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Energy Supply
Technical Work Group

Summary List of Pending Priority Policy Options for Analysis

	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($\$/tCO_2e$)	Level of Support
		2012	2020	Total (2008–2020)			
ES-1	Promotion of renewable energy (zoning and siting incentives for centralized facilities)	0.2	0.5	3.3	$89	$27.0	Pending
ES-2	Technology-focused initiatives for electricity supply (biomass co-firing, energy storage, fuel cells, landfill gas, clean energy incentives)	U	U	U	U	U	Pending
ES-3	GHG cap-and-trade (with a hypothetical allowance auction price at $7/tCO2e)						
	a. account for all reduction under an auction-based C&T	U	16.66	U	U	-26.9	Pending
	b. account for only capped level of reduction	U	6.95	U	U	-36.4	Pending
ES-4	CCSR incentives, requirements and/or enabling policies (administration, regulation, liability, incentives)	0.0	3.4	27.2	$2,001	$73.5	Pending
	Low efficiency	0.0	3.2	25.8	$1,230	$47.8	
	Medium efficiency	0.0	3.4	27.2	$2,001	$73.5	
	High efficiency	0.0	3.6	28.8	$3,002	$104.2	
ES-5	Clean Distributed Generation: standards, incentives and barrier removal for distributed generation, including combined heat and power (CHP), district heating and cooling, landfill gas, solar, and other forms of renewable energy.						Pending
	ES-5a Distributed Generation	0.3	1.1	6.7	$250	$37.5	
	ES-5b Combined Heat & Power	0.3	1.0	6.3	$90	$14.4	
ES-6	Integrated resource planning (IRP) with or without re-regulation and/or state energy plan	U	U	U	U	U	Pending
ES-7	Renewable Portfolio Standard	5.2	13.8	100.7	$2,589	$25.7	Pending
ES-8	Efficiency improvements and repowering existing plants						Pending
	ES-8a Biomass component	1.2	2.0	17.9	$389	$21.8	
	ES-8b Repowering component	0.5	2.9	15.5	$980	$63.2	
ES-9	Carbon (GHG) tax (at $1/tCO2e)	U	0.1	U	U	$355	Pending
ES-10	Generation Performance Standards						Pending
	GPS - 1125 lb CO_2e per MWh	6.2	6.6	74.3	$5,155	$69.4	

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	Policy Option	GHG Reductions ($MMtCO_2e$) 2012	2020	Total (2008–2020)	Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/tCO_2e$)	Level of Support
	GPS - 1100 lb CO_2e per MWh	7.1	7.6	85.4	$5,926	$69.4	
	GPS - 1050 lb CO_2e per MWh	8.9	9.6	107.7	$7,469	$69.4	
	Sector Total After Adjusting for Overlaps*	5.0	18.1	114.3	-5,464	-48	
	Reductions From Recent Actions	TBD	TBD	TBD	TBD	TBD	
	Sector Total Plus Recent Actions	TBD	TBD	TBD	TBD	TBD	

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ES-1: Promotion of Renewable Energy Resources

Policy Description

This policy option focuses on encouraging renewable energy development by removing regulatory and financial barriers to large-scale centralized facilities as well as on-site generation. It is directed primarily on revising existing statutes and regulations to:

- Streamline and encourage, modernize zoning and siting rules and processes;
- Ensure that any State resource planning process includes consideration of renewable energy projects;
- Develop a clean energy fund to provide for revolving loans (through bonds or any other effective financing mechanisms).
- Make use of long-term contracts for offshore wind and renewables

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In addition, this option would include efforts to facilitate greater use of existing State authority for performance-based contracting of renewable energy projects. The goal of these proposals is to encourage investment in renewable energy by helping to overcome impediments to increased use in Maryland.

For purposes of this policy option, renewable sources include the following tier 1 sources defined in the Maryland Renewable Portfolio Standard: solar energy, wind energy, qualifying biomass, methane from the anaerobic decomposition of organic materials in a landfill or wastewater treatment plant, geothermal energy, ocean energy (including energy from waves, tides, current, and thermal differences), fuel cells that produce energy from designated tier 1 renewable energy sources, and small hydroelectric power meeting specified criteria. (See MD CODE sec. 7-701)

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Policy Design

- **Goals:** This option will achieve an increase in the use of Tier 1 renewable energy alternatives through the relaxation of zoning and siting requirements and the use of long-term contracts for Tier 1 electricity sources. Specifically, the policy targets an increase of Tier 1 renewable energy alternatives at the rate of 0.1% of total MD utility production, starting in 2009 and extending through 2020.

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- **Timing:** This policy would be intended to come into effect in 2009 and would continue indefinitely as an enabling mechanism for other climate-related policies.

- **Parties Involved:** Maryland Public Service Commission, Maryland Dept. of Natural Resources, and Maryland Dept. of Environment**.**

- **Other:** Energy service companies, financial community, renewable energy developers, environmental community; local government

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Implementation Mechanisms

The proposed implementation mechanism for this option is the revision of local zoning laws, the Certificate of Public Convenience and Necessity (CPCN) process before the Public Service Commission (PSC), and resource planning procedures by the PSC (as developed by appropriate state and local agencies).

In addition, it is recommended that the state develop model zoning ordinances and permitting code amendment to allow local government to begin the conversation of establishing clean energy zones to enable streamlined planning and permitting approval.

Coordination with Federal, state and local economic development authorities is needed to prioritize clean energy in certain economic development zones.

Related Policies/Programs in Place

There are several state efforts in place that are related to this option, as follows:

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Existing CPCN exemption for wind projects ≤ 25 MW.

Renewable Portfolio Standard that requires a certain percentage of renewable electricity to be purchased by Load Serving Entities.

Large municipal purchases of clean energy with preferential regional purchasing clauses (e.g. Montgomery County Wind Power Purchasing Group).

Under an IQC process, DGS is currently finalizing the qualifications of a group of firms who develop renewable energy projects, specifically solar, wind and biomass, as the State plan to enter into a long term Power Purchase Agreement with a successful qualified firm.

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Types(s) of GHG Reductions

Renewable generation can reduce fossil fuel use in power generation and correspondingly reduce CO2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

	Policy Option	GHG Reductions ($MMtCO_2e$) 2012	2020	Total (2008–2020)	Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/tCO₂e)	Level of Support
ES-1	Promotion of renewable energy (zoning and siting incentives for centralized facilities)	0.2	0.5	3.3	$89	$27.0	Pending

The policy evaluated includes the increase of Tier 1 renewable energy alternatives at the rate of 0.1% of total MD utility production each year from 2009 through 2020. These increases are assumed to result solely from the easing of zoning and site requirements and the use of long-term contracts for Tier 1 electricity sources. The current analysis does not quantify the effects or costs associated with establishing a clean energy fund. The increase in Tier 1 production is assumed to result in a comparable reduction in electricity production from coal. GHG reductions range

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from 0.17 $MMtCO_2e$ in 2012 to 0.50 $MMtCO_2e$ in 2020, with a cumulative reduction of 3.30 $MMtCO_2e$. The cost of these reductions is estimated to be 27.0 2005$/tCO2e.

Data Sources:

Emission projections data come from: 1) CCS inventory and forecast studies of respective states, or 2) publicly available data from EIA *Annual Energy Outlook 2007* for states lacking detailed bottom up assessments.

1) RS Means. 2007. *Heavy Construction Cost Data*. Kingston, MA.

2) EIA. 2007. *Assumptions for the Annual Energy Outlook 2007: with Projections to 2030*, supplemental table spreadsheet "sup_t2t3.xls" for Mid-Atlantic states. http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options*. http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.

4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland*. http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

5) Energy Information Agency Report entitled: "*Assumptions for the Annual Energy Outlook 2006: with projections to 2025*", 2006

Quantification Methods:

Emissions of GHG from displaced coal power were compared to GHG emissions from Tier 1 power sources used to replace coal power. The difference in emissions is the net GHG reduction for this policy option. Total costs are calculated from levelized net present value (NPV) costs of power production, adjusted for Maryland construction and fuel costs.

Key Assumptions:

Tier 1 renewable energy alternatives increase linearly over time at a rate of 0.1% per year for all in-state production.

Increases in Tier 1 renewable power displace only coal power production.

The renewable energy alternatives were assumed to be apportioned as follows: Wind, 65%; Landfill Gas, 10%; Biomass, 10%; Solar, 10%; and Geothermal, 5%.

Key Uncertainties

Development of financial mechanism by 2009.

Additional Benefits and Costs

Reduction in electric transmission and distribution system; reduced air pollution; increased space in landfills.

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3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options.*
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Feasibility Issues

System integration of intermittent power generation; adequacy of electric transmission capacity; restructuring of zoning and siting requirements, development of financial mechanism; restructuring of State planning procedures.

It is likely that there are technical feasibility issues regarding the degree to which biomass co-firing would lead to the risk of wear, corrosion, slagging and fouling in the combustion system.

Status of Group Approval

(to be completed at a future stage)

Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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ES-2: Technology-focused initiatives for electricity supply

Policy Description

Technology and innovation play a critical role in the development of economic processes, including energy production and use. Major progress in climate change policy requires improvements to technologies as well as increased rates of technology adoption and use. Trends toward smaller scale in energy production technology, combined with the impact of automation and remote system controls, present challenges to current business models and operational procedures. This policy is an umbrella covering several technology-related policy options that together can contribute to GHG emission reductions in Maryland.

