THE CENTER FOR
CLIMATE STRATEGIES

www.climatestrategies.us

Enhancements to the EmPower Maryland and Maryland Renewable Portfolio Standard Clean Energy Programs

Pathways To Cut Pollution, Save Cash, Create Jobs, and Grow the State's Economy

by

William Dougherty[1], James McGarry[2], Hal Nelson[3], Thomas Peterson[4,5], Adam Rose[6], and Dan Wei[6]

Authors collaborated with the Center for Climate Strategies (CCS) through the following affiliations: [1]Stockholm Environmental Institute, US, [2]The Chesapeake Climate Action Network, [3]Claremont Graduate University, [4]The Center for Climate Strategies, [5] Johns Hopkins University, and [6]The University of Southern California. Kevin Lucas of the Maryland Energy Administration provided peer review of this report.

The authors would like to thank the Town Creek Foundation, the Keith Campbell Foundation for the Environment, the Abell Foundation, the Bancroft Foundation, and the Rockefeller Brothers Fund for support of this project. With the continued support of these funders, CCS is able to share climate policy research and analysis as an open-source service to the public.

EXECUTIVE SUMMARY

Introduction

The 2013 Maryland Greenhouse Gas Reduction Plan, submitted by Governor Martin O'Malley to the Maryland Legislature July 2013, provides a comprehensive set of sector-based policy and program actions to meet and exceed the legislative emissions reductions target of 25% below 2006 levels established in the Greenhouse Gas Emissions Reduction Act of 2009. That plan shows that through actions that the state has already taken to reduce GHG emissions, Maryland is on track to reduce emissions by 16% below 2006 levels by 2020. This study found that through significant and achievable improvements to the state's flagship renewable energy policy – the Renewable Portfolio Standard – and the state's energy efficiency program – EmPOWER Maryland – the state can achieve the extra 9% reduction necessary to achieve the 25% reduction goal while creating over 20,000 new jobs in the state.

The goal of this report is to provide an independent analysis of some of the key elements of the Plan in terms of greenhouse gas (GHG) reductions and macroeconomic impact. In particular we examined the Regional Greenhouse Gas Initiative (RGGI), EmPOWER Maryland, and the RPS. Maryland's Greenhouse Gas Reduction Plan found that the current suite of programs that have been deployed across the state to reduce GHG emissions are on track to reduce emissions by approximately 16 percent by 2020. To achieve the extra 9 percent necessary to reach the 25 percent reduction goal, Maryland needs to implement new programs or enhance existing programs to reduce an extra 9.2 million metric tons of carbon dioxide-equivalent (MMtCO_2e) annually. This report lays out a path to achieve those extra emissions reductions through program enhancements to EmPOWER Maryland and the RPS.

The analysis involved several stages and was informed by sustained and rigorous exchanges among the report authors, the Maryland Department of the Environment and the Maryland Energy Administration. The first stage was to determine the gap between the state's 2020 reduction goal and the current suite of GHG reduction programs. Next, we determined the "existing reductions" in GHG emissions that could be reasonably expected from RGGI, EmPOWER, and the RPS programs in 2020 assuming no changes in policy. Then, we quantified the additional reductions that could be achieved by program enhancements sufficient to close the emissions gap. And finally, we looked at the macroeconomic impact that these policies would have on Maryland GDP and job creation.

The Center for Climate Strategies (CCS) and The Chesapeake Climate Action Network worked as stakeholders with the Maryland Department of the Environment and the Maryland Energy Administration to improve the policy design and analysis for the policy realms that are included in this report. All recommendations made in this report, however, were made independently from the state and these recommendations are separate but complementary to the recommendations made in Maryland's Greenhouse Gas Reduction Plan. This report and its program recommendations are intended to be used to guide interested parties that want to implement policies that would help the state achieve its 25% reduction goal. The results of this analysis are summarized below and provided in the Full CCS Report.

Key Findings

1. *Emissions Reductions*

Regional Greenhouse Gas Initiative (RGGI)

RGGI is a cooperative effort by nine Northeast and Mid-Atlantic States to design and implement a regional cap-and-trade program to reduce carbon dioxide emissions from power plants in the region. While an enormously helpful framework for reducing emissions that can underwrite various clean energy initiatives such as EmPOWER and the RPS, RGGI itself was not judged to be a driver of incremental GHG reductions. RGGI was therefore not quantified as an emissions reduction program. It must be noted, however, that this analysis presumed that the RGGI cap would remain at its current level of 165 million tons, to be reduced gradually by 10% by 2018. If programmatic changes occur and the cap is lowered, it is very likely that RGGI could drive emissions reductions beyond the enabling/framework policy structure envisioned here.

EmPower Maryland

Launched in 2008, EmPOWER Maryland sets out an ambitious state energy efficiency and conservation target of reducing per-capita electricity consumption across the state by 15 percent below 2007 levels by 2015. While this program has made some progress to-date, current trends indicate the program is on track to achieve only 60% of the 2015 goal, or a roughly 9% per-capita electricity reduction. This report further assumes that without any further programmatic changes, EmPOWER will continue to reduce per-capita electricity consumption by 9% out to 2020. Under the current trajectory, EmPOWER Maryland is on track to reduce 7.8 $MMtCO_2e$ in 2020.

This report looked at a series of three scenarios for achieving demand reductions, each with increasing incremental demand reduction targets. The logic behind the development of the three scenarios is developed from the intersection of the energy efficiency supply curve with selected avoided cost levels. The low scenario (0.3% annual sales reductions) is the rate that, if implemented in 2013-2015 would enable Maryland to reach demand side management (DSM) goals of approximately 11% by 2015. The high scenario (2.25% of annual sales reductions) represents aggressive DSM programs in Maryland that mimic the levels achieved in Vermont and Massachusetts. The medium scenario (1.5% annual sales reductions) is a rough average of the high and low scenarios. The EmPOWER programs are assumed to be implemented in 2013.

We also included natural gas and combined heat and power (CHP) scenarios in the three scenarios. CHP targets were held constant in all three scenarios while the natural gas targets equaled the annual electricity targets. The CHP target of 556 MW by 2020 was chosen based on the economic potential for CHP that was cited in the Maryland Energy Administration's 2013 *Report to the Senate Finance Committee and House Economic Matters Committee to Discuss Whether to Modify EmPOWER Maryland Targets beyond 2015*[1].

In addition to EmPOWER's current trajectory, expanding this program to the medium scenario would reduce approximately 8.2 $MMtCO_2e$. Combined with the RPS enhancements and adjusted for overlap, the medium EmPOWER scenario of reducing electricity and natural gas consumption across the state by 1.5% annually out to 2020 along with developing 556 MW of CHP capacity would reduce emissions to levels sufficient to close the 9.2 $MMtCO_2e$ reduction gap by 2020. To close the emissions gap reported in the state's Plan, this report recommends that the state adopt the medium-scenario enhancements to EmPOWER Maryland, which involve setting higher efficiency targets out to 2020 and expanding the program beyond electricity to include both natural gas and new efficient on-site power systems.

The Renewable Energy Portfolio Standard

Maryland passed its RPS in 2004. By setting a minimum threshold for how much of a state's electricity comes from renewable energy, the original intent of the RPS was to establish a market for new sources of renewable electricity generation and to realize the associated economic and environmental benefits. In 2020 Maryland's law requires that the state attain 18% of its electricity from renewable sources, increasing to 20% renewables by 2022. Under the current trajectory, Maryland's RPS is on track to reduce approximately 6.4 $MMtCO_2e$ in 2020.

---

[1] http://energy.maryland.gov/empower3/documents/EmPOWERPlanningFinalReport2013-01-16.pdf

This report examined two sets of RPS enhancements. The first was removing carbon-intensive fuel sources – black liquor and wood waste from old inefficient facilities – from Tier-1 RPS eligibility. The second enhancement was increasing the overall RPS goal to 25% by 2020.

In addition to the RPS's current trajectory, removing black liquor and wood waste from old inefficient facilities from Tier-1 RPS eligibility would reduce approximately 2.1 MMtCO$_2$e. Increasing the RPS to 25% by 2020 would then reduce an additional 2.9 MMtCO$_2$e. Combined with the EmPOWER enhancements and adjusted for overlap, enhancing the RPS would reduce emissions to levels sufficient to close the 9.2 MMtCO$_2$e reduction gap. To close the emissions reduction gap reported in the state's Plan, this report recommends that the state adopt a 25% RPS by 2020 that does not include black liquor or old inefficient wood waste facilities.

Fuel Switching: Maryland is a net importer of electricity from the Pennsylvania Jersey Maryland Interconnection LLC (PJM) electricity grid region. This results in electric generation taking place beyond state borders to satisfy electric consumption within the state's borders. The GHG emissions associated with this imported net generation are accounted for in the analysis by assigning a GHG intensity to electricity imports. The assumed fuel switching case estimated that natural gas comprised about 30.4% share of imports in 2020, an increase from 4.9% in 2006. GHG reductions from fuel switching were calculating based on the difference between gas making up 4.9% of imports in 2020 and 30.4% in 2020, with the increased share of gas being offset by decreased coal combustion.

It is important to note that the methodology matters when calculating the GHG benefits of switching from coal to gas. When measured at the point-of-combustion, natural gas burns about twice as clean as coal offering exceptional GHG reduction benefits. However, when other factors such as full fuel cycle emissions and the global warming potential of methane are taken into account, the benefits of coal-to-gas fuel switching can be all but erased.

Emissions Quantification Methodology: This analysis was undertaken such that greenhouse gas (GHG) reductions are reported on either a full fuel cycle or point-of-combustion basis. Full fuel cycle emissions account for the entire fuel chain; from the point of extraction to the point of actual combustion at the power station. When measuring the full fuel cycle emissions from natural gas, a range of sensitivities were developed to account for the methane leakage rate from gas procured through hydraulic fracturing. Unsurprisingly, we found that as the methane leakage rate increases, the GHG reduction benefits of fuel switching from coal to natural gas decreases.

CO$_2$-equivalent emissions from gas were measured on a 100-year horizon when calculating the global warming potential of methane in this analysis. When measured over a shorter 20-year time horizon, the global warming potential of each methane molecule is 72 to 105 times more potent than a molecule of CO$_2$. Emissions due to the leakage would have been much higher if they had been measured on a 20-year time horizon, which is the time-horizon that many scientists say we must drastically reduce GHG emissions to avoid climate tipping points. More information on the importance of methane leakage when developing the full fuel cycle emissions from natural gas can be found in Appendix 3.

Further study is needed to determine the full fuel cycle emissions of natural gas on a 20-year time horizon. Given the uncertainties around the full emissions profile of gas, any efforts to reduce GHG emissions in the near and medium term should focus on reducing all fossil fuel use including natural gas.

Combined Programs

If EmPOWER Maryland, the RPS, and RGGI maintain their current trajectory, and fuel switching maintains its assumed pace, the combined programs will reduce emissions by approximately 16.6 MMtCO$_2$e. Under this scenario, statewide emissions will decrease by only 16.5% below 2006 levels by 2020, thus creating a 9.2 MMtCO$_2$e gap.

If EmPOWER is expanded to the medium scenario and the RPS is increased to 25% by 2020 without black liquor and old inefficient wood waste facilities, and fuel switching maintains its assumed pace, the combined programs will reduce approximately 25.9 MMtCO$_2$e. Under this scenario, statewide emissions decrease by 25.1% below 2006 levels by 2020 and there is 0.1 MMtCO$_2$e cushion for other policy sectors of the state's GHG reduction Plan.

In order to achieve the 25% reduction goal mandated by Maryland's 2009 Greenhouse Gas Reduction Act, EmPOWER Maryland should be expanded to the medium scenario and the RPS should be increased to 25% by 2020 without black liquor and old inefficient wood waste facilities.

Table 1 below summarizes the emissions results from analyzing the aforementioned existing programs and the recommended program enhancements.

Table 1. GHG Reductions from Existing and Enhanced EmPOWER Maryland and Maryland Renewable Portfolio Standard

Impacts of Baseline and New Policies	2020 MMTCO2e
Minimum GGRA Reduction Goal (25% below 2006 levels)	55.3
GGRA Reduction Trajectory: Existing Programs (from GGRA Plan)	46.1
GGRA Reduction Gap	9.2
Existing EmPOWER reductions	7.8
Existing RPS reductions	6.4
Fuel Switching (30% imported natural gas)	6.1
RGGI	0.0
Existing Policies (EmPOWER, RPS) + Fuel Switching	20.4
Existing Policies (EmPOWER, RPS) + Fuel Switching (after adjusting for overlaps)	16.6
Existing Policies (EmPOWER, RPS) + Fuel Switching: Contribution to Maryland's Overall Reduction Goal	30%
Enhanced EmPOWER – medium scenario	16.04
Enhanced RPS – 25% x 2020, restricted black liquor and wood waste	11.5
Fuel Switching (30% imported natural gas)	6.1
Enhanced Policies (EmPOWER, RPS) + Fuel Switching	33.6

Enhanced Policies (EmPOWER, RPS) + Fuel Switching (after adjusting for overlaps)	25.9
Enhanced Policies (EmPOWER, RPS) + Fuel Switching: Contribution to Maryland's Overall Reduction Goal	47%
Additional Reductions from Enhanced EmPOWER & Enhanced RPS	9.3
GGRA Reduction Trajectory: Enhanced RPS & EmPOWER0	55.4
GGRA Reduction Gap	-0.1

2. Macroeconomic Impacts

The macroeconomic impacts of the RPS and EmPOWER Maryland were analyzed, focusing on gross state product (GSP) and employment, using the regression model based Macroeconomic Screening Tool (MST). Five policy scenarios were identified to be analyzed in the MST. This report recommends scenario five, which involves credible and significant enhancements to EmPOWER Maryland and the RPS, and would create 22,700 jobs and $2.6 billion in net economic benefit by 2020. The scenarios were:

Scenario 1: (Base Case Scenario): Existing RPS (18% by 2020) and Existing EmPOWER implementation. This scenario assumed that the current RPS law would remain unchanged and that black liquor and wood waste would account for 17 percent of RPS compliance in 2020. It also assumed that EmPOWER would achieve 60 percent of its 2015 goal.

Scenario 2: Current RPS (18 percent by 2020) with old black liquor and wood waste moved to Tier 2 and current EmPOWER implementation. This scenario assumed that the current RPS law would be amended to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would achieve 60% of its 2015 goal.

Scenario 3: Current RPS (18 percent by 2020) with old black liquor and wood waste moved to Tier 2 and 1.5% annual EmPOWER (medium scenario for EmPOWER). This scenario assumed that the current RPS law would be amended to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would reduce electricity and natural gas consumption in Maryland by 1.5 percent annually starting in 2013 and that the state would develop 556 MW of CHP capacity by 2020.

Scenario 4: Current RPS (18 percent by 2020) with old black liquor and wood waste moved to Tier 2 and 2.25% annual EmPOWER (high scenario for EmPOWER). This scenario assumed that the current RPS law would be amended to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would reduce electricity and natural gas consumption in Maryland by 2.25 percent annually starting in 2013 and that the state would develop 556 MW of CHP capacity by 2020.

Scenario 5 (recommended scenario): Aggressive RPS (25 percent by 2020) with old black liquor and wood waste moved to Tier 2 and 1.5% annual EmPOWER (medium scenario for EmPOWER). This scenario assumed that the current RPS law would be amended to both increase the overall compliance goal to 25 percent by 2020, and to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would reduce electricity and natural gas consumption in Maryland by 1.5 percent annually starting in 2013 and that the state would develop 556 MW of CHP capacity by 2020.

Table 2. Macroeconomic Impacts of EmPOWER Maryland and Maryland Renewable Portfolio Standard Scenarios

Scenario	Change in GDP (2013-2020 NPV) (M 2010$)	Change in Jobs (2013-2020) (job-years)	Average Annual Employment Impact (jobs)
1	$1,454	151,302	18,913
2	$1,488	153,111	19,139
3	$2,962	180,218	22,527
4	$3,373	187,460	23,432
5	$2,587	181,860	22,733

Table 3. Macroeconomic Impacts of EmPOWER Maryland and Maryland Renewable Portfolio Standard Scenarios (Incremental to Baseline)

Scenario	Change in GDP (2013-2020 NPV) (M 2010$)	Change in Jobs (2013-2020) (job-years)	Average Annual Employment Impact (jobs)
1	-	-	-
2	$34	1,809	226
3	$1,508	28,916	3,614
4	$1,919	36,158	4,519
5	$1,133	30,558	3,820

In scenario 1, EmPOWER and the RPS will increase Maryland GDP by $1.45 billion and create 151,302 Maryland job-years over seven years. In other words, this scenario would sustain 18,913 jobs per year.

In scenario 2 (removing black liquor and old inefficient wood waste facilities from Tier 1), EmPOWER and the RPS will increase Maryland GDP by $1.49 billion and create 153,111 Maryland job-years over seven years. In other words, this scenario would sustain 19,139 jobs per year. Scenario 2 would increase GDP by $34 million and provide 1,809 more job-years beyond the levels projected for the current EmPOWER and RPS policies. Scenario 2 would sustain 226 jobs per year beyond the levels projected for the current EmPOWER and RPS policies.

In scenario 3 (removing black liquor and old inefficient wood waste facilities from Tier 1; increasing to “medium scenario” EmPOWER), EmPOWER and the RPS will increase Maryland GDP by $2.96 billion and create 180,218 Maryland job-years over seven years. In other words, this scenario would sustain 22,527 jobs per year. Scenario 3 would increase GDP by $1.5 billion and provide 28,916 more job-years beyond the levels projected for the current EmPOWER and RPS policies. Scenario 3 would sustain 3,614 jobs per year beyond the levels projected for the current EmPOWER and RPS policies.

In scenario 4 (removing black liquor and old inefficient wood waste facilities from Tier 1; increasing to "high scenario" EmPOWER), EmPOWER and the RPS will increase Maryland GDP by $3.37 billion and create 187,460 Maryland job-years over seven years. This scenario would sustain 23,432 jobs per year. Scenario 4 would increase GDP by $1.9 billion and provide 36,158 more job-years beyond the levels projected for the current EmPOWER and RPS policies. Scenario 4 would sustain 4,519 jobs per year beyond the levels projected for the current EmPOWER and RPS policies.

In scenario 5 (removing black liquor and old inefficient wood waste facilities from Tier 1; Increasing the RPS goal to 25% by 2020; increasing to "medium scenario" EmPOWER), EmPOWER and the RPS will increase Maryland GDP by $2.59 billion and create 181,860 Maryland job-years over seven years. This scenario would sustain 22,733 jobs per year. Scenario 5 would increase GDP by $1.1 billion and provide 30,558 more job-years beyond the levels projected for the current EmPOWER and RPS policies. Scenario 5 would sustain 3,820 jobs per year beyond the levels projected for the current EmPOWER and RPS policies.

Under the status quo, EmPOWER Maryland and the RPS will support over 18,900 jobs per year and deliver $1.45 Billion in net economic benefits by 2020. If moderate improvements are made to the EmPOWER Maryland and RPS programs, the benefits will increase to over 22,700 jobs per year and nearly $2.6 billion in net economic output. The policy recommendations in this report would increase the employment and economic growth potential of Maryland's clean energy programs by approximately 3,800 jobs and $1.1 billion in additional economic output beyond the status quo.

The Full Report contains background information and analysis for the Enhanced EmPOWER Maryland and Enhanced Maryland Renewable Portfolio Standard Scenarios for the Governor's Plan, as follows:

- Chapter 1. Empower Maryland Analysis and Discussion
- Chapter 2. Maryland Renewable Portfolio Standard Analysis and Discussion
- Chapter 3. Macroeconomic Analysis Results and Discussion
- Appendix 1. Additional Details on Empower Maryland Analysis
- Appendix 2. Sensitivity Analysis for the Maryland Renewable Portfolio Standard
- Appendix 3. Analysis of full Life Cycle Emissions of Natural Gas

All documents are available at www.climatechange.us.

Chapter 1. EmPower Maryland, Discussion and Analysis of Upgrade Scenarios

Introduction

This chapter provides a policy-level overview of the modeling framework, analytical approach, key data assumptions, source materials and steps to quantify the costs and benefits of EmPower Maryland on a standalone basis using a full fuel cycle analysis. It also summarizes the costs and benefits of the EmPower demand-side efficiency policy. This chapter is intended to provide an independent analysis of additional actions that may be needed in Maryland to achieve the greenhouse gas (GHG) emission reductions called for in the Maryland Greenhouse Gas Reduction Act of 2009 (GGRA).

Overall summary

To estimate GHG reductions from EmPOWER in the baseline case, we used the amount of EmPOWER reductions estimated in the Regional Greenhouse Gas Initiative (RGGI) reference case forecast of approximately 60% of the 15% per capita goal, including transmission and distribution losses.[2] The reference case sales forecast for the residential, commercial and industrial sectors in 2020 are estimated at approximately 80,000 GWh.

