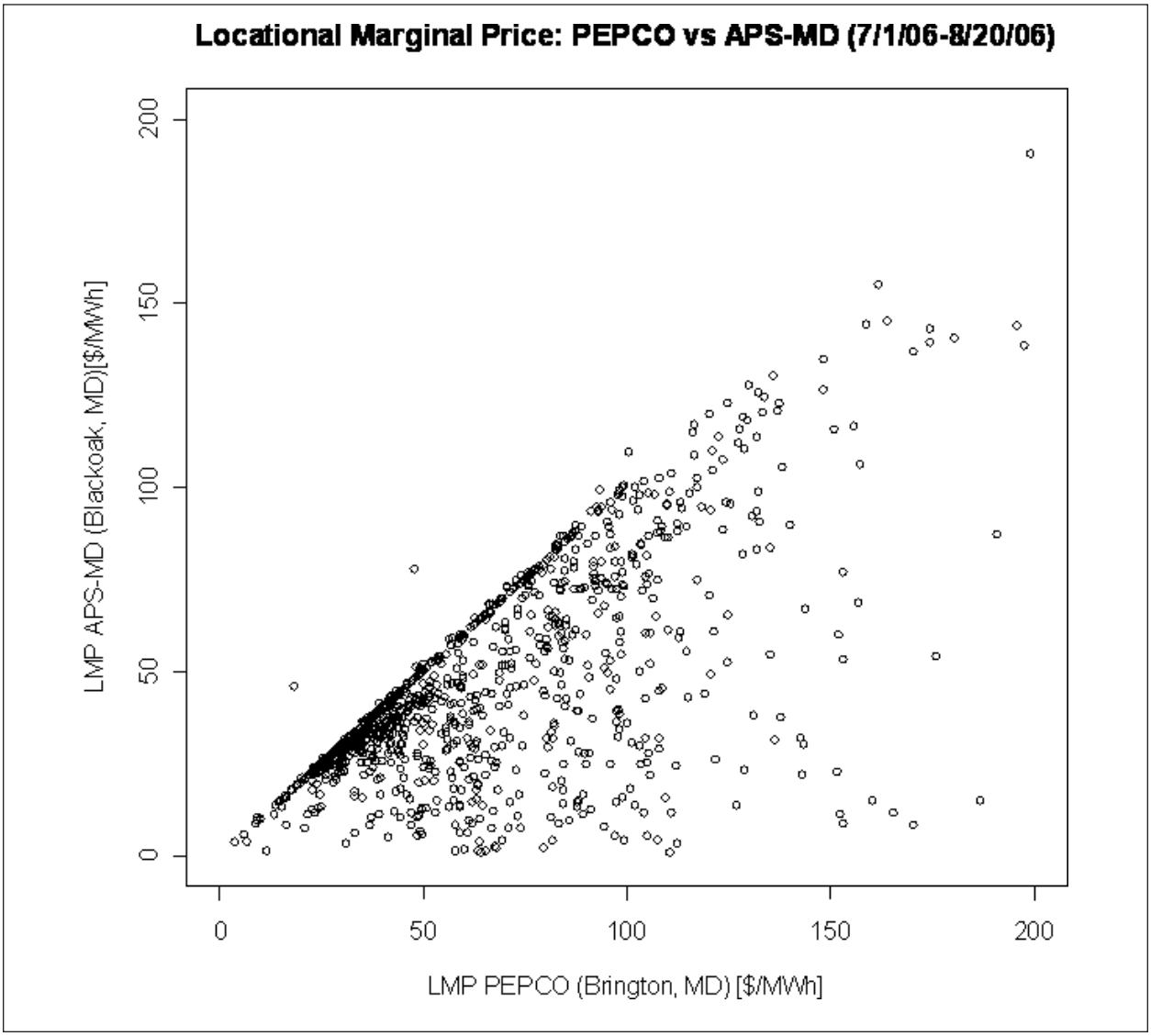


Figure D.2.2. Analysis of the PJM Locational Marginal Prices for Two Selected Buses in APMD and PEPCO_BGE Zones. (N = 998, Student t test rejects null hypothesis (H0: LMPPEPCO=LMPAPS-MD), t = 15.17, p<0.001), transmission, and long run contract positions (which affect the amount of market power being exercised).



To maintain consistency with the Haiku analysis, the estimated generating capacity for the future years (i.e., 2010, 2015, 2020, and 2025) from Haiku was directly incorporated in the JHU-OUTEC model. The same operating capacity for each season was maintained for each type of plant. However, it is necessary to disaggregate the Haiku model generators to seventeen individual zones and thirteen owners, with two competitive fringes in AP and VP. These owners include ten large companies and a "competitive fringe", which is assumed to behave competitively. The location and ownership of existing generators by zone was identified using latitude-longitude information from eGRID (USEPA, 2005), EIA (Energy Information Agency) (EIA, 2005), and USEPA (2006).

Since JHU-OUTEC is an operating model that does not consider generation investment, only the following categories of costs need to be considered in simulating the power market:

- non-fuel variable operations and maintenance costs, from the Haiku output
- fuel costs, from the Haiku output
- emissions costs (USEPA Clean Air Interstate Rule, USEPA Clean Air Mercury Rule, the NOx SIP call for summer NOx emissions, and the RGGI CO_2).

Because the JHU-OUTEC study area is smaller than the regions covered by those programs, the prices of these allowances are treated as exogenous in this analysis. In contrast, in Haiku, with its national scope, these prices can be calculated endogenously through the interplay of supply and demand. However, the shadow prices of emissions arising from the Maryland Healthy Air Act are obtained endogenously, since all affected plants are in the model.

It was assumed that all individual generating units that are within a single Haiku "Model Plant" grouping have the same costs and the same ratio of operating capacity to nameplate capacity. The transmission and capital costs considered by Haiku are not included in JHU-OUTEC, although congestion costs associated with the use of the grid are.

Haiku and JHU-OUTEC differ in their treatment of reserves markets. JHU-OUTEC has a market for operating reserves, and here it is assumed that operating reserves must be provided by the market equal to 7.5 percent of the load in the block, broadly consistent with PJM policy. A single operating reserves market is considered for PJM, although locationally constrained markets can also be modeled. Revenues from the PJM capacity market are not considered here but are analyzed in Section 8 Electricity Reliability.

An important factor in the market power analysis is ownership of the generating assets. All else being equal, a concentrated market will pose substantially higher risk of market power problems than a less concentrated market. The ten largest companies considered in this analysis are:

- Allegheny Electric System
- American Electric Power
- Conectiv
- Dominion
- Constellation
- Mirant
- PECO
- PPL
- PSE&GF
- Reliant

In this analysis, the primary source of ownership data is EIA Form 860 (EIA, 2005). For units not in EIA 860, an internet search (USEPA, 2006) or personal contact was used to confirm ownership. To ensure an appropriate representation of the potential of market power under the current ownership, it is assumed that operational decisions (generation and sale) are controlled by the parent company, replacing any subsidiaries with the corresponding parent company. Where detailed information on ownership was available, the capacity of existing jointly-owned units was split among the firms in proportion to their fraction of ownership. Where such information was not available, the company responsible for operating the plant was assumed to operate it in its interests (if one of the larger companies above), exercising market power in the oligopolistic scenarios. Other assumptions, such as assigning control to the owner with majority ownership, could instead be applied to study market power in the presence of partial ownership (Amundsen and Bergman, 2002).

New capacity that Haiku constructs is allocated to each zone and owner based on the proportion of existing generation by type and ownership. If this procedure results in unrealistically small capacity additions, those amounts are instead distributed among the other owners or zones, as appropriate.

One challenge in coordinating Haiku and JHU-OUTEC is the distribution of spatially aggregate regional electricity load data from Haiku to the specific zones in JHU-OUTEC model (e.g., from the Maryland Haiku region to BGE_2, BGE_ PEPCO, APMD, and DPLC). For simplicity, it was assumed that the relative proportions of each Haiku region's load that are assigned to each zone will not vary significantly over the simulated years. Therefore, load was allocated to the nodes in JHU-OUTEC in accordance with PJM historical data in 2001 (PJM, 2001).

The same number and duration of periods used by Haiku (12 periods per year of varying length) are used here. Linear demand functions with -0.2 elasticity are assumed, but are shifted downwards to account for the difference between wholesale and retail prices for energy (the latter including distribution costs, for example). This downward shift in demand functions decreases the effective elasticity. Adjustments are also made for distribution losses (about 6 percent). Finally, JHU-OUTEC

assumes that quantity demanded in a given period is a function only of price in that period, whereas Haiku has more complicated relationships (e.g., Haiku averages marginal costs over periods within a season).

This analysis assumes that bulk flow traded between the NY Independent System Operator (NY in Haiku) and the JHU-OUTEC region is through the JCPL-1 (Jersey Central Power & Light) and PN (Pennsylvania Electric Company) consistent with flow and line data shown in PowerWorld (PowerWorld 2003). The proportion for different nodes is based on the analysis of PJM's flow data. For flows from the west (Ohio) (OHMI in Haiku), these are assumed to be through zone APS (western Pennsylvania and West Virginia)

Network data, including transmission capacities (thermal or surge impedance loading (SIL) limits, as appropriate) and reactances required for deriving PTDFs, were obtained from the PowerWorld website (PowerWorld, 2003). Only the 500 kV grid is considered, which is the backbone of the PJM system. The transmission map for PJM was examined for lines that connect the zones. When more than one line connects two zones, the aggregate corridor capacity and reactance were calculated as follows:

- The corridor reactance Rc was calculated by the following formula for combining the reactance of parallel lines: Rc = 1/(i (1/Ri)), where Ri is the reactance of an individual circuit i in that corridor.
- The corridor capacity CAPc (in mega-volt-amperes, MVA) was obtained by modeling the lines as being in parallel; the corridor capacity is determined by which of the individual line limits is first met as the load flowing through the corridor increases. The formula is: CAPc = MINi (CAPi(k (1/Rk))/(1/ Ri)). This formula is derived by noting that if CAPc MVA is flowing through the corridor, then the share of that flow on circuit i is CAPc(1/ Ri)/(k (1/Rk)).
- A corridor's capacity in MW (real power) is obtained by multiplying the MVA capacity by 0.9 to account for real power flows.

In 2015, additional transmission capacity is assumed to come on-line. Information on the capacity and reactance of those lines was obtained from publicly available sources.

As is well known, the extent to which a supplier can benefit from exercising market power depends on the degree to which it is pre-committed, through forward contracts or vertical integration, to providing a particular amount of energy to the market. For instance, the lack of such contracts was a primary contributor to the 2000-2001 California market crisis, while the presence of such contracts in the summer of 2006 allowed California to meet record demand without the large price increases seen during the crisis. The electricity market is highly vertically integrated in the JHU-OUTEC study region. According to Mansur (2007), 53 to 59 percent of power in PJM is self-supplied by vertically integrated utilities: about 30 percent through short- or long- term bilateral contracts, and only 10 to 15 percent of power transactions are through the spot market. The remaining 1 to 2 percent is imported.