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Policy Design

- **Goals:** This set of policies would provide state government and other private and public parties with resources and incentives for analysis, targeted R&D, market development, and adoption of GHG-reducing technologies that are not covered by other policies. The overall goals would be: a) to position Maryland as a world leader in climate-related technology development and deployment; b) to achieve actual emission reductions from technology investments, and c) to develop state industries with high in-state and export capability. The policy should especially target landfill gas combustion for power generation, use of biomass co-firing in existing coal fired units, energy storage and use of fuel cells.

- **Timing:** This policy would be intended to come into effect in 2008 and 2009 and would continue indefinitely as an enabling mechanism for other climate-related policies.

- **Parties Involved:** Maryland government. Private and public partners on a voluntary basis.

- **Other:** NA

Implementation Mechanisms

An R&D budget line item would be created to fund a small staff in the appropriate state agency, most likely the MEA, or an agency to be determined. This group would follow technology trends and identify critical technology pathways as well as opportunities for collaboration and funding from other sources.

If the effort does not overlap with current MEA policy, the state should investigate the formation of a Clean Technologies Innovation Program funded at the state level to provide grants and incentives as they are identified by the state along with other sources of public input into the prioritization process. Two models would be the California Public Interest Energy Research (PIER) program and the New York Energy Research and Development Agency (NYSERDA). Utilities would be able to apply as partners for these funds.

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Finally, the state's regulated utilities and independent power producers would be allowed to devote a percentage of their sales revenue to substantial R&D projects on a voluntary basis as part of their overall energy supply portfolios. The invested capital portion of these projects would be given advantageous cost recovery as an incentive to carry out such projects. This policy could be relaxed when effective climate change policy comes into effect, although there may still be merit in continuing some level of incentive for utility R&D effort even when climate policy is in place.

Related Policies/Programs in Place

There are several state efforts in place that are related to this option, as follows: a) innovation including biotechnology, agriculture, transportation etc, b) renewable development, c) tax credits and federal incentives, and d) technology-specific policies such as hybrid vehicle or solar pilot programs and incentives.

Types(s) of GHG Reductions

Various, from no direct reductions to direct offset of emitting fuels, processes, etc. to actual uptake and use of GHGs thus removing them from the atmosphere.

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Estimated GHG Reductions and Net Costs or Cost Savings

By consensus, this option was not quantified.

Data Sources: Not applicable.

Quantification Methods: Not applicable.

Key Assumptions: Not applicable.

Key Uncertainties

Funding level stability

Ability to identify productive technology pathways

Measures of success and program oversight

Additional Benefits and Costs

None.

Feasibility Issues

Requires broad range of skills for effective administration.

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Status of Group Approval

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Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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ES-3 Cap-and-Trade

Policy Description

Use of competitive forces within a cap and trade regime will provide the incentives for economic investment and efficient technological innovations necessary to achieve the desired environmental improvements. Under a GHG emissions trading program, the regulatory agency sets a maximum limit or *cap* on the total amount of emissions (in tons) of greenhouse gases (e.g., CO_2 or CO_2 equivalent for other covered gasses). The *cap* limits emissions from all covered facilities in a specific sector (e.g., electric generation). The program generally requires that the *cap* will be reduced over a period of years to achieve emission reduction targets.

The regulatory agency implements an emissions trading program by creating and distributing a specific number of *allowances* for use by regulated entities. An *allowance* represents an authorization to emit a specific amount of a pollutant (generally measured in tons) during a particular *compliance period*. The total amount of *allowances* cannot exceed the *cap*, thereby limiting total emissions.

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At the end of each compliance period, each regulated entity must demonstrate that it possessed sufficient allowances to cover all emissions of the capped pollutant. If an entity releases emissions (for a particular compliance period) in excess of the allowances it holds, it can meet the program requirements by buying additional allowances from entities that have excess allowances due to reduced emissions. This exchange of allowances is called a *trade*. In effect, the seller of the allowances is rewarded for reducing its pollution below its number of allowances and the buyer of the allowances must pay a premium for releasing emissions in excess of its allocated level.

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Through trading, participants with lower costs of compliance can choose to over-comply and sell their additional reductions to participants for whom compliance costs are higher. In this fashion, overall costs of compliance are lower than they would otherwise be. Programs that sell or auction allowances, as opposed to distributing them freely, rely less upon trading since the entity that over-complies with expected emissions reductions will avoid the cost of purchasing the allowances in the first place. The entity that requires additional allowances can purchase them at auction or from a secondary market. The compliance obligation for the cap-and-trade program can be imposed "upstream" (at the fuel extraction or import level) or "downstream" at points of fuel consumption or points of emissions.

One key policy issue in designing a cap-and-trade program relates to the treatment of energy efficiency and renewable energy (EERE). Unless a cap-and-trade program is well-designed, it will not assure the maximum achievable GHG reductions from renewable energy and energy efficiency projects.

There are several policy options available to assure that EERE development results in overall CO2 emission reductions under a GHG emissions trading program. For example, Maryland could adopt a key optional section of the model rule issued by the Regional Greenhouse Gas Initiative (RGGI). This optional section authorizes States to retire allowances on behalf of

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voluntary purchases of renewable energy. However, if EERE programs and projects are not accounted for under the cap (through the retirement of allowances or in setting the level of the cap) in any future GHG emissions trading program that might be established in Maryland, then they will not affect the overall level of CO_2 emissions.

Among the other important considerations in designing a cap and trade program are: The geographic scope, the sources and sectors to which it would apply; the baselines for these sources and sectors; the level and timing of the cap; and what, if any offsets, would be allowed. Other issues to consider include which greenhouse gases are covered; whether there is linkage to other trading programs; banking and borrowing of allowances, and early reduction credit.

Maryland is already a partner in the Regional Greenhouse Gas Initiative, a cap-and-trade program for large electric power plants. As a result, nearly all of the questions regarding the program design and implementation have been resolved through the RGGI process. The MWG supports continued active involvement in RGGI and encourages consideration of the expansion of RGGI to sectors beyond the power sector if the federal government fails to enact a credible national cap and trade program in 2009. For the purpose of this recommendation a credible national program must require at least a 20% reduction from current emission levels for covered sectors by 2020.

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1. Set the caps.¶
2. Create a timeline for state agencies to design programs to meet the cap.¶
3. Establish a trading system so that parties covered by those programs can buy and sell emission allowances.¶

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Policy Design

- **Goals:** Caps for electric power plants should match the RGGI goals, which are 2005 emissions starting in 2009 through 2014, followed by a 10 percent reduction through 2019. Other sectors could be included if RGGI were to expand by sector. If this were to happen the resulting reductions should contribute to the State goal, which is anticipated to be 25% below 2006 emissions by 2020 and 90% below 2006 emissions by 2050. These caps should be revisited periodically to reflect current scientific understanding of climate change.
- **Timing:** The state should meet the timing requirements set by RGGI for electric power plants, specifically the adoption of Maryland's RGGI Rule in sufficient time to allow a January 1, 2009 program start. Non-RGGI sectors should be studied for potential inclusion in RGGI and pursue complementary policies and measures in order to meet the state goal.
- **Parties Involved:** As a member of RGGI, Maryland must coordinate with the other members on matters involving the electric power sector. The MWG believes that a credible national cap and trade program is preferable to regional efforts like RGGI, and as stated above encourages enactment of such a program by Congress before the end of 2009. However, in the event that this does not happen and the RGGI members seek expansion of the program to include other sectors, Maryland should design its program to blend into the expanded regional effort. Maryland should advocate for expansion of RGGI to as many sources as practical, including major industrial emitters, the transportation sector, and the buildings sector (particularly state and university new buildings). Inclusion of those sectors that are easier to regulate can begin prior to more complicated sectors.

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- **Other:** For offsets that are a part of the cap-and-trade system, care should be taken that local jurisdictions can apply for offsets for qualifying programs which they create.

  Linkages to external comparable programs should be explored. The state should strongly advocate links to other regional or national programs of equal strength and effectiveness.

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Implementation Mechanisms

There are three key implementation mechanisms. The first concerns the designation of the entity responsible for acquiring and surrendering allowances for emissions, or "point of regulation". In some sectors, such as major industrial emissions, this is simply the in-state entity operating the facility from which the emissions are released.

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RGGI has adopted a production-based (smokestack) system for the electrical power sector but is considering modifying this approach to incorporate greater consideration of load-based (consumer) emissions. The Western Climate Initiative states are considering a more load-based approach.

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If RGGI were to expand to include additional sectors there will likely be a need to vary the "point of regulation" depending on the sector. There are many pros and cons to each approach which should be comprehensively fleshed out in the program development phase.

The transportation sector offers a challenge because a program requiring the surrender of allowances from the end users of motor fuels would be complex and is generally thought to be unworkable. Therefore, transportation sector emissions should be regulated upstream, focusing on the entity that imports or distributes the petroleum in the state.

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Natural gas also should be regulated upstream, again focusing on the entity that imports the natural gas into the state. Major industrial emissions should be regulated at the point of emissions, except to the extent emissions are associated with natural gas and petroleum that has already been regulated upstream. Emissions of certain high global-warming potential gases may also be regulated upstream of their usage (e.g. at the distribution level) if more practical.