The next step was to perform a series of three scenarios for achieving demand reductions, each with increasing incremental demand reduction targets. The logic behind the development of the three scenarios is developed from the intersection of the energy efficiency supply curve with selected avoided cost levels. The low scenario (0.3%) is the rate that, if implemented in 2013-2015 would enable Maryland to reach demand side management (DSM) goals of approximately 11% by 2015. The high scenario (2.25%) represents aggressive DSM programs in Maryland that mimic the levels achieved in Vermont and Massachusetts. The medium scenario (1.5%) is a rough average of the high and low scenarios. The EmPOWER programs are assumed to be implemented in 2013.

We also included natural gas and combined heat and power (CHP) scenarios in the three scenarios. CHP targets were held constant in all three scenarios while the natural gas targets equaled the annual electricity targets. The CHP target of 556 MW by 2020 was chosen based on the economic potential for CHP that was cited in the Maryland Energy Administration's 2013 Report to the Senate Finance Committee and House Economic Matters Committee to Discuss Whether to Modify EmPOWER Maryland Targets beyond 2015[3].

The following two tables summarize GHG reductions from the three scenarios compared to the estimated EmPOWER targets for direct and full fuel cycle (FFC) emissions. In the baseline scenario where EmPOWER achieves 60% of its reduction goal, or 9% per-capita electricity reduction below 2007 levels, EmPOWER falls short of its 2020 target by 1.0 MMT CO_2e. The results from the .30 scenario indicate that if EmPOWER reduces electricity and natural gas consumption by .3% annually, in addition to expanding CHP, Maryland will surpass its GHG targets from the sector by approximately 2.7 MMT CO_2. Further, even a modest expansion of

---

[2] Power Supply analysis performed for CCAN based on sales forecasts provided by Kevin Lucas from MEA on 9-26-12.

[3] http://energy.maryland.gov/empower3/documents/EmPOWERPlanningFinalReport2013-01-16.pdf

EmPOWER to 1.5% of sales beginning in 2013 along with CHP will result in a 7.2 MMT reduction surplus. The high scenario could surpass the 2015 EmPOWER target with a 9.8 MMT CO_2e cushion for other sectors.

	Scenario					
	0.3%		1.50%		2.25%	
Direct Emissions (MMTCO2e)	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
EmPOWER Reduction Target (MT)	7.3	8.8	7.3	8.8	7.3	8.8
EmPOWER in MD Baseline	5.6	7.8	5.6	7.8	5.6	7.8
Expanding EmPOWER (2013-2020)	-0.4	1.8	1.0	5.3	1.9	7.4
Expand EmPOWER DSM for Natural Gas	0.3	0.9	0.7	1.8	0.9	2.3
Combined Heat and Power	0.4	1.0	0.4	1.0	0.4	1.0
Total (Baseline, Expand EmPOWER, Gas, CHP)	6.0	11.6	7.8	16.0	8.8	18.6
Additional Reductions Available	**-1.3**	**2.7**	**0.5**	**7.2**	**1.6**	**9.8**

	Scenario					
	0.3%		1.50%		2.25%	
Full Fuel Cycle Emissions (MMTCO2e)	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
EmPOWER Reduction Target FFC (MT)	8.0	9.7	8.0	9.7	8.0	9.7
EmPOWER in MD Baseline	6.2	8.7	6.2	8.7	6.2	8.7
Expanding EmPOWER (2013-2020)	-0.4	1.9	1.1	5.9	2.1	8.2
Expand EmPOWER DSM for Natural Gas	0.4	1.2	0.9	2.3	1.2	3.0
Combined Heat and Power	0.4	0.9	0.4	0.9	0.4	0.9
Total (Baseline, Expand EmPOWER, Gas, CHP)	6.6	12.6	8.6	17.7	9.8	20.7
Additional Reductions Available (Shortfall)	**-1.4**	**2.9**	**0.6**	**8.0**	**1.8**	**11.0**

The following table shows estimated demand reductions for the electric sector as well as first year spending for DSM programs. The budgets assume incentives equal to 50% of the DSM measures' incremental costs. The results for the scenarios are not simply multipliers between Low/Medium/High as more aggressive targets (expressed as percent of sales) lead to lower GWh reductions in later years as loads get smaller from DSM program because incremental savings are greater than forecasted load growth. These reductions can be compared to the 80,000 GWh reference case sales forecast for Maryland in 2020.

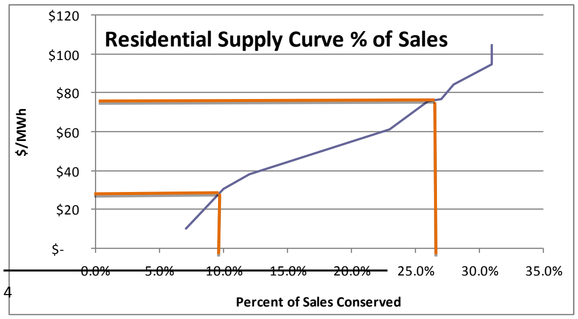
GWh Reductions (all electricity options)	2015	2016	2017	2018	2019	2020
Low Scenario	2351	3028	3709	4392	5079	5769
Medium Scenario	5062	6640	8220	9802	11386	12974
High Scenario	6746	8864	10973	13073	15166	17251
Annual Public Electric Incentives ($M) at 0.5 % Level	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Low Scenario	$ 167	$ 98	$ 100	$ 103	$ 105	$ 108
Medium Scenario	$ 313	$ 244	$ 246	$ 249	$ 251	$ 254
High Scenario	$ 403	$ 331	$ 332	$ 333	$ 334	$ 334

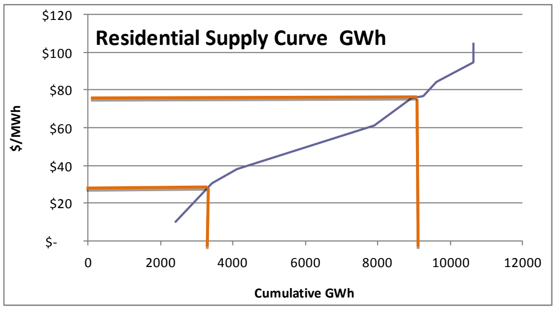
The following table provides illustrative rate and bill impacts for the estimated effects of the electricity DSM programs. The $/MWh rate impact is simply the first year DSM costs ($M) divided by the annual GWh sales forecast. The $/MWh avoided electricity expenditures is the annual avoided electricity expenditures ($M) divided by annual GWh sales forecast for the residential and commercial sectors.

$/MWh Rate Impact (RCI) [Also monthly bill impact for 1000 kWh]	2015	2016	2017	2018	2019	2020
Low Scenario	$ 2.26	$ 1.30	$ 1.31	$ 1.33	$ 1.34	$ 1.35
Medium Scenario	$ 4.25	$ 3.25	$ 3.23	$ 3.21	$ 3.19	$ 3.17
High Scenario	$ 5.47	$ 4.41	$ 4.36	$ 4.29	$ 4.24	$ 4.18
$/MWh Avoided Electricity Bill Expenditures (Res/Comm) [Also monthly bill impact for 1000 kWh]	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Low Scenario	$ 0.77	$ 1.01	$ 1.25	$ 1.48	$ 1.71	$ 1.93
Medium Scenario	$ 3.82	$ 5.00	$ 6.15	$ 7.26	$ 8.33	$ 9.36
High Scenario	$ 5.72	$ 7.46	$ 9.15	$ 10.75	$12.30	$13.77

Avoided Costs And EmPower Targets

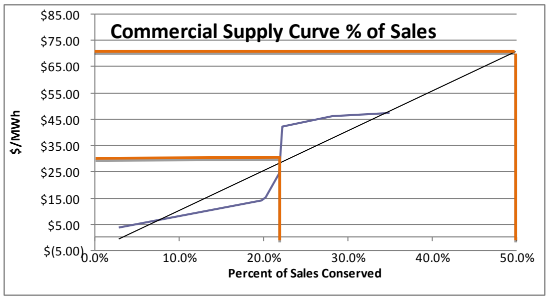
The graphs below are derived from ACEEE (2008) and are updated to $2010 and include a 25% adder for DSM program fixed costs. The residential graphs show DSM potentials on the horizontal axis and cost on the vertical axis. The results show that using an avoided cost of approximately $30 results in about 9% cost effective residential DSM, or about 3,300 GWh in 2020. Using our estimate of avoided costs that includes the elements commonly included in a total resource cost (TRC) test, the achievable residential potential is over 25%.[4]

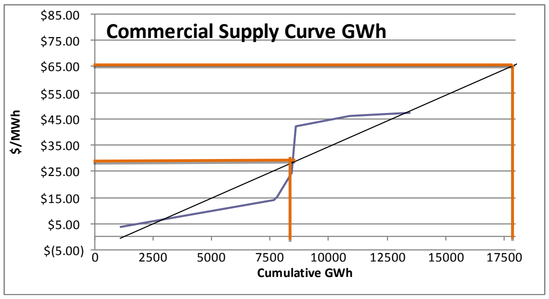




4

The following graphs show the commercial supply curve. The supply curve shows that the current $30 avoided cost can achieve DSM reductions of nearly 25% of sales (~9000 GWh) with over 35% available below $50. Commercial DSM supplies are cheaper, although little is known about DSM measures that are at the higher end of the supply curve such as more efficient building shell retrofits with large supply potentials.

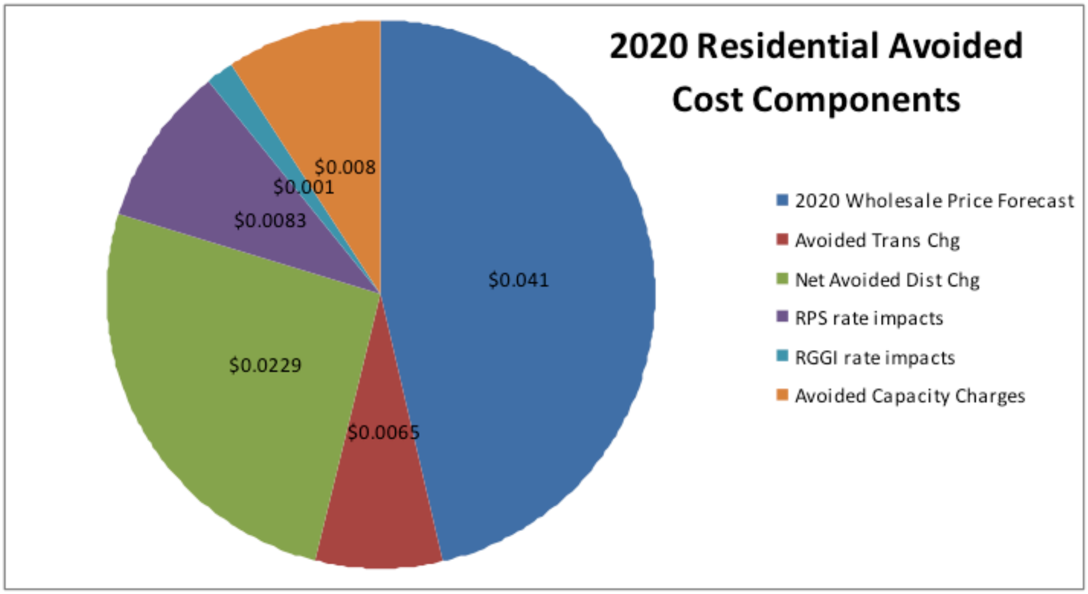




Maryland should consider the long term implications of setting an avoided cost rate. Clearly, for the state to attain its GHG targets through cost effective DSM, a higher avoided cost will be required. There are ample supplies of DSM in the state that can be used over the next several decades to cost-effectively reduces GHGs. An extremely low avoided cost will inhibit these efforts. The current ~$30/MWh avoided cost is even lower than current and forecasted wholesale electricity costs and neglects avoided distribution costs as well as other social costs that are included in best practices methodologies such as the California Standard Practice Manual.[5] We estimate avoided costs based on the categories in the California Manual which results in a load weighted avoided cost greater than $80/MWh. Note that generation cost is less than 50% of the total cost. The methodology associated with our calculations is included in the appendix.

---

[5] http://www.energy.ca.gov/greenbuilding/documents/background/07-J_CPUC_STANDARD_PRACTICE_MANUAL.PDF



Detailed Results

We also prepared detailed results that breakdown reductions between the residential, commercial and industrial sectors and provide cost effectiveness ($/ton CO_2) results. The cost effectiveness results are largely similar between full fuel cycle and direct emissions methodologies so we only present the direct emissions results.

Low Scenario Results. ***NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.***

Policy	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2012–2020 (Million 2010$)	Cost-Effectiveness ($\$/tCO_2e$) 2012-2020
		Annual 2015	Annual 2020	Cumulative through 2020		
	EmPOWER in RGGI Baseline (60% of 9,200 GWh target)					
60% of EmPOWER	EmPOWER electricity (GHGs estimated with approx 0.56 CO2/MWh in 2020	5.6	7.8	NA	NA	NA
Scenario	**2013-2015 Actions to Meet 2015 EmPower Gap**					
0.30%	Residential actions in 2015 at 0.003	-0.2	-0.2	-1.2	59	-51
0.30%	Commercial actions in 2015 at 0.003	-0.2	-0.2	-1.3	103	-79
0.30%	Industrial actions in 2015 at 0.003	0.0	0.0	-0.2	12	-57
	SubTotal	**-0.4**	**-0.4**	**-2.7**	**174**	**-65**

Expanding EmPOWER (2016 on, plus Natural Gas and CHP)						
0.015 Cumulative % of Sales by 2020 Target	Residential	0	0.9	2	-37	-19
0.015 Cumulative % of Sales by 2020 Target	Commercial	0	1.0	2	-124	-58
0.015 Cumulative % of Sales by 2020 Target	Industrial	0.0	0.2	0.3	-11.7	-34
	2016-2020 SubTotal	**0.0**	**2.1**	**4.4**	**-173**	**-39**
0.024 % of Sales by 2020 Target	Expand EmPOWER DSM for Natural Gas	0.3	0.9	4.1	-101	-25
556 MW by 2020 Target	Combined Heat and Power	0.4	1.0	4.9	-124	-25
	Natural Gas and CHP SubTotal	**0.8**	**2.0**	**9.0**	**-225**	**-25**
	Total (Baseline, 2013-2015 Actions, Expand EmPOWER, Gas, CHP)	**6.0**	**11.6**			
	EmPOWER Reduction Target	7.3	8.8			
	Additional Reductions Available (Shortfall)	-1.3	2.7			

Medium Scenario Results. ***NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.***

Policy	**Policy Recommendation**	**GHG Reductions ($MMtCO_2e$)**			**Net Present Value 2012–2020 (Million 2010$)**	**Cost-Effectiveness ($\$/tCO_2e$) 2012-2020**
		Annual 2015	**Annual 2020**	**Cumulative through 2020**		
	EmPOWER in RGGI Baseline (60% of 9,200 GWh target)					
60% of EmPOWER	EmPOWER electricity (GHGs estimated with approx 0.56 CO2/MWh in 2020	5.6	7.8	NA	NA	NA
Scenario	**2013-2015 Actions to Meet 2015 EmPower Gap**					
1.50%	Residential actions in 2015 at 0.015	0.4	0.4	3.1	-157	-50

1.50%	Commercial actions in 2015 at 0.015	0.5	0.5	3.5	-276	-79
1.50%	Industrial actions in 2015 at 0.015	0.1	0.1	0.6	-32	-57
	SubTotal	**1.0**	**1.0**	**7.2**	**-465**	**-65**
Expanding EmPOWER (2016 on, plus Natural Gas and CHP)						
0.075 Cumulative % of Sales by 2020 Target	Residential	0	1.9	8	-503	-64
0.075 Cumulative % of Sales by 2020 Target	Commercial	0	2.1	9	-720	-82
0.075 Cumulative % of Sales by 2020 Target	Industrial	0.0	0.3	1.4	-91.2	-64
	2016-2020 SubTotal	**0.0**	**4.3**	**18.0**	**-1314**	**-73**
0.12 % of Sales by 2020 Target	Expand EmPOWER DSM for Natural Gas	0.7	1.8	8.1	-201	-25
556 MW by 2020 Target	Combined Heat and Power	0.4	1.0	4.9	-124	-25
	Natural Gas and CHP SubTotal	**1.1**	**2.8**	**13.0**	**-325**	**-25**
	Total (Baseline, 2013-2015 Actions, Expand EmPOWER, Gas, CHP)	**7.8**	**16.0**			
	EmPOWER Reduction Target	7.3	8.8			
	Additional Reductions Available (Shortfall)	0.5	7.2			

High Scenario Results. ***NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.***

Policy	**Policy Recommendation**	**GHG Reductions ($MMtCO_2e$)**			**Net Present Value 2012–2020 (Million 2010$)**	**Cost-Effectiveness ($\$/tCO_2e$) 2012-2020**
		Annual 2015	**Annual 2020**	**Cumulative through 2020**		
	EmPOWER in RGGI Baseline (60% of 9,200 GWh target)					
60% of EmPOWER	EmPOWER electricity (GHGs estimated with approx 0.56 CO2/MWh	5.6	7.8	NA	NA	NA

	in 2020					
Scenario	**2013-2015 Actions to Meet 2015 EmPower Gap**					
2.25%	Residential actions in 2015 at 0.0225	0.8	0.8	5.7	-290	-50
2.25%	Commercial actions in 2015 at 0.0225	0.9	0.9	6.4	-508	-79
2.25%	Industrial actions in 2015 at 0.0225	0.1	0.1	1.0	-59	-57
	SubTotal	**1.9**	**1.9**	**13.2**	**-857**	**-65**
Expanding EmPOWER (2016 on, plus Natural Gas and CHP)						
0.1125 Cumulative % of Sales by 2020 Target	Residential	0	2.4	11	-783	-69
0.1125 Cumulative % of Sales by 2020 Target	Commercial	0	2.7	13	-1075	-85
0.1125 Cumulative % of Sales by 2020 Target	Industrial	0.0	0.4	2.1	-138.8	-67
	2016-2020 SubTotal	**0.0**	**5.5**	**26.1**	**-1997**	**-76**
0.18 % of Sales by 2020 Target	Expand EmPOWER DSM for Natural Gas	0.9	2.3	10.5	-262	-25
556 MW by 2020 Target	Combined Heat and Power	0.4	1.0	4.9	-124	-25
	Natural Gas and CHP SubTotal	**1.3**	**3.4**	**15.5**	**-385**	**-25**
	Total (Baseline, 2013-2015 Actions, Expand EmPOWER, Gas, CHP)	**8.8**	**18.6**			
	EmPOWER Reduction Target	7.3	8.8			
	Additional Reductions Available (Shortfall)	1.6	9.8			

Residential, Commercial and Industrial (RCI) Quantification Approach and Assumptions

This section outlines the data sources and methodologies used to quantify the greenhouse gas (GHG) impacts and costs for the EmPOWER policy options. The analysis first calculates gross costs, which include the incremental capital, labor, and fuel (if appropriate) costs of the efficient technology over the assumed baseline technology. Administrative (program, evaluation, marketing, and outreach) costs are also included in the costs of RCI energy efficiency. Next, gross benefits from avoided energy expenditures are calculated. Net cash flows (costs or benefits) are then calculated, which are gross costs less gross benefits. Finally, the net present value (NPV) of this stream of net cash flows is derived.

The gross costs in each year are derived from:

- The quantity of energy savings (gigawatt-hours per billion BTU [GWh/BBtu]) for each year is determined from the goal and timing section of each policy option.
- The above costs of the incremental energy-efficient equipment is multiplied by the quantity of energy savings (GWh/BBtu) assumed mitigated in each year. This gives the total gross cost of the policy option in each year.