Because of the lack of publicly available data on forward contracting positions, the extreme bounding case of no forward contracts was simulated. This results in the largest price mark-ups under the oligopoly assumption. Comparing these bounding results to the competitive case provides an upper bound to the effects of assuming oligopoly rather than competition when projecting the effect of Maryland joining RGGI. There are six major vertically integrated load serving entities (LSE): Constellation (contracted with BGE), PECO (Philadelphia Electric Company), PPL and PSEG, Virginia Electric Power (VP) and Allegheny Power (WV). The remaining companies are independent suppliers. The native load of those vertically integrated load serving entities (LSEs) is defined as the corresponding nodal load net of customer load served by alternative suppliers. For independent power suppliers, their contracted load is the load of LSEs that sold their generation assets to the suppliers (net of supply from alternative suppliers). This analysis assumes that for each merchant supplier who built new plants, that it contracts 90 percent of its capacity to the nodes where its plants are located. Additional adjustments are applied such that market structure is consistent with the fact that PEPCO and PPL are the major two LSEs in an old PJM footprint having a long position in the spot market (Mansur, 2003).

D.2.2 Transmission Network Updates

Because transmission is a crucial component of the model, the latest plans for transmission enhancements into Maryland at the EHV (500kV or 765kV) level were reviewed. In the 2007 CIER RGGI report (pp. 144-145), three projects were described that were at that time planned for completion by 2015:

- A 500 kV corridor proposed by Allegheny Power from the Wylie substation in West Virginia to the Kemptown substation in Maryland;
- A 765 kV corridor from West Virginia to New Jersey proposed by American Electric Power (AEP) (AEP, 2007); and
- The Mid-Atlantic Power Pathway (MAPP), consisting of a collection 500 kV and 230 kV circuits from the Virginia side of the Potomac River through southern Maryland, across the Chesapeake Bay to the Eastern Shore of Maryland, and finally to Delaware (PJM, 2006).

In the analysis of last year, it was assumed that two out of the three projects would be completed: MAPP and the Allegheny Power projects. Based on the project descriptions, it was estimated that 4000 MW more transmission capacity would be provided from West Virginia and Virginia to central Maryland, and 1800 MW more capacity from central Maryland to points east. It was assumed as a rough approximation that half of this capacity (2900 MW) could be used to import more generation capacity under the PJM capacity market auction (the Reliability Pricing Model, RPM), broadly consistent with the ratio of 500 kV line capacity into Central Maryland to the amount of capacity (5100 MW) anticipated to be allowed under RPM in 2010. Thus, it was assumed that 2900 MW + 5100 MW, or 8000 MW of capacity import capability would be available under RPM to the Southwest MAAC area of PJM (which includes the most populous area of Maryland) in 2015.

Since January 2007, these plans have been modified somewhat, but not in ways that change the total numbers. As described below, the Allegheny Power line, now called TrAIL (Trans-Allegheny Interstate Line), has been rerouted, and is now proposed to end in PEPCO territory in Virginia, not Maryland (see Figure D.2.3). It would have a capacity of as much as 2400 MW. However, Maryland Public Service Commission staff (MPSC 2007a) argue that this line would still enhance import capability to central Maryland, so it is assumed that the proposal would have the same effect on import capability as the proposal that was considered last year. The AEP proposal (now called PATH, "Potomac-Applachian Highline") now extends only from West Virginia to central Maryland, with the extension to New Jersey being postponed. The 765 kV portion of the circuit could carry as much as 5000 MW, while the twin circuit 500 kV portion that connects the line into Maryland will have roughly the same capability.

It should be pointed out that not all of the capacity of these lines would be allocated to Maryland. The Maryland Public Service Commission (MPSC, 2007b) suggests, for instance, that only 23 percent of the transfer capacity of TrAIL and PATH should be credited to Maryland.

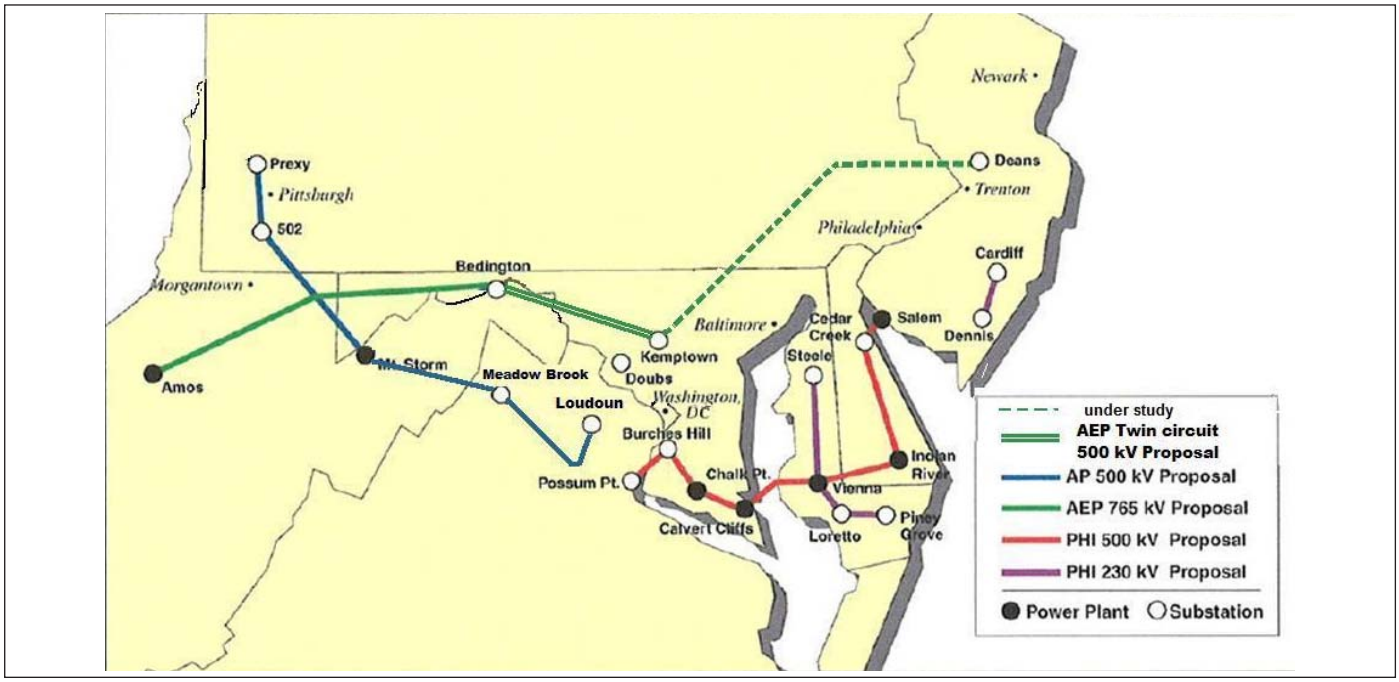
A staff expert of the Maryland PSC (MPSC, 2007a) recommends that the completion dates for the PATH and TrAIL lines be assumed by the PSC to be several years later than the proposed in-service dates of 2011 and 2012, respectively. MPSC (2007a) describes the status of the permit applications for the lines in various jurisdictions as of Oct. 2007.

Meanwhile, some minor upgrades of lines feeding Maryland have increased transmission capacity into the state by approximately 500 MW (4800 to 5300 MW) (MPSC 2007a).

Since the proposed lines have essentially the same capacity as the three proposals described in the Jan. 2007 CIER RGGI report, the same assumptions are made concerning Maryland import capability in Haiku and the generation capacity analysis. This assumption was that two of the proposed projects would be completed by 2015. However, as MPSC (2007a), no transmission projects of this magnitude have been successfully completed in this region within the last 20 years, and even much smaller projects (the 230 kV, 2.1 mile line extension described by MPSC, 2007a) have encountered significant opposition and delay. So realistic scenarios are possible in which only one or even none of the lines are completed.

The only other transmission update in JHU-OUTEC concerns a new Pennsylvania-New Jersey 500 kV line that is to be in place by 2015. In Haiku, the only update is increased capacity between New Jersey and Long Island, NY, resulting from installation of a new DC line.

Figure D.2.3. Three Proposed High Voltage Transmission Line Additions in the Maryland Region



D.2.3 JHU-OUTEC Model Formulation

This section introduces the model formulation. First, the notation (variables and parameters) used in the model is defined, followed by a presentation of the model formulation and the derivation of the equilibrium conditions (see Chen and Hobbs (2005). For background on the theory and properties of complementarity-based oligopolistic power market models, see Hobbs and Helman (2004) and Metzler et al. (2003).

D.2.3.1 Notation

Throughout this report, parameters and sets are denoted in capitals, whereas the lower-case letters refer to variables and indices. Dual variables are designated with lower-case Greek letters. The expression "x ⊥ y" means $x^T y = 0$, where x and y are vectors.

Set and Indices

$f, g \in F$	Generating firms
$F^c \subset F$	Set of Cournot firms
$h, h' \in H$	Generating unit
$H(i, f) \subset H$	Set of *f*'s generators at node *i*
$H^{HAAM}(i, f) \subset H$	Set of f's generators at node *i* whose emissions are included in the Healthy Air Act for Maryland
$i, j \in I$	Nodes in network
$t, t' \in T$	Period

Parameters

B_t	Duration of period *t* in the load duration curve approximation [hours]
C_{fih}	Marginal production cost of generator *fih* , which including emissions cost from Clean Air Interstate Rule, State Implementation Plan Call, Regional Greenhouse Gas Initiative [$/MWh]
E_{fih}	Emission rate of generator *fih* [lbs/MWh]
P^F_{fjt}	Price for forward contracted power sale by firm *f* in node *j* in period *t* [$/MWh]
P^0_{jt}, Q^0_{jt}	Vertical and horizontal intercepts of demand curve at node *j* in period *t* [$/MWh, MW]
$PTDF_{ki}$	Power transfer distribution factor for a unit power injection at an arbitrary hub node and unit withdrawal at node *i* for transmission interface *k* [MW/MW]
R_{fih}	Maximum operating reserve that can be provided by generator *fih* [MW]
RM	Required operating reserve as a fraction of total load [dimensionless]
S^F_{fit}	Forward contracted sales for firm *f* at node *j* in period *t* [MW]
T_k	Upper thermal limit of interface (transmission corridor) *k* [MW]
X_{fih}	Production capacity of generator *fih* [MW]

Variables

p^E_{jt}	Price of power at node *j* in *t* period [$/MWh]
$p^{pollutant}_f$	Dual variable for the Healthy Air Act for Maryland firm *f* [$/ton]
p^R_t	Reserve market price in period *t* for Maryland (p^{RMD}_t) and non-Maryland (p^{ROT}_t) [$/MW]
r_{fiht}	Operating reserve provided by generator *fih* in period t [MW]
s_{fjt}	Total spot and forward power sales by firm *f* at node *j* in period *t* [MW]
w_{it}	Transmission charge to move power from hub to node *i* [$/MWh] (endogenous to market but exogenous to producers)
x_{fiht}	Power output of generator *fih* in period *t* [MW]
y_{it}	Amount of power delivered from hub to node *i* by grid operator in period *t* [MW]
λ_{kt}	Dual variable associated with upper limit of power flow through interface *k* in period *t* [$/MW]
ρ_{fiht}	Dual variable associated with capacity constraints for generator *fih* in period *t* [$/MW]
θ_{ft}	Dual variable for *f*'s sale/output balance in period *t* [$/MW]
η_{fiht}	Dual variable for plant *fih*'s reserve upper bound in *t* [$/MW]

The remaining portions of this section are structured as follows. First, the decision problems for specific entities including: power suppliers, the grid operator, consumers, and an arbitrageur are introduced. Secondly, the first-order KKT (Karush-Kuhn-Tucker) conditions associated with each variable are derived. Finally, the KKT conditions together with market clearing conditions are collected and the market equilibrium problem in the form of a linear complementarity problem is defined.