Allowances may be distributed by auction or given free-of-charge to covered entities. The State of Maryland has decided to auction 100% of its RGGI allowances. Maryland may want to consider a different allowance distribution approach for new sectors if and when they are added.

The second key implementation mechanism concerns offsets. Offsets are out-of-sector emissions reductions or carbon sequestration projects that are recognized by the program as qualifying for allowance credit. By definition, offsets must be measures that are not required by the program, and they cannot be required by any emissions reduction program in most cases. They provide an incentive for low-cost investments in emissions reductions as an alternative to higher-cost in-sector reductions or allowance purchases. Offsets should be subject to stringent standards to ensure their environmental integrity, and should be limited to ensure that the overwhelming majority of emission reductions come from covered sectors. Any offsets allowed under the program should be real, verifiable, surplus, permanent, and enforceable.

Related Policies/Programs in Place

A Carbon Tax (ES-9) is seen as a complementary policy, applying to sectors not covered by the cap and trade.

Types(s) of GHG Reductions

All 6 statutory GHGs (CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride)

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Estimated GHG Reductions and Net Costs or Cost Savings

Model scenarios for the Cap and Trade policy are limited to the ten RGGI states and the power sector. Runs were performed assuming two initial allowance allocation strategies: (1) all allowances are freely given to regulated sources and (2) all allowances are auctioned. Due to the nature of some state emission caps and the state allowance budgets in 2020, allowance prices could not be projected to the exact dollar level. Instead, multiple runs were conducted assuming prices ranging from $1 to $7 per tCO2. Given that Maryland has decided to auction all allowances, only those results are presented here. Results from the free distribution model are given in the Annex to this report. In the auction case with a hypothetical allowance price of $7/tCO2, each state would utilize all its mitigation potential with a marginal cost less than $7/tCO2 before purchasing allowances from the auctioneer. As a result, the total emission reductions achieved by the 10 states in this case are 41.50 MMtCO2. Although considerable amounts of un-used mitigation potentials of some states such as MD and MA in the free granting case are associated with cost savings, the total cost savings of mitigation in the auction case (2.53 billion) are even higher than the total mitigation cost savings in the free granting case (1.94 billion). In addition, in the auction case, many states would reduce more emissions than required by the state mitigation target. The reason is that there is a penalty for each unit of CO2 emitted even if it is below the cap—this is the price of an auctioned permit that is required to emit. The additional reductions achieved by these states can, however, be saved for future use.

Comparing the two auction prices of $7 and $1, the amount the states choose to reduce by mitigation options (41.50 MMtCO2 vs. 39.62 MMtCO2, respectively) and the amount to be bought from the auctioneer (134.79 MMtCO2 vs. 136.68 MMtCO2, respectively) differ slightly. The trend is that the higher the auction price, the more the states choose to mitigate on their own and the less they buy from the auctioneer. The big difference of these two cases is the total auction cost. And this difference is primarily due to the difference in the two auction price levels.

At an assumed allowance price of $7 per ton in 2020, regulated sources within Maryland can expect to mitigate 16.66 $MMtCO_2e$ at a total cost savings of $604 million. In addition, they will purchase 22.17 million allowances (1 allowance mitigates 1 ton of CO_2) at a total cost of $155 million. The net savings is therefore $449 million. The expected cost savings from mitigation without the cap and trade would be approximately $408 million (assuming Maryland would only comply to the state cap set by RGGI—17.9% reduction of 2020 BAU-- and would not pursue further mitigation even there are additional cost saving potentials), yielding a net cap and trade program savings to Maryland of $41 million in 2020. This does not include any savings that might be realized through the expenditure or application of auction revenues ($155 million). The cost-effectiveness of the auction-based C&T is computed in two alternative ways. The first way is to compute the cost-effectiveness by dividing the total net cost (mitigation cost plus auction cost) by all the emission reductions undertaken by MD under the C&T. The second way is to divide the total net cost by just the capped level of CO2e reductions. The former yields a cost-effectiveness of -$26.9/tCO2e and the latter yields a cost-effectiveness of -$36.4/tCO2e. Please note the second way of computation would reduce some of the double counting of benefits with other policy options.

At an assumed allowance price of $1 per ton in 2020, regulated sources within Maryland can expect to mitigate 15.7 $MMtCO_2e$ at a total cost savings of $608 million. In addition, they will purchase 23 million allowances (1 allowance mitigates 1 ton of CO_2) at a total cost of $23 million. The net savings is therefore $585 million. Compared with the expected cost savings

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from mitigation without the cap and trade ($408 million), the net cap and trade program savings to Maryland is $177 million in 2020. Again, this does not include any savings that might be realized through the expenditure or application of auction revenues ($23 million).

Data Sources:

Emission projections data come from: 1) CCS inventory and forecast studies of respective states, or 2) publicly available data from EIA *Annual Energy Outlook 2007* for states lacking detailed bottom up assessments.

Reduction potentials and cost-effectiveness data of mitigation options for the states are used to develop the cost curves. The data sources are:

1) Connecticut Governor's Steering Committee on Climate Change. 2005. *2005 CT Climate Change Action Plan*. http://www.ctclimatechange.com/StateActionPlan.html.

2) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options.* http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.

3) Maine Department of Environmental Protection. 2004. *Final Maine Climate Action Plan 2004*. http://www.maine.gov/dep/air/greenhouse/.

4) Center for Clean Air Policy and New York GHG Task Force. 2003. *Recommendations to Governor Pataki for Reducing New York State Greenhouse Gas Emissions.* http://www.ccap.org/pdf/04-2003_NYGHG_Recommendations.pdf

5) Rhode Island Greenhouse Gas Process. 2002. *Rhode Island Greenhouse Gas Action Plan.* http://righg.raabassociates.org/.

6) Vermont Governor's Commission on Climate Change. 2007. *Final Report and Recommendations of the Governor's Commission on Climate Change.* http://www.anr.state.vt.us/air/Planning/htm/ClimateChange.htm.

There are no direct mitigation options data for MA, NJ, NH, and DE. Marginal cost curves for these four states are developed based on cost curves of RI, NY, CT, and MD, respectively.

Quantification Methods:

In this study, a non-linear programming model of emission allowance trading is used. This model is based on the well established principles of the ability of unrestricted permit trading to achieve a cost-effective allocation of resources in the presence of externalities.[1] The model requires equalization of marginal cost of all trading participants with the equilibrium permit price. This

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[1] See, for example, T. Tietenberg, 1985. *Emissions Trading: An Exercise in Reforming Pollution Policy*, Washington, DC, Resources for the Future.

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ensures minimization of total net compliance costs for each state and minimization of total abatement costs for the cap-and-trade program as a whole.[2]

The marginal cost curves of the states are developed based on the reduction potential and mitigation cost/saving data of individual options that contribute to the emission reductions from power sector. These options not only include those designed directly for the electricity supply sector (such as promotion of renewable energy utilization, repowering existing plants, generation performance standards, etc.), but also include options in RCI sectors that contribute to the reduction of electricity consumption (e.g., demand-side management, energy efficiency appliances, building codes, etc.). The emission reduction potentials of these options are adjusted by multiplying the percentage of electricity consumption to total energy consumption in the RCI sector. RCI options that relate entirely to reduction of other fossil fuels consumption (such as gas, oil) are not included in the cost curves.

Key Assumptions:

The purpose of the simulations is to illustrate the economic impacts of the RGGI cap and trade program to Maryland under particular design scenarios.

All emissions considered are production-based and are gross emissions (excluding sinks).

The economic modeling conducted in this study helps to analyze the potential GHG reductions and associated cost for Maryland under several scenarios of different design configurations using the following variables: allocation methods (auctioning vs. free granting of permits), hypothetical allowance prices (at the range of \$1 to \$7 per tCO2). . . .

A full list of assumptions adopted in the simulation model is presented in the Appendix.

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Key Uncertainties

Market prices are bound to fluctuate and allowance price spikes and crashes are not uncommon in new programs as the market gains experience. RGGI has incorporated a number of design features to mitigate these tendencies but only actual experience after allowances are offered for sale will prove the point.

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Additional Benefits and Costs

Additional benefits include the apparent effect on regulated entities that the anticipation of the program is already encouraging decisions resulting in reduced emissions, even before the program starts. The successful launch of a regional Cap and Trade program to limit GHG emissions will have an effect on policy makers in non-RGGI states and in Washington, D.C.

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[2] See, for example, B. Stevens, and A. Rose, 2002. "A dynamic analysis of the marketable permits approach to global warming policy: A comparison of spatial and temporal flexibility," *Journal of Environmental Economics & Management* 44(1):45–69; A. Rose, T. Peterson, and Z. Zhang, 2006. "Regional Carbon Dioxide Permit Trading in the United States: Coalition Choices for Pennsylvania," *Penn State Environmental Law Review* 14(2):203–229.

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Feasibility Issues

Feasibility issues have been exhaustively studied through the RGGI development and design phases and have been resolved to the satisfaction of the ten member states. Some questions remain, especially within the context of expansion of the program to additional sectors. The feasibility of extending the Cap and Trade to stationary sources similar to power plants has been tested in the U.S. (SO_2, NO_x), Europe and elsewhere. Application of the approach to some other sectors remains untested and therefore should continue to be studied carefully before implementation.