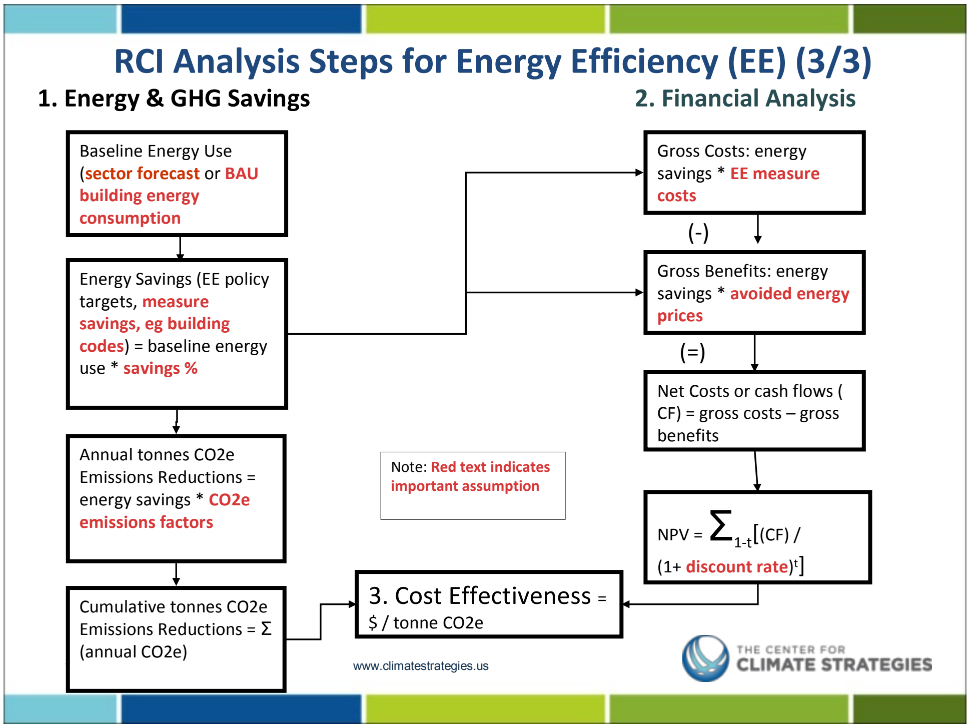
The gross benefits in each year are derived from:

- The avoided prices of energy, which are the avoided energy expenditures (or bill savings) from the RCI policies.
- The quantity of energy (GWh/BBtu) used to calculate the gross benefits is the amount of energy as calculated for gross costs above, plus the assumed losses from transmission and distribution.
- The gross benefit is the avoided energy price multiplied by the quantity of energy assumed mitigated in each year.
- The net costs or benefits in each year are derived from: Gross benefits are subtracted from gross costs in each year through 2020 to give a net cash flow for each time period. Negative values represent positive economic cash flows.

Net Present Value

The NPV of this stream of cash flows is then calculated using a 5% real discount rate to estimate a discounted, lump sum cost (or benefit) in 2010 dollars to the state from the program in 2012 (assuming the relevant 2012–2020 implementation schedule). The relationship between the elements of the quantification is shown in Figure 1.

Figure 1: Quantification Elements



RCI Analysis Steps for Energy Efficiency (EE) (3/3)

1. Energy & GHG Savings

2. Financial Analysis

Baseline Energy Use (sector forecast or BAU building energy consumption)

Energy Savings (EE policy targets, measure savings, eg building codes) = baseline energy use * savings %

Annual tonnes CO2e Emissions Reductions = energy savings * CO2e emissions factors

Cumulative tonnes CO2e Emissions Reductions = Σ (annual CO2e)

Gross Costs: energy savings * EE measure costs

(-)

Gross Benefits: energy savings * avoided energy prices

(=)

Net Costs or cash flows (CF) = gross costs – gross benefits

NPV = $\sum_{1\text{-}t}[(CF) / (1+ \text{discount rate})^{t}]$

3. Cost Effectiveness = $ / tonne CO2e

Note: Red text indicates important assumption

www.climatestrategies.us

THE CENTER FOR CLIMATE STRATEGIES

Maryland RCI Assumptions

This section documents the assumptions used to calculate the costs and supplies of CO2 reductions in Maryland.

Avoided Energy Cost Calculations

Avoided costs components are intended to approximate the costs used in a total resource cost test. Electricity costs begin with 2011 wholesale electricity prices for the PJM-SW region PJM. Price changes from 2012-2020 are based on the changes in electricity prices from the 2012 Annual Energy Outlook reference case. Avoided distribution is included in California Standard Practices Manual (2001) for Total Resource Cost test (p. 20). Transmission and distribution charges from BGE tariffs are included less assumed allowed Rate of Return. This excludes Administrative Cost Charges, Taxes, EE charges, other program charges. However, RPS and RGGI costs are included as they are considered social costs. RGGI costs assume $2/ton allowance prices averaged over 2012-2012. RPS program costs are calculated with the methodology for the Distributed Resource Cost model for California DSM[6].

Natural gas avoided costs for the each RCI sector come from 2011 EIA State Energy Data as a base year. Forecasts are generated by applying the annual change for natural gas retail prices

---

[6] http://ethree.com/public_projects/cpuc4.php

from the 2012 Annual Energy Outlook reference case. Retail prices are reduced by the estimated utility rate of return (9.4%) to reflect only the social costs associated with natural gas supplies.

Avoided Cost Estimates

Natural Gas	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Residential	$ 10.92	$ 10.97	$ 10.70	$ 10.85	$ 10.85	$ 10.91	$ 11.01	$ 11.16	$ 11.33
Commercial	$ 9.48	$ 9.59	$ 9.41	$ 9.54	$ 9.49	$ 9.51	$ 9.56	$ 9.70	$ 9.85
Industrial	$ 7.32	$ 7.84	$ 7.98	$ 8.13	$ 8.02	$ 8.01	$ 8.05	$ 8.19	$ 8.35
Load Weighted Average	$ 8.13	$ 8.53	$ 8.56	$ 8.71	$ 8.63	$ 8.63	$ 8.69	$ 8.83	$ 9.00
Electricity	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Residential	$ 89.21	$ 89.08	$ 88.96	$ 88.84	$ 88.72	$ 88.59	$ 88.47	$ 88.35	$ 88.23
Commercial	$ 86.76	$ 86.64	$ 86.52	$ 86.39	$ 86.27	$ 86.15	$ 86.03	$ 85.91	$ 85.79
Industrial	$ 77.31	$ 77.19	$ 77.07	$ 76.94	$ 76.82	$ 76.70	$ 76.58	$ 76.46	$ 76.34
Load Weighted Average	$ 86.32	$ 86.20	$ 86.08	$ 85.96	$ 85.83	$ 85.71	$ 85.59	$ 85.47	$ 85.35

Natural gas prices are taken from 2010 EIA retail natural gas prices by sector and reduced by 3% for 2011. Forecasted price changes for 2012-2020 come from the EIA Annual Energy Outlook reference case for the Mid-Atlantic region.
http://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PIN_DMcf_a.htm

Electricity Avoided Cost Calculations Methodology

$/kWh	**Residential**	**Commercial**	**Industrial**
2020 Wholesale Price Forecast	$ 0.041	$ 0.041	$ 0.041
Avoided Trans Chg	$ 0.0065	$ 0.0042	$ 0.0042
Avoided Distribution Charge	$ 0.0253	$0.02511	$0.01468
(Less Allowed Utility ROR at 9.4%)	$ 0.0024	$ 0.0024	$ 0.0014
Net Avoided Dist Chg	$ 0.0229	$ 0.0227	$ 0.0133
RPS rate impacts	$ 0.0083	$ 0.0083	$ 0.0083
RGGI rate impacts	$ 0.001	$ 0.001	$ 0.001
Avoided Capacity Charges	$ 0.008	$ 0.008	$ 0.008
Total Avoided Non Generation Chgs	$ 0.05	$ 0.04	$ 0.04
Total Avoided Cost	**$ 0.088**	**$ 0.086**	**$ 0.076**
Excludes Allowed ROR, Administrative Cost Charges, Taxes, EE charges, other program charges.			

Calculation of Avoided Renewable Costs

Costs Associated with Avoided Renewable Electricity ($/perMWh)

	2012-2020 Average
Avoided Wholesale Electricity Price	$41.43
Avoided Cost of Marginal Renewable Resource Cost ($/MWh) (Biogenic Waste)	$103.68

Capacity Value of Renewables ($/MWh)	$4.02
Renewable Premium ($/MWh)	$58.22
Avoidable Renewable Cost ($/MWh Sales)	$8.34

The avoided renewable cost is the renewable premium multiplied times the RPS target in each year.
http://ethree.com/public_projects/cpuc4.php
Distributed Resource Avoided Cost Calculator

RGGI rate impacts ($/MWh)	**$1.28**	**$2/ton CO2 * average CO2 intensity**

The capacity benefits from EE are included in the avoided costs using the following assumptions:

Capacity Credit for EE

Reported Annualized Savings (MWh)	743,923
Reported Coincident Peak Demand Reduction (MW)	115.065
Implied Capacity Factor	74%
MW Demand Reduction Per MWh	**0.00015**

Source:
BGE 2nd Qtr 2012 EmPower Program Savings
EmPower results per measure.xls
Total EE&C Programs Subtotal

Capacity Credit Calculations	**2012-2020 Average**
Avoided Capacity Price ($/kW/yr)	$ 52.84
Avoided Capacity Benefits from EE ($/MWh)	$ 8.173

Source:
BGE Historical 2010 Wholesale Prices
Unchanged 2010-2020

Avoided CO_2

Full fuel cycle emissions are calculated with a FFC adder based on the difference in statewide power supply GHG emissions for FFC (.64 tons CO_2/MWh) and direct emissions (.57 tons

CO_2/MWh) developed for the EmPOWER analysis. The adder was approximately (.57/.49) = 16.3% for all years.

Natural Gas Full fuel cycle Emissions Factor includes an adder for full fuel cycle emissions that is estimated at 21.82%, based on point of combustion factor of 50,305 kg/TJ and a Full fuel cycle factor of 61,282 kg/TJ.

Sector Sales	Percent
Residential	43%
Commercial	48%
Industrial	8%

Source:

Sales from MEA
RCI percent from 2011 MD State Electricity Data from the EIA. Applied to all years 2012-2020
http://www.eia.gov/electricity/data/state/

Natural Gas DSM Costs

The levelized cost of natural gas demand side management is estimated from the GDS report Natural Gas Energy Efficiency Potential in Maryland.[7] The report does not include the $/MMBTU assumptions for costs of saved gas. $/MMBTU costs are extrapolated from the report using 2012 program costs assuming a 5% real discount rate and a 10 year measure life.

Levelized Costs of All Fuel EE Total Costs ($/MMBTU)	
Residential	**$9.93**
Commercial	**$5.01**
Industrial	**$2.09**

Electricity DSM Costs

The costs of electricity DSM come table 14 of the ACEEE 2008 report (p. 33)[8]:

Levelized Cost of Electric Energy Efficiency--Total Costs	**(2010$/MWh)**
Residential	**$49.87**
Commercial	**$25.57**
Industrial	**$33.24**
Load Weighted Average	**$37.02**

---

[7] http://energy.maryland.gov/empower2020/documents/NaturalGasEnergyEfficiencyPotentialinMaryland.pdf

[8] ACEEE. 2008. Energy Efficiency: Resources for Meeting Marylands Electricity Needs. E082. http://www.aceee.org/sites/default/files/publications/researchreports/e082.pdf

The ACEEE costs were converted to $2010 and a 25% adder for Fixed Costs (admin, marketing, Monitoring and Evaluation) is added.

The data for the DSM supply curve (ACEEE, 2008) indicates that nearly 28% of residential electricity can be conserved at a cost of less than $85/MWh. Approximately 35% of commercial electricity can be conserved at a cost of less than $50/MWh:

Residential Measures	**End Use %**	**$2010 $/MWh**
Lighting	7%	$ 10
Electricity Use Feedback	3%	$ 31
Plug Loads	2%	$ 38
HVAC	11%	$ 61
New Homes	3%	$ 75
Refrigeration	1%	$ 77
Furnace Fans	1%	$ 84
Water heating	3%	$ 95
Appliances	0%	$ 105
Total	**31%**	
Commercial Measures	**End Use %**	**$2010 $/MWh**
Office Equipment	2.8%	$ 3.84
Lighting	17.0%	$ 14.06
Appliances and Other	0.4%	$ 15.34
Refrigeration	1.6%	$ 24.29
Water heating	0.4%	$ 42.19
New Buildings	6.0%	$ 46.03
HVAC	6.7%	$ 47.31
Total	**35%**	

Other Assumptions

T& D Losses	**6.25%**

2010 State Electricity Profile for MD

Real Discount Rate	**5%**

Assumption

CHP Assumptions

CHP costs and emissions reductions use data from several data sources. Supply estimates come from the MD CHP report prepared by the US DOE Mid Atlantic Clean Energy Center.[9] Cost

---

[9] US DOE. 2010. MARYLAND COMBINED HEAT AND POWER MARKET ASSESSMENT. http://energy.maryland.gov/empower2020/index.html

estimates are from Hedman, et al (2012).[10] Consistent with a total research costs test approach, state incentives such as 0% interest loans are not included in the cost effectiveness analysis, only the $10/MWh federal tax credit which is scheduled to expire at the end of 2016.

The CHP analysis utilizes two natural gas price forecasts. CHP units are assumed to pay the full retail price for gas developed from the Annual Energy Outlook price forecasts. However, the avoided costs of gas in the analysis are 9.4% lower to reflect a total resource cost test.

	New CHP Fuel			
CHP Types (Sector/Fuel)	**Natural Gas**	**Coal**	**Petroleum**	**Biomass**
Commercial CHP (MW)	**100%**	**0%**	**0%**	**0%**
Industrial CHP (MW)	**100%**	**0%**	**0%**	**0%**

	Displaced Boiler Fuel			
CHP Types (Sector/Fuel)	**Natural Gas**	**Coal**	**Petroleum**	**Biomass**
Commercial CHP	**80%**	**0%**	**20%**	**0%**
Industrial CHP	**24%**	**24%**	**42%**	**10%**

	$2010	**For Year 2020**	
Avoided T&D Charges	**Commercial**	**Industrial**	**Source**
Demand Charge kW month	**$-**	**$2.65**	BGE General Service Large - Sched. GL (>60 kw), Primary Service
Transmission Charge Customer/ kW / Month	**$-**	**$-**	
Capacity Value ($/MW)	**$126**	**$126**	PJM-SW Capacity Forecast
Capacity Credit ($MWh)	**$14.38**	**$14.38**	Calculation based on capacity factor and On-Peak Factor
T&D Losses	**5.6%**	**5.6%**	Electricity Inventory and Forecast.
CHP Characteristics			
CHP Technology	**Recip Engine**	**Gas Turbine**	
CHP Unit Size MW	**0.80**	**40.00**	
Heat Rate BTU/kWh	**9,750**	**8,990**	Hedman et al. (2012) Tables 38-40.
Capacity Factor	**80%**	**80%**	Hedman et al. (2012) Table A-2.

---

[10] Hedman, Bruce, Ken Darrow, Eric Wong, Anne Hampson. ICF International, Inc.2012. *Combined Heat and Power: 2011-2030 Market Assessment.* California Energy Commission. CEC-200-2012-002. http://www.energy.ca.gov/2012publications/CEC-200-2012-002/CEC-200-2012-002.pdf

On-Peak Factor	**80%**	**80%**	Assumes same as capacity factor
Heat Recovered from CHP (Power to heat ratio)	**80%**	**90%**	Hedman et al. (2012) Table A-2. Ind. Reduced for cooling markets
Installed Capital Costs $/kW	**$1,817**	**$2,868**	Hedman et al. (2012) Tables 38-40.
O&M Costs $/MWh	**$13.50**	**$5.00**	Hedman et al. (2012) Tables 38-40.
Economic Life/years	**15**	**20**	Hedman et al. (2012) Tables 38-40.
Natural Gas Fuel Percent	**100%**	**100%**	Assumption
Levelized Cost of Electricity $/MWh	**$140**	**$97**	Calc
Avoided Thermal Charges $/MWh	**$41**	**$45**	Calc
Avoided Capacity Tariff Charges $/MWh	**$-**	**$3**	Calc
Avoided Capacity Costs $/MWh	**$14**	**$14**	
Net Generation Cost $/MWh	**$84**	**$34**	Calc
Avoided Price of Power $/MWh	**91**	**81**	Assumption
MW Capacity	**326**	**230**	Policy Targets
Avoided Boiler Characteristics			
Displaced boiler efficiency	**80%**	**80%**	MD Assumption
Fixed O&M $/MMBTU	**$0.07**	**$0.07**	Assumption
Variable O&M $/MMBTU	**$0.07**	**$0.07**	Assumption

Other CHP Assumptions

Phase-in Year:	**2013**
First Reporting Year:	**2015**
Terminal Year:	**2020**
Goals and Timing	
CHP Target in 2020 (MW)	**556**
CHP Target in 2030 (MW)	**556**
CHP Target in 2035 (MW)	**556**
MD CHP Report: 10 year target with $10 MWh AEC. P. 7	
Commercial Share of CHP MW (all years)	**58.7%**
Industrial Share of CHP MW (all years)	**41.3%**
Figure 13 in MD CHP Report (technical potential)	
Number of Unscheduled Outages per year	**3**
# of months CHP unit must pay demand charges	
CHP Financing Rate	**10.0%**
Cross policy assumption	

Share of Industrial MWh for Export	**39.6%**

Figure 13 in MD CHP Report (technical potential)

Federal Tax Credit	**10.0%**
Sunset date (December of)	**2016**

Consistent with existing Federal Business tax credit

Chapter 2. Maryland Renewable Portfolio Standard Analysis and Discussion

Chapter 2: Maryland Renewable Portfolio Standard,

Introduction

This chapter provides a policy-level overview of the modeling framework, analytical approach, key data assumptions, source materials and steps to quantify the costs and benefits of Maryland's Renewable Portfolio Standard (RPS) on a standalone basis. It also summarizes the costs and benefits of the RPS with MD's EmPOWER demand-side efficiency policy on an integrated basis. Results are quantified using both point-of-combustion and full fuel cycle methodologies. This chapter is intended to provide an independent analysis of additional actions that may be needed in Maryland to achieve the greenhouse gas (GHG) emission reductions called for in the Maryland Greenhouse Gas Reduction Act of 2009 (GGRA).

Overall summary

If EmPOWER Maryland and the RPS maintain their current trajectory, and fuel switching maintains its assumed pace, the combined programs will reduce emissions by approximately 16.6 $MMtCO_2e$. Under this scenario, statewide emissions will decrease by only 16.5% below 2006 levels by 2020, thus creating a 9.2 $MMtCO_2e$ gap.

If EmPOWER is expanded to the medium scenario and the RPS is increased to 25% by 2020 without black liquor and old inefficient wood waste facilities, and fuel switching maintains its assumed pace, the combined programs will reduce approximately 25.9 $MMtCO_2e$. Under this scenario, statewide emissions decrease by 25.1% below 2006 levels by 2020 and there is 0.1 $MMtCO_2e$ cushion for other policy sectors of the state's GHG reduction Plan.

In order to achieve the 25% reduction goal mandated by Maryland's 2009 Greenhouse Gas Reduction Act, EmPOWER Maryland should be expanded to the medium scenario and the RPS should be increased to 25% by 2020 without black liquor and old inefficient wood waste facilities.

Table 1 below summarizes the emissions results from analyzing the aforementioned existing programs and the recommended program enhancements.

Table 1: Overall summary

The tables below summarize the results of the RPS and integrated demand/supply analyses under various assumptions as noted in the tables.