D.2.3.2 Decision Models for Market Players

D.2.3.2.1 Consumers

The model represents the bulk power consumption decisions by consumers using linear inverse demand curves.

$$p_{jt}^{E} = P_{jt}^{0} - (P_{jt}^{0} / Q_{jt}^{0})(\sum_{f} s_{fjt} + a_{jt}), \forall j, t \qquad (11)$$

D.2.3.2.2 Producers

The model assumes that the bulk of power sales are in the form of bilateral contracts between producers and consumers, with the producer paying the system operator for transmission services necessary to deliver the power. When modeling oligopolistic competition, a few firms with substantial capacity are designated as strategic firms, engaging in Cournot (quantity) strategies in the energy market.

$$\begin{aligned} & MAX_{x_{fiht}, s_{fjt}, r_{fiht}} \sum_{j,t} (P_{jt}^{0} - (P_{jt}^{0} / Q_{jt}^{0}) \sum_{g} s_{gjt} - w_{jt}) B_t (s_{fjt} - S_{fjt}^{F}) \\ & + \sum_{j,t} B_t P_{fjt}^{F} S_{jit}^{F} + \sum_{i,h \in H(i,f),t} p_t^{R} r_{fiht} \\ & - \sum_{t} \sum_{i,h \in H(i,f)} B_t (C_{fih} - w_{it}) x_{fiht} \end{aligned} \qquad (12)$$

subject to

$$x_{fiht} + r_{fiht} \le X_{fih}, \forall i, h \in H(i,f), t \qquad (\rho_{fiht}) \qquad (13)$$

$$r_{fiht} \le R_{fih}, \forall i, h \in H(i,f), t \qquad (\eta_{fiht}) \qquad (14)$$

$$\sum_{j} s_{fjt} = \sum_{i,h \in H(i,f)} x_{fiht}, \forall t \qquad (\theta_{ft}) \qquad (15)$$

$$\sum_{i,h \in H(i,f)} B_t E_{fiht}^{pollutant} x_{fiht} \le CAP^{pollutant} \qquad (p_{ft}^{pollutant}) \qquad (16)$$

$$\forall s_{fjt}, r_{fiht}, x_{fiht} \ge 0$$

Each producer maximizes its profit by choosing its generation levels xfiht, operating reserves rfiht and sales sfjt for each period. The term P0jt – (P0jt/Q0jt)∑gsgjt-wjt is the per MWh revenue of spot electricity sales to j's consumers, net of wjt, the transmission charge paid to the grid operator to bring power to consumers from the hub. This expression shows that the strategic generators recognize their ability to influence power prices through the inverse demand curve (equation 11). Meanwhile, ∑i,tBtPFfitSFfit is the locked-in revenue received by generators through forward contracts with customers; this is exogenous (or fixed) to the model and for forward contract prices PFfit. The term ∑i,h∈H(I,f),tpRtrfiht comprises revenues from the reserve market. This analysis assumes that Maryland has a separate operating reserves market, while the rest of the power control areas are operated under another reserves market. The prices of reserves are assumed to not affect consumer quantity demanded. The Cfih-wit term is the per MWh cost of producing electricity from plant h, where -wjt is the price charged by the transmission operator to bring generation to the hub. (That price term is negative, since the generator actually provides counterflow from the node to hub.) It is assumed that the direct cost of operating reserves is negligible.

As for constraints, in addition to non-negativity restrictions, producers have several types of constraints. The first type includes capacity constraints. One such constraint limits the power output xfiht plus operating reserve rfiht to be no more

than the generator's derated capacity. The analysis assumes that generators incur no cost when keeping units synchronized with the grid without producing power. The second capacity constraint limits the amount of reserves from a generator. The third is an energy balance constraint, where the energy generation and sales have to be equal during each period. The fourth constraint (equation 16) only applies to generators located in Maryland that are subject to the Healthy Air Act for Maryland for two pollutants: NOx and SO_2. The total annual emissions of NOx and SO_2 cannot exceed the specified cap.

D.2.3.2.3 Power Arbitrageur

An arbitrageur is introduced to simulate a POOL-type market, in which the transmission cost between two nodes equals the difference in spot prices (Metzler et al., 2003). The arbitrageur is assumed to have perfect knowledge of the equilibrium power prices, and it moves power from the low-price nodes to the high-price nodes to maximize its profit.

$$MAX_{a_{it}} \sum_{i,t} B_t (p_{it}^E - W_{it}) a_{it} \tag{17}$$

subject to

$$\sum_i B_t a_{it} = 0 \ \forall t \qquad (p_t^H) \tag{18}$$

D.2.3.2.4 Grid Operator

The operator allocates scarce transmission capacity among demands for transmission services:

$$MAX_{y_{it}} \sum_{i,t} B_t w_{it} y_{it} \tag{19}$$

subject to

$$\sum_i PTDF_{ki} y_{it} \le T_k \ , \ \forall t \qquad (\lambda_{kt}) \tag{20}$$

The flow in the network is governed by the power transfer distribution factors (PTDFs) derived from the linearized dc approximation (Schweppe et al., 1988). The constraints associated with the grid operator are that the total flow has to be no more than the upper bound (Tk) for interface k based on thermal or other limits. A transmission corridor will generally have flow limits in both directions; this is represented by defining two interfaces k for each corridor, one for each direction. It is assumed that the grid operator is a regulated entity that allocates transmission capacity efficiently among demands for transmission service. This is the is equivalent of a price-taking assumption for the operator (Cardell et al., 1997).

D.2.3.2.5 Market Clearing Conditions

There are two sets of market clearing conditions: transmission and operating reserve pricing. The transmission condition requires that the demand for transmission service from each node equals the quantity supplied by the grid operator in each period. The second condition determines prices of the operating reserves markets: if there is more reserve capacity available in the market than required, the reserve market price pRt is zero; otherwise, it is positive. There are two sets of prices associated with the reserve market: Maryland (pRMDt) and Non-Maryland (pROTt).

$$\sum_f s_{fit} + a_{it} - \sum_{f,h \in H(i,f)} x_{fiht} = y_{it}, \forall i,t \tag{mc1}$$

$$0 \le p_t^R \perp \sum_{f,i} s_{fit} RM - \sum_{f,i,h \in H(i,f)} r_{fiht} \le 0, \forall t \tag{mc2}$$

These conditions are essential to calculating a market equilibrium. Not only does each commodity's clearing condition ensure balance of the physical system but it also implicitly generates a price by forcing demand and supply to equilibrate.

D.2.3.3 Market Equilibrium Model

The next step in developing the model is to derive the Karush-Kuhn-Tucker (KKT) conditions for each of the market participant's optimization problems. The market equilibrium problem is then defined as the collection of all KKT conditions for all the above problems together with the market-clearing conditions. The resulting complementarity problem can then be implemented in GAMS and solved with the complementarity solver PATH (Brooke et al., 1998). The complete market equilibrium problem is as follows.

Consumers: Demand function (11)

Producers:

For s_{fjt}, $\forall\, j, t, f \in F$

$$0 \le s_{fjt} \perp P_{jt}^0 - (P_{jt}^0 / Q_{jt}^0)(\sum_g s_{gjt} + a_{it}) - (P_{jt}^0 / Q_{jt}^0)(s_{fjt} - S_{fjt}^F) - w_{jt} - \theta_{ft} \le 0 \qquad (f1)$$

(For price-takers, this simplifies to: $0 \le s_{fjt} \perp p_{jt}^E - w_{jt} - \theta_{ft} \le 0$, with pEjt calculated from (11))

(For generators under the Healthy Air Act for the Maryland, (f2) is augmented with additional terms:

$$0 \le x_{fiht} \perp -(C_{fih} - w_{it})B_t - \rho_{fiht} + \theta_{ft}B_t - E_{fiht}^{NOx} p_f^{NOx} - E_{fiht}^{SO2} p_f^{SO2} \le 0 \qquad (f2)$$

$$0 \le \rho_{fiht} \perp x_{fiht} + r_{fiht} - X_{fih} \le 0 \qquad (f3)$$

$$\sum_j s_{fjt} = \sum_{i,h \in H(i)} x_{fiht} \qquad (f4)$$

$$0 \le r_{fiht} \perp p_t^R - \rho_{fiht} - \eta_{fiht} \le 0 \qquad (f5)$$

$$0 \le \eta_{fiht} \perp r_{fiht} - R_{fiht} \le 0 \qquad (f6)$$

Arbitrageur:

$$p_{it}^E - W_{it} - p_t^H = 0 \qquad (a1)$$

$$\sum_i B_t a_{it} = 0 \qquad (a2)$$

Grid Operator:

$$w_{it}B_t - \sum_k PTDF_{ki}\lambda_{kt} = 0 \qquad (g1)$$

$$0 \le \lambda_{kt} \perp \sum_i PTDF_{ki} y_{it} - T_k \le 0 \qquad (g2)$$

Market Clearing Conditions: (mc1)-(mc2) above.

D.3 IMPLAN

In order to quantify the economic impact of joining RGGI, Regional Economic Studies Institute (RESI) utilized the IMPLAN input/output model. This model enumerates the employment and fiscal impact of each dollar earned and spent by the following: employees of the new business, other supporting vendors (business services, retail, etc.), each dollar spent by these vendors on other firms and each dollar spent by the households of the new business' employees, other vendors' employees, and other businesses' employees.

To quantify the economic impact of a new business entering into an area, economists measure three types of economic impacts: direct, indirect, and induced. The direct economic effects are generated as new businesses hire workers to fill new positions. The indirect economic impacts occur as new firms purchase goods and services from other firms. In either case, increases in employment generate corresponding increases in household income—as new job opportunities are created and income levels rise. This drives the induced economic impacts that result from households increasing their purchases at local businesses.