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Status of Group Approval

(to be completed at a future stage)

Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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ES-4: Combined Capture, Storage, and Reuse (CCSR) incentives, requirements and/or enabling policies

Policy Description

Carbon Capture and Storage for integrated gasification combined cycle (IGCC) is being tested and shows promise as a technology for coal-fired power plants to move toward coal use with zero or very low emissions of CO2. More recently, a new technology is being tested which can capture CO2 from conventional coal-fired plants. IGCC involves partially combusting coal under high pressure to produce a synthetic gas, which is then turned into electricity via combined cycle combustion. Use of technology for existing plants could save considerable cost by retrofitting conventional plants as well as building new IGCC power plants.

Policy Design

- **Goals:** Require the replacement of an existing coal-powered station with an Integrated Gasification Combined Cycle (IGCC) Unit with CCSR by 2013.

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Deleted: Require CCSR for all new plants and retrofit existing plants with best available technology by 2020

- **Timing:** As noted above.
- **Parties Involved:** All power producers operating qualifying facilities in Maryland, independent power producers, and state regulators. Also, recognizing that these are emerging technologies there will be a need to harmonize the legal and regulatory framework through coordination with other states and federal agencies.
- **Other:** Not applicable.

Implementation Mechanisms

There are four key aspects to the implementation of this option in Maryland, as follows:

- Require development of the legal and regulatory frameworks needed for geologic storage of CO2 – new regulations should address issues of CO2 ownership in storage and liability for same. State environmental agencies should develop permitting processes for underground storage, including guidance on pipelines, drilling, storage, measurement, monitoring and verification.
- Support comprehensive assessments of geologic reservoirs at state and federal levels to determine storage potential and feasibility.
- Evaluate the feasibility of CO2 transport via pipeline and "advanced sequestration" (i.e., mineralization, carbon nano-fibers) if Maryland determines it does not have sufficient in-state storage opportunities.
- Provide tax incentives for CCS and seek grants and participation from the Federal government. Joint projects should be sought with Pennsylvania and West Virginia as these states have similar facilities and coal shafts that can be used for sequestration.

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Related Policies/Programs in Place.

None.

Types(s) of GHG Reductions

Carbon dioxide from coal-fired power plants.

Estimated GHG Reductions and Net Costs or Cost Savings

	Policy Option	GHG Reductions ($MMtCO_2e$) 2012	GHG Reductions ($MMtCO_2e$) 2020	GHG Reductions ($MMtCO_2e$) Total (2008–2020)	Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/t$CO_2$e)	Level of Support
ES-4	CCSR incentives, requirements and/or enabling policies (administration, regulation, liability, incentives)	0.0	3.4	27.2	$2,001	$73.5	Pending
	Low efficiency	0.0	3.2	25.8	$1,230	$47.8	
	Medium efficiency	0.0	3.4	27.2	$2,001	$73.5	
	High efficiency	0.0	3.6	28.8	$3,002	$104.2	

The policy includes the installation of a single IGCC/CCSR unit rated at 600 MW. Compared to the cost of a standard pulverized coal unit, an IGCC with CCS ranges from 26% to 48% more costly on a levelized basis. This represents approximately 12% of Maryland's current coal capacity. The plant is assumed to come on line in 2013. Reductions in existing sources will come exclusively from traditional coal plants. Three carbon capture efficiencies based on analyses presented by the IPCC in their 2007 energy supply report were evaluated: low (81%), medium (86%) and high (91%). Transportation and geologic storage costs are from the range of values included in the IPCC technical report and assume a total of 250 kilometers of transportation prior to storage. GHG reductions ranged from 3.2 to 3.6 $MMtCO_2e$ in 2020. Cumulative GHG reductions through 2020 range from 25.8 to 28.8 $MMtCO_2e$. Depending on the carbon capture efficiency assumption used, cost effectiveness varies between $47.8 and $104.2 2005$/tCO_2e.

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Data Sources:

Emission projections data come from: 1) CCS inventory and forecast studies of respective states, or 2) publicly available data from EIA *Annual Energy Outlook 2007* for states lacking detailed bottom up assessments.

1) RS Means. 2007. *Heavy Construction Cost Data*. Kingston, MA.

2) EIA. 2007. *Assumptions for the Annual Energy Outlook 2007: with Projections to 2030.* http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options.* http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.

4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland*. http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

5) IPCC. 2007. *2007: Energy Supply*. In *Climate Change 2007: Mitigation of Climate Change.* http://www.ipcc.ch/ipccreports/ar4-wg3.htm.

6) IPCC. 2005. *IPCC Special Report: Carbon Dioxide Capture and Storage.* http://www.ipcc.ch/ipccreports/srccs.htm

Quantification Methods:

Emissions of GHG from displaced coal power were compared to GHG emissions from IGCC units used to replace existing coal power. The difference in emissions is the net GHG reduction for this policy option. Total costs are calculated from levelized NPV costs of power production, adjusted for Maryland construction and fuel costs. A range of costs are provided for this option, since it is an unproven technology and uncertainty exists with respect to actual construction and operations costs. The final GHG reduction and cost values reported are based on central tendency input parameter values.

Key Assumptions:

A single 600 MW IGCC plant comes on-line in 2013.

Increases in IGCC power displace existing coal power production.

Recommended parameter values from the IPCC report are used to estimate costs and efficiencies for this option.

Key Uncertainties

CCSR technologies are under development and it is not known whether the efficiencies will ultimately fall within the IPCC projections. Likewise, the cost of these technologies may increase if currently unforeseen obstacles to commercialization are found, or costs may decrease if technological breakthroughs occur. Finally, while 2013 is generally believed to be a reasonable start of operations date for the first CCSR plant in Maryland, it is possible, for the reasons just stated and others that use of CCSR might be delayed.

It is unclear if and how the new source review provisions of the Clean Air Act would affect the promotion of plant upgrades.

Additional Benefits and Costs

Reduced air pollution; installation of more efficient technology.

Feasibility Issues

Technology currently in demonstration stage.

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4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland.* http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf. ¶

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4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland.* http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf. ¶
5) IPCC. 2007. *2007: Energy Supply*, In *Climate Change 2007: Mitigation of Climate Change.*

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Status of Group Approval

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Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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ES-5: Clean Distributed Generation (renewables and combined heat and power)

Policy Description

This policy option reflects a suite of financial incentives to encourage investment in distributed renewables and combined heat and power. Financial incentives for distributed renewables could include: (1) direct subsidies for purchasing/selling distributed renewable technologies given to the buyer/seller; (2) tax credits or exemptions for purchasing/selling distributed renewable technologies given to the buyer/seller; (3) tax credits or exemptions for operating distributed renewable energy facilities; (4) feed-in tariffs, which provide direct payments to distributed renewable generators for each kWh of electricity generated from a qualifying renewable facility; (5) tax credits for each kWh generated from a qualifying renewable facility; (6) R&D funding to support development of distributed renewable technologies; (7) net metering; (8) financial incentives or assurance of cost recovery for regulated utilities that make reasonable and prudent investments in utility-owned or customer-owned distributed renewable energy resources and (9) a clean energy grants program. Maryland should strive toward capital buy downs and production incentives such that there is full payback over 25-30 years to those who install distributed renewable options.

Combined heat and power (CHP) refers to any system that simultaneously or sequentially generates electric energy and utilizes the thermal energy that is normally wasted. CHP is sometimes called "recycled energy" because the same energy is used twice. The recovered thermal energy can be used for industrial process steam, space heating, hot water, air conditioning, water cooling, product drying, or nearly any other thermal energy need in the residential, commercial, and industrial sector. The end result is significantly increased efficiency over generating electric and thermal energy separately. CHP can reduce GHG emissions by increasing the overall efficiency of fuel use and reducing transmission line loss with the co-location of heat and power facilities. CHP also lends itself to the use of biofuels, an important Maryland emphasis. However, there are numerous barriers to CHP, including inadequate information, institutional barriers, high transaction costs because of small projects, high financing costs because of lender unfamiliarity and perceived risk, "split incentives" between building owners and tenants, and utility-related policies like interconnection requirement, high standby rates, exit fees, etc. The lack of standard offer or long-term contracts, payment at avoided cost levels, and lack of recognition for emissions reduction value provided also creates obstacles. Policies to remove these barriers can include: improved interconnection policies, improved rates and fees policies, streamlined permitting, recognition of the emission reduction value provided by CHP and clean distributed generation, financing packages and bonding programs, power procurement policies, education and outreach, etc.

Financial incentives for CHP could include: direct subsidies for purchasing/selling CHP systems given to the buyer/seller; tax credits or exemptions for purchasing/selling CHP systems given to the buyer/seller; tax credits or exemptions for operating CHP systems; feed-in tariff, which is a direct payment to CHP owners for each kWh of electricity or BTU of heat generated from a

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qualifying CHP system; and tax credits for each kWh or BTU generated from a qualifying CHP system.

Policy Design

- **Goals:** Undertake a concerted effort to revise its regulatory policies and remove institutional barriers in order to allow distributed renewable and CHP to compete on a level playing field with other sources of electric and thermal energy. Set a goal for distributed renewable generation equal to 1% of all electricity sales in the state by 2020, with a start-up year of 2010. Set a goal for combined heat and power equal to 15% of in-state CHP technical potential at commercial and industrial facilities by 2020, with a start-up year of 2010.
- **Timing:** As noted above.
- **Parties Involved:** Financial incentives would be administered by a state agency and provided to individuals, commercial enterprises, and industrial enterprises.
- **Other:** A source of funds to cover these financial incentives would need to be determined. It may be possible to link incentives to (or condition them upon) the manufacture within Maryland of associated equipment.