Impacts of Baseline and New Policies	2020 MMTCO2e	Type of Emissions-Factor Used
Minimum GGRA Reduction Goal (25% below 2006 levels)	55.3	
GGRA Reduction Trajectory: Existing Programs (from GGRA Plan)	46.1	
GGRA Reduction Gap	9.2	
Existing EmPOWER reductions	7.8	

Existing RPS reductions	6.4	Point-of-Combustion
Fuel Switching (30% imported natural gas)	6.1	
RGGI	0.0	
Existing Policies (EmPOWER, RPS) + Fuel Switching	20.4	
Existing Policies (EmPOWER, RPS) + Fuel Switching (after adjusting for overlaps)	16.6	
Existing Policies (EmPOWER, RPS) + Fuel Switching: Contribution to Maryland's Overall Reduction Goal	30%	
Enhanced EmPOWER – medium scenario	16.04	
Enhanced RPS – 25% x 2020, restricted black liquor and wood waste	11.5	
Fuel Switching (30% imported natural gas)	6.1	
Enhanced Policies (EmPOWER, RPS) + Fuel Switching	33.6	
Enhanced Policies (EmPOWER, RPS) + Fuel Switching (after adjusting for overlaps)	25.9	
Enhanced Policies (EmPOWER, RPS) + Fuel Switching: Contribution to Maryland's Overall Reduction Goal	47%	
Additional Reductions from Enhanced EmPOWER & Enhanced RPS	9.3	
GGRA Reduction Trajectory: Enhanced RPS & EmPOWER0	55.4	
GGRA Reduction Gap	-0.1	

Table 2: Summary of RPS results (point-of-combustion emission factors, BAU Fuel Switching case). ***NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.***

Summary of results (point-of-combustion)		**Utility GHG Emissions in 2020 (million tons CO2e)**		**Emission savings, consumption basis (MMtCO2e)**		**NPV, consumption basis (million 2010$)**	**Cost-effectiveness, consumption basis ($2010/tCO2e saved)**
					Cumulative		
Policy	Assumptions	**Production**	**Consumption**	**2020**	**2012-20**	**2012-20**	**2012-20**
Enhanced RPS; no energy efficiency	Biomass & black liquor EXCLUDED in RPS Biogenic emissions INCLUDED RPS INCREASED to 25% x	34.6	43.6	11.5	55.805	$3,523	$63

	2020						
	Imports assumed from PJM						
	NO Natural Gas Expansion						

Table 3: Summary of RPS results (fuel cycle emission factors, BAU Fuel Switching case). ***NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.***

Summary of results (point-of-combustion)		**Utility GHG Emissions in 2020 (million tons CO2e)**		**Emission savings, consumption basis (MMtCO2e)**		**NPV, consumption basis (million 2010$)**	**Cost-effectiveness, consumption basis ($2010/tCO2e saved)**
					Cumulative		
Policy	Assumptions	**Production**	**Consumption**	**2020**	**2012-20**	**2012-20**	**2012-20**
Enhanced RPS; no energy efficiency	Biomass & black liquor EXCLUDED in RPS Biogenic emissions INCLUDED RPS INCREASED to 25% x 2020 Imports assumed from PJM NO Natural Gas Expansion	37.2	47.5	12.3	68.166	$3,523	$52

Table 4: Summary of integrated demand/supply results (point-of-combustion emission factors, BAU Fuel Switching case). ***NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.***

		Utility GHG Emissions in 2020 (million tons CO2e)		Emission savings, consumption basis (MMtCO2e)		NPV, consumption basis (million 2010$)	Cost-effectiveness, consumption basis ($2010/tCO2e saved)
					Cumulative		
Policy	Assumptions	Production	Consumption	2020	2012-20	2012-20	2012-20
Enhanced RPS; Enhanced energy efficiency included	Biomass & black liquor EXCLUDED in RPS Biogenic emissions INCLUDED RPS INCREASED to 25% x 2020 Imports assumed from PJM NO Natural Gas Expansion	36.2	32.8	24.1	128.091	-$3,955	-$31

Table 5: Summary of integrated demand/supply results (fuel cycle emission factors, BAU Fuel Switching case). ***NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.***

		Utility GHG Emissions in 2020 (million tons CO2e)		Emission savings, consumption basis (MMtCO2e)		NPV, consumption basis (million 2010$)	Cost-effectiveness, consumption basis ($2010/tCO2e saved)
					Cumulative		
Policy	Assumptions	Production	Consumption	2020	2012-20	2012-20	2012-20
Enhanced RPS; Expanded energy efficiency included	Biomass & black liquor EXCLUDED in RPS Biogenic emissions INCLUDED RPS INCREASED	38.9	35.3	26.7	153.149	-$3,955	-$26

	to 25% x 2020						
	Imports assumed from PJM						
	NO Natural Gas Expansion						

Option Quantification Status

There were a total of 2 power supply options that were evaluated as part of the power supply analysis. The standalone quantification status of each of these options is briefly summarized below.

- Renewable Portfolio Standard and Incentives for Grid-Based Renewable Generation: This policy option ***was quantified*** as per the assumptions and sensitivities discussed below.
- Regional Greenhouse Gas Initiative (RGGI): This policy option is considered as an enabling/framework policy and was therefore ***not quantified*.**
    - It must be noted that this analysis presumed that the RGGI cap would remain at its current level of 165 million tons, to be reduced gradually by 10% by 2018. If however, programmatic changes occurred and the cap was lowered, it is possible that RGGI could drive emissions reductions beyond the enabling/framework policy structure envisioned here.

Overall Approach

This section provides an overview of the boundaries for the analysis as well as the modeling framework used.

Boundaries for the Analysis

The starting point for power supply analysis is the information provided by the Maryland Energy Administration (MEA) regarding the projected retail electricity sales and generation resource mix over the period 2006-2020. This information represents the “Business-as-Usual” (BAU) scenario against which all comparisons were made. Much of the information that was available used to develop this BAU scenario was obtained from Mr. Kevin Lucas at the MEA and was integrated as the starting assumptions in the quantification of the RPS. Additional information was obtained from other state-specific sources, including the Long-term Electricity Report for Maryland, as identified in the List of References.

The period of analysis for Power Sector Demand options is 2006 the benchmark year in the GGRA, and 2020. It is important to note, however, that historical data regarding retail sales was provided only for the years 2006 and 2007. Retail electricity sales, MD net generation, and net imported electricity levels for 2009, 2010 - and in the case of retail sales, 2011 - were projected values even though actual historical levels were available for these years.

As used in this write-up, “costs” refers to the direct incremental or additional costs associated with achieving a greenhouse gas reduction benefit relative to the BAU scenario. “Benefits” refers to the fuel savings and greenhouse gas emission reductions achieved by the policies. Other types of costs (e.g., impact on gross state product) or benefits (e.g., job creation, market transformation) were not considered in the quantification.

Modeling Framework

The modeling framework for the analysis of all options was calibrated to the time and budget constraints of the effort. Hence, a heuristic analysis framework was used that was able to produce acceptable results within the time allotted for the various supply/demand policies and sensitivities envisioned. Members of the CCAN/MEA analytical team involved build the outputs largely on the best available resource/technology assumptions and expert judgment.

The limits of this approach is that analyses to assess loss of load probability, simulate power plant dispatch, estimate capacity expansion, assess the need for increased regulation resources, and conduct power flow analysis for transmission planning are necessarily left unaddressed. Such analyses are essential to a full characterization of the costs and benefits of the standalone and integrated policies.

Methodological issues

There are several methodological issues that needed to be addressed during the course of the analysis. The approach to each of the major issues is briefly discussed in the subsections below.

Treatment of RPS Incremental Costs

The net incremental cost of the RPS was calculated multiplying the forecasted price of RECs by the anticipated REC demand. According to Maryland’s Long Term Electricity Report, “a REC is equal to the gap in revenue required to fully compensate energy developers for the cost and expense of constructing, owning, and operating a renewable energy facility given the revenue stream obtained from the sale of energy and capacity from the renewable energy project, that is, the REC price is equal to costs (including a reasonable return on investment) minus revenues from energy and capacity sales.”[11]

If there were a depressive effect on wholesale prices as a result of low marginal cost renewables coming online, that savings would likely translate into an increase in the price per REC (assuming technology costs remain the same). The REC indicates that there is a price above and beyond what would otherwise be paid for electricity and therefore seems to be a reasonable proxy for incremental cost.

The Maryland Energy Administration provided the forecasted price of RECs.

Treatment of intermittent renewable generation

---

[11] MD DNR, Power Plant Research Program. "Long-term Electricity Report for Maryland." Maryland Department of Natural Resources Power Plant Research Program, 1 Dec. 2011

Recent wind integration studies have shown that with large penetration of intermittent renewables (i.e., greater than 20%), power system performance degrades with the same automatic generation control strategies and amounts of regulation services as today's systems have. To address this issue in the analysis, it was assumed that balancing services would ramp up and down, as needed, to provide backup generation capability during periods when intermittent generation is not coincident with peak load. Such generation serves the purpose of adding storage to the system for intermittent resources with low capacity credit. The GHG emissions associated with this backup generation were included in the calculation of absolute levels of emissions.

Treatment of reliability

Electric system reliability corresponds to the performance of the system when it is under stress of some kind, such as when some lines or power stations are out of service. One component of electric system reliability is the ability to meet electricity demand of the customers at all times, taking into account scheduled and unscheduled outages of system facilities. Another component is the ability of the system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system facilities. Given the time and budget constraints of the analysis process, neither component could be addressed.

Treatment of technology learning

Technology learning refers to the well-documented experience of declining capital costs of renewable energy technologies with increasing levels of market penetration of solar PV, onshore wind, offshore wind, and wood-fired technologies. The methodology used by the EIA in development of the Annual Energy Outlooks[12] assumes that capital costs at the national level decrease by about 10% for each doubling of cumulative international installed capacity However, given the short planning period (i.e., 2012-2020), learning effects were not incorporated into the analysis.

Treatment of emission factors

The analysis was undertaken such that GHG reductions are reported on either a full fuel cycle or point-of-combustion basis. Full fuel cycle emissions account for the entire fuel chain; from the point of extraction to the point of actual combustion at the power station. Point-of-combustion emissions account only for the emissions produced at the power station. Fuel cycle CO2-equivalent factors were developed for fossil (coal, oil, natural gas), biomass, and nuclear generation. Point-of-combustion CO2-equivalent factors were developed for fossil- and biomass-fired generation. A summary of CO2-equivalnet assumptions is provided in the Table below.

Table 6: CO2-equivalent emission factor assumptions, biogenic emissions included

---

[12] See the Electricity Market Module of the National Energy Modeling System: Model Documentation Report, September 2008, DOE/EIA-M068(2008), page 70)

Resource	Point-of-Combustion	Fuel fuel cycle
Hydropower	0	0
Wastewater treatment gas	249	249
Landfill gas	24,801	32,708
Animal manure	249	249
Woody residues	90,776	109,633
Geothermal	0	0
Tidal current	0	0
Wave	0	0
Offshore Wind	0	0
Solar	0	0
Wind (onshore)	0	0
Waste heat	0	0
MSW	87,838	87,838
Black liquor	90,776	109,633
Coal	90,144	94,004
Natural gas – Conventional Drilling	50,303	65,482
Natural gas – Hydraulic Fracturing	50,303	58,298 – 93,940
Blast furnace gas	50,305	50,305
Nuclear	0	3,698
Diesel	70,105	87,316

Treatment of in-state margin

As incremental renewable generation is brought online in Maryland due to the RPS, an equivalent amount of fossil based generation is displaced. While the actual annual shares change throughout the planning period, by 2020 the margin was assumed to consist of about 91% coal and 9% natural gas. These levels were inferred from a review of the most recent RGGI net generation outputs for Maryland for resources displaced in moving from the RGGI High scenario to the RGGI Reference scenario.

Treatment of out-of-state emissions

Maryland is a net importer of electricity from the PJM power pool over the planning period. This results in electric generation taking place beyond state borders to satisfy electric consumption within the state's borders. The GHG emissions associated with this imported net generation are accounted for in the analysis by assigning CO2 intensity to electricity imports. Three different CO2 intensities were considered. In the BAU, PJM resource mix assumes a constant mix of resources. Two alternative cases were considered, a case in which natural gas comprised about 19% share in 2020, and one in which natural gas comprised about 30.4% share in 2020. The table below summarizes the assumed CO2 intensities of electricity imports into Maryland over the 2012-2020 period for these three cases.

Table 7: BAU CO2 intensity of imported electricity into Maryland (ton CO2 per MWh)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
MDE BAU	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
19% NG share in 2020	0.53	0.52	0.52	0.52	0.51	0.51	0.51	0.51	0.51
30% NG share in 2020	0.52	0.51	0.50	0.48	0.47	0.47	0.46	0.45	0.45

Emissions associated with net generation that occurs only within the state's borders are termed "production basis" emissions. These are tracked separately in order to be able to make direct comparisons with the RGGI annual targets for Maryland. The GHG emissions associated with net generation that occurs both within and beyond the state's borders are termed "consumption basis" emissions. These are ultimately the basis by which to evaluate the extent to which Maryland achieves GRRA targets.

Quantification Tool

A transparent and easy-to-navigate set of spreadsheets was developed to integrate cost/performance assumptions, renewable generation targets, demand-side reductions, methodological approach, data sources, etc. into the quantification framework. The set of spreadsheets was then incorporated into a simple hyperlinked (i.e., point and click) tool that has been provided to the process for ease of review of methods/assumptions, as well as a straightforward way to explore potential sensitivity analyses during the process.

Policy Scenarios

Six different policy scenarios are discussed in this chapter. They are as follows:

Existing RPS: Utility and non-utility electricity suppliers must obtain 18 percent of their electricity from Tier-1 renewable sources by 2020 and 20 percent by 2022. There is a 2 percent solar carve-out that reaches maturity in 2020. All currently eligible Tier-1 renewable sources under Maryland's RPS were assumed to remain eligible out to 2020.

Enhanced RPS: Utility and non-utility electricity suppliers must obtain 25 percent of their electricity from Tier-1 renewable sources by 2020. There is a 2 percent solar carve-out that reaches maturity in 2020. Restrictions are placed on eligible renewable sources so that all "qualifying biomass" facilities that went into commercial operation before 2005 or achieve less than a 65 percent total system efficiency get moved to Tier 2. This policy was assumed to gradually remove all "black liquor" and "wood waste" facilities. It should be noted, however, that this policy would not preclude new and efficient biomass facilities from qualifying in the future. For more information on the emissions, net present value, and cost-effectiveness of raising the RPS goals, see appendix XXX.

Existing EmPOWER: EmPOWER Maryland achieves 60 percent of its 15 percent per-capita electricity consumption reduction goal. The demand-side analysis write-up provides additional details.

Enhanced EmPOWER: Starting in 2013, Maryland achieves 1.5% annual reductions in both electricity and natural gas consumption, and develops 556 MW of CHP capacity by 2020. The demand-side analysis write-up provides additional details.

Overview of the Business-as-Usual Scenario

This section provides an overview of the details underlying the BAU scenario. The BAU scenario is important because it represents the conditions to which the impacts of the RPS policy and the integrated demand/supply policies are compared.

Historical data, 2006-2011

Historical data was obtained from the MEA for the years 2006 and 2007. This information closely matched historical data contained in the EIA's state electricity profile for Maryland. For the historical period 2008-2010, projected values from the MEA were used. A summary of the differences between actual historical data for the 2006-2011 and the values used in the analysis for this period are summarized in the Table that follows. Since annual growth rates for retail sales over the 2012-2020 period are based upon a projected rather than historical base year, the use of projected values rather than actual values during the historical period has the effect of propagating the differences shown in Table 3 throughout the planning period.

Table 8: Difference between historical data and MEA assumptions, retail sales and net generation

		2005	2006	2007	2008	2009	2010	2011
Retail sales (GWh)	MEA	68,366	63,173	66,011	66,929	67,797	68,761	69,862
	Actual	68,366	63,173	65,390	63,326	62,590	65,335	68,246
	Difference from MEA	0	0	-621	-3,603	-5,207	-3,426	-1,616
Net generation (GWh)	MEA	73,675	67,595	70,136	71,112	70,034	73,059	74,228
	Actual	73,675	67,907	71,366	69,009	67,429	70,152	73,278
	Difference from MEA	0	312	-1,230	-2,103	-2,604	-2,907	-950

BAU Outputs through 2020

As noted earlier, the BAU Scenario relied on assumptions provided by MEA. A summary of assumptions for retail sales, net generation, and GHG emissions is provided in Tables 2, 3, and 4.

The Table below shows a breakdown in retail sales by sector. For the 2010-2020 period for which the projected sectoral breakdown was not available, it was assumed that the shares in 2006 were reasonable. These shares were 42.5% for residential, 47.1% for commercial, 9.6% for industrial, and 0.7% for transport. An average annual growth rate of 1.52% per year was assumed for each sector.

Table 9: BAU sectoral retail electricity sales, 2010-2020 (GWh)

Sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Residential	29,285	29,754	30,232	30,625	31,032	31,427	31,957	32,470	33,000	33,536	34,086
Commercial	32,359	32,877	33,405	33,840	34,290	34,726	35,311	35,878	36,464	37,056	37,663
Industrial	6,593	6,698	6,806	6,895	6,986	7,075	7,194	7,310	7,429	7,550	7,674
Transport	525	533	542	549	556	563	573	582	591	601	611
Total	68,761	69,862	70,984	71,909	72,865	73,791	75,035	76,239	77,484	78,743	80,033

The Table below shows a breakdown in utility/non-utility net generation by resource for the BAU scenario. This table reflects a BAU default assumption in the MDE BAU scenario in which natural gas-fired accounts for about 5% of total PJM net generation in 2020, which is based on the 2006 baseline year PJM natural gas-fired generation level. An alternative “Assumed Fuel Switching” assumption was also included in the RPS and integration scenarios that assume that natural gas-fired generation can account for up to 30.4% of total PJM net generation in 2020, with the additional natural gas-fired generation displacing coal-fired generation. Additionally, in the “Assumed Fuel Switching” scenario, the same annual rate of growth for PJM natural gas-fired generation was applied for Maryland natural gas-fired generation, albeit from a lower baseline. Net imports account for between 33% (in 2010) and 35% (in 2020) of the total net generation to satisfy Maryland demand over the planning period.

Table 10: BAU net generation for utilities and non-utilities, 2010-2020 (GWh)

Resource	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Coal	29,9	30,1	30,2	30,4	30,5	30,7	30,8	31,0	31,1	31,3	31,4
Natural Gas	1,78	2,00	2,24	2,51	2,81	3,15	3,52	3,95	4,42	4,96	5,55
Other Gases	332	332	332	332	332	332	332	332	332	332	332
Petroleum	756	807	862	921	983	1,05	1,12	1,19	1,27	1,36	1,45
Nuclear	13,8	13,8	13,8	13,8	13,8	13,8	13,8	13,8	13,8	13,8	13,8
Large Hydroelectric	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06
Small-scale hydro	35	35	35	35	35	35	35	35	35	35	35
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0
Onshore wind	0	0	0	0	0	0	0	0	0	0	0
Landfill gas	58	58	58	58	58	58	58	58	58	58	58
Biomass	17	17	17	17	17	17	17	17	17	17	17
Biogenic MSW	388	388	388	388	388	388	388	388	388	388	388
Black liquor	163	163	163	163	163	163	163	163	163	163	163
Wastewater	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Non-biogenic MSW	305	305	305	305	305	305	305	305	305	305	305
Net imports	24,1	24,3	25,1	25,6	26,1	26,5	27,3	27,9	28,5	29,1	29,6
Total (production basis)	49,728	50,141	50,585	51,062	51,576	52,131	52,732	53,385	54,094	54,867	55,711

Total (consumption basis)	73,831	74,519	75,717	76,703	77,722	78,711	80,037	81,321	82,650	83,993	85,369

The Table below shows a breakdown in BAU point-of-combustion CO2 equivalent emissions from utility/non-utility net generation by resource. In the Table that directly follows, production- and consumption-basis CO2-equivalent totals using full fuel cycle emission factors are provided (natural gas is from 30% hydraulic fracturing w/ a 4% methane leakage rate measured over a 100-year timeframe, 70% conventional drilling).

Table 11: Resource-specific summary of BAU CO2-equivalent emissions, 2010-2020 (million tons, point-of-combustion)

Resource	201	201	201	201	201	201	201	201	201	201	202
Coal	29.5	29.6	29.8	29.9	30.1	30.2	30.4	30.5	30.7	30.8	31.0
Natural Gas	1.3	1.5	1.7	1.9	2.1	2.3	2.6	2.9	3.3	3.7	4.1
Other Gases	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Landfill gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogenic MSW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black liquor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wastewater treatment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-biogenic MSW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Net imports	13.7	13.9	14.3	14.6	14.9	15.1	15.5	15.9	16.2	16.6	16.9
Total (production basis)	**33.3**	**33.7**	**34.1**	**34.4**	**34.9**	**35.3**	**35.8**	**36.4**	**36.9**	**37.6**	**38.2**
Total (consumption basis)	**47.0**	**47.5**	**48.3**	**49.0**	**49.7**	**50.4**	**51.3**	**52.2**	**53.2**	**54.1**	**55.1**

Table 12: Overall summary of BAU CO2-equivalent emissions summary, 2010-2020 (million tons, full fuel cycle emission factors)

Resource	20	20	20	20	20	20	20	20	20	20	20
Total (production basis, BAU Fuel Switching)	35.1	35.6	36.0	36.5	37.0	37.6	38.2	38.8	39.5	40.3	41.1
Total (consumption basis BAU Fuel Switching)	51.1	51.7	52.7	53.5	54.4	55.3	56.4	57.4	58.6	59.8	61.0
Total (production basis, Assumed Fuel Switching)	35.1	35.5	36.0	35.8	35.7	35.8	35.9	36.1	36.4	36.8	37.3
Total (consumption basis, Assumed Fuel Switching)	50.1	50.4	51.2	51.0	51.0	51.0	51.3	51.7	52.2	52.6	55.1

Overview of the RPS Scenario

This section provides an overview of the details underlying the analysis of Maryland RPS policy. The analysis characterizes the impacts of the RPS on the in-state electric generation mix, as well as the CO2 intensity of imported power.

RPS overall requirements

Maryland's RPS requirements are defined relative to total retail electricity sales. Utilities and non-utilities are obliged to either generate required levels of renewable power or purchase renewable energy credits. The table below summarizes the required shares of renewable energy by Tier and/or resource, as well as the total levels of renewable generation for compliance with the RPS. The table that immediately follows indicates the spatial distribution of the renewable generation (i.e., whether in-state or out-of-state) as well as its type (i.e., either existing or incremental).