Consider the following example. A new firm opens in a region and directly employs 100 workers. The firm purchases supplies, both from outside the region as well as from local suppliers. This leads to increased business for local firms, thereby creating jobs for approximately 100 additional workers. This is the indirect effect. The workers at the firm and at suppliers spend their income mostly in the local area, creating jobs for, hypothetically, another 50 workers. This is the induced effect. The direct, indirect, and induced effects, theoretically, result in 250 jobs created from the original 100 jobs. Thus, in terms of employment, the total economic impact of the hypothetical firm in our example is 250.[5]

D.3.1 What is IMPLAN?

IMPLAN is an economic impact assessment software system. The system was originally developed and is now maintained by the Minnesota IMPLAN Group (MIG). It combines a set of extensive databases concerning economic factors, multipliers and demographic statistics with a highly refined and detailed system of modeling software. IMPLAN allows the user to develop local-level input-output models that can estimate the economic impact of new firms moving into an area, as well as, the impacts of professional sports teams, recreation and tourism, and residential development. The model accomplishes this by identifying direct impacts by sector. It then develops a set of indirect and induced impacts by sector through the use of industry-specific multipliers, local purchase coefficients, income-to-output ratios, and other factors and relationships.

There are two major components to IMPLAN: data files and software. An impact analysis using IMPLAN starts by identifying expenditures in terms of the sectoring scheme for the model. Each spending category becomes a "group" of "events" in IMPLAN, where each event specifies the portion of price allocated to a specific IMPLAN sector. Groups of events can then be used to run impact analysis individually or can be combined into a project consisting of several groups.

The hallmark of IMPLAN is the specificity of its economic datasets. The database includes information for 528 different industries (generally at the four or five digit North American Industrial Classification level), and 21 different economic variables. Along with these data files, national input-output structural matrices detail the interrelationships between and among these sectors. The database also contains a full schedule of Social Accounting Matrix (SAM) data. All of these data are available at the national, state, and county level.

A primary strength of the IMPLAN system is its flexibility. It allows the user to augment any of the data or algorithmic relationships within each model in order to more precisely account for regional relationships. This includes inputting different output-to-income ratios for a given industry, different wage rates, and different multipliers where appropriate. IMPLAN also provides the user with a choice of trade-flow assumptions, including the modification of regional purchase coefficients, which determine the mix of goods and services purchased locally with each dollar in each sector. Moreover, the system also allows the user to create custom impact analyses by entering changes in final demand. This flexibility is a critically important feature in terms of the RESI proposed approach. RESI is uniquely qualified to develop data and factors tailored to this project, and, where appropriate, overwrite the default data contained in the IMPLAN database.

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[5] Total economic impact is defined as the sum of direct, indirect and induced effects.

Another major advantage of IMPLAN is its credibility and acceptance within the profession. There are over 500 active users of IMPLAN databases and software within the federal and state governments, universities, and among private sector consultants. Table D.3.1 provides a sampling of IMPLAN users.

Table D.3.1. Sampling of IMPLAN Users

Academic Institutions

Alabama A&M University
Albany State University
Auburn University
Cornell University
Duke University
Iowa State University
Michigan Tech University
Ohio State
Penn State University
Portland State University
Purdue University
Stanford University
Texas A&M University
University of California – Berkeley
University of Wisconsin
University of Minnesota
Virginia Tech
West Virginia University
Marshall University College of Business

Federal Government

Argonne National Lab
Federal Emergency Management Agency (FEMA)
US Dep't of Agriculture, Forest Service
US Dep't of Agriculture, Econ Research Service
US Dep't of Interior, Bureau of Land Mgmt
US Dep't of Interior, Fish and Wildlife Service
US Dep't of Interior, National Parks Service
US Army Corps of Engineers

State Governments

MD Dep't of Natural Resources
Missouri Dep't of Economic Dev.
California Energy Commission
Florida Division of Forestry
Illinois Dep't of Natural Resources
New Mexico Dep't of Tourism
South Carolina Empl Security
Utah Dep't of Natural Resources
Wisconsin Dep't of Transportation

Private Consulting Firms

Coopers & Lybrand
Batelle Pacific NW Laboratories
Boise Cascade Corporation
Charles River Associates
CIC Research
BTG/Delta Research Division
Crestar Bank
Deloitte & Touche
Ernst & Young
Jack Faucett Associates
KPMG Peat Marwick
Price Waterhouse LLP
SMS Research
Economic Research Associates
American Economics Group, Inc.
L.E. Peabody Associates, Inc.
The Kalorama Consulting Group
West Virginia Research League

The centerpiece of an economic impact study is the classification of impacts. In the case of the RGGI impacts, the direct impacts include the creation of jobs in specific industries and businesses. Indirect impacts measure the positive effect on the economy resulting from businesses selling goods and services to households. Induced impacts include the effects of increased household spending resulting from direct and indirect effects. Put another way, direct impacts are the immediate impacts of the RGGI jobs. Indirect and induced impacts are derivative, flowing from direct impacts.

Indirect and induced impacts are estimated by applying multipliers to direct impacts. Multipliers are factors that are applied to a dollar expended toward a particular use. These factors estimate the total value of that dollar as it moves through the economy. For instance, suppose that a dollar is spent in a certain industry. That dollar will increase the number of jobs in that industry by a certain amount. Furthermore, some of the money will go to pay the increased earnings in that industry, resulting in higher personal income. In turn, consumers will spend a share of that increase in personal income. Thus, the ultimate impact of a dollar initially spent in a certain industry is greater than its direct impact on the earnings of that industry. Multipliers are industry-specific factors that estimate the value of a dollar spent in an industry, including not only its direct impacts, but also its indirect and induced impacts.

RESI integrates the IMPLAN model into its methodology for conducting the economic impact analysis of the RGGI impacts. By developing a schedule of related direct impacts, the study team then creates sets of direct impact vectors, to be inputted into IMPLAN. The resulting runs then produce indirect and induced impacts related to those direct impact vectors.

The primary advantage of the RESI approach is that it provides geographic and industry-wide detail without sacrificing attention to the individual characteristics of RGGI impacts and the state. The geographic and industry detail are provided by the IMPLAN databases, upon which IMPLAN models are constructed. The attention to the unique characteristics and situation of these households are preserved because RESI will develop the direct impact vectors outside of the model, tailoring them to Maryland and its related job market, and utilizing the IMPLAN runs to develop indirect and induced impacts, vis-à-vis those tailored direct impact vectors.

The intimate relationship between the RESI impact model and RGGI's unique situation will be further preserved and enhanced by another aspect of the proposed RESI methodology. RESI tailored the operation of the IMPLAN model itself to Maryland and its counties. Using its extensive knowledge of the Maryland economy, RESI augmented the information contained in the IMPLAN model with detailed assumptions about parameters such as multipliers and output-to-employment ratios.