Implementation Mechanisms

There are five key aspects to the implementation of this option in Maryland, as follows:

- Information and education.
- Technical assistance.
- Financial incentives.
- Regulatory policies.
- Codes and standards.

Related Policies/Programs in Place

None.

Types(s) of GHG Reductions

Reductions in emissions of carbon dioxide from combustion sources.

Estimated GHG Reductions and Net Costs or Cost Savings

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The incentives and other mechanisms proposed in this option generally benefit two classes of technologies: distributed generation and combined heat and power. These have been analyzed separately and may be aggregated to reflect the total impact of the measures themselves. The coal replacements in CHP are assumed to be 90% natural gas and 10% biomass. The DG replacements are 50% wind and 25% each of landfill gas and solar/PV technology. The results on the Summary table are broken out by technology because the results from each are quite different. For example, the expected cost per ton of CO_2e mitigated for distributed generation technologies is $37.5. This compares to a cost of $14.4 per ton mitigated for the CHP technologies. Over the study period of 2008 through 2020, CHP incentives and measures are projected to mitigate 6.3 $MMtCO_2e$, while DG measures are expected to mitigate 6.7 $MMtCO_2e$.

	Policy Option	GHG Reductions ($MMtCO_2e$) 2012	2020	Total (2008–2020)	Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/t$CO_2e$)	Level of Support
ES-5	Clean Distributed Generation: standards, incentives and barrier removal for distributed generation, including combined heat and power (CHP), district heating and cooling, landfill gas, solar, and other forms of renewable energy.						Pending
	ES-5a Distributed Generation	0.3	1.1	6.7	$250	$37.5	
	ES-5b Combined Heat & Power	0.3	1.0	6.3	$90	$14.4	

Data Sources:

Emission projections data come from: 1) CCS inventory and forecast studies of respective states, or 2) publicly available data from EIA *Annual Energy Outlook 2007* for states lacking detailed bottom up assessments.

1) RS Means. 2007. *Heavy Construction Cost Data*. Kingston, MA.

2) EIA. 2007. *Assumptions for the Annual Energy Outlook 2007: with Projections to 2030.* http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options.* http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.

4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland*. http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

5) IPCC. 2007. *2007: Energy Supply*, In *Climate Change 2007: Mitigation of Climate Change.* http://www.ipcc.ch/ipccreports/ar4-wg3.htm.

6) ACEEE. 2008. *Maryland's Clean Energy Future: Potential for Energy Efficiency and Demand Response to Meet Electricity Demands in Maryland.* http://www.aceee.org/pubs/e082.htm

7) NREL and GRI. 2003. *Gas-Fired Distributed Energy Resource Technology Characterizations*. http://www.nrel.gov/analysis/pdfs/2003/2003_gas-fired_der.pdf

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Quantification Methods:

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Emissions of GHG from displaced coal power were compared to GHG emissions from CHP and DG sources. The difference in emissions is the net GHG reduction for this policy option. Total costs are calculated from levelized NPV costs of power production, adjusted for Maryland construction and fuel costs.

Key Assumptions:

For CHP, 15% of total technical potential (613 MW of 4084 MW) could be economically achieved.

For DG, 1% of total projected 2025 in-state energy production (495 MW) could be economically achieved.

CHP and DG use increases linearly over a 15 year period, starting in 2010.

Existing coal is displaced by these options.

Key Uncertainties

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It is unclear what level incentives need to be to encourage the installation of DG. Additionally, information about CHP in Maryland is limited, leading to uncertainty among policy makers and the regulated community.

Additional Benefits and Costs

Reduced dependence on fossil fuels with use of biofuels; reduced air pollution.

Feasibility Issues

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Design and implementation of tax credits; decreasing real or perceived risk associated with financing.

Status of Group Approval

(to be completed at a future stage)

Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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ES-6: Integrated Resource Planning

Policy Description

Integrated Resource Planning (IRP) is a regulatory process by which alternative solutions for reliably meeting electric demand are identified and evaluated to determine a least-cost or least-risk approach to achieving specific goals. The goal of IRP is to evaluate the costs, benefits, and risks of feasible options for meeting or modifying electric demand on a consistent basis. Accomplishing this goal requires an objective review of energy supply options (from both conventional and renewable energy sources) and energy-efficiency options (demand-side management) prior to approving utility expansions of generation or transmission. Although the Maryland Public Service Commission (PSC) utilized IRP from the late 1980s through the mid-1990s, this regulatory approach was discontinued when the State restructured its electric markets pursuant to the Electric Customer Choice and Competition Act of 1999.

IRP can be implemented in States with either traditional approaches for regulating electric utilities or in those with market-based regulation. However, policymakers must carefully design the IRP framework to assure its effectiveness under the existing regulatory regime.

IRP provides a state resource adequacy method that evaluates many different options for meeting future electricity demands and selects the optimal mix of resources that minimizes the cost of electricity supply while meeting reliability needs and other objectives, such a increasing the state's production of renewable energy sources. An IRP framework would strive to achieve the following: (a) evaluate all options, from both the supply and demand sides, in a fair and consistent manner; (b) minimize risks of cost increases to all stakeholders; and (c) consider environmental impacts (including greenhouse gas emissions from both in-state and out-of-state generation sources serving Maryland customers); and (d) create a flexible plan that allows for uncertainty and permits adjustment in response to changed circumstances.

The use of IRP would help to better align environmental and energy supply policies because it would require consideration of more options than current law and would require the consideration of a longer time horizon in making resource decisions. IRP could be accomplished by action on the part of the PSC to establish a process by which the state determines energy resources needed to meet demand and issues a competitive Request for Proposal (RFP) to meet that demand. The PSC can determine the parameters of the RFP that meet the overall goals of the state: electricity supply and reliability, demand reductions, and environmental protection in the most cost-effective manner to the consumer. Also the PSC could direct or encourage utilities to invest in advanced metering, information exchange infrastructure and usage control technologies to enable customers to reduce their electricity consumption and demand.

Moreover, in the IRP process, the PSC should consider the risk of cost increases associated with future regulation of emissions of greenhouse gases (*e.g.*, CO2), conventional pollutants (*e.g.*, NOx and SO2) and hazardous pollutants (*e.g.*, mercury) when evaluating both supply-side (*e.g.*, new power plants) and demand-side (*e.g.*, energy efficiency) resource options. In addition, the IRP plans should evaluate a broad range of possible fuel costs and consider the risks of fuel price increases and volatility. The plans also should consider the risk mitigation benefits of energy efficiency and renewable energy.

Policy Design

- **Goals:** To develop a comprehensive state resource adequacy plan for Maryland that meets the reliability, environmental, and economic policies of the state. The plan should support and attempt to balance all three goals.
- **Timing:** The IRP process could be implemented by 2009. The PSC can conduct a hearing and get draft resource needs to meet Load Serving Entity demand in 2008 with the first IRP plan and RFP issued by early 2009.
- **Parties Involved:** PSC, Maryland Energy Administration, Maryland Department of Environment, regulated electric utilities, environmental and consumer advocates, renewable energy industry, energy efficiency industry, financial community.

Implementation Mechanisms

This is an option that requires changes to PSC rules and/or new legislation.

Related Policies/Programs in Place

- The PSC is currently pursuing a number of proceedings and reports that are examining IRP-related issues at a policy level and detailed program level. These proceedings and reports include Docket 9111 (demand-side management and energy efficiency programs), Docket 9117 (utility provision of standard offer service), and the December 2007 interim report to the legislature on electricity regulation and regulatory structure.
- Numerous other states have implemented IRP and can provide examples for Maryland. Delaware is currently working on implementation of its IRP, and its plan should be considered in developing regulatory options. In addition, the National Action Plan for Energy Efficiency, coordinated by the U.S. Department of Energy and the Environmental Protection Agency, has compiled information on IRP best practices. (See http://www.epa.gov/cleanenergy/pdf/napee/napee_chap3.pdf), and the Lawrence Berkeley National Laboratory has conducted extensive research analyzing the treatment of renewable energy and energy efficiency in the IRPs of more than a dozen Western States. (See http://eetd.lbl.gov/ea/ems/rplan-pubs.html)

Types(s) of GHG Reductions

Greater reliance on renewable energy and energy efficiency would reduce dependence on electricity produced by burning coal and other fossil fuels, thereby reducing emissions of carbon dioxide and other greenhouse gases.

Estimated GHG Reductions and Net Costs or Cost Savings

By consensus, this option was not quantified.

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Data Sources: Not applicable.

Quantification Methods: Not applicable.

Key Assumptions: Not applicable.

Key Uncertainties

Not applicable.

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Additional Benefits and Costs

Reduced dependence on fossil fuels, reduced air pollution and enhanced electric resource portfolio diversity

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Feasibility Issues

Feasibility issues are focused on the ability to implement the required changes to PSC rules and/or pass new legislation.