Table 13: Required renewable generation shares and total levels for compliance with Maryland's RPS

Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Solar	0.0%	0.1%	0.0%	0.3%	0.5%	0.8%	1.0%	1.3%	1.5%	1.8%	2.0%
Other Tier I	3.0%	5.0%	6.4%	8.0%	10.0%	10.0%	12.0%	12.2%	14.4%	15.7%	16.0%
Tier II	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%	0.0%	0.0%
Total	5.5%	7.5%	9.0%	10.7%	13.0%	13.3%	15.5%	15.9%	18.4%	17.4%	18.0%
Total (GWh)	3,799	5,240	6,325	7,694	9,436	9,777	11,630	12,122	14,257	13,701	14,406

Table 14: Required renewable generation level assumptions, by physical region and type, for compliance with Maryland's Existing RPS (GWh)

Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
In MD (incremental)	17	388	424	532	788	1,171	1,477	1,810	2,178	2,589	3,050
In MD (EXISTING)	218	606	606	606	606	606	606	606	606	606	606
Outside MD (incremental)	1,686	2,112	3,223	4,482	5,874	5,832	7,379	7,538	9,305	8,339	8,582
Outside MD (EXISTING)	1,877	2,134	2,136	2,074	2,168	2,168	2,168	2,168	2,168	2,168	2,168
Total	3,799	5,240	6,389	7,694	9,436	9,777	11,630	12,122	14,257	13,701	14,406

RPS resource-specific assumptions

The table below summarizes the assumptions regarding resource-specific renewable generation mix (in-state qualifying renewables, solar and offshore wind only) as well as the split between existing and incremental renewable generation for compliance with the RPS.

Table 15: Breakdown in total renewable net generation mix for compliance with Existing RPS (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BAU Qualifying hydro	429	429	429	429	429	429	429	429	429	429	429
BAU other qualifying renewables	1,634	2,740	2,742	2,680	2,774	2,774	2,774	2,774	2,774	2,774	2,774
RPS - solar	17	35	71	180	364	553	750	953	1,162	1,378	1,601
RPS - Other Tier I	0	289	1,372	2,608	4,047	4,176	5,801	6,060	7,955	9,120	9,603
RPS - Tier II	1,719	1,747	1,775	1,798	1,822	1,845	1,876	1,906	1,937	0	0
Total	3,799	5,240	6,389	7,694	9,436	9,777	11,630	12,122	14,257	13,701	14,406
Total incremental renewable generation to comply with RPS	**17**	**324**	**1,443**	**2,788**	**4,411**	**4,730**	**6,552**	**7,013**	**9,117**	**10,498**	**11,203**

In-state and out-of-state RPS resource-specific assumptions

The table below summarizes the assumptions regarding the assumed in-state resource-specific renewable generation mix. The table that directly follows provides a summary of the assumed out-of-state resource-specific renewable generation mix

Table 16: In-state renewable generation to comply with Existing RPS (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small-scale hydro	35	35	35	35	35	35	35	35	35	35	35
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	17	35	71	180	364	553	750	953	1,162	1,378	1,601
Onshore wind	0	315	315	315	386	472	578	708	867	1,062	1,301
Landfill gas	20	58	58	58	58	166	169	169	169	169	169
Biomass	0	0	0	0	0	0	0	0	0	0	0
Biogenic MSW	0	388	388	388	388	388	388	388	388	388	388
Black liquor	163	163	163	163	163	163	163	163	163	163	163
Wastewater gas	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Total	236	994	1,030	1,138	1,394	1,777	2,083	2,416	2,784	3,195	3,656

Table 17: Out-of-state renewable generation to comply with Existing RPS (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small-scale hydro	394	394	394	394	394	394	394	394	394	394	394
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0
Onshore wind	0	366	1,449	2,685	3,302	3,237	4,752	4,881	6,617	7,588	7,831

Landfill gas	478	478	478	478	478	478	478	478	478	478	478
Biomass	332	386	500	377	1,128	1,128	1,128	1,128	1,128	1,128	1,128
Biogenic MSW	0	0	0	0	0	0	0	0	0	0	0
Black liquor	673	875	764	825	919	919	919	919	919	919	919
Wastewater gas	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Total	3,563	4,246	5,359	6,556	8,042	8,000	9,547	9,706	11,473	10,506	10,750

RPS Net generation and CO2-equivalent outputs through 2020

The Table that follows shows a breakdown in utility/non-utility net generation by resource for the RPS scenario. This table reflects a “BAU Fuel Switching” default assumption in the MDE BAU scenario.

Table 18: Existing RPS net generation, 2010-2020 (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	30,16	30,88	31,05	29,49	29,28	28,98	28,81	28,62	28,40	28,27	28,16
Natural Gas	1,579	1,130	1,339	2,312	2,722	3,118	3,518	3,954	4,429	4,835	5,230
Other Gases	332	332	332	332	332	332	332	332	332	332	332
Petroleum	756	807	862	921	983	1,050	1,121	1,197	1,279	1,366	1,459
Nuclear	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83
Large Hydroelectric	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069
Small-scale hydro	35	35	35	35	35	35	35	35	35	35	35
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	17	35	71	180	364	553	750	953	1,162	1,378	1,601
Onshore wind	0	315	315	315	386	472	578	708	867	1,062	1,301
Landfill gas	20	58	58	58	58	166	169	169	169	169	169
Biomass	17	17	17	17	17	17	17	17	17	17	17
Biogenic MSW	388	388	388	388	388	388	388	388	388	388	388
Black liquor	163	163	163	163	163	163	163	163	163	163	163
Wastewater	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Non-biogenic MSW	305	305	305	305	305	305	305	305	305	305	305
Net imports	24,15	24,15	24,87	26,28	26,79	27,22	27,94	28,58	29,20	29,76	30,30
Total (production basis)	49,678	50,367	50,842	50,418	50,932	51,487	52,088	52,741	53,450	54,223	55,067
Total (consumption basis)	73,831	74,519	75,717	76,703	77,722	78,711	80,037	81,321	82,650	83,993	85,369

The Table below shows a breakdown in point-of-combustion CO2 equivalent emissions from utility/non-utility net generation by resource for the BAU Fuel Switching case.

Table 19: Resource-specific summary of existing RPS CO2-equivalent emissions (BAU Fuel Switching), 2010-2020 (million tons, point-of-combustion)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	29.7	30.4	30.5	29.0	28.8	28.5	28.3	28.2	27.9	27.8	27.7
Natural Gas	1.2	0.9	1.0	1.7	2.1	2.4	2.7	3.0	3.4	3.7	4.0
Other Gases	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small-scale hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Landfill gas	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogenic MSW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black liquor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wastewater Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tidal current	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-biogenic MSW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Imports	13.8	13.9	13.7	13.4	13.7	13.9	13.6	13.9	13.3	13.2	13.7
Total (production basis)	**33.3**	**33.8**	**34.2**	**33.4**	**33.6**	**33.7**	**33.9**	**34.1**	**34.4**	**34.6**	**34.9**
Total (consumption basis)	**47.1**	**47.6**	**47.9**	**46.8**	**47.2**	**47.6**	**47.5**	**48.0**	**47.7**	**47.8**	**48.6**

The Table below shows a breakdown in existing RPS scenario point-of-combustion CO2 equivalent emissions from utility/non-utility net generation by resource for the Assumed Fuel Switching case.

Table 20: Resource-specific summary of existing RPS CO2-equivalent emissions (Assumed Fuel Switching), 2010-2020 (million tons, point-of-combustion emission factors)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	29.7	29.7	29.8	28.3	27.4	26.4	25.5	24.7	23.8	23.0	22.2
Natural Gas	1.2	1.4	1.6	1.8	2.1	2.4	2.8	3.2	3.7	4.3	4.9
Other Gases	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small-scale hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Landfill gas	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogenic MSW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black liquor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wastewater Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tidal current	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-biogenic MSW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Imports	13.1	12.9	12.7	12.1	12.2	12.2	11.7	11.8	11.3	11.0	13.3
Total (production basis)	33.3	33.6	34.0	32.7	32.2	31.6	31.2	30.9	30.6	30.3	30.3
Total (consumption basis)	46.4	46.5	46.7	44.8	44.4	43.9	42.9	42.7	41.8	41.4	43.6

The Table below shows the production- and consumption-basis CO2-equivalent totals using full fuel cycle emission factors (natural gas is from 30% hydraulic fracturing w/ a 4% methane leakage rate, 70% conventional drilling).

Table 21: Overall summary of existing RPS CO2-equivalent emissions summary, 2010-2020 (million tons, full fuel cycle emission factors)

Resource	201	201	201	201	201	201	201	201	201	201	202
Total (production basis, BAU Fuel Switching)	35.2	35.6	36.0	35.5	35.7	36.0	36.3	36.7	37.0	37.4	37.9
Total (consumption basis BAU Fuel Switching)	51.6	52.0	52.0	50.8	51.7	52.3	52.1	52.8	52.4	53.3	53.4
Total (production basis, Assumed Fuel Switching)	35.2	35.5	36.0	34.8	34.3	33.9	33.5	33.3	33.2	33.1	33.2
Total (consumption basis, Assumed Fuel Switching)	50.7	50.9	50.8	48.8	48.7	48.4	47.5	47.4	46.6	46.7	48.5

When compared to the BAU scenario, the existing RPS achieves substantial reductions in CO2-equivalent emissions. A summary of reductions appears in the Table below.

Table 22: Overall summary of CO2-equivalent emission reductions achieved by the RPS, 2010-2020 (million tons)

Emission factor	**Fuel Switching**	**Basis**	**Reductions in 2020**	**Cumulative reductions, 2012-2020**
Point-of-combustion	BAU	Production	3.3	16.8
		Consumptio	6.4	34.3
	Assumed	Production	8.0	39.8
		Consumptio	11.5	71.3
Fuel cycle	BAU	Production	3.4	17.6
		Consumptio	6.6	38.2
	Assumed	Production	7.9	39.6

		Consumptio	11.2	74.5

Existing RPS incremental cost outputs through 2020

The Table below shows a breakdown in the incremental costs associated with the RPS for the Assumed Fuel Switching case over the 2010-2020 period. The net present value of these incremental costs over the 2012-2020 period comes to $2,983 million (2010$) on a consumption basis and $1,387 million (2010$) on a production basis. The cost effectiveness of the RPS is therefore $40/tCO2e avoided on a consumption basis over the 2012-2020 period.

Table 23: Incremental costs of the RPS for Assumed Fuel Switching case, 2010-2020 (million 2010$) *NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost*

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small-scale hydroelectric	$0	$0	$0	$1	$1	$1	$1	$1	$1	$1	$1
Geothermal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Solar/PV	$6	$11	$17	$41	$78	$113	$146	$149	$173	$147	$240
Onshore wind	$0	$1	$1	$5	$12	$13	$15	$17	$19	$23	$39
Landfill gas	$0	$0	$0	$1	$2	$4	$4	$4	$4	$4	$5
Biomass	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biogenic MSW	$0	$1	$1	$7	$12	$10	$10	$9	$9	$8	$12
Black liquor	$0	$0	$0	$3	$5	$4	$4	$4	$4	$3	$5
Wastewater treatment gas	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tidal current	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Wave	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Non-biogenic MSW	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Imports (RPS policy only)	$5	$7	$12	$83	$187	$166	$197	$184	$214	$224	$322
Total (production basis)	**$7**	**$13**	**$20**	**$57**	**$109**	**$146**	**$180**	**$184**	**$210**	**$186**	**$302**
Total (consumption basis)	**$12**	**$19**	**$32**	**$140**	**$296**	**$312**	**$377**	**$368**	**$424**	**$410**	**$624**

Impact of removing black liquor and old inefficient biomass power plants from RPS eligibility

The removal of black liquor and other old inefficient biomass power plants from Tier-1 eligibility in the RPS results in an increase in renewable energy generation from other Tier-1 sources. Based on technology prices and trends, it was assumed that this would come from now onshore wind. The table below summarizes the assumptions regarding the assumed in-state resource-specific renewable generation mix. The table that directly follows provides a summary of the assumed out-of-state resource-specific renewable generation mix.

Table 25: In-state renewable generation to comply with RPS, Restricted Biomass (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small-scale hydro	35	35	35	35	35	35	35	35	35	35	35
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	17	35	71	180	364	553	750	953	1,162	1,378	1,601
Onshore wind	0	315	315	315	389	480	593	733	905	1,117	1,380

Landfill gas	20	58	58	58	58	166	169	169	169	169	169
Biomass	0	0	0	0	0	0	0	0	0	0	0
Biogenic MSW	0	388	388	388	388	388	388	388	388	388	388
Black liquor	163	163	163	163	163	163	163	163	163	0	0
Wastewater gas	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Total	236	994	1,030	1,138	1,397	1,785	2,098	2,440	2,822	3,087	3,572

Table 26: Out-of-state renewable generation to comply with RPS, Restricted Biomass (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small-scale hydro	394	394	394	394	394	394	394	394	394	394	394
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0
Onshore wind	0	366	1,449	2,685	3,299	4,934	6,443	6,562	8,285	9,742	9,962
Landfill gas	478	478	478	478	478	478	478	478	478	478	478
Biomass	332	386	500	377	1,128	33	33	33	33	0	0
Biogenic MSW	0	0	0	0	0	0	0	0	0	0	0
Black liquor	673	875	764	825	919	309	309	309	309	0	0
Wastewater gas	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Total	1,877	2,499	3,584	4,758	6,217	6,147	7,656	7,776	9,498	10,614	10,834

The removal of black liquor and other old inefficient biomass power plants from Tier-1 eligibility in the RPS also results in an impact on CO2 emissions. The Table below compares point-of-combustion and fuel cycle CO2 equivalent emission reductions for the BAU and Assumed Fuel Switching cases in 2020, with and without these resources.

Table 27: Summary of CO2-equivalent emission reduction impact of black liquor and wood waste eligibility under the RPS, 2020 (million tons, consumption basis)

Emission Factor	**Eligibility of black liquor & wood waste**	**Fuel Switching**	**2020**
Point-of-combustion	Yes	BAU	6.4
		Assumed	11.5
	No	BAU	8.6
		Assumed	13.6
Fuel cycle	Yes	BAU	6.6
		Assumed	11.2
	No	BAU	9.1
		Assumed	13.8

Impact of increasing the overall RPS goals and removing black liquor and old inefficient biomass power plants from RPS eligibility

Increasing the RPS goal from 20% by 2022 to 25% by 2020, in addition to removing of black liquor and other old inefficient biomass power plants from Tier-1 eligibility, results in a further increase in renewable energy generation from other Tier-1 sources. Based on technology prices and trends, it was assumed that this would come from now onshore wind. The table below summarizes the assumptions regarding the assumed in-state resource-specific renewable generation mix. The table that directly follows provides a summary of the assumed out-of-state resource-specific renewable generation mix.

Table 28: In-state renewable generation to comply with RPS, Restricted Biomass (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small-scale hydro	35	35	35	35	35	35	35	35	35	35	35
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	17	35	71	180	364	553	750	953	1,162	1,378	1,601
Onshore wind	0	315	315	315	395	495	621	779	977	1,226	1,537
Landfill gas	20	58	58	58	58	166	169	169	169	169	169
Biomass	0	0	0	0	0	0	0	0	0	0	0
Biogenic MSW	0	388	388	388	388	388	388	388	388	388	388
Black liquor	163	163	163	163	163	163	163	163	0	0	0
Wastewater gas	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Total	236	994	1,030	1,138	1,403	1,800	2,126	2,487	2,731	3,195	3,730

Table 29: Out-of-state renewable generation to comply with RPS, Restricted Biomass (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Small-scale hydro	394	394	394	394	394	394	394	394	394	394	394
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	0	0	0	0	0	0	0	0	0	0	0
Onshore wind	0	366	1,449	3,062	3,730	6,856	8,440	10,042	11,660	13,788	15,407
Landfill gas	478	478	478	478	478	478	478	478	478	478	478
Biomass	332	386	500	377	1,128	33	33	33	33	0	0
Biogenic MSW	0	0	0	0	0	0	0	0	0	0	0
Black liquor	673	875	764	825	919	309	309	309	309	0	0
Wastewater gas	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Total	1,877	2,499	3,584	5,136	6,648	8,069	9,654	11,255	12,874	14,660	16,279

Increasing the RPS goal from 20% by 2022 to 25% by 2020, in addition to removing of black liquor and other old inefficient biomass power plants from Tier-1 eligibility, also results in an impact on CO2 emissions. The Table below compares point-of-combustion and fuel cycle CO2 equivalent emission reductions for the BAU and Assumed Fuel Switching cases in 2020 of increasing the RPS goal, with and without black liquor and wood waste.

Table 30: Summary of CO2-equivalent emission reduction impact of increasing the RPS goal, with and w/out black liquor and wood waste eligibility under the RPS, 2020 (million tons, consumption basis)

Emission Factor	Eligibility of black liquor & wood waste	Fuel Switching	2020
Point-of-combustion	Yes	BAU	9.4
		Assumed	13.8
	No	BAU	11.5
		Assumed	15.9
Fuel cycle	Yes	BAU	9.7
		Assumed	13.7
	No	BAU	12.3
		Assumed	16.2

Overview of the integrated RPS/EmPOWER MD Scenario

This section provides an overview of the details underlying the integration of demand and supply policies in Maryland. The analysis characterizes the impacts of the RPS and EmPOWER MD on the in-state electric generation mix, the CO2 intensity of imported power, as well as the incremental costs and GHG reductions.

Overall requirements for existing demand side and EmPOWER Maryland policies

Maryland's EmPOWER requirements are defined relative to total retail electricity sales. Utilities and non-utilities are obliged to implement energy efficiency programs that will lead to quantifiable electricity savings. The table below summarizes the required savings called for in the existing version of the EmPOWER policy. The Table that directly follows provides a summary of additional savings required in an update to the EmPOWER policy. The demand-side analysis write-up provides additional details.

Table 31: Maryland Retail Sale reductions from existing MD demand-side policies, 2010 through 2020 (GWh)

Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Residential	1,012	1,595	2,283	2,892	3,477	4,030	4,403	4,685	4,985	5,291	5,638
Commercial	1,134	1,788	2,559	3,241	3,897	4,517	4,934	5,251	5,587	5,930	6,319
Industrial	184	290	415	526	633	733	801	852	907	963	1,026
Commercial CHP	0	0	0	0	0	0	0	0	0	0	0
Industrial CHP	0	0	0	0	0	0	0	0	0	0	0
All Sectors	2,330	3,674	5,257	6,659	8,006	9,282	10,138	10,788	11,479	12,184	12,983

Table 32: Maryland Retail Sale reductions from New EmPOWER MD demand-side policy, 2010 through 2020 (GWh)

Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Residential	1,012	1,595	2,283	2,892	3,477	4,030	5,725	6,652	7,591	8,530	9,477
Commercial	1,134	1,788	2,559	3,241	3,897	4,517	6,416	7,455	8,508	9,561	10,622
Industrial	184	290	415	526	633	733	1,041	1,210	1,381	1,552	1,724
Commercial	0	0	0	327	653	980	1,241	1,502	1,763	2,024	2,143

CHP											
Industrial CHP	0	0	0	230	460	690	875	1,059	1,243	1,427	1,510
All Sectors	2,330	3,674	5,257	7,729	10,219	12,664	15,298	17,878	20,487	23,094	25,476

Net generation and CO2-equivalent outputs from integrated demand/supply policies, BAU RPS & Existing EmPOWER MD

The Table that follows shows a breakdown in utility/non-utility net generation by resource for the integrated demand/supply scenario. This table reflects a BAU Fuel Switching scenario in PJM and Maryland and existing RPS & EmPOWER implementation.

Table 33: Integrated demand/supply net generation (BAU Fuel Switching, existing RPS, existing EmPOWER), 2010-2020 (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	30,16	30,88	31,05	29,50	29,31	29,05	28,91	28,75	28,57	28,48	28,40
Natural Gas	1,579	1,132	1,344	2,315	2,724	3,119	3,518	3,954	4,429	4,843	5,254
Other Gases	332	332	332	332	332	332	332	332	332	332	332
Petroleum	756	807	862	921	983	1,050	1,121	1,197	1,279	1,366	1,459
Nuclear	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83
Large Hydroelectric	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069
Small-scale hydro	35	35	35	35	35	35	35	35	35	35	35
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	17	33	66	163	324	484	649	818	990	1,165	1,341
Onshore wind	0	315	315	315	386	472	578	708	867	1,062	1,301
Landfill gas	20	58	58	58	58	166	169	169	169	169	169
Biomass	17	17	17	17	17	17	17	17	17	17	17
Biogenic MSW	388	388	388	388	388	388	388	388	388	388	388
Black liquor	163	163	163	163	163	163	163	163	163	163	163
Wastewater	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Non-biogenic MSW	305	305	305	305	305	305	305	305	305	305	305
Net imports	21,66	20,25	19,29	19,20	18,28	17,36	17,17	17,11	17,00	16,82	16,50
Total (production basis)	**49,677**	**50,366**	**50,838**	**50,418**	**50,932**	**51,487**	**52,088**	**52,741**	**53,450**	**54,223**	**55,067**
Total (consumption basis)	**71,341**	**70,616**	**70,131**	**69,627**	**69,216**	**68,849**	**69,265**	**69,859**	**70,453**	**71,047**	**71,575**

The Table below shows a breakdown in point-of-combustion CO2 equivalent emissions from utility/non-utility net generation by resource. For PJM imports, the BAU Fuel Switching case and existing RPS & EmPOWER implementation is assumed.