E. Haiku and Oligopolistic Modeling Results

Table E.1. Haiku Modeling Results for the Electrticity Sector in Maryland

	Fraction of RGGI allowance auction proceeds used to fund electricity consumption efficiency											
Scenario	25%				50%				100%			
Year	2010	2015	2020	2025	2010	2015	2020	2025	2010	2015	2020	2025
Electricity Price ($/MWh)												
Residential	97.7	93.3	90.9	95.0	97.1	91.7	90.9	94.9	97.0	92.6	89.3	94.2
Commercial	80.2	75.9	75.4	79.0	79.8	74.7	75.3	79.0	79.6	75.4	73.9	78.4
Industrial	63.2	59.1	59.9	63.2	62.8	58.0	59.7	63.2	62.6	58.5	58.4	62.7
CC Average	82.7	78.2	77.6	81.4	82.2	77.0	77.5	81.4	82.0	77.7	76.1	80.9
Electricity Consumption (BkWh)												
Residential	31.1	30.2	31.2	32.0	30.9	29.9	30.7	31.2	30.6	29.1	29.8	30.3
Commercial	21.2	22.2	23.6	25.3	21.0	21.9	23.1	24.6	20.8	21.3	22.4	23.7
Industrial	21.2	21.0	20.7	20.4	21.0	20.6	20.2	19.8	20.8	20.0	19.5	19.0
CC Total	73.4	73.3	75.6	77.6	73.0	72.4	74.0	75.6	72.3	70.4	71.8	73.0
Line Loss	4.6	4.3	4.4	4.6	4.6	4.3	4.3	4.5	4.6	4.1	4.2	4.3
Total	78.0	77.6	80.0	82.2	77.6	76.6	78.3	80.1	76.9	74.5	76.0	77.3
Electricity Expenditure (B$)												
Residential	3.04	2.81	2.84	3.03	3.00	2.74	2.79	2.96	2.97	2.69	2.67	2.86
Commercial	1.70	1.68	1.78	2.00	1.68	1.63	1.74	1.94	1.66	1.60	1.65	1.86
Industrial	1.34	1.24	1.24	1.29	1.32	1.20	1.21	1.25	1.30	1.17	1.14	1.19
CC Total	6.07	5.74	5.86	6.32	6.00	5.57	5.73	6.16	5.93	5.47	5.46	5.91
Efficiency Reductions (BkWh)												
Residential	0.39	0.46	0.55	0.56	0.53	0.63	0.74	0.76	0.72	0.83	0.99	1.03
Commercial	0.24	0.31	0.38	0.40	0.33	0.42	0.51	0.54	0.44	0.56	0.67	0.73
Industrial	0.26	0.32	0.35	0.35	0.36	0.43	0.47	0.46	0.48	0.57	0.63	0.62
CC Total	0.89	1.09	1.28	1.31	1.22	1.48	1.72	1.76	1.64	1.96	2.29	2.38
DCI ($/MWh)												
Residential	12.9	15.2	17.3	18.1	18.0	21.3	24.6	25.9	25.4	30.5	34.9	38.0
Commercial	14.0	16.5	18.9	19.9	19.7	23.3	27.1	28.5	27.8	33.5	38.7	42.2
Industrial	13.0	15.2	17.6	18.6	18.3	21.5	25.3	26.8	25.9	31.1	36.2	39.8
Payments to DCI (M$)												
Residential	5.0	7.0	9.4	10.2	9.6	13.4	18.2	19.5	18.1	25.5	34.6	39.3
Commercial	3.4	5.1	7.1	8.0	6.5	9.8	13.7	15.4	12.3	18.6	26.0	30.7
Industrial	3.4	4.8	6.2	6.5	6.5	9.3	12.0	12.4	12.3	17.6	22.7	24.7
CC Total	11.7	16.9	22.8	24.7	22.5	32.5	43.8	47.3	42.8	61.7	83.3	94.7
Free Riders	2.9	4.2	5.7	6.1	5.6	8.1	10.9	11.8	10.6	15.3	20.6	23.7
Administration	9.8	14.1	19.0	20.5	18.7	27.0	36.4	39.3	35.4	51.0	68.8	78.8
Total	24.4	35.2	47.5	51.3	46.9	67.6	91.2	98.4	88.9	128.0	172.8	197.2
RGGI Allowance Price ($/ton CO2)	2.80	4.11	6.04	6.51	2.68	3.94	5.79	6.24	2.53	3.72	5.47	6.27
Generation by fuel (BkWh)												
Coal	29.8	23.8	28.2	28.6	30.0	23.7	27.2	28.5	29.7	23.0	25.9	28.6
Natural gas	13.0	14.5	13.3	13.9	13.0	14.4	13.1	13.2	12.8	13.9	12.9	12.6
Nuclear	13.4	13.5	13.7	13.8	13.4	13.5	13.7	13.8	13.4	13.5	13.7	13.8
Oil	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0
Non-Hydro Renewables	3.2	3.2	3.8	4.4	3.0	3.0	3.8	4.4	3.0	3.1	3.7	4.2
Hydro	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Other Fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Generation Subtotal	61.1	56.9	60.7	62.6	61.2	56.6	59.5	61.7	60.7	55.4	58.0	61.0
Net Imports	16.9	20.8	19.3	19.6	16.4	20.0	18.8	18.3	16.1	19.1	18.0	16.3
Total	78.0	77.6	80.0	82.2	77.6	76.6	78.3	80.1	76.9	74.5	76.0	77.3
Capacity (GW)												
Coal	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Natural Gas	3.9	3.9	3.9	6.0	3.8	4.0	4.0	6.1	3.7	3.7	3.7	6.0
Nuclear	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Oil	2.3	2.3	1.8	1.8	2.8	2.8	1.8	1.8	2.4	2.4	1.8	1.8
Non-Hydro Renewables	0.5	0.5	0.6	0.7	0.5	0.5	0.6	0.7	0.5	0.5	0.6	0.7
Hydro	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Other Fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14.2	14.2	13.8	16.0	14.6	14.8	14.0	16.1	14.0	14.0	13.5	16.0
Existing & Planned by 2004	12.7	12.7	12.2	12.2	13.2	13.2	12.2	12.2	12.8	12.7	12.1	12.1
New	1.5	1.5	1.6	3.8	1.4	1.7	1.8	3.9	1.3	1.3	1.4	3.8
Emissions												
NOx (k tons)	22.9	19.7	20.2	20.3	23.1	19.7	19.8	20.0	22.6	19.2	19.0	19.7
SO2 (k tons)	38.0	24.2	25.1	26.8	43.3	24.1	24.4	26.1	36.5	23.6	23.9	26.3
C02 (M tons)	38.7	33.5	37.1	37.9	38.9	33.5	36.0	37.3	38.5	32.3	34.5	37.0
Hg (lbs)	285	215	236	238	308	214	231	235	282	210	220	236
HAA NOx (k tons)	14.7	11.4	12.7	12.8	14.9	11.4	12.3	12.7	14.5	11.1	11.7	12.7
HAA SO2 (k tons)	30.6	20.7	22.0	22.4	35.9	20.5	21.3	21.8	29.2	20.2	20.8	22.0
RGGI C02 (M tons)	180.6	174.3	170.6	163.0	181.0	174.8	169.7	163.1	180.6	174.5	169.4	163.2
Marginal Cost Components ($/MWh)												
Generation	41.0	38.1	42.4	44.4	40.9	38.0	41.8	44.2	40.4	37.7	40.9	43.8
Reserve	15.4	15.2	8.8	10.1	15.0	14.1	9.2	10.1	15.5	15.1	8.9	9.8
Transmission	6.1	6.1	6.1	6.2	6.1	6.1	6.1	6.2	6.1	6.1	6.1	6.2
Distribution	30.3	30.2	30.3	30.4	30.3	30.2	30.3	30.4	30.3	30.2	30.4	30.5
Stranded Assets	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calibrators	-10.1	-11.4	-10.0	-9.7	-10.2	-11.4	-10.1	-9.5	-10.3	-11.4	-10.2	-9.4
Total of Marginal Cost Components	82.7	78.2	77.6	81.4	82.2	77.0	77.5	81.4	82.0	77.7	76.1	80.9
CC Average Electricity Price	82.7	78.2	77.6	81.4	82.2	77.0	77.5	81.4	82.0	77.7	76.1	80.9
Fuel Prices												
Delivered Coal ($/MMBtu)	2.0	2.0	2.0	2.1	2.0	2.0	2.0	2.1	2.0	2.0	2.0	2.1
Delivered Nat Fas ($/MMBtu)	6.1	5.8	6.0	6.2	6.2	5.8	6.0	6.2	6.2	5.8	6.0	6.2
Delivered Oil ($/MMBtu)	6.5	5.5	5.9	6.2	6.5	5.5	5.9	0.0	6.5	5.5	5.9	6.2
Minemouth Coal ($/ton)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wellhead Nat Gas ($/kft^3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table E.2A. JHU-OUTEC: Perfect Competition Results for Bulk Energy Market Only

Bulk Energy Market Outcome		2010 1a Comp 25%	2010 1b Comp 50%	2010 1c Comp 100%	2015 1a Comp 25%	2015 1b Comp 50%	2015 1c Comp 100%	2020 1a Comp 25%	2020 1b Comp 50%	2020 1c Comp 100%	2025 1a Comp 25%	2025 1b Comp 50%	2025 1c Comp 100%
Market Revenues M$	Generator Revenue	1814	1818	1839	1886	1914	1940	2168	2336	2353	2476	2519	2597
	Generation Fuel Cost	998	998	1013	1103	1108	1127	1262	1368	1345	1458	1470	1509
	Consumers Bulk Energy Bill	2767	2820	2836	2789	2879	2924	3229	3359	3489	3571	3707	3837
Energy Demanded (BkWh)		73.4	74.5	74.9	74.0	75.7	76.4	77.0	78.2	79.7	79.7	81.8	83.3
Quantity-Weighted Prices $/MWh	MD	37.7	37.9	37.9	37.7	38.0	38.3	41.9	43.0	43.8	44.8	45.3	46.1
	PA	39.5	39.4	39.5	38.1	37.7	37.7	41.2	41.7	42.0	44.2	44.4	45.5
	NJ + DE	43.7	43.6	43.7	43.9	44.1	44.0	50.0	50.4	50.5	53.9	54.0	54.7
Energy Sources Billion kWh	Coal	29.0	28.7	29.0	31.5	31.5	31.5	31.7	32.8	32.7	33.3	33.2	33.3
	Natural Gas	0.9	1.0	1.1	1.0	1.1	1.2	1.6	2.7	2.0	3.6	3.9	4.3
	Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	13.4	13.4	13.4	13.6	13.6	13.6	13.7	13.7	13.7	13.8	13.8	13.8
	Hydro	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Wind	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Biomass	1.0	0.9	1.1	1.0	0.9	1.1	1.3	1.7	1.7	1.0	1.0	1.1
	Landfill Gas	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total Generation	48.1	47.9	48.5	51.0	50.9	51.3	52.2	54.8	54.0	55.6	55.9	56.4
	Imported Energy	25.3	26.6	26.4	23.1	24.8	25.1	24.8	23.4	25.7	24.0	25.9	26.9
	% of Load	34.5	35.7	35.3	31.2	32.7	32.9	32.2	29.9	32.2	30.2	31.7	32.3
MD CO2 Emissions (Mtons)		31.1	30.8	31.2	33.7	33.7	33.8	34.0	35.7	35.3	36.4	36.4	36.8

Table E.2B. JHU-OUTEC: Oligopolistic Results for Bulk Energy Market Only

Bulk Energy Market Outcome		2010			2015			2020			2025		
		2a Olig25%	2b Olig50%	2c Olig100%	2a Olig25%	2b Olig50%	2c Olig100%	2a Olig25%	2b Olig50%	2c Olig100%	2a Olig25%	2b Olig50%	2c Olig100%
Market Revenues M$	Generator Revenue	3127	3261	3334	3155	3205	3196	3727	3829	3796	4139	4180	4197
	Generation Fuel Cost	1133	1183	1222	1203	1216	1222	1419	1443	1455	1552	1562	1571
	Consumers Bulk Energy Bill	3899	4064	4093	3960	4101	4134	4681	4822	4916	5244	5424	5550
Energy Demanded (BkWh)		63.6	64.5	64.9	65.6	67.0	67.9	68.4	69.1	71.2	71.4	73.4	74.9
Quantity-Weighted Prices $/MWh	MD	61.3	63.0	63.0	60.4	61.2	60.9	68.4	69.8	69.0	73.5	73.9	74.1
	PA	59.8	60.8	60.9	59.8	60.0	60.1	66.6	67.4	67.2	72.0	72.2	73.2
	NJ + DE	61.7	62.5	62.5	62.9	63.6	63.5	72.5	73.9	72.4	78.7	79.0	79.7
Energy Sources Billion kWh	Coal	32.3	31.5	32.5	32.5	32.5	32.5	32.8	32.8	32.8	33.1	33.1	33.1
	Natural Gas	1.4	2.3	2.4	1.4	1.6	1.5	2.7	3.0	2.9	4.2	4.3	4.3
	Oil	0.1	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
	Nuclear	13.4	13.4	13.4	13.6	13.6	13.6	13.7	13.7	13.7	13.8	13.8	13.8
	Hydro	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Wind	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Biomass	1.0	0.9	1.1	1.0	0.9	1.1	1.1	1.3	1.5	0.6	0.7	0.7
	Landfill Gas	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total Generation	52.0	52.3	53.6	52.7	52.9	52.9	54.5	55.0	55.0	55.9	56.1	56.1
	Imported Energy	11.6	12.3	11.3	12.9	14.2	14.9	13.9	14.1	16.2	15.5	17.3	18.8
	% of Load	18.2	19.0	17.4	19.6	21.1	22.0	20.4	20.5	22.7	21.6	23.6	25.1
MD CO2 Emissions (Mtons)		34.9	34.7	35.8	35.4	35.5	35.4	36.3	36.5	36.4	37.2	37.3	37.3

F. ADDITIONAL INFORMATION ON STATEWIDE ENERGY EFFICIENCY PROGRAMS

This appendix provides additional details, including data and calculations, for Section 10.

F.1 Calculations for Comparable Annual Spending for Maryland

In Section 10 of this report, comparable annual spending for Maryland is provided to demonstrate what Maryland would have to spend to be on par with the New York-Maine average or the Vermont spending levels.