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Status of Group Approval

(to be completed at a future stage)

Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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ES-7: Renewable Portfolio Standard

Policy Description

A renewable portfolio standard (RPS) is a policy requiring investor-owned electric utilities and power importers to supply a certain percentage of retail electricity from renewable energy sources by a stipulated date. Utilities can satisfy the RPS requirement by generating renewable energy themselves or by purchasing renewable energy credits (REC) from a renewable energy generator. A REC is equal to 1 kWh of eligible and verified renewable electricity produced. Eligible renewable sources and energy efficiency applications are defined in the current RPS.

Currently, Maryland's RPS includes the following components:

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Tier 1 resources (truly clean renewables) must constitute 1% of load in 2006, increasing to 20% in 2022.

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Tier 2 resources (which are less environmentally friendly) may currently constitute 2.5% of load, but will decrease to 0% by 2019.

Solar PV must constitute 0.005% of load in 2008, increasing to 2% by 2022.

The alternative compliance fee (ACF) is $20/MWh for Tier 1 and $15/MWh for Tier 2. Load associated with industrial sources has a lower ACF. The solar ACF starts at $450/MWh in 2008 and decreases to $50/MWh by 2023.

Renewable projects in the PJM region or a distribution region adjacent to the PJM region are eligible for Maryland RECs. This stretches the geographic scope from Illinois to New York to Virginia.

Maryland is the only state that allows existing hydropower in its RPS. Therefore, Maryland ratepayer dollars are going to operators of existing hydropower dams in other states.

This proposed policy would increase the Tier 1 requirements from 20% in 2022 to 20% in 2020.

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Policy Design

- **Structure:** Strengthen the existing RPS to achieve 20% renewable energy by 2020, ramping up from a start data of 2008. Do not make any changes to the Tier 2 timeline or percentages. In addition,
  - Reduce the size of the geographic region to the core PJM states – Maryland, Pennsylvania, Delaware and New Jersey.
  - Raise the alternative compliance fee to $50.
  - Remove existing hydropower from the list of eligible resources.
  - Give ten percent extra credit for projects that create substantial numbers of jobs in Maryland.

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- **Timing:** As noted above.
- **Parties Involved:** All load-serving entities providing electricity over utility distribution lines in Maryland. The RPS requirement applies to electricity supplied to Maryland customers.
- **Other:** Not applicable.

Implementation Mechanisms

This is a policy requiring a legislative act by the MD legislature.

Related Policies/Programs in Place

The option is a strengthened version of the existing RPS.

Types(s) of GHG Reductions

Carbon dioxide from displaced coal, NG combined cycle and combustion turbine facilities; Methane through the use of animal waste-to-energy and landfill gas-to-energy (LFGE) resources; and aerosols from displaced coal.

Estimated GHG Reductions and Net Costs or Cost Savings

	Policy Option	GHG Reductions ($MMtCO_2e$) 2012	GHG Reductions ($MMtCO_2e$) 2020	GHG Reductions ($MMtCO_2e$) Total (2008–2020)	Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/tCO_2e)	Level of Support
ES-7	Renewable Portfolio Standard	5.2	13.8	100.7	$2,589	$25.7	Pending

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This policy evaluates the net changes in GHG emissions as a result of the implementation of a renewable portfolio standard. The requirements of the standard are outlined in the Policy Description section and represents an increase over current legislation of 9.5% for Tier 1 by 2022 (see Policy Description). The Tier 1 renewable energy alternatives are assumed to be apportioned as follows: Wind, 80%; Landfill Gas, 2%; Biomass, 10%; and Geothermal, 8%. Solar and Tier 2 sources were not implemented, as the requirements of the policy are already met by existing hydropower. Hydropower is assumed to go to zero in 2019 as with the current RPS. Tier 1 RPS was initiated in 2006 and Tier 2 in 2008. Cumulative GHG reductions through the study period are estimated to be 100.7 $MMtCO_2e$ at a cost per ton mitigated of $25.7.

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Data Sources:

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Emission projections data come from: 1) CCS inventory and forecast studies of respective states, or 2) publicly available data from EIA *Annual Energy Outlook 2007* for states lacking detailed bottom up assessments.

1) RS Means. 2007. *Heavy Construction Cost Data*. Kingston, MA.

2) EIA. 2007. *Assumptions for the Annual Energy Outlook 2007: with Projections to 2030.* http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options.* http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.

4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland.* http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

5) Maryland General Assembly (SB 209). 2008. Renewable Portfolio Standard Percentage requirements.

Quantification Methods:

Emissions of GHG from coal were compared to GHG emissions from Tier 1 renewables used to replace coal power production. The difference in GHG emissions from coal to renewables is the net GHG reduction for this policy option. Total costs are calculated from levelized NPV costs of power production, adjusted for Maryland construction and fuel costs.

Key Assumptions:

Coal is the only power source displaced by Tier 1 renewable energy.

Key Uncertainties

Requirements for 10 per cent extra credit; timing for legislation. The current estimates do not include provisions of subsection (a)(2) from section 7-703 of the RPS standard. Those exclusions will alter the total GHG reductions and associated costs.

Additional Benefits and Costs

Reduced air pollution; reduced dependence on fossil fuels.

Feasibility Issues

System integration of intermittent power generation; adequacy of electric transmission capacity.

It is likely that there are technical feasibility issues regarding the degree to which biomass co-firing would lead to the risk of wear, corrosion, slagging and fouling in the combustion system

Status of Group Approval

(to be completed at a future stage)

Level of Group Support

(to be completed at a future stage)

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Barriers to Consensus

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ES-8 Efficiency Improvements and Repowering Existing Plants

Policy Description

This policy would promote the identification and pursuit of cost-effective emissions reductions from existing generating units through improving their operating efficiency, adding biomass, or other fuel changes. This policy would complement a Generation Performance Standard (which applies to new plants and new units) by applying to existing units. Given that CO2 emissions have not previously been the focus of state regulation, and given that existing units have not been the focus of resource planning, it is expected that there are as-yet unidentified opportunities to reduce emissions from existing facilities that will be cost-effective, particularly once CO2 limits are in place. This policy would, in time, result in the identification of a portfolio of technological options for reducing greenhouse gas emissions and allow state utilities to share the opportunities they have identified.

Key aspect of the options include a) requiring utilities to evaluate their existing generating units for opportunities to improve their emissions profile through efficiency improvements, the addition of biomass or other fuel changes. This evaluation would be part of an overall plan identifying cost-effective options for reducing system CO2 emissions on a short-term and long-term basis; b) requiring utilities to pursue cost-effective options for reducing their emissions profile through measures identified above; and c) creating financial incentives that reward such emissions reductions. The terms "cost effective" would be defined by some objective measure, such as cost per ton of carbon equivalent.

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Policy Design

- **Goals:** The repowering option should seek to achieve biomass co-firing at existing coal stations at its upper practical limit of 8% by 2014 (i.e., not requiring major capital investments) by 2015, with a ramp-up starting in 2010. This option would set a goal of repowering 30% of eligible coal stations with natural gas by 2020.
- **Timing:** As noted above.
- **Parties Involved:** The option applies to Maryland electric load serving entities.
- **Other:** Not applicable.

Implementation Mechanisms

The planning and emission reduction requirements would be implemented through planning processes already implemented by the Public Utilities Commission.

Related Policies/Programs in Place

The option is an important counterpart to the Generation Performance Standard (GPS), which only covers new financial commitments. It complements a cap and trade policy by ensuring that

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utilities pursue cost-effective potential emission reductions rather than the more obvious option of purchasing emission allowances (with the projected price of allowances being a key part of the definition of "cost effective" reductions).

Types(s) of GHG Reductions

All 3 major GHG emissions (i.e., CO_2, methane, nitrous oxide).

Estimated GHG Reductions and Net Costs or Cost Savings

	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/t$CO_2e$)	Level of Support
		2012	2020	Total (2008–2020)			
ES-8	Efficiency improvements and repowering existing plants						Pending
	ES-8a Biomass component	1.2	2.0	17.9	$389	$21.8	
	ES-8b Repowering component	0.5	2.9	15.5	$980	$63.2	

This policy option evaluates the effect of co-firing biomass in existing coal plants and re-powering existing coal plants with natural gas. The biomass portion of the policy assumes that biomass provides 8% of power at existing coal-fired plants. The transition to biomass starts in 2010 and is fully implemented in 2014. The cost associated with biomass is assumed to be $3.40 per million btu, based on values in a 2006 biomass feasibility report prepared for the State of Maryland, entitled "The Potential for Biomass Co-firing in Maryland" (DNR 12-2242006-107, PPES-06-02).

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The re-powering portion of this policy assumes that by 2020 about several coal-powered stations in Maryland are repowered with NGCC technology. In practice, this will be a lumpy process, with steps in GHG reductions achieved as new repowered units come online. For simplicity, the option was modeled as NGCC performance, replacing existing coal performance at a rate of 3% per year, starting in 2011. The conversion of coal plants to NG may reduce the effect of the biomass option. This reduction has not been quantified.

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Total GHG reductions through the study period are roughly equal between the two measures, with biomass co-firing yielding 17.8 $MMtCO_2e$, and repowering yielding 15.5 $MMtCO_2e$. Biomass is expected to be a lower-cost option at 21.8 \$/tCO_2e, versus 63.2 \$/tCO_2e for repowering.

Data Sources:

Emission projections data come from: 1) CCS inventory and forecast studies of respective states, or 2) publicly available data from EIA *Annual Energy Outlook 2007* for states lacking detailed bottom up assessments.