Table 34: Resource-specific summary of integrated demand/supply CO2-equivalent emissions (BAU Fuel Switching, existing RPS, existing EmPOWER), 2010-2020 (million tons, point-of-combustion)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	29.7	30.4	30.5	29.0	28.8	28.6	28.4	28.3	28.1	28.0	27.9
Natural Gas	1.2	0.9	1.0	1.7	2.1	2.4	2.7	3.0	3.4	3.7	4.0
Other Gases	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small-scale hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Landfill gas	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogenic MSW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black liquor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wastewater Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tidal current	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-biogenic MSW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Imports	12.4	11.7	10.7	9.6	9.2	8.8	8.1	8.0	7.3	6.8	6.9
Total (production basis)	**33.3**	**33.8**	**34.2**	**33.4**	**33.6**	**33.8**	**34.0**	**34.2**	**34.5**	**34.8**	**35.2**
Total (consumption basis)	**45.7**	**45.5**	**44.9**	**43.0**	**42.8**	**42.6**	**42.1**	**42.3**	**41.8**	**41.6**	**42.1**

The Table below shows a breakdown in integrated demand/supply point-of-combustion CO2 equivalent emissions from utility/non-utility net generation by resource, in the assumed Fuel Switching and existing RPS & EmPOWER cases.

Table 35: Resource-specific summary of integrated demand/supply CO2-equivalent emissions (Assumed Fuel Switching, existing RPS, existing EmPOWER), 2010-2020 (million tons, point-of-combustion emission factors)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	29.7	29.7	29.8	28.3	27.4	26.5	25.6	24.8	24.0	23.2	22.4
Natural Gas	1.2	1.4	1.6	1.8	2.1	2.4	2.8	3.2	3.7	4.2	4.9
Other Gases	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small-scale hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Landfill gas	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogenic MSW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black liquor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wastewater Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tidal current	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-biogenic MSW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Imports	11.8	10.9	9.9	8.7	8.3	7.9	7.1	7.0	6.3	5.9	8.0
Total (production basis)	**33.3**	**33.6**	**34.0**	**32.8**	**32.2**	**31.7**	**31.3**	**31.0**	**30.7**	**30.5**	**30.5**
Total (consumption basis)	**45.1**	**44.5**	**43.9**	**41.5**	**40.6**	**39.6**	**38.4**	**38.0**	**37.1**	**36.5**	**38.5**

The Table below shows the production- and consumption-basis CO2-equivalent totals using full fuel cycle emission factors.

Table 36: Overall summary of integrated demand/supply (existing RPS, existing EmPOWER) CO2-equivalent emissions summary, 2010-2020 (million tons, full fuel cycle emission factors)

Resource	201	201	201	201	201	201	201	201	201	201	202
Total (production basis, BAU Fuel Switching)	33.3	33.8	34.2	33.4	33.6	33.8	34.0	34.2	34.5	34.8	35.2
Total (consumption basis, BAU Fuel Switching)	45.7	45.5	44.9	43.0	42.8	42.6	42.1	42.3	41.8	41.6	42.1
Total (production basis, Assumed Fuel Switching)	33.3	33.6	34.0	32.8	32.2	31.7	31.3	31.0	30.7	30.5	30.5
Total (consumption basis, Assumed Fuel Switching)	45.1	44.5	43.9	41.5	40.6	39.6	38.4	38.0	37.1	36.5	38.5

When compared to the BAU scenario, the integrated demand/supply policies with existing RPS and EmPOWER implementation achieve substantial reductions in CO2-equivalent emissions. A summary of reductions appears in the Table below.

Table 37: Overall summary of CO2-equivalent emission reductions achieved by BAU integrated demand/supply policies (existing RPS, existing EmPOWER), 2010-2020 (million tons)

Emission factor	**Fuel Switching**	**Basis**	**Reductions in 2020**	**Cumulative reductions, 2012-2020**
Point-of-combustion	BAU	Production	3.1	16.1
		Consumptio	14.9	90.2
	Assumed	Production	7.8	39.1
		Consumptio	18.5	119.5

Fuel cycle	BAU	Production	3.2	16.6
		Consumptio	13.9	90.9
	Assumed	Production	7.9	39.9
		Consumptio	17.3	120.4

Net generation and CO2-equivalent outputs from integrated demand/supply policies, RPS Enhancements

The Table that follows shows a breakdown in utility/non-utility net generation by resource for the integrated demand/supply scenario. This table reflects a BAU Fuel Switching scenario in PJM and Maryland, Enhanced RPS implementation (25% x 2020 and restricted black liquor and wood waste), and Enhanced EmPOWER implementation (1.5% annual reductions in electricity and natural gas, 556 MW of CHP development. The demand-side analysis write-up provides additional details.)

Table 38: Integrated demand/supply net generation (BAU Fuel Switching, Enhanced RPS, Enhanced EmPOWER), 2010-2020 (GWh)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	30,16	30,88	31,05	29,51	29,31	29,05	28,92	28,77	28,60	28,50	28,41
Natural Gas	1,579	1,132	1,344	2,315	2,725	3,119	3,519	3,954	4,429	4,844	5,255
Other Gases	332	332	332	332	332	332	332	332	332	332	332
Petroleum	756	807	862	921	983	1,050	1,121	1,197	1,279	1,366	1,459
Nuclear	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83	13,83
Large Hydroelectric	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069	2,069
Small-scale hydro	35	35	35	35	35	35	35	35	35	35	35
Geothermal	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	17	33	66	160	313	458	597	730	855	974	1,091
Onshore wind	0	315	315	315	395	495	621	779	977	1,226	1,537
Landfill gas	20	58	58	58	58	166	169	169	169	169	169
Biomass	17	17	17	17	17	17	17	17	17	17	17
Biogenic MSW	388	388	388	388	388	388	388	388	388	388	388
Black liquor	163	163	163	163	163	163	163	163	163	163	163
Wastewater	0	0	0	0	0	0	0	0	0	0	0
Tidal current	0	0	0	0	0	0	0	0	0	0	0
Wave	0	0	0	0	0	0	0	0	0	0	0
Non-biogenic MSW	305	305	305	305	305	305	305	305	305	305	305
Net imports	21,66	20,25	19,29	18,07	15,93	13,76	11,69	9,585	7,433	5,232	3,233
Total (production basis)	**49,677**	**50,366**	**50,838**	**50,418**	**50,932**	**51,487**	**52,088**	**52,741**	**53,450**	**54,223**	**55,067**
Total (consumption basis)	**71,341**	**70,616**	**70,131**	**68,490**	**66,865**	**65,255**	**63,783**	**62,325**	**60,883**	**59,455**	**58,300**

The Table below shows a breakdown in point-of-combustion CO2 equivalent emissions from utility/non-utility net generation by resource. For PJM imports, the BAU Fuel Switching case, enhanced RPS implementation, and enhanced EmPOWER implementation are assumed.

Table 39: Resource-specific summary of integrated demand/supply CO2-equivalent emissions (BAU Fuel Switching, Enhanced RPS, Enhanced EmPOWER), 2010-2020 (million tons, point-of-combustion)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	29.7	30.4	30.5	29.0	28.8	28.6	28.4	28.3	28.1	28.2	28.1
Natural Gas	1.2	0.9	1.0	1.7	2.1	2.4	2.7	3.0	3.4	3.7	4.0
Other Gases	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small-scale hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Landfill gas	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogenic MSW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black liquor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.0
Wastewater Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tidal current	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-biogenic MSW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New CHP	0.0	0.0	0.0	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.1
Net Imports	12.4	11.7	10.7	8.8	7.8	4.6	2.9	1.3	-0.3	-2.3	-3.3
Total (production basis)	**33.3**	**33.8**	**34.2**	**33.6**	**34.0**	**34.3**	**34.7**	**35.1**	**35.5**	**35.8**	**36.2**
Total (consumption basis)	**45.7**	**45.5**	**44.9**	**42.4**	**41.8**	**38.9**	**37.6**	**36.4**	**35.2**	**33.5**	**32.8**

The Table below shows a breakdown in integrated demand/supply point-of-combustion CO2 equivalent emissions from utility/non-utility net generation by resource, in the assumed Fuel Switching, Enhanced RPS, and Enhanced EmPOWER cases.

Table 40: Resource-specific summary of integrated demand/supply CO2-equivalent emissions (Assumed Fuel Switching, Enhanced RPS, Enhanced EmPOWER), 2010-2020 (million tons, point-of-combustion emission factors)

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	29.7	29.7	29.8	28.3	27.4	26.5	25.6	24.9	24.0	23.4	22.5
Natural Gas	1.2	1.4	1.6	1.8	2.1	2.4	2.8	3.2	3.7	4.2	4.9
Other Gases	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Petroleum	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3
Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Small-scale hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar/PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Landfill gas	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biogenic MSW	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Black liquor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.0
Wastewater Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tidal current	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-biogenic MSW	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
New CHP	0.0	0.0	0.0	0.2	0.4	0.5	0.7	0.8	0.9	1.1	1.1
Net Imports	11.8	10.9	9.9	8.0	7.1	4.0	2.6	1.2	-0.1	-1.7	-0.5
Total (production basis)	**33.3**	**33.6**	**34.0**	**32.9**	**32.6**	**32.2**	**32.0**	**31.8**	**31.7**	**31.5**	**31.4**
Total (consumption basis)	**45.1**	**44.5**	**43.9**	**41.0**	**39.7**	**36.3**	**34.6**	**33.1**	**31.6**	**29.8**	**31.0**

The Table below shows the production- and consumption-basis CO2-equivalent totals using full fuel cycle emission factors.

Table 41: Overall summary of integrated demand/supply CO2-equivalent emissions summary (enhanced RPS, enhanced EmPOWER), 2010-2020 (million tons, full fuel cycle emission factors)

Resource	201	201	201	201	201	201	201	201	201	201	202
Total (production basis, BAU Fuel Switching)	35.1	35.5	36.0	35.6	36.0	36.5	37.0	37.5	37.8	38.4	38.9
Total (consumption basis, BAU Fuel Switching)	49.9	49.6	48.6	45.7	45.3	40.8	39.3	38.0	36.3	35.9	35.3
Total (production basis, Assumed Fuel Switching)	35.2	35.5	36.0	35.0	34.7	34.5	34.3	34.3	34.1	34.2	34.4
Total (consumption basis, Assumed Fuel Switching)	49.2	48.7	47.7	44.3	43.3	38.3	36.5	34.9	33.1	32.4	34.0

When compared to the BAU scenario, the integrated demand/supply policies with enhanced RPS and EmPOWER policies achieve substantial reductions in CO2-equivalent emissions beyond those achieved in either the BAU or existing policies scenarios. A summary of reductions appears in the Table below. Note that these reductions also include reduced emissions from natural gas thermal savings. The demand-side analysis write-up provides additional details.

Table 42: Overall summary of CO2-equivalent emission reductions achieved by integrated demand/supply policies (enhanced RPS, enhanced EmPOWER), 2010-2020 (million tons)

Emission factor	Fuel Switching	Basis	Reductions in 2020	Cumulative reductions, 2012-2020
Point-of-combustion	BAU	Production	3.9	10.5
		Consumptio	24.1	128.1
	Assumed	Production	8.6	33.5
		Consumptio	25.9	150.7
Fuel cycle	BAU	Production	4.6	11.4
		Consumptio	26.7	153.1
	Assumed	Production	9.1	33.4
		Consumptio	28.1	174.6

Incremental cost outputs from integrated demand/supply policies

The Table below shows a breakdown in the incremental costs associated with the integration of demand and supply policies over the 2010-2020 period in the assumed Fuel Switching, Enhanced RPS, and Enhanced EmPOWER cases. The net present value of these incremental costs over the 2012-2020 period comes to -$3,508 million (2010$) on a consumption basis and $136 million (2010$) on a production basis. The cost effectiveness of the integrated demand/supply policies is therefore -$20/tCO2e avoided on a consumption basis.

Table 43: Incremental costs of the integrated demand/supply policies, 2010-2020 (million 2010$). *NOTE: Negative figures represent net-savings for Maryland, positive figures represent net-cost.*

Resource	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
(NEW EMPOWER-MD policies only)	$0	$0	$0	$14	$24	$33	$99	$134	$162	$188	$206
(EXISTING EMPOWER-MD policies only)	$0	$0	$0	$8	$15	$23	$0	$0	$0	$0	$0
Small-scale hydroelectric	$0	$0	$0	$1	$1	$1	$1	$1	$1	$1	$1
Geothermal	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Solar/PV	$6	$10	$16	$36	$67	$94	$116	$114	$128	$104	$164
Onshore wind	$0	$1	$1	$5	$12	$13	$16	$18	$22	$26	$46
Landfill gas	$0	$0	$0	$1	$2	$4	$4	$4	$4	$4	$5
Biomass	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Biogenic MSW	$0	$1	$1	$7	$12	$10	$10	$9	$9	$8	$12
Black liquor	$0	$0	$0	$3	$5	$4	$4	$4	$4	$0	$0
Wastewater treatment gas	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tidal current	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Wave	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Non-biogenic MSW	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Net Imports (RPS policy only)	$5	$6	$11	$78	$168	$174	$190	$195	$202	$210	$313
Net imports (NEW EMPOWER-MD policies only)	$0	$0	$0	-$67	-$132	-$190	-$244	-$327	-$407	-$450	-$529
Net imports (EXISTING EMPOWER-MD policies only)	-$217	-$275	-$390	-$452	-$509	-$547	-$581	-$604	-$627	-$614	-$663
Total (in-state)	$7	$12	$18	$74	$138	$183	$251	$284	$328	$330	$434
Total (consumption)	-$205	-$256	-$361	-$367	-$336	-$379	-$385	-$453	-$503	-$524	-$446
Natural Gas (Heating)	$0	$0	$0	-$6	-$12	-$19	-$23	-$27	-$32	-$38	-$45

Chapter 3. Macroeconomic Analysis of EmPOWER Maryland and the Maryland Renewable Portfolio Standard

I. Introduction

To support the design and analysis of clean energy program enhancements in Maryland, macroeconomic impacts of the Maryland Renewable Portfolio Standard (RPS) and Maryland EmPower Program (demand-side efficiency policy) was performed, focusing on gross state product (GSP) and employment, using a regression model based Macroeconomic Screening Tool (MST).

The results of the MST show that under the status quo, EmPOWER Maryland and the RPS will support net increases of over 18,900 jobs per year and deliver $1.45 billion in net economic benefits by 2020. If moderate improvements are made to the EmPOWER Maryland and RPS programs, the benefits will increase to over 22,700 jobs per year and nearly $2.6 billion in net economic output. The policy recommendations in this report would increase the employment and economic growth potential of Maryland's clean energy programs by approximately 3,800 jobs and $1.1 billion in additional economic output beyond the status quo.

This regression model is based on the Regional Economic Models, Inc. (REMI) macro econometric simulations of climate action plans for four U.S. states. The multivariate statistical model examines the relationship between the macroeconomic impact results yielded by the REMI model and various microeconomic costs, structural linkages and other characteristics of the mitigation options (see, e.g., Rose et al., 2011).

This summary is organized as follows. The macro input data of the MD RPS and EmPOWER policies used in the MST, which are obtained from the microeconomic quantification of the two policies, are summarized in Section 2. Section 3 presents the macroeconomic impact results we obtained from running the MST. Section 4 introduces the MST, including the basic data used, the functional form of the regression model, and the implications of the regression coefficients. Section 5 presents how we adjust the MST to be applied to Maryland. Section 6 presents a full documentation of the MST

II. Input Data for the MST

Five scenarios are identified to be analyzed in the MST:

Scenario 1: (Base Case Scenario): Existing RPS (18% by 2020) and Existing EmPOWER implementation. This scenario assumed that the current RPS law would remain unchanged and that black liquor and wood waste would account for 17 percent of RPS compliance in 2020. It also assumed that EmPOWER would achieve 60 percent of its 2015 goal.

Scenario 2: Current RPS (18 percent by 2020) with old black liquor and wood waste moved to Tier 2 and current EmPOWER implementation. This scenario assumed that the current RPS law would be amended to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would achieve 60% of its 2015 goal.

Scenario 3: Current RPS (18 percent by 2020) with old black liquor and wood waste moved to Tier 2 and 1.5% annual EmPOWER (medium scenario for EmPOWER). This scenario assumed that the current RPS law would be amended to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would reduce electricity and natural gas consumption in Maryland by 1.5 percent annually starting in 2013 and that the state would develop 556 MW of CHP capacity by 2020.

Scenario 4: Current RPS (18 percent by 2020) with old black liquor and wood waste moved to Tier 2 and 2.25% annual EmPOWER (high scenario for EmPOWER). This scenario assumed that the current RPS law would be amended to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would reduce electricity and natural gas consumption in Maryland by 2.25 percent annually starting in 2013 and that the state would develop 556 MW of CHP capacity by 2020.

Scenario 5 (recommended scenario): Aggressive RPS (25 percent by 2020) with old black liquor and wood waste moved to Tier 2 and 1.5% annual EmPOWER (medium scenario for EmPOWER). This scenario assumed that the current RPS law would be amended to both increase the overall compliance goal to 25 percent by 2020, and to remove all pre-2005 black liquor and wood waste facilities from Tier-1 RPS eligibility. It also assumed that EmPOWER would reduce electricity and natural gas consumption in Maryland by 1.5 percent annually starting in 2013 and that the state would develop 556 MW of CHP capacity by 2020.

Tables 5 and 6 present the major input data (direct net cost and upfront capital investment requirement) we use in the MST for the two policies and for different scenarios.

Table 5. Discounted Direct Net Cost of MD RPS and EmPOWER (5% discount rate)

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2013-2020 NPV**
Scenario 1 RPS	115	239	247	296	287	328	314	321	2,147
Scenario 1 EmPOWER	-379	-422	-449	-501	-518	-534	-527	-561	-3,892
Scenario 2 RPS	115	239	247	296	287	328	314	321	2,147
Scenario 2 EmPOWER	-379	-422	-449	-501	-518	-534	-527	-561	-3,892
Scenario 3 RPS	113	231	235	272	256	283	263	262	1,915
Scenario 3 EmPOWER	-431	-526	-603	-647	-705	-766	-782	-866	-5,326
Scenario 4 RPS	112	228	229	264	246	270	248	245	1,843
Scenario 4 EmPOWER	-448	-557	-646	-684	-751	-819	-838	-931	-5,674

Scenario 5 RPS	118	241	273	310	313	335	320	332	2,243
Scenario 5 EmPOWER	-431	-526	-603	-647	-705	-766	-782	-866	-5,326

Table 6. Discounted Capital Investment Requirement of MD RPS and EmPOWER (5% discount rate)

	2013	2014	2015	2016	2017	2018	2019	2020	2013-2020 NPV
Scenario 1 RPS	$224	$421	$521	$438	$454	$477	$510	$551	$3,596
Scenario 1 EmPOWER	$330	$302	$272	$0	$0	$0	$0	$0	$904
Scenario 2 RPS	$224	$423	$524	$443	$461	$487	$523	$569	$3,655
Scenario 2 EmPOWER	$330	$302	$272	$0	$0	$0	$0	$0	$904
Scenario 3 RPS	$218	$405	$495	$391	$391	$404	$428	$474	$3,205
Scenario 3 EmPOWER	$720	$688	$772	$515	$519	$491	$465	$429	$4,599
Scenario 4 RPS	$215	$397	$482	$375	$372	$383	$405	$449	$3,079
Scenario 4 EmPOWER	$900	$853	$923	$654	$646	$607	$571	$526	$5,681
Scenario 5 RPS	$218	$409	$500	$400	$404	$423	$456	$513	$3,323
Scenario 5 EmPOWER	$720	$688	$772	$515	$519	$491	$465	$429	$4,599

For MD RPS, the direct net cost and the capital investment are computed in the following way:

1) The direct net cost is computed as the product of the MD renewable energy credit (REC) (which is same for all qualified RPS) and the total MWh of renewable electricity (in-state plus imported) paid by the MD customers.
2) The capital investment is computed by summing the investment requirement of all in-state renewable generation.