Table F.1 shows the average of the spending measures for New York and Maine. These spending measures can be used to determine a comparable annual spending for Maryland based on Maryland's population, GDP, and electricity consumption. For example, the comparable spending for Maryland based on population is calculated by multiplying the average spending per person in New York and Maine by Maryland's population. Similarly, the comparable spending for Maryland based on GDP and electricity consumption are calculated by multiplying the average spending per unit GDP and the average spending per million kWh consumed by Maryland's GDP and electricity consumption, respectively. The average of these three comparable spending values is $41.6 million. The comparable spending for Maryland was also calculated using the spending measures for Vermont. The average of the three comparable spending values for Maryland based on Vermont's measures is $145.6 million per year.

Table F.1. Comparable Annual Spending for Maryland Based on Spending Measures for NY, VT, and ME

Measure	Mid-level Spending Measures (average of NY and ME)	Comparable Spending/yr for MD ($million)	VT Spending Measures	Comparable Spending/yr for MD ($million)
Population	$6.30	35.4	$22.44	$126.0
GDP	0.02%	39.0	0.06%	$149.1
Million kWh Consumed	$742	50.4	$2,379	$161.5
Average	-	$41.6	-	$145.6

Sources: U.S. Census Bureau, EIA, NYSERDA, Efficiency Vermont, Efficiency Maine

F.2 Budgets and Program Cost-Effectiveness for Case Study States

New York's energy efficiency programs are administered by the New York State Energy Research and Development Authority (NYSERDA). In both Vermont and Maine, efficiency programs are administered by independent entities: Efficiency Vermont and Efficiency Maine. This section presents detailed descriptions and budgets for these efficiency programs as well as program cost-effectiveness.

F.2.1 New York

Table F.2. Descriptions of NYSERDA's Energy Efficiency Programs

Commercial/Industrial	Description
Peak Load Management	Offers financial incentives to allow participation in dynamic retail pricing, commodity purchase, and managing financial risk; provides incentives for equipment and technical solutions that enable significant demand reduction
Enhanced Commercial/Industrial Performance	Provides information and incentives to improve existing building loads, non-building loads, and process equipment; allows customers, ESCOs, and contractors access to multiple incentive strategies
New York Energy $mart Business Partners	Business partners are allies that agree to work with NYSERDA to promote energy-efficient products and services; in exchange, business partners gain access to special training, tools, guidelines, and performance incentives
New York Energy $mart Loan Fund and Financing	Expands the availability of low-interest capital to help implement energy efficiency projects and process improvements
Energy Smart Focus	Marketing and transformation effort that provides services to facilitate and encourage sector-specific energy efficiency improvements and practices
High Performance New Buildings	Encourages energy-efficient design and building practices among architects and engineers through design team incentives and recognition and urges them to inform building owners about the long-term advantages of building to higher energy efficiency standards; offers incentives to reward progressively better designs
FlexTech Technical Assistance	Provides customers with objective and customized information to facilitate wiser energy efficiency, energy procurement, and financing decisions; provides cost-shared technical assistance for detailed energy efficiency studies
Residential/Low-Income	**Description**
Single Family Home Performance	Supports market development through recruitment, training and incentives for builders and contractors in order to encourage them to offer energy efficient options; markets the benefits of energy efficiency to residential customers in order to increase demand for efficient products and services
Multifamily Building Performance	For new buildings, provides technical assistance to mid-stream market participants and incorporates renewable technologies, advanced metering technologies, real-time pricing strategies, and combined heat and power systems; for existing buildings, develops market-based business opportunities for building auditors, financial packagers, designers, architects, and construction inspectors in order to enhance the energy services infrastructure; low-income component provides technical and financial assistance to low-income building owners and their tenants to make efficiency improvements
Market Support	Provides support services to the building performance and low-income programs by increasing the availability of energy-efficient products and by increasing consumer demand
Communities and Education	Offers market infrastructure development for both short-term program support and long-term market development for residential energy efficiency with the aim of helping to develop an energy-conscious society
EmPower New York	Provides energy efficiency services, particularly lighting and refrigerator replacements, to utility customers earning less than

	60% of the state median income and households enrolled in utility low-income payment assistance programs; coordinates with the delivery of federal weatherization services
Buying Strategies and Awareness	Four initiatives serving low-income households including securing discounts on purchases of home heating oil, working to increase participation in all low-income energy efficiency and energy assistance programs, and providing a forum to discuss issues relevant to the low-income sector

Source: NYSERDA 2007a.

Table F.3. NYSERDA Energy Efficiency Budget for 1998-2006 and for 2006-2011

NYSERDA	Budget ($millions)			% of Program Area Budget	% of Total Budget
	1998-2006	2006-2011	Total Budget		
Program Areas					
Commercial/Industrial	359.2	276.7	635.9	37.8%	34.0%
Residential	167.1	135.0	302.1	18.0%	16.2%
Low-Income	128.4	190.2	318.6	19.0%	17.0%
R&D	210.8	182.0	392.8	23.4%	21.0%
Marketing	16.0	15.0	31.0	1.8%	1.7%
Program Areas Total	**$881.5**	**$798.9**	**$1,680.4**	**100.0%**	**89.8%**
Other Costs					
Program Administration	65.5	62.7	128.2	-	6.9%
Metrics and Evaluation	16.5	17.9	34.4	-	1.8%
Environmental Disclosure	1.9	0.0	1.9	-	0.1%
NYS Cost Recovery Fee	9.0	16.4	25.4	-	1.4%
Other Costs Total	**$92.9**	**$97.1**	**$189.9**	-	**10.2%**
Total New York Energy $mart	**$974.3**	**$896.0**	**$1,870.3**	-	**100.0%**

Source: NYSERDA 2007a.

Table F.4. Cost-Effectiveness of New York Energy $mart Programs in 2006

NYSERDA		Undiscounted Program Costs/kWh Saved	Levelized Program Costs/kWh Saved	Levelized Customer Costs/kWh Saved	Levelized Total Costs/kWh Saved
Commercial/ Industrial	Peak Load Management	0.016	0.024	0.010	0.034
	Enhanced C/I Performance	0.008	0.012	0.011	0.023
	Business Partners	0.006	0.008	0.002	0.010
	High Performance New Buildings	0.006	0.009	0.006	0.015
	FlexTech Technical Assistance	0.001	0.002	0.014	0.016
	Total Commercial/Industrial	**0.006**	**0.009**	**0.013**	**0.022**
Residential/ Low-Income	Single Family Home Performance	0.115	0.207	0.099	0.306
	Multifamily Building Performance	0.141	0.240	0.106	0.346
	Market Support Residential	0.004	0.005	0.013	0.018
	EmPower New York	0.028	0.043	0.007	0.050
	Total Residential/Low-Income	**0.015**	**0.021**	**0.031**	**0.052**
Total[12]		**0.010**	**0.016**	**0.023**	**0.039**

Sources: NYSERDA 2006; NYSERDA 2007a; NYSERDA 2007b.
* Levelized costs are adjusted for the present value of the lifetime energy savings

[1] Total costs include costs such as administration, marketing, and evaluation, while costs for individual programs and program sectors only include program costs.

F.2.2 Vermont

Table F.5. Descriptions of Efficiency Vermont's Programs

Program	Description
Business New Construction	Works with Vermont's commercial design and construction community to improve the efficiency and performance of new construction projects
Business Existing Facilities	Provides prescriptive incentives for businesses, contractors, and suppliers and customized services for special needs; customized services include technical assistance, cash-flow analysis, financial incentives, and partnering with other service providers to offer needed services including design assistance and financing packages
Residential New Construction	Provides services to builders and buyers of new homes to support them in building to Vermont ENERGY STAR Homes criteria including ENERGY STAR labeling, energy code support, plan reviews, technical assistance, site inspections, energy ratings, and performance testing
Efficient Products	Promotes ENERGY STAR qualified products by providing consumer rebates, participating in retailer buy-downs and manufacturer markdowns, supporting retailers with promotions, and educating consumers
Existing Homes	Provides services to acquire energy savings in the existing homes market through multiple approaches that include limited and targeted direct services, particularly focused on low-income residents; technical assistance and information; and through supporting other energy product and service providers

Source: Efficiency Vermont, 2007.

Table F.6. Efficiency Vermont's 2006 Budget

Budget Item	Services and Initiatives 2006[13]	
Operating Costs	Cost	% of Total Cost
Administration	$110,385	0.8%
Services and Initiatives	$3,242,775	23.2%
Marketing/Business Development	$2,528,147	18.1%
Information Systems	$493,667	3.5%
Subtotal Operating Costs	**$6,374,975**	**45.5%**
Incentive Costs		
Incentives to Participants	$4,265,543	30.5%
Incentives to Trade Allies	$50,001	0.4%
Subtotal Incentive Costs	**$4,315,544**	**30.8%**
Technical Assistance Costs		
Services to Participants	$3,167,886	22.6%
Services to Trade Allies	$146,034	1.0%
Subtotal Tech. Assist. Costs	**$3,313,920**	**23.7%**
Total Efficiency Vermont Costs	**$14,004,438**	**51.4%**
Total Participant Costs	**$12,337,677**	**45.3%**
Total Third Party Costs	**$906,334**	**3.3%**
Total Services and Initiatives Costs	**$27,248,449**	**100%**

Source: Efficiency Vermont, 2007.

[2] Excluding customer credit.

Table F.7. Cost-Effectiveness of Efficiency Vermont Programs in 2006

Efficiency Vermont		Undiscounted Program Costs/kWh Saved	Adjusted* Program Costs/kWh Saved	Adjusted* Customer Costs/kWh Saved	Adjusted* Total Costs/kWh Saved
Commercial/ Industrial	Business New Construction	0.030	0.043	0.027	0.072
	Business Existing Facilities	0.015	0.022	0.021	0.044
	Total Commercial/Industrial	**0.018**	**0.026**	**0.022**	**0.049**
Residential/ Low-Income	Residential New Construction	0.067	0.103	0.029	0.143
	Efficient Products	0.011	0.013	0.039	0.054
	Existing Homes	0.031	0.051	0.024	0.080
	Total Residential/Low Income	**0.025**	**0.035**	**0.034**	**0.072**
Total		**0.022**	**0.031**	**0.027**	**0.059**

Source: Efficiency Vermont, 2007.
* Levelized costs are adjusted for the present value of the lifetime energy savings

F.2.3 Maine

Table F.8. Descriptions of Efficiency Maine's Programs

Program	Description
Residential Lighting	Provides incentives for efficient lighting products; recruits retailers to promote efficient lighting to consumers; works with electrical wholesale houses to reach electrical contractors and encourage them to install CFLs; recruits retail partners for in-store recycling program
Business	Provides financial incentives and technical assistance; implemented largely through program allies including contractors, wholesalers, and associations
Low Income	Installs energy-efficient refrigerators, freezers, and CFLs for low-income consumers
Building Operator Certification	Trains facility managers to identify energy-efficiency opportunities through the use of advanced building equipment controls, the installation of energy-efficient equipment, and simple preventive maintenance
High Performance Schools	Provides financial and technical assistance needed to commission better designs and install more efficient equipment in new school buildings
Education & Training	Introduces electricity and energy efficiency to 4th-12th grade classes; provides technical training to professionals

Source: Efficiency Maine, 2006a.