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1) RS Means. 2007. *Heavy Construction Cost Data*. Kingston, MA.

2) EIA. 2007. *Assumptions for the Annual Energy Outlook 2007: with Projections to 2030.* http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options.* http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.

4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Co-firing in Maryland*. http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

Quantification Methods:

Emissions of GHG from coal were compared to emissions from co-fired biomass with the same heating potential. Additionally, coal GHG emissions were compared to GHG emissions from equivalent NGCC power units for the repower portion of this policy option. The difference in emissions from coal to biomass and NGCC is the net GHG reduction for this policy option. Total costs are calculated from levelized NPV costs of power production, adjusted for Maryland construction and fuel costs.

Key Assumptions:

Biomass co-firing initiates in 2010 and increases linearly over a 5 year period to a maximum of 8% of energy input at converted plants.

Estimated ‘Warrior Run’ conversion costs are representative of future conversion costs.

Increased demand for biomass does not alter fuel costs.

Conversion from coal to NGCC occurs at a rate of 3% per year, starting in 2010.

Existing coal power is displaced by both biomass and NGCC.

Key Uncertainties

This analysis used a conservative set of assumptions regarding the availability of biomass feedstock within short distances of candidate power plants. The use of this resource for this purpose may compete with other recommendations under considerations by the MWG. These assumptions must be reevaluated if competing uses for this resource are also recommended.

It is unclear how the New Source Review provisions of the Clean Air Act would affect the promotion of plant upgrades.

Additional Benefits and Costs

Reduced air pollution; reduced dependence on fossil fuels.

Feasibility Issues

It is likely that there are technical feasibility issues regarding the degree to which biomass co-firing would lead to the risk of wear, corrosion, slagging and fouling in the combustion system

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4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland*. http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf. ¶

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4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland*. http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf. ¶
Quantification Methods:¶
Emissions of GHG from coal were compared to emissions from co-fired biomass with the same heating potential. Additionally, coal GHG emissions were compared to GHG emissions from equivalent NGCC power units for the repower portion of this policy option. The difference in emissions from coal to biomass and NGCC is the net GHG reduction for this policy option. Total costs are calculated from levelized NPV costs of power production, adjusted for Maryland construction and fuel costs. ¶
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Key Assumptions:¶
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Status of Group Approval

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Level of Group Support

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Barriers to Consensus

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ES-9: Carbon (GHG) tax

Policy Description

A carbon tax would be a tax on fossil fuels according to the amount of CO2 emitted by their combustion. Carbon tax and cap & trade systems work toward similar ends in opposite ways. With the cap and trade, the government sets a limit on the tons of pollution that will be released and the market establishes the price. With a carbon tax, the government sets the price and the market drives the level of emissions. The Carbon Tax and Cap and Trade programs are seen as complementary measures. One of the benefits of the tax is that it can be more easily applied across all sectors, however the ES TWG recommends that the cap and trade program should be the primary market mechanism with the carbon tax used as a supplementary measure in those sectors where transaction costs or other concerns make the use of the cap and trade less desirable. Like most market-based approaches, it should be applied as broadly as possible, and would be best if applied nation-wide. On the negative side, it is politically difficult to apply a new tax, particularly since other taxes are expected to be rise to cover the Maryland budget deficit. Many economists argue that the carbon tax is the most efficient way to ensure that product prices reflect the cost of the greenhouse gas emissions generated in their manufacture and use. Administrative costs are low for the carbon tax and the impact on prices is predictable. The tax could be imposed upstream, based for example on the carbon content of fuels (electricity generators or distributors), at the point of combustion and emission or at the point of sale (gasoline, natural gas). Although taxed entities would pass some or all of the cost on to consumers, there would be competitive pressure to find cost-effective ways to lower (or offset) emissions. Consumers who see the implicit cost of GHG emissions in products and services could adjust their behavior to lower emissions and reduce cost. Revenues collected could offset other taxes, be applied to incentivize low emission alternatives, be directed for relief to parties that are disproportionately impacted by the tax, or rebates could be created for CO2 controls or offsets that prevent atmospheric emissions.

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It is assumed that the cost of the tax would be passed down to the ultimate consumer, such as residential and commercial utility ratepayers for electricity. In order to achieve the stated goal, the amount of the tax must be high enough to trigger financial and behavioral decisions toward conservation or a shift to lower emitting fuels.

Policy Design

- **Goals:** Make the cost of inefficient or higher CO2 emitting activities more expensive than alternatives, thereby creating a financial incentive to change behavior away from activities that result in CO2 emissions. The tax should include safety valves to reduce low-income impacts and minimize detrimental economic consequences. One option is to make the tax "revenue neutral," (an equal amount of other state taxes would be reduced so that the "net" to the state is zero); or the revenue from the tax could be used to develop or promote alternatives that reduce CO2 emissions. The amount of the tax should be high enough to contribute to the reduction targets specified in the cap-and-trade option (see ES-3).

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- **Timing:** Pegged to the timing of the cap-and-trade option (see ES-3).
- **Parties Involved:** Major payers would be refiners or distributors of transportation and heating fuels in Maryland and commercial and industrial sources consuming energy for production or other commercial use.
- **Other:** Technical Advisory Committee – The TWG recognizes that more in-depth analysis of the carbon tax and its interactions with the cap and trade and other policies will be required than is possible within the current process. It is therefore recommended that a Technical Advisory Committee be convened to study the proposal in greater depth, receive additional public comment and offer recommendations on the specifics of how a supplemental carbon tax should be enacted and applied.

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Implementation Mechanisms

This option requires legislation and detailed tax collection system. Specifics of the implementation should be developed through an in-depth investigation as recommended under "Other" above.

Related Policies/Programs in Place

The RGGI cap and trade program and ES-3 are seen as complementary policies.

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Types(s) of GHG Reductions

Reductions in emissions of carbon dioxide from combustion sources.

Estimated GHG Reductions and Net Costs or Cost Savings

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As explained in more detail in the Annex, Maryland can meet its state goal using only negative cost (cost saving) policies and measures. As a result, the incentives for additional GHG mitigation investments provided by a carbon tax are not needed to achieve the goal in principle, because it "pays" emitters to undertake reductions on their own. However, if there is concern about impediments to such voluntary action or if Maryland desired to achieve additional reductions over and above those required by the cap, and possibly through other policies capitalizing on the existence of zero or negative mitigation cost options, a carbon tax could be created offering the following costs and benefits. Modeling indicates that for each dollar per ton of emissions from non-power sector sources in Maryland, approximately 100,000 tons of CO_2e will be mitigated. Assuming the state goal of 25% below 2006 emissions is achieved in 2020, this leaves 47.6 $MMtCO_2e$ being emitted from sectors other than the power sector. The implementation of the remaining (unused) negative cost mitigation options beyond the accomplishment of the state goal would reduce the emissions from the non-power sector further from 47.6 to 35.5 MMtCO2e. Therefore, a $1 per ton carbon tax would 'cost' $35.5 million (the emitters need to pay $1 tax per every ton of the remaining 35.5 MMtCO2e emissions) and yield 0.1 million tons of reduced emissions, for a cost per ton of $355. This does not take into consideration how the State of Maryland might apply the tax revenues to offset some of this cost.

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Data Sources:

Emission projections data come from CCS inventory and forecast analysis of Maryland.

Reduction potentials and cost-effectiveness data of mitigation options of Maryland non-power sectors are used to develop the cost curves. This data is provided by other TWGs.

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Quantification Methods:

The mitigation options list of the non-C&T sectors in Maryland are used in order to evaluate:

A. whether the contributions of mitigation options from all the non-C&T sectors would meet the state goal and,
B. if not, what would be the carbon tax level to non-C&T sectors to achieve the goal; and,
C. if the mitigation options meet the state goal, how many incremental tons of CO2 will be abated for each incremental dollar of carbon tax.

Some RCI sector options that entirely or partially contribute to electricity consumption reduction are included in the options list to develop the MD power sector mitigation cost curve used in ES-3. To avoid double-counting, the emissions mitigation potential related to electricity consumption reduction of those options are not included in the analysis here.

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Key Uncertainties

We assume all the negative cost mitigations beyond the state goal would happen without any incentives from a carbon tax. Therefore, for the $1 carbon tax case, the non-power sectors would choose to pay the tax rather than mitigate those emissions that would have a unit reduction cost higher than $1 per ton. However, in practice, it is unclear how much the incentive (the tax rate) should be to encourage all the investments in negative cost opportunities.

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Additional Benefits and Costs

The availability of $35.5 million in tax revenues per dollar of tax could provide Maryland with a range of additional benefits as a direct result of this policy. Investments in research and development that produce technological breakthroughs might not only produce greater and more cost-effective emissions reductions, they might also pay dividends in the form of new jobs and economic growth.

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Feasibility Issues

~~**(to be completed at a future stage)**~~ Any new tax, even if it is designed to be revenue neutral (revenues offset existing taxes), presents a substantial political challenge, especially in a tight economy. Also, at this point no U.S. state has enacted a carbon tax so the effort necessary to convince affected groups would be greater than would be the case if there were favorable experience from another U.S. jurisdiction. Administration of the tax would not present particular challenges unless its design included classes of entities that have not previously been subject to similar taxes.