Compared with Scenario 1 (Base Case Scenario), in which the policies represent those that are already in place, the numbers shown in Tables 5 and 6 indicate that the higher the energy efficiency target of EmPOWER, the more capital investment is required. However, since the energy efficiency measures can more than pay off the investment cost through fuel cost savings, higher net savings (the difference between total savings and total costs) can be expected from EmPOWER with higher energy efficiency target. For RPS, the direct net cost remains the same as long as the total required consumption of renewable electricity stays the same, since the Renewable Electricity Credit per MWh is the same for different types of renewables in Maryland. The capital investment requirement increases with the increasing stringency of the RPS. However, with the same percentage requirement on RPS, higher EmPOWER energy efficiency target would help lower the direct net cost and investment requirement of RPS, since as more energy consumption is saved with respect to the Base Case, less electricity generation (in MWh) would be needed from renewables.

III. Macroeconomic Impacts of MD RPS and EmPOWER

Table 7 presents the macroeconomic impacts in terms of gross state product (GSP) and employment of MD RPS and EmPOWER policies for different scenarios.

Table 7. GSP and Employment of MD RPS and EmPOWER for Different Scenarios

	Change in GDP (2013-2020 NPV) (M 2010$)	Change in Jobs (2013-2020) (job-years)	Average Annual Employment Impact (jobs)
Scenario 1 RPS	-$657	93,345	11,668
Scenario 1 EmPOWER	$2,111	57,957	7,245
Scenario 1 Total	**$1,454**	**151,302**	**18,913**
Scenario 2 RPS	-$623	95,154	11,894
Scenario 2 EmPOWER	$2,111	57,957	7,245
Scenario 2 Total	**$1,488**	**153,111**	**19,139**
Scenario 3 RPS	-$568	82,663	10,333
Scenario 3 EmPOWER	$3,530	97,555	12,194
Scenario 3 Total	**$2,962**	**180,218**	**22,527**
Scenario 4 RPS	-$543	79,214	9,902
Scenario 4 EmPOWER	$3,915	108,246	13,531
Scenario 4 Total	**$3,373**	**187,460**	**23,432**
Scenario 5 RPS	-$943	84,305	10,538
Scenario 5 EmPOWER	$3,530	97,555	12,194
Scenario 5 Total	**$2,587**	**181,860**	**22,733**

For Scenario 1 (Base Case Scenario), the implementation of the MD RPS and EmPOWER policies is expected to result in an increase in gross state product (GSP) of $1.45 billion in net present value over the planning period of 2013 to 2020, with RPS being estimated to result in slightly negative impacts and EmPOWER yielding positive impacts. The employment gain is expected to be about 151 thousand job-years over the entire planning period. The average annual job increase is about 19 thousand. About 60% of the job gains would come from the implementation of RPS. The major reason that the RPS policy yields slightly negative GSP impact, but positive employment impact is that sectors benefiting directly and indirectly from the implementation of RPS (such as wind and solar electricity generation) are relatively more labor intensive than the conventional fossil fuel-based electricity generation sector.

Scenario 2 results in slightly higher GSP and employment gains compared with Scenario 1. The direct net costs of the two scenarios are the same. The total capital investment requirement of Scenario 2 is about $60 thousand higher than Scenario 1 due to the incremental investment needed for the in-state wind power generation. The additional investment is the reason that drives the slightly higher macro gains for Scenario 2.

With medium and high efficiency targets of EmPOWER in Scenarios 3 and 4, the estimated GSP gains for the two policies together are $3.0 billion and $3.4 billion, respectively. The average annual employment gains are 22.5 thousand and 23.4 thousand, respectively. The more stimulating economic impacts of these two scenarios, compared with Scenario 1, are mainly resulted from the higher electricity bill savings of the electricity customers. This in turn result in higher business profits and higher purchasing power of consumers in Maryland, thus stimulating the state economy.

Compared with Scenario 3, Scenario 5 has the same efficiency target of EmPOWER, but more stringent goal in RPS. Lower GSP gains, but higher employment gains are estimated for this scenario compared with Scenario 3. This is again because, in general, RPS results in slightly negative GSP impact, but positive employment impact, due to the fact that the renewable electricity generation is more labor-intensive than the conventional fossil fuel based electricity generation.

IV. The Macroeconomic Screening Tool

Section VI presents a full documentation of the MST. In this section, we cover the main features of the Tool.

The microeconomic analysis of a GHG mitigation policy option provides the estimates on the direct (or on-site) costs and savings of implementing the option. The evaluation of the comprehensive macroeconomic impacts of the policy options requires the application of sophisticated macroeconomic modeling tools. It also usually requires considerable expertise and time. In order to perform quick, but still reasonably accurate r analyses of the likely macroeconomic impacts of various climate mitigation options at an earlier phase of the policy evaluation process, a reduced-form statistical model has been developed.

1. Basic Data

The basic data utilized for the regression analyses are taken from a set of macroeconomic analyses on the state's Climate Action Plans undertaken by the researchers in conjunction with the Center for Climate Strategies (see peer-reviewed studies by Rose and Wei, 2012; Rose et al., 2011; Miller et al., 2010; Wei and Rose, 2011). The economic impact analysis results of 92 GHG mitigation options from four states are used in the construction of the regression model: Florida, Pennsylvania, Michigan, and New York.

The dependent variables explained by the statistical regression analyses are the Net Present Value (NPV) of Gross State Product (GSP) impacts (in million 2005$) and employment impacts (in thousand job-years) over the entire planning period of each individual mitigation option.

Estimates of these impacts are derived from the results generated by the Regional Economic Model, Inc. Policy Insight Plus (REMI PI+) macroeconometric model.[13]

The two main explanatory variables included in the regression model are the NPV of direct net cost of a GHG mitigation option and the NPV of the investment requirements of this option. These data come from the microeconomic analysis of the policy options undertaken through a Delphi-type process (expert elicitation) by a group of experts comprising sector-specific Technical Working Groups (TWG) in each state.

2. Functional Form of the Regression Models

Except for the two main explanatory variables (the direct net cost and investment requirement), the regression model also includes eight binary ("dummy", or "categorical") variables to help explain the option-specific characteristics. Four sectoral binary variables are included to indicate the sector in which the mitigation policy is implemented (Energy Supply (ES); Residential, Commercial and Industrial (RCI); Transportation and Land Use (TLU); and Agriculture, Forestry and Waste Management (AFW) Sectors, respectively). "Construction" (CONST) is a binary variable that indicates whether or not the mitigation option involves a capital investment in construction (e.g., building a new power plant). "Manufacturing" (MFG) is a binary variable that indicates that the option represents a capital investment in equipment or appliance manufacturing. "Government Subsidy" (GS) is a binary variable indicating whether or not the mitigation option receives state government aid. And finally, "Consumption Reallocation" (CR) indicates that the mitigation option results in a shift in the composition of consumer expenditures, such as reducing spending on electricity, gas, and other fuels, and increasing consumption in energy-efficient appliances and other consumption categories.

The regression analysis is performed with the application of two alternative functional forms: a shorter-form model and an extended-form model. The functional form of the extended-form regression model is given by equation 1. This is also the regression model we use in this study. In the extended-form model, we include interaction terms of the sectoral binary variables with the direct net cost variable and with the investment requirement variable. Using interaction terms, the effects of direct net cost and investment requirement are estimated for each sector.

---

[13] The Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI^+) Model is the most widely used macroeconometic model to analyze the economic impact of energy and climate policies in the U.S. The REMI Model has evolved over the course of 30 years of refinement (see, e.g., Treyz, 1993). It is a packaged program, but is built with a combination of national and region-specific data. Compared with other widely used macroeconomic modeling tools, the REMI PI+ Model is superior in terms of its forecasting ability. It is also comparable to computable general equilibrium (CGE) models in terms of analytical power and accuracy. Government agencies in practically every state in the U.S. have used a REMI Model for a variety of purposes, including evaluating the impacts of the change in tax rates, the exit or entry of major businesses in particular or economic programs in general, and, more recently, the impacts of energy and/or environmental policy actions (Rose et al., 2011).

$$
\begin{aligned}
y = {} & \beta_1 DNC * ES + \beta_2 DNC * RCI + \beta_3 DNC * TLU + \beta_4 DNC * AFW + \\
& \beta_5 INV * ES + \beta_6 INV * RCI + \beta_7 INV * TLU + \beta_8 INV * AFW + \\
& \beta_9 ES + \beta_{10} RCI + \beta_{11} TLU + \beta_{12} AFW + \beta_{13} CONST + \beta_{14} MFG + \beta_{15} GS + \beta_{16} CR + \varepsilon
\end{aligned}
$$
(1)

where

y:	Annualized NPV of the GSP impacts of a policy option or annualized employment impact of a policy option
DNC:	Annualized NPV of the direct net cost of a policy option
INV:	Annualized NPV of investment requirement
ES:	Energy Supply policy option binary variable
RCI:	Residential, Commercial, Industrial policy option binary variable
TLU:	Transportation and Land Use policy option binary variable
AFW:	Agriculture, Forestry, and Waste Management policy option binary variable
CONST:	Capital investment on building constructions, which has stimulus impacts to the construction sector (binary variable)
MFG:	Capital investment on equipment, which has stimulus impacts to the machinery and equipment manufacturing sectors (binary variable)
GS:	Policy option that receives state government subsidy (assuming government spending decreases by the same amount elsewhere) (binary variable)
CR:	Policy option that results in consumer consumption reallocation and increased purchasing power of the consumers (binary variable)
β_1 to β_{16} :	Regression coefficients
ε	Error term

Appendix Tables 2 and 3 present the results of the shorter-form model and the extended-form model for GSP impacts, respectively. Appendix Tables 4 and 5 present the results of the regression models for the employment impacts.

3. Implications of the Regression Coefficients

Both the regression models of GSP impacts and employment impacts indicate that the direct net costs of mitigation options have significant effects to the overall macroeconomic impacts. The coefficients of the interaction terms of direct net cost with the four sector binary variables are all negative. This indicates that options with higher direct net cost are expected to result in less favorable GSP and employment impacts. The models also show the statistically significant role of a policy option's investment requirement on the macroeconomic impacts of the option. The positive signs of the coefficients of the interaction terms of investment requirement with the sector binary variables indicate that holding other independent variables constant, high investment is expected to generate higher macro gains to the state economy.

The coefficients of some of the other binary variables are also statistically significant in both models. Examples are the "CONST" and "MFG" variables. In addition, the positive signs of these two variables indicate that holding all the other variables constant, if a mitigation option involves capital investment in construction sector and equipment manufacturing sectors, there will be a positive influence on a state's overall macroeconomy.

Appendix A presents a more detailed summary on the implications of the regression model coefficients.

V. Adjustment Made to the MST to be Used for Maryland

Since the regression model have been developed based on REMI modeling results of 92 individual GHG mitigation options for the four states: FL, PA, MI, and NY, the direct application of the regression model should be for individual options and for a state that has a size of economy similar to the weighted average size of the four states. If these regression models are applied to evaluate the likely macroeconomic impacts of policy options at different scales, policy bundles that aggregate options from one sector together, or mitigation options implemented at different geographical levels, the direct net cost and investment requirement values of the options need to be scaled-up or scaled-down to the individual option level, as well as to the appropriate geographic level, before applying the regression equations. Then the results we obtain from the regression models should be once again scaled back to an economy the size of our study state.

A number of parameters were considered to be used to compute the scaling factor. These include gross state product, population, total fossil fuel consumption, and total GHG emissions. For each parameter, we first compute the weighted average value of the four states based on the number of data points from each state included in the regression model. Then we compute the ratio of MD value over the 4-state weighted average value. The basic data and the calculated scaling factors based on alternative parameters are presented in the tables below.

Table 1. Basic State Data

	2011 GSP (millions of 2005$)	2011 Population	2010 Total Fossil Fuel Consumption (Trillion BTU)	2009 Total GHG Emissions (MMtCO2e)
FL	661,091	19,057,542	3,555	257
PA	500,443	12,742,886	3,471	280
MI	337,427	9,876,187	2,321	188
NY	1,016,350	19,465,197	2,716	207
MD	264,373	5,828,289	985	80

Table 2. Weights for the Four States

State	Number of Data Points in the Regression Models	Share of Data Points
FL	21	23%
PA	42	46%
MI	20	22%
NY	9	10%

Total	92	100%

Table 3. Four-State Weighted Average Values

	2011 GSP (millions of 2005$)	2011 Population	2010 Total Fossil Energy Consumption (Trillion BTU)	2009 Total GHG Emissions (MMtCO2e)
4-State Weighted Ave	552,144	14,218,697	3,167	248

Table 4. Scaling Factors Computed Based on Alternative Parameters

	2011 GSP (millions of 2005$)	2011 Population	2010 Total Fossil Energy Consumption (Trillion BTU)	2009 Total GHG Emissions (MMtCO2e)
MD to 4-state weighted average ratio	0.48	0.41	0.31	0.32

We use the scaling factor of 0.48, which is calculated based on GSP, to make the adjustment to the MST. The reasons that we did not include the other parameters in determining the scaling factors are: 1) population is not a very relevant factor since it does not really have an explicit role in the REMI macroeconomic analyses; 2) scaling factors computed on the basis of fossil fuel consumption and GHG emissions are close to each other, as the two variables are highly correlated. We did not include these two variables in the final scaling factor calculation is because the direct costs (obtained from the micro quantifications) are a reflection of emissions, and thus the fossil energy use, i.e., these two factors are already taken into account in the micro input data we use in the MST.

VI. An Introduction to the Macroeconomic Screening Tool

When policymakers and stakeholders consider the impacts of potential options to mitigate greenhouse gas (GHG) emissions or sequester carbon, a major question often asked is: "how will these options affect the local, state, or national economy?" Calculation of the *microeconomic* (direct) costs or cost savings of policy options is a generally straightforward application of accounting and cost-engineering. However, the analysis of the *macroeconomic* impacts of a policy—the effects of the policy on future employment and income, for example—typically requires considerable expertise and the application of sophisticated modeling tools. Moreover, the cost and time involved in performing a full macroeconomic study is often prohibitive at an earlier phase of the policy evaluation process. The Macroeconomic Screening Tool is a reduced form statistical model that can be used to quickly and relatively inexpensively predict the likely macroeconomic impacts of various climate mitigation options. To the extent that most of these options are related to energy, the model also can be used to evaluate some major aspects of energy policy.

The model we have developed is based on multivariate analyses of the relationships between macroeconomic impacts and various microeconomic costs, structural linkages within the economy, and the characteristics of the mitigation options evaluated. In this appendix, Section 1 introduces the basic data we used in the regression analyses. The development and summary results of regression models for GDP and employment impacts are described in Sections 2 and 3, respectively. Section 4 briefly summarizes the strengths and weaknesses of these regression models, describes how they might be applied to results of the evaluation of direct costs of mitigation options to prepare estimates of the macroeconomic impacts of those options.

1. Basic Data

The basic data utilized for the regression analyses are taken from a set of macroeconomic analyses undertaken by the researchers in conjunction with the Center for Climate Strategies for the states of Florida, Pennsylvania, Michigan, and New York. These state-based analyses evaluated the macroeconomic impacts of a comprehensive set of GHG emission mitigation options, the critical features of which were specified in each respective state's Climate Action Plan (Rose and Wei, 2012; Rose et al., 2011; Miller et al., 2010; Wei and Rose, 2011). The variables analyzed by the regression tool are the estimated microeconomic and macroeconomic impacts of a pooled cross-section of mitigation options. The mitigation options were identified, and the microeconomic impacts were analyzed by sets of sector-specific technical working groups in each state, with each technical working group comprised of a broad set of stakeholders. The dependent variables to be explained by the statistical regression analyses are the Net Present Value (NPV) of Gross State Product (GSP) impacts (in million 2005$) and employment impacts (in thousand job-years) of each individual mitigation option. Estimates of these impacts are derived from the results generated by the Regional Economic Model, Inc. Policy Insight Plus (REMI PI$^+$) macroeconometric model. These results in turn are shaped by the values and interactions of many independent variables, the most relevant of which are carried over in the reduced form model (see, e.g., Rose et al., 2011).

Given the diversity of the four states from which modeling results were taken, there is also a great deal of variation in the macroeconomic impacts across the states. For this reason, the data analyzed here are "noisy", and some adjustments must be made in order for the analysis to attain the required inferential asymptotic qualities (i.e., to be able to provide mathematically reliable results). The planning horizon used for Florida and Michigan was 17 years (from 2009 to 2025), for New York 20 years (from 2011 to 2030) and for Pennsylvania 12 years (from 2009 to 2020). Given the differences in planning horizons, and non-linearities present in the macroeconomic impacts across years (e.g., some policy options may have more long-run benefits, whereas others may have more immediate-term benefits), in the regression model for GSP impacts, our dependent variable considers GSP impacts on an annualized basis; i.e., the NPV of GSP impacts across a planning horizon is divided by the number of years of its planning horizon. In the regression model for employment impacts, the annualized employment impact is used. We first compute the total employment impact in terms of job-years of a policy option as the simple sum of each year's employment impacts over the planning horizon. The average employment impact is then computed by dividing the total employment impact by the number of years in each state's planning horizon.

The two main explanatory variables are the NPV of the direct net cost ("*DNC*") of a GHG mitigation option over the entire planning horizon and the NPV of the investment requirements

(“*INV*”) over the same time period, which are obtained from the microeconomic analyses of the individual policy options in the respective state climate action plans. Analogous to the dependent variable, the annualized direct net cost and investment requirements are calculated by dividing the NPVs of the direct net cost and investment requirements, respectively, by the number of years in the planning horizon. For the direct net cost variable, a positive value indicates that the option has been estimated in a climate action plan to result in a direct net cost, and a negative value indicates that the direct effect of the option will be cost-saving.

The regression model also includes eight binary (“dummy”, or “categorical”) variables to help explain the option-specific characteristics. The variables *ES*, *RCI*, *TLU*, and *AFW* indicate the sector in which the mitigation policy is implemented (Energy Supply; Residential, Commercial and Industrial; Transportation and Land Use; and Agriculture, Forestry and Waste Management Sectors, respectively). These variables have a value of 1 when the policy option is applied to the respective sector, and zero when the option is applied to other sectors. These sectoral binary variables are also used in interaction terms in the regression model to assign the direct costs (or net savings) and the investment requirements of each option to the sector that implements the option. “Construction” (*CONST*) is a binary variable that indicates whether or not the mitigation option involves a capital investment in construction (e.g., building a new power plant). “Manufacturing” (*MFG*) is a binary variable that indicates that the option represents a capital investment in equipment or appliance manufacturing. “Government Subsidy” (*GS*) is a binary variable indicating whether or not the mitigation option receives state government aid. And finally, “Consumption Reallocation” (*CR*) indicates that the mitigation option results in a shift in the composition of consumer expenditures, such as reducing spending on electricity, gas, and other fuels, and increasing consumption in energy-efficient appliances and other consumption categories.

Appendix Table 1 provides the descriptive statistics of all of the independent variables used in our regression model. Here statistics for interaction terms, such as “*DNC* TLU*” or “*INV*TLU*”, describe the annualized NPV of the direct net cost (or investment requirement) of policy options in each sector. The references to Model 1 through 4 in Table 1 pertain to the different regression models discussed below.