Table F.9. Efficiency Maine's 2006 Budget

Budget Item	Cost	% of Total Cost
Incentive Costs		
Incentives to Participants	$4,718,845	53.2%
Incentives to Trade Allies	$0	0.0%
Subtotal Incentives	**$4,718,845**	**53.2%**
Program Delivery Costs		
Implementation and Technical Assistance	$3,073,226	34.6%
Marketing	$706,427	8.0%
Subtotal Program Delivery Costs	**$3,779,654**	**42.6%**
Administrative and Management Costs	**$375,849**	**4.2%**
Total Efficiency Maine Costs	**$8,874,348**	**100.0%**

Source: Efficiency Maine, 2006b.

Table F.10. Cost-Effectiveness of Efficiency Maine Programs in 2006

Efficiency Maine		Undiscounted Program Costs/kWh Saved	Adjusted* Program Costs/kWh Saved	Adjusted* Customer Costs/kWh Saved	Adjusted* Total Costs/kWh Saved
Commercial/ Industrial	Business	0.013	0.018	0.022	0.040
	Building Operator	0.004	0.004	0.106	0.111
	Total Commercial/Industrial	**0.013**	**0.017**	**0.031**	**0.049**
Residential/ Low- Income	Residential Lighting	0.008	0.010	0.011	0.021
	Low Income	0.053	0.063	0.000	0.063
	Total Residential/Low-Income	**0.013**	**0.016**	**0.010**	**0.025**
Total		**0.013**	**0.017**	**0.020**	**0.037**

Source: Efficiency Maine, 2006b.
* Levelized costs are adjusted for the present value of the lifetime energy savings

G. Related Maryland Programs and Data

This report explores the impacts of using different percentages of auction revenue to support efficiency programs. There are several ways that the auction revenue could be allocated to achieve the goal of supporting energy efficiency programs. A wide range of programs already exist and the funds could be used to augment these budgets. Secondly, new programs could be created to take advantage of new opportunities for technological and behavioral changes in support of efficiency improvements. Finally, a combination of these approaches could be used. This appendix summarizes information on efficiency programs in Maryland, program budgets, related policies, and the available data for their characterization.

Table G.1. Summary of Maryland's Energy Efficiency Programs as of April 2008

Program	Description	Administering Organization	Comments
State Agency Loan Program (SALP)	Revolving fund that gives zero-interest loans to state agencies for energy efficiency improvements.	MEA	Repayments are made from the agency's fuel and utility budget, based on the avoided energy costs of the project.
Community Energy Loan Program (CELP)	Revolving fund that provides low-interest loans to local governments and non-profits for energy efficiency improvements.	MEA	The cost savings generated by the improvements are the main source of revenue for repaying loans.
Industrial Energy Assessment	Free energy audits for Maryland industries.	MEA, partnership with University of Maryland and US Department of Energy (DOE).	
Maryland Industries for the Future	Extension program to boost productivity and efficiency in nine energy intensive industries.	MEA and MD Dept. of Business and Economic Development	
Industrial Energy Efficiency Clearinghouse	Information clearinghouse for industrial energy efficiency.	MEA and Alliance to Save Energy	
Energy Performance Contracting (EPC)	Mechanism to fund energy efficiency measures for larger projects (above $1M) designed and installed by an ESCO and paid through money saved from reduced energy consumption, through 15-year contracts.	MEA, Department of General Services (DGS), ESCOs[1]	$395 million have been loaned since 1995.
Farm Energy Audit Program	Reimbursable energy audits for farmers if they implement recommendations stemming from audits to increase energy efficiency.	MEA	Begun in 2007. Each audit costs $250.
Maryland Home Performance with Energy Star	Commercial service of energy audits and improvements for homeowners and buyers, with certified auditors.	MEA, Private Companies	MEA lists certified auditors but customers pay full costs.

Sources: MEA 2008a, NCSU 2007.

[1] MEA gives administrative support to state agencies. Performance contracts for government are managed by MD General Services Administration. Implemented through Energy Service Companies

SMECO - Energy Star Home Program[2]	Special ENERGY STAR mortgages for energy efficient homes that give discounted interest rates, cash back and other incentives.	Southern Maryland Electric Cooperative	$2,500 extra on upfront costs, $15 extra to monthly mortgage. Only valid in SMECO service area.
Weatherization Assistance Program[3]	Weatherization services at no cost for eligible low-income homeowners and renters.	Department of Housing and Community Development (DHCD), DOE	DHCD provides weatherization for about 1000 households and furnace repairs for about 255 households annually.
Electric Universal Service Program (EUSP)[4]	Assistance to pay energy bills plus help with energy efficiency measures to reduce bills.	Office of Home Energy Programs, Department of Human Resources	
Maryland Energy Assistance Program (MEAP)[5]	Provides assistance with home heating bills and to replace broken or inefficient furnaces.	Office of Home Energy Programs, Department of Human Resources	
Rebuild America	Public private partnerships to improve energy efficiency and promote renewable energy in schools and other public buildings.	MEA and DOE	
Corporate Income Tax Credit for Green Buildings	Tax credit for green building construction up to 8% of total cost	MEA, Comptroller of Maryland	Credits were exhausted rapidly. As of 2008, 13 projects listed.
Personal Income Tax Credit for Green Buildings	Green building tax credit for developers.	MEA, Comptroller of Maryland	
Property tax exemption for high performance buildings	Property tax credit for silver-or higher rated green buildings.	Various counties and municipalities	
Energy Efficiency Partnership of Greater Washington	Partnership to finance building retrofits with accrued energy savings over time (ESCO model).	PEPCO energy services, Hannon Armstrong, Virginia Tech	Active in the whole Washington metro area.

Table G.2. Program Budgets for 2007 for the State Agency Loan Program (SALP), Community Energy Loan Program (CELP), and Weatherization Assistance Program Along with Estimated Administrative Costs and Administrative Costs as a Percentage of Total Costs for SALP and CELP

Program	Budget	Administrative Costs	Administrative Costs as % of Total Cost
State Agency Loan Program	$1,000,000	$30,000	3.00%
Community Energy Loan Program	$1,500,000	$75,279	5.02%
Weatherization Assistance Program	$5,400,000	N/A	N/A

Source: MD General Assembly 2005, MD General Assembly 2006.

[2] SMECO 2007
[3] DHCD 2007
[4] DHR 2007a
[5] DHR 2007b

Related Energy Efficiency Policies

Fare Decoupling

Maryland has already decoupled electricity profits from energy consumption with Baltimore Gas & Electric Co. (BGE) and Washington Gas to reduce the disincentive for utilities to encourage energy conservation. If there is aggressive energy conservation and revenue is lost due to decreased electricity sales, utilities can increase distribution rates to cover fixed costs. It is expected that the Public Service Commission will finalize decoupling with the other Maryland utilities in 2008 (MEA 2008a).

Building Codes

Maryland has adopted the latest building code of the International Energy Conservation Code (2006). Because the State of Maryland is a "Home-Rule-State", the enforcement of the codes depends on county or municipal governments. Through the Department of General Services, the State mandates that state capital projects meet at least LEED Silver standards. The Maryland legislature in its 2008 session passed a bill mandating all new state buildings and public schools to meet the LEED Silver standard. The state will fund 50 percent of the local share of increased school construction costs until 2014.

Appliance Standards

Maryland has in place energy efficiency standards for commercial refrigeration cabinets, large-packaged air-conditioning equipment and unit heaters through the Energy Efficiency Standards Act (EESA). The standards for other appliances in the act were preempted by federal appliance standards included in the Energy Policy Act of 2005. Many appliances are not yet covered by either state or federal standards, however. California, for instance, has 21 products covered by standards outside federal legislation.

Research and Development

In its State Energy Efficiency Scorecard, ACEEE (Eldridge et al. 2007) does not give Maryland any points for state-level investment in research and development related to energy efficiency. However, there are R&D efforts at the State level, such as the University of Maryland's Center for Environmental Energy Engineering, which conducts research on energy conversion systems and thermal management systems for buildings, transportation and electronic cooling (ACEEE 2008).

Combined Heat and Power

Combined heat and power (CHP), or cogeneration, plants are small oil or gas fired power plants that capture the excess thermal energy produced from electricity generation for heating and/or cooling systems for institutional, commercial and industrial buildings. This technology greatly increases the overall energy efficiency of the power plant, from an average 33 percent to as much as 85 percent (Eldridge et al., 2007). Currently, there are 18 CHP facilities in Maryland with a combined capacity of 829 MW (Eldridge et al., 2008). Some of these are district heating and cooling system (DHC), basically CHP plants serving a wider district, usually a downtown area. There are DHC systems in Downtown Baltimore, University of Maryland College Park, The Johns Hopkins University and the US Naval Academy in Baltimore.

ACEEE estimated a remaining economic potential of 291 MW of CHP capacity with natural gas as fuel in Maryland. However, the estimated technical potential for facilities to have CHP plants is much larger (4,084 MW). Furthermore, ACEEE estimated that CHP can deliver up to 9 percent of the energy efficiency savings in the whole state by 2025. ACEEE recommends giving incentives to commercial and industrial customers to implement CHP plants at their facilities. (Eldridge et al., 2008). Environment Maryland (Ridlington and Heavner, 2007) recommends CHP as a strategy for reducing greenhouse gas emissions in Maryland. According to their study, combined heat and power would save 1.3 million metric tons of CO_2 by 2010 and 2.6 million metric tons by 2020 if implemented to 1900 MW of potential.

Environment Maryland (Ridlington and Heavner, 2007) points out that CHP has a regulatory burden in terms of air quality permitting and local building codes, in addition to the limitation of relying almost exclusively on natural gas. Furthermore, no financial incentives exist for CHP plants in Maryland, nor is it included as an eligible tier for the Renewable Portfolio

Standard. Nevertheless, some incentives are in place: CHP plants are not subject to the RGGI emissions cap, and there are in Maryland interconnection rules that allow for distributed generation – CHP facilities connected to the grid.

Renewable Energy in Maryland

In 2006, non-hydro renewable energy accounted for 1.3 percent (629 GW/h) of electricity generated in Maryland, actually a net decrease since 2000 when 818 GW/h were generated by renewables (EIA 2006). The MEA 2007 strategic plan states that because of growing demand, increased transmission congestion and limited power generation supply in-state, renewable energy generation in state is necessary to complement energy efficiency (MEA 2008b).

Renewable energy programs are relatively new in Maryland. A description of them follows in Table G.3 with budgets for the solar energy grant program in Table G.4 and data from tax credits for green buildings and clean energy production in Table G.5.

Table G.3. Renewable Energy Programs in Maryland [6]

Program	Description	Administering Organization	Comments
Local Option - Property Tax Credit	Property tax credit for buildings equipped with solar, geothermal or qualifying energy conservation device.	Various counties and municipalities	
Special Property Assessment for Solar Heating & Cooling[7]	The assessed value of a property for tax purposes will not include the solar energy heating and cooling systems.	Dept. of Assessments and Taxation	
Property Tax Exemption for Residential Solar Energy Systems[8]	Property tax exemption of solar energy devices.	Dept. of Assessments and Taxation	
Clean Energy Production Tax Credit	Production tax credit for renewable energy for hydro, biomass, waste, geothermal, wind and solar.	MEA, Comptroller of Maryland	0.85 cents/kWh or 0.5 cents/kWh for co-fired electricity. The program has a cap of $25 million and a duration of five years.
Windswept grant program	Grants for small scale wind installations of up to $5000 ($3,000 for residential).	MEA	Began in 2007.
Solar energy grant	Rebates of 20% of system costs up to $5000 for non-residential solar PV and $3000 for residential; and $2000 for solar water heating.[9]	MEA	Began in 2005.
Geothermal heat pump rebate	Rebates up to $1000 for geothermal heat pump installation.[10]	MEA	Began in 2005.

Sources: MEA 2008a, NCSU 2007.

[6] Excluding transportation and biofuels
[7] DAT 2007
[8] Ibid. op.cit.
[9] In the 2008 legislative session, the Maryland Assembly increased solar PV grant caps to $2500 per KW capacity or $10,000 per system, while solar water heating grants were increased to the lesser of $3000 or 30% of costs.
[10] In the 2008 legislative session, the Maryland Assembly increased geothermal heat pump grants to the lesser of $1000 per ton or $3000 for residential units, or $1000 per ton or $10000 for non-residential units.

Table G.4. Program Budgets for the Solar Energy Grant Program (Funding Solar Photovoltaics, Solar Water Heaters and Geothermal Heat Pumps)

Fiscal Year	Budget	Solar energy grants awarded	Geothermal grants awarded	Ratio awarded/budgeted
2005	$103,500	$103,500 (44)	$0 (0)	100.0%
2006	$75,000	$75,000 (30)	$0 (0)	100.0%
2007	$1,500,000	$261,075 (129)	$78,000 (78)	17.4%
2008 (until 12/31/07)	$675,000	$90,409 (41)	$64,000 (64)	13.4%
TOTAL	$2,353,500	$529,984 (244)	$142,000 (142)	28.6%

Source: MD General Assembly 2008.

Table G.5. Tax Credits for Renewable Energy in Maryland[11]

Tax credit	Allocation cap	Tax Years	Number of Returns	Amount claimed as of April 1, 2008	Comments
Photovoltaic and solar energy property	$2,000 per unit	2000-2004	579 (20 corporate, 559 individuals)	$268,114	Tax credit expired, rollover was not allowed
Clean Energy Production Tax credit	$25 million	2000-2004: 2006-2010	0	0	Rollover allowed
Green Building Tax Credit	$25 million (already exhausted)	2003-2011	7	$813,552	Rollover allowed

Maryland's Renewable Portfolio Standard

Renewable Portfolio Standards are one mechanism whereby the State mandates a given percentage of electricity to be obtained from renewable sources. Maryland's current RPS, which took effect in 2006, mandated that by 2006, 3.5 percent, and by 2022, 9.5 percent of electricity should come from Tier 1 renewables (solar, wind, geothermal, ocean, biomass, landfill gas and small (<30 MW) hydroelectric power), with 2 percent coming from solar photovoltaic. An additional 2.5 percent is mandated from Tier 2 (large hydroelectric, poultry litter and municipal solid waste) until 2019. Non-compliance payments by utilities are $20 per MWh of non-compliance of Tier 1 shortfalls and $15 per MWh of Tier 2 shortfalls. (MEA 2008b)

Up to now, utilities have met their requirements by acquiring renewable energy power from anywhere in the PJM area, so the RPS hasn't actually prompted much investment in renewables within Maryland according to MEA (2008b). This is reflected in the absence of tax credits claimed for clean energy production.

The Maryland legislature recently approved a new RPS. It increased the requirement for renewables to 20 percent by 2022. The geographic scope of renewable options was reduced to the PJM region or within a control area adjacent to the PJM region if electricity is delivered into the region. The compliance fee increased from $20 to $40 per MW/h for shortfalls. With this new legislation, incentives should be higher for renewable energy facilities to be constructed within the state (Ridlington and Heavner, 2007; Madsen et al., 2008; Eldridge et al., 2008).

[11] Comptroller of Maryland. Bureau of Revenue Estimates. April 7, 2008

Net Metering

Net metering allows independent generators to sell power back to the grid. In Maryland, systems of up to two megawatts (MW) owned or leased by residents, businesses, schools or government entities that generate electricity using solar, wind or biomass resources are eligible for net metering.

Review of Energy Efficiency and Renewable Energy Programs

Loan Programs

As of December 2005, the State Agency Loan Program (SALP) had dedicated over $14.6 million in loans to installing energy efficiency measures, such as efficient lighting, controls, and boilers, in state agencies. According to the MEA Budget Analysis for FY 2007 (MD General Assembly 2006), the estimated savings amounted to nearly $2.6 million. Unfortunately, no data was available for actual kW/h saved. The report stated that on average, it takes approximately five years for a State agency to achieve the energy cost savings necessary to pay back the loan.

Since 2006, there has been renewed interest in the program from State agencies given the rising utility costs, but MEA has not yet increased the program's budget.

The Community Energy Loan Program (CELP), as of December 2005, loaned $12.8 million for 51 projects for a total estimated savings of $3.2 million. Participants need around five years to achieve the energy savings necessary to pay back the loans. Unfortunately, no data was available for actual kW/h saved or for overall performance of the project.

A representative from the Maryland Municipal League interviewed for this study stated that for local governments, loans and grants are a preferred mechanism for assistance on energy efficiency. An MEA staff member concurred that the programs should be expanded to meet demand. Given that the SALP targets state agencies, the savings generated have a positive fiscal impact as well. The EmPOWER Maryland goal contemplates expanding these programs.

Energy Performance Contracting (EPC)

As of 2006, the EPC program had been operating for over 13 years and had generated energy cost savings to the state of over $115 million at 18 state building projects with a capital investment of over $100 million (D&A, 2006). MEA is trying to direct state agencies towards the EPC as demand for the State Agency Loan Program soars (MD General Assembly 2006). ACEEE points out that this innovative financing mechanism is a model to follow in other states (Eldridge et al., 2007). An evaluation of the program in 2006 (D&A, 2006) pointed out that the program is technically solid although it should allow more Energy Service Companies (ESCOs) to participate and increase the number of projects per year. Although the contracting and legal support provided by MEA is adequate, the report indicates that marketing and outreach towards state agencies is limited and annual fees charged by the Department of General Services are high. Another hurdle for contracting was the requirement of a security guarantee from ESCOs to protect from savings shortfalls. However, both the fees and the guarantee were deemed essential by MEA and the DGS, as quoted in the budget analysis for FY 2008 (MD General Assembly 2007).

Grants for Renewable Energy

MEA was not able to fully allocate the money appropriated for solar and geothermal grants in 2007, and again, in 2008. This can be explained because of the huge increase in funding –from $75,000 in 2006 to $1,500,000 in 2007, while the amounts of the grants remained small. According to MEA (2008b), the grant amounts for either solar or geothermal are not enough incentive for homeowners to install these solutions, and they are not cost-effective for them given the large upfront costs. For instance, a solar photovoltaic residential system can cost up to $20,000, and yet the Maryland grant would only cover $3,000 of these.

It is arguable that many of the people that are taking advantage of the grants would have installed the solar panels anyway in the absence of the grants, whereas many people that are interested don't see enough of an incentive in the grants. Therefore, the grants could potentially be serving, to a large part, free riders. However, there is no conclusive evidence for this.

A coarse comparison of grants with the solar energy tax credits, which were available between 2000 and 2004, suggests that the tax credits were more effective in attracting customers to implement solar energy, given that in 5 years 559 individuals

and businesses claimed the credit for $268,000, whereas between 2005 and 2008 144 solar grants were awarded for $530,000. However, it could also be the case that many people interested in solar invested in it when the tax credits were available, and there were fewer of those people on the market when the grants were established.

The Maryland Assembly passed a bill in its 2008 legislative session augmenting the cap of the grants for solar photovoltaic, passive solar and geothermal heat pump installations, with the rationale that there be a higher incentive for customers to install them. Solar photovoltaic grants were increased to the lesser of $10,000 or $2,500 per kW of installed capacity. Solar water heater grants were raised to the lesser of $3,000 or 30 percent of the installed costs, and for geothermal heat pumps, the amounts increased to $1,000 per ton or $3,000 for residential and $10,000 for non-residential uses

The grants for wind power were set up in late 2007, but MEA is confident it will allocate its seed money of $15,000 shortly.

Tax Credits

The Green Building Tax Credit was rapidly exhausted and has not been reauthorized. In the Alternative Energy Conference (Towson University, 2008), two experiences of companies making use of this tax credit were showcased. They argued that the tax credit made their green buildings a cost effective investment, although they mentioned that they had to forgo some of the measures contemplated in LEED, although keeping in line with the certification, to keep costs in check.

According to DSIRE (NCSU 2007), in October 2007 the first credit certificate of the Clean Energy Production Tax Credit valued at $770,661 was awarded to a 3MW landfill methane gas project at the Baltimore County Eastern Sanitary Landfill. The credit has not spurred investment in renewables otherwise, although it has been in place for a few years. This may be attributable to the high flexibility of the initial Renewable Portfolio Standard in Maryland that allowed renewable generation from a wide geographic scope.

In interviews with Maryland stakeholders, tax credits were favored as an incentive mechanism, particularly by representatives from the farming, manufacturing and renewable energy sector. An MEA staff member pointed out that they are better than grants for many people because grants are taxable income, although an energy consultant interviewed cautioned that other people prefer grants if their tax liability is small.

Low Income Programs

According to an officer from the Department of Housing and Community Development who oversees the program, the Weatherization Assistance Program (WAP) is effective and should be scaled up. Utilities are providing some assistance, but the limited number of providers for weatherization activities is often perceived as a hurdle. In 2006, 2,478 households received Weatherization Assistance in Maryland (US DOE, 2008)

Gillingham et al. (2006) write in an overview of the WAP at the national level that cumulative energy savings and cost-effectiveness of these activities are hard to determine. In 2001, the DOE stated that nationwide, a benefit of $2.10 is gained for every dollar spent on weatherization.

Although the Maryland Energy Assistance Program (MEAP) and the Electric Universal Service Program (EUSP) have limited energy efficiency assistance besides their principal objective to assist with electric and home heating bill payments, no data was found on the expenditures related to the energy efficiency portions.