Table 8. Descriptive Statistics

	Mean	Standard Deviation	Minimum Value	Maximum Value
D.V.: Annual Gross State Product Impact (y)(in Models 1 and 2)	-23.30	194.39	-886.00	532.74
D.V.: Annual Employment Impact (y)(in Models 3 and 4)	2.20	4.81	-5.57	22.59
Direct Net Cost (DNC)	60.13	165.53	-279.12	1,075.39
Investment Requirement (INV)	114.97	233.51	0.00	1420.13
$DNC \times ES$	-0.21	65.55	-528.23	259.59
$DNC \times RCI$	-22.41	81.99	-488.34	79.46
$DNC \times TLU$	-15.06	150.40	-886.00	532.74
$DNC \times AFW$	14.39	61.23	-30.39	423.38
$INV \times ES$	44.64	158.59	0.00	1268.71

$INV \times RCI$	26.42	151.41	0.00	1420.13
$INV \times TLU$	24.35	98.85	0.00	666.98
$INV \times AFW$	19.55	79.58	0.00	541.28
ES	0.17	0.38	0	1
RCI	0.24	0.43	0	1
TLU	0.24	0.43	0	1
AFW	0.35	0.48	0	1
CONST	0.38	0.49	0	1
MFG	0.57	0.50	0	1
GS	0.22	0.41	0	1
CR	0.35	0.48	0	1

$$
\begin{aligned}
y = {} & \beta_1 DNC * ES + \beta_2 DNC * RCI + \beta_3 DNC * TLU + \beta_4 DNC * AFW + \\
& \beta_5 INV * ES + \beta_6 INV * RCI + \beta_7 INV * TLU + \beta_8 INV * AFW + \\
& \beta_9 ES + \beta_{10} RCI + \beta_{11} TLU + \beta_{12} AFW + \beta_{13} CONST + \beta_{14} MFG + \beta_{15} GS + \beta_{16} CR + \varepsilon
\end{aligned}
$$

(1)

where

y: Annualized NPV of the GSP impacts of a policy option
DNC: Annualized NPV of the direct net cost of a policy option
INV: Annualized NPV of investment requirement
ES: Energy Supply policy option binary variable
RCI: Residential, Commercial, Industrial policy option binary variable
TLU: Transportation and Land Use policy option binary variable
AFW: Agriculture, Forestry, and Waste Management policy option binary variable
CONST: Capital investment on building constructions, which has stimulus impacts to the construction sector (binary variable)
MFG: Capital investment on equipment, which has stimulus impacts to the machinery and equipment manufacturing sectors (binary variable)
GS: Policy option that receives state government subsidy (assuming government spending decreases by the same amount elsewhere) (binary variable)
CR: Policy option that results in consumer consumption reallocation and increased purchasing power of the consumers (binary variable)
β_1 to β_{16} : Regression coefficients
ε Error term

2. Regression Model for GSP Impacts

The functional form of the regression model for the GSP impacts is given by equation 1. The first four terms of the model are the interaction terms of sectoral binary variables and the direct net cost of an option. These four interaction terms describe the direct net cost impacts of the options applied to different sectors on GSP. The following four terms are the interaction terms of sectoral binary variables and the investment requirement associated with an option. These four interaction terms describe the impact of investment requirement of the options coming from different sectors on GSP. The next four terms describe sectoral impacts (we assume that options from different sectors have inherent differences in addition to the direct net cost and investment requirement impacts captured by the interaction terms) of the policy option on GSP. The final four terms describe the GSP impacts of the option related to whether or not the option involves construction investment, manufacturing investment, government subsidies, and consumption reallocation.

We suppress the intercept term in our model. This is warranted on theoretical grounds, due to the fact that in the absence of a policy change there would be no incremental change in the Gross State Product of a state or regional economy. This also enables us to explicitly display the effects of our four binary sectoral variables (inclusion of the intercept would force us to exclude one sectoral category from the regression model to use it as the reference sector for the other sectoral binary variables, and in such a case, the coefficients of the sectoral binary variables included in the regression model need to be interpreted as the differential impact of the modeled sector with respect to the reference sector). Our analysis also implicitly assumes that the extant economies, as described by the coefficients and equations in the REMI models for each state, are in equilibrium. To account for potential heteroskedasticity (a violation of one of the basic regression modeling assumptions, which requires that the modeling errors have a constant variance across the observations), we used the robust Huber-White standard error in the inference, which allows the fitting of a regression model with residuals having non-constant variances.

Appendix Tables 2 and 3 provide the results of our multivariate statistical analysis.[14] We ran both a shorter-form model (Model 1) and an extended-form model (Model 2), which includes interaction terms to evaluate the individual sectoral impacts of the direct net costs and investment requirements associated with GHG mitigation policy options.

Comparatively speaking, Model 2 has a more robust summary measure, as indicated by a multiple correlation coefficient (R-squared) value of about 0.706. This indicates that Model 2 explains about 71 percent of the variance in the macroeconomic impacts of the policies in terms of impact on GSP across our pooled sample. In addition, both models have relatively robust fitness measures, as indicated by the F-statistic, reflecting that our models have included a proper set of explanatory variables.

Model 1 indicates that the direct costs of mitigation options constitute a significant determinant of the overall macroeconomic impacts on GSP. Based on the results of Model 1, when the other variables are held constant at their mean values, when the annualized direct net cost of an average mitigation option decreases by one million dollars, the annualized GSP impact is expected to increase by about $0.51 million.

---

[14] We use SAS statistical software to run the regression analyses.

Looking at the sectoral decomposition of the direct cost effects, the coefficients of the interaction terms of direct net cost with the four sector binary variables (in Model 2) are all negative, which indicates that options with higher direct net cost are expected to result in less favorable GSP impacts. All of the interaction terms with respect to direct net cost are statistically significant in Model 2. Based on the results of Model 2, when all the other variables are held constant at their mean values, a one million dollar decrease in direct net costs for average mitigation options in the ES, RCI, TLU, and AFW sectors is expected to increase the annualized GSP impact by $1.35, $0.42, $0.32, and $0.56 million, respectively.

Model 1 also indicates the statistically significant role of a policy option's investment requirement on GSP. If all of the other variables are held constant at their mean values, when the annualized investment requirement of an average mitigation option is increased by one million dollars, the annualized GSP impact is expected to increase by about $0.31 million. All of the interaction terms related to investment requirement are statistically significant in Model 2. If we hold all of the other variables constant at their mean values, a one million dollar increase in investment requirements for an average mitigation option in the ES, RCI, TLU, and AFW sectors is expected to increase the annualized GSP impact by $0.57, $0.22, $0.12, and $0.63 million, respectively.

The sectoral binary variables, which try to capture the inherent difference (other than direct net cost and investment requirements) of options from different sectors, however, lack statistical significance across the board in both Model 1 and in Model 2 as well, except for the Energy Supply sector. It is

Table 9. Results of the Regression Analysis for GSP Impact -- Model 1

	Coefficient Estimate	**Robust Std. Error**	**t value**	**Pr(>|t|)**
Direct Net Cost (DNC)	-0.50849	0.14818	-3.43	0.0009 ***
Investment Requirement (INV)	0.30935	0.08151	3.8	0.0003 ***
ES	-15.2713	36.12262	-0.42	0.6736
RCI	-18.6371	43.07392	-0.43	0.6664
TLU	-45.6551	34.2209	-1.33	0.1859
AFW	6.82947	19.80065	0.34	0.731
CONST	40.9052	28.68755	1.43	0.1577
MFG	25.12787	23.92716	1.05	0.2967
GS	21.58814	33.03709	0.65	0.5153
CR	-17.4876	35.88405	-0.49	0.6273

*p<0.1, ** p<0.05, *** p<0.01[15]

N=92; R^2 (0.528)[16]; F-statistic (9.17); Overall Model P-value: <0.0001

---

[15] If the p-value is smaller than or equal to the significance level (i.e., 10%, 5%, or 1%), we can reject the null hypothesis that the coefficient is equal to zero at the respective significance level.

Table 10. Results of the Regression Analysis for GSP Impact – Model 2

	Coefficient Estimate	Robust Std. Error	t value	Pr(>|t|)
$DNC \times ES$	-1.35132	0.22856	-5.91	<.0001 ***
$DNC \times RCI$	-0.42324	0.18436	-2.3	0.0244 **
$DNC \times TLU$	-0.3222	0.06381	-5.05	<.0001 ***
$DNC \times AFW$	-0.55739	0.26138	-2.13	0.0362 **
$INV \times ES$	0.57483	0.08749	6.57	<.0001 ***
$INV \times RCI$	0.21987	0.0624	3.52	0.0007 ***
$INV \times TLU$	0.12494	0.04967	2.52	0.014 **
$INV \times AFW$	0.62741	0.32297	1.94	0.0558 *
ES	-67.1751	29.48118	-2.28	0.0255 **
RCI	-10.0924	40.19154	-0.25	0.8024
TLU	-27.1883	23.82043	-1.14	0.2573
AFW	-19.6457	19.21369	-1.02	0.3098
Construction Inv. (CONST)	39.40858	23.274	1.69	0.0945 *
Manufacturing Inv. (MFG)	42.30628	23.69611	1.79	0.0782 *
Government Subsidy (GS)	27.21523	35.96879	0.76	0.4516
Consumption Reallocation (CR)	-9.33769	29.18293	-0.32	0.7499

*p<0.1, ** p<0.05, *** p<0.01

N=92; R^2 (0.7061); F-statistic (11.41); Overall Model P-value: <0.0001

It is important to control for differences in each sector's mitigation options, but our models show there to be no statistically significant difference between sectors (other than the impacts of direct net cost and investment requirement that are captured in the interaction terms). The only exception is the ES sector. Holding all of the other variables constant, an average ES option tends to have a lower stimulus effect on GSP compared with an average option from other sectors.

The coefficient estimate of the variable pertaining to the capital investment to the construction sector is positive and significant in Model 2. This means that those mitigation options that involve a capital investment expenditure in the construction sector (for example, investments in building industrial plants, electricity generation facilities, highways, or other infrastructure) have an overall positive impact on a state's macroeconomy. Based on the results of Model 2, holding all the other variables fixed at their mean values, if a mitigation option involves capital investment in construction (i.e., the value of the *CONST* binary variable changes from zero to one), the overall impact on the annualized GSP is expected to be an increase of $39 million.

---

[16] The "R^2" represents the percentage of variance in the dependent variable that can be explained by the regression model.

Simulating the macroeconomic impact of construction capital investment increases in REMI results in two types of effects: 1) increases in capital costs in the sectors that undertake the mitigation actions, and 2) increases in the final demand for goods and services in the construction sector. In general, the former yields negative impacts on the economy, while the latter yields positive impacts. The positive sign of the construction investment binary variable indicates that the positive effects are expected to exceed the negative effects in the four states to which the model was applied.

The coefficient estimate of the variable pertaining to the capital investment in the equipment manufacturing sector is positive and significant as well. This means that those mitigation options that involve investments in manufactured equipment also have a strong positive influence on a state's overall macroeconomy. Based on the results of Model 2, holding all the other variables fixed, if a mitigation option involves capital investment in equipment and machinery (for example, energy-efficient appliances, vehicles, equipment, and other manufactured devices), that is, the value of the *MFG* binary variable changes from zero to one, the overall average impact on the annualized GSP is expected to be an increase of $42 million.

Those options that include subsidies from a state government have an overall positive, but insignificant, effect on GSP. In REMI, the state government subsidy is simulated in two ways. Stimulus effects arise from increased spending by households or increased investment in sectors that receive the subsidies, while dampening effects stem from the decrease of the same amount of government spending elsewhere. The positive sign of this variable indicates that, in the four states whose macroeconomic modeling results form the basis for the regression model, it is expected that the stimulus effects of directing government subsidies to mitigation options in general can more than offset the dampening effects associated with decreased government spending in other areas.

Mitigation options that include consumption reallocation have only a minimal influence on a state's GSP, on the average. Whereas some mitigation options that include a consumption reallocation have overall positive effects on a state's GSP and others have overall negative effects, based on the results of Model 2, an average mitigation option that includes a consumption reallocation has a $9 million lower positive effect on GSP if all the other variables are held constant at their mean values. Again, however, this relationship is not statistically significant.

3. Regression Model for Employment Impacts

We developed similar regression models to that shown in equation 1 to estimate the employment impacts of climate mitigation options. The dependent variable in this case is the annualized employment impact over the entire planning horizon in terms of person-years. All of the independent variables included in the employment impact regression models are the same as those included in the corresponding GSP impact regression models.

Appendix Tables 4 and 5 provide the results of the regression analyses for employment impacts. Similar to the modeling of GSP impacts, we ran both a shorter-form model (Model 3) and an extended-form model (Model 4). The former model includes one independent variable each pertaining to the direct net costs and investment requirements, respectively, associated with the implementation of the GHG mitigation options, while in the latter model we include interaction terms to evaluate the individual sectoral impacts of the direct net costs and of investment requirements associated with the options implemented in corresponding sectors. Comparatively speaking, Model 4 has a more robust summary measure than Model 3, as indicated by a multiple correlation coefficient (R-squared) value of about 0.818 for Model 4.

The direct net cost of an option provides a significant determinant of the overall employment impact of this option. Based on the results of Model 3, holding all of the other variables constant at their mean values, decreasing the annualized direct net cost of an average mitigation option by one million dollars yields an annualized employment impact increase of about 8.0 person-years.

Model 4, which includes the interaction terms of direct net costs in each sector with sectoral binary variables, provides a sectoral decomposition of the effects stemming from changes in direct net cost. The coefficients of the four interaction terms of direct net cost with the four sector dummies are all negative, which indicate that options with higher direct net cost are expected to result in less favorable employment impacts. According to Model 4, the coefficient estimates show that the most statistically-significant variation across the direct cost variable occurs in the ES, RCI, and TLU sectors. Holding the non-sectoral binary variables constant at their mean values, a one million dollars decrease in direct net cost of an average mitigation option in the ES, RCI, and TLU sector is expected to increase the annualized employment impacts by 6.9, 13.9, and 6.8 person-years, respectively.

Table 11. Results of the Regression Analysis for Employment Impact -- Model 3

	Coefficient Estimate	Robust Std. Error	t value	Pr(>|t|)
Direct Net Cost (DNC)	-0.00796	0.00156	-5.12	<.0001 ***
Investment Requirement (INV)	0.01262	0.00334	3.78	0.0003 ***
ES	-0.21873	1.10047	-0.2	0.8429
RCI	-1.76341	0.98457	-1.79	0.077 *
TLU	-2.43864	0.75563	-3.23	0.0018 ***
AFW	0.21951	0.53983	0.41	0.6853
Construction Inv. (CONST)	1.78956	0.74764	2.39	0.019 **
Manufacturing Inv. (MFG)	0.52155	0.63639	0.82	0.4148
Government Subsidy (GS)	1.57442	1.03985	1.51	0.1338
Consumption Reallocation (CR)	0.60102	0.84894	0.71	0.481

*p<0.1, ** p<0.05, *** p<0.01

N=92; R^2 (0. 5666); F-statistic (10.72); p-value: <0.0001

Table 12. Results of the Regression Analysis for Employment Impact – Model 4

	Coefficient Estimate	Robust Std. Error	t value	Pr(>|t|)
$DNC \times ES$	-0.00685	0.00317	-2.16	0.0336 **
$DNC \times RCI$	-0.0139	0.00518	-2.68	0.0089 ***
$DNC \times TLU$	-0.00682	0.0013	-5.27	<.0001 ***
$DNC \times AFW$	-0.0004	0.00953	-0.04	0.9668
$INV \times ES$	0.03435	0.00294	11.68	<.0001 ***
$INV \times RCI$	0.0065	0.00183	3.55	0.0007 ***
$INV \times TLU$	0.00559	0.00124	4.52	<.0001 ***
$INV \times AFW$	0.03117	0.00816	3.82	0.0003 ***
ES	-2.4217	0.84469	-2.87	0.0054 ***
RCI	-0.17693	0.85537	-0.21	0.8367
TLU	-0.29185	0.55862	-0.52	0.6029
AFW	-0.12096	0.39319	-0.31	0.7592
Construction Inv. (CONST)	1.07622	0.54972	1.96	0.0539 *
Manufacturing Inv. (MFG)	0.35161	0.51444	0.68	0.4964
Government Subsidy (GS)	-0.23254	0.6049	-0.38	0.7017
Consumption Reallocation (CR)	-0.22678	0.69917	-0.32	0.7466

*p<0.1, ** p<0.05, *** p<0.01

N=92; R^2 (0. 818); F-statistic (21.4); p-value: <0.0001

Model 3 also indicates that the impact of a policy option's investment requirement on employment is statistically significant. If all the other variables are held constant at their mean values, when the annualized investment requirement of an average mitigation option is increased by one million dollars, the annualized employment impact is expected to increase by about 12.6 job-years. In Model 4, all of the sector-specific interaction terms for investment requirement are statistically significant at the significance level of 0.01. If we hold all the other variables constant at their means, a one million dollars increase in investment requirement for an average mitigation options in each of the ES, RCI, TLU, and AFW sectors are expected to increase the annualized employment impacts by 34.3, 6.5, 5.6, and 31.2 job-years, respectively.

Based on the results of Model 4, the sectoral binary variables again lack statistical significance except for the ES sector. That means, across our sample, the sectoral impact has no statistically discernible difference (other than the impacts of direct net cost and investment requirement that are captured in the interaction terms) on employment impacts results except for the ES sector mitigation options. Holding all the other variables constant, an average ES option tend to have lower stimulus effects to the economy in terms of employment impact compared with an average option from other sectors.

The coefficient estimate of the variable pertaining to capital investment in mitigation options that is directed to the construction sector is positive and significant in both models. This means that, holding all the other variables constant at their mean values, those mitigation options that involve a capital investment expenditure in the construction sector are expected to result in more employment gains than those options that do not. The coefficient of the binary variable pertaining to the capital investment in equipment is also positive but not statistically significant. The positive sign of the coefficient means those mitigation options that involve investments in equipment are also expected to lead to a stronger positive effects on job creation. The higher value of the coefficient of *CONST* (the construction sector investment binary variable) than the coefficient of *MFG* (the equipment manufacturing sector investment binary variable) comes about for two reasons. First, in most states, the construction sector has a higher Regional Purchase Coefficient (RPC) than the equipment manufacturing sector. This indicates that, dollar for dollar, capital investments in the construction sector are more stimulating to the in-state job market than investments in equipment manufacturing, whose demand is satisfied by a greater proportion of imports of equipment and related items from out of state. Second, compared with the equipment manufacturing sectors, the construction sector is relatively more labor-intensive.

The coefficients of the binary variables pertaining to the state government subsidy and consumption reallocation are positive in Model 3, but negative in Model 4. These two variables, however, are not statistically significant in either model.

4. Model Applications

In response to the need for an affordable and rapid use policy screening tool to evaluate the likely macroeconomic impacts of GHG mitigation policy options at an earlier phase of their design process, we developed a reduced-form statistical model that can be used to quickly predict the likely GDP and employment impacts of these various climate mitigation options. The reduced-form models are developed based on microeconomic impact assessment results from state stakeholder processes and REMI macroeconometric modeling results of climate action plans for four states (Florida, Pennsylvania, Michigan, and New York), which include the analyses of 92 mitigation policy options across these states.

The application of the reduced-form model requires the following input data: micro evaluation results of the direct net costs and investment requirements of one or more mitigation policy options, as well as information on the characteristics of options. The option characteristics data include the sector in which the option is implemented, whether or not an option involves capital investment in construction and/or equipment, whether or not an option receives a government subsidy, and finally whether the option results in consumer consumption reallocation.

The reduced-form models presented above have been developed based on REMI modeling results of 92 individual GHG mitigation options at the state level. Therefore, the direct application of the regression model should be for individual options at the state level in order to appropriately capture the impacts of the binary variables included in the model. If these regression models are applied to evaluate the likely macroeconomic impacts of policy options at different scales, policy bundles that aggregate options from one sector together, or mitigation options implemented at different geographical levels, the direct net cost and investment requirement values of the options need to be scaled-up or scaled-down to the individual option level, as well as to the appropriate geographic level before applying the regression equations. Then the results we obtain from the regression models should be once again scaled back to an economy that has the size of our study state. For example, when we apply the models to evaluate the potential macroeconomic impacts of mitigation options for a state only with half the size of the weighted average size of the four states, the estimated direct net cost and investment requirement of an option need to be first divided by a scaling factor of 0.5 to scale up from the study state level to the weighted average level of the four states before applying the regression models to the input data. Then the regression application results need to be multiplied by 0.5 to get back to the study state level estimations of GSP and employment impacts.

Note also that the results pertain to conditions in which we assume that about two-thirds of the investment in mitigation options does not displace investment in ordinary plant and equipment. This requires that additional investment funds become available by attracting investors from outside the state, attracting federal subsidies, or using in-region business retained earnings. State governments can take actions to promote the first two of these conditions, while the third is dependent on general market conditions, e.g., profits, and hence retained earnings, are lower in economic recession years.

References:

Miller, S., Wei, D., and Rose, A. 2010. *The Macroeconomic Impact of the Michigan Climate Action Council Climate Action Plan on the State's Economy*. Report to Michigan Department of Environmental Quality. http://www.climatestrategies.us/ewebeditpro/items/O25F22416.pdf.

Rose, A. and Wei, D. 2012. "Macroeconomic Impacts of the Florida Energy and Climate Change Action Plan," *Climate Policy* 12(1): 50-69.

Rose, A., Wei, D., and Dormady, N. 2011. "Regional Macroeconomic Assessment of the Pennsylvania Climate Action Plan," *Regional Science Policy and Practice* 3(4): 357-79.

Treyz, G. 1993. *Regional Economic Modeling: A Systematic Approach to Economic Forecasting and Policy Analysis*. Boston: Kluwer.

Wei, D. and Rose, A. 2011. *The Macroeconomic Impact of the New York Climate Action Plan: A Screening Analysis*. Report to New York State Energy Research and Development Authority.

Appendix 1. Additional Details on Empower Maryland Analysis

Appendix 2. Sensitivity Analysis for the Maryland Renewable Portfolio Standard

Appendix 3. Analysis of full Life Cycle Emissions of Natural Gas