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Status of Group Approval

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Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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ES-10 Generation Performance Standard

Policy Description

A generation performance standard (GPS) is a mandate that requires Load Serving Entities (LSEs) to acquire electricity on an average portfolio basis, with the portfolio meeting a per-unit emission rate below a specified standard. A GPS portfolio will incentivize investment in new low-carbon generation with overall lower greenhouse gas emissions in Maryland. A portfolio approach also is a mechanism to control cost to the consumer as well, balancing the energy supply and environmental goals of the state.

The GPS will be modeled after the existing Renewable Portfolio Standard program with the exception that the GPS standard must be met from Maryland generation. This will help encourage renewable energy sources and will also fit well with any state resource planning process for new generation.

Policy Design

- **Goals:** The general goal of the policy is to encourage the purchase of energy and capacity from low-carbon or renewable technologies. In particular, the generation performance standard portfolio would require that 100% of their energy portfolio emit an average of no more than a specified number of pounds of CO_2 per megawatt-hour. In response to suggestions made by the MWG, the analysis has been run using three potential GPS standards; 1050, 1100 and 1125 pounds per MWh. The GPS would be designed to harmonize with policies that seek to reduce greenhouse gas emissions by promoting greater use of renewable energy sources.

- **Timing:** The program could be implemented by 2015 so as to provide time for new sources to be built.

- **Parties Involved:** The program would apply to any LSE selling energy to retail consumers in the state of Maryland, both competitive and those on Standard Offer Service. Public Service Commission would need to manage similar to the RPS portfolio obligation.

- **Other:** Not applicable.

Implementation Mechanisms

Implementation would be through the Public Utilities Commission, which would develop a GPS program similar in design to the current RPS program to ensure compliance with the generation performance standard.

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Related Policies/Programs in Place

A Renewable Portfolio Standard is currently in place in Maryland and under ES-7 it would be strengthened. The GPS as proposed here would be applied separately from the RPS, in other words the separate requirements of the two standards would not be additive. In addition ES-8, Energy Efficiency Improvements and Repowering coal generation plants would complement this policy by reducing emissions from existing plants.

Types(s) of GHG Reductions

Reduces carbon dioxide emissions from fossil-fuel electric generators, and promotes low carbon alternatives to fossil fuel generators.

Deleted: This policy quantifies the effect on GHG of implementing a GPS that stipulates that the average emission rate for the entire energy portfolio (in-state and imports) be less than 1,050, 1,100 and 1,125 pounds of CO2 per MWh. An analysis of the current electricity mix in Maryland indicates that the average energy intensity is about 1,200 pounds CO2 per MWh. These values are based on averages from different energy sources. This analysis does not consider the emissions associated with the marginal MWh from any one source type or location (i.e., electricity via a dedicated power line from West Virginia). Replacement of existing coal was assumed to be 90% NGCC and 10% wind.

Estimated GHG Reductions and Net Costs or Cost Savings

	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/tCO_2e$)	Level of Support
		2012	2020	Total (2008–2020)			
ES-10	Generation Performance Standards						Pending
	GPS - 1125 lb CO_2e per MWh	6.2	6.6	74.3	$5,155	$69.4	

The 1,050 standard yielded 8.9 and 9.6 MMtCO2e reductions in 2012 and 2020, respectively, and 107.7 MMtCO2e cumulatively between 2008 and 2020.

The 1,100 standard yielded 7.1 and 7.6 MMtCO2e in 2012 and 2020, respectively, and 85.4 MMtCO2e cumulatively between 2008 and 2020.

The 1,125 standard yielded 6.2 and 6.6 MMtCO2e in 2012 and 2020, respectively, and 74.3 MMtCO2e cumulatively between 2008 and 2020.

The cost effectiveness of each of these three standards is $69.4/tCO2e.

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Data Sources:

Emission projections data come from: 1) CCS inventory and forecast studies of respective states, or 2) publicly available data from EIA *Annual Energy Outlook 2007* for states lacking detailed "bottom up" assessments.

1) RS Means. 2007. *Heavy Construction Cost Data*. Kingston, MA.

2) EIA. 2007. *Assumptions for the Annual Energy Outlook 2007: with Projections to 2030.* http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options.* http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.

4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland.* http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

Quantification Methods:

This policy quantifies the effect on GHG of implementing a GPS that stipulates that the average emission rate for the entire energy portfolio (in-state and imports) be less than 1,050, 1,100 and 1,125 pounds of CO_2 per MWh. An analysis of the current electricity mix in Maryland indicates that the average energy intensity is about 1,200 pounds CO_2 per MWh.

Key Assumptions:

This analysis does not consider the emissions associated with the marginal MWh from any one source type or location (i.e., electricity via a dedicated power line from West Virginia). Replacement of existing coal was assumed to be 90% NGCC and 10% wind.

Key Uncertainties

None.

Additional Benefits and Costs

Reduced air pollution; increased renewable power produced in Maryland.

Feasibility Issues

None.

Status of Group Approval

(to be completed at a future stage)

Level of Group Support

(to be completed at a future stage)

Barriers to Consensus

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Appendix to MD ES Policy Options

Analysis of Cap and Trade among Power Sectors of RGGI states and Carbon Tax in Maryland Non-C&T Sectors

A. Free Allocation of Allowances

The Non-linear Programming (NLP) Model we used in the study is capable of analyzing various environmental policy instruments, including cap & trade, carbon taxes, and regulations, under a variety of conditions. For cap & trade, for example, the latter includes: free granting vs. auctioning, upper limits on permit prices, offsets, banking, etc.

Because of the extensive availability of low-cost mitigation options, in some cases the supply of allowances in a cap & trade (C&T) would exceed the demand for allowances at all positive allowance prices. Hence, trading would not be possible (we cannot obtain a feasible solution for a positive allowance price from our model that equalizes supply and demand of allowances in the market). Instead, we analyze two scenarios with different assumptions for allowance price levels that resolve this problem. We then evaluate the supply and demand of allowances from each state, and the costs/savings of individual states before and after entering the C&T system.

Example scenario: Marginal Cost (MC) = Allowance Price = $7/tCO2

1. According to the initial RGGI allowance allocation, ME, NH, VT, and RI do not have any GHG mitigation targets, since the allocated allowances to these states (see Column 3 of Table 1) exceed their 2020 BAU emission levels (see Column 2 of Table 1). For the remaining 6 states, which have binding mitigation goals, the reduction target (%) is computed in Column 4 of Table 1. Next, we calculate the reduction potential level in percentage terms at MC=$7 (see Column 3 of Table 2). If this percentage is lower than the one shown in Column 4 in Table 1, the state would be a buyer of allowances. As shown in Column 4 of Table 2, CT and NJ would be the buyers. In total, the allowances demand from these two states is 5.36 MMtCO2. The allowance selling states would be DE, MD, ME, NH, NY, VT, MA, and RI.

2. After achieving its own reduction target (41.94% below 2020 BAU level), the total allowances available for DE to sell with mitigation cost less than $7 are 0.23 MMtCO2. We assume the remaining RGGI allowance demand (5.36-0.23=5.13 MMtCO2) would be provided by the other 7 allowance selling states evenly, i.e., each of the selling states would sell 5.13/7=0.73 MMtCO2 in the market.

3. MD, NY, and MA do not have over-allocated allowances to sell. Therefore, they will provide all of the 0.73 MMtCO2 allowances by autarkic (their own) mitigation actions with costs less than $7/tCO2 (after achieving their own state mitigation targets, these three states still have the capability to reduce emissions with cost less than $7/tCO2). ME, NH, RI, and VT will decide how much of the allowances they sell would come from autarkic mitigation actions and how much would come from the excess allowances they possess. To gain the largest profit, these four states would choose to utilize all the cost-saving mitigation potentials inside the state first, since selling these allowances would bring them not only the cost-savings associated with the

implementation of the mitigation options, but also the revenues from selling the allowances at the price of $7/tCO2. After exhausting cost-saving mitigation potentials, they will next choose to sell the excess allowances they hold. They can sell these allowances without incurring any mitigation cost. After using up the excess allowances, these three states would be willing to sell those allowances they can achieve through autarkic mitigation actions with costs less than $7/tCO2.

The simulation results of the scenario with allowance price equal to $7/tCO2 are shown in Table 3. Simulation results of the scenario that assumes allowance price to be $1/tCO2 are presented in Table 4. In this case, DE would be the third buyer besides CT and NJ, since the state autarkic mitigation potentials with marginal cost less than $1 fall short of meeting the state target (though DE's demand of allowance is very small (0.06 MMtCO2e) compared with the other two buyers CT and NJ). We also did similar simulations with assumptions of allowance price at $3/tCO2 and $5/tCO2. These two cases yield similar simulation results as the $7 case, with only CT and NJ as the buyers. From the three cases with price at the levels of $3, $5, and $7, the results show that there is a negative relationship between the level of allowance price and the amount of allowances traded among the states. Approximately, allowance transactions are reduced 11 thousand tCO2 with each increased dollar in the allowance price.

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Table 1. RGGI States 2020 Emission Projections and Caps

	2020 BAU Emissions (MMtCO2)	Cap/Budget (MMtCO2)	Reduction Target (%)	Allowance beyond BAU (MMtCO2)	Reduction Target (MMtCO2)
CT	13.26	9.09	31.45%	0.00	4.17
DE	11.07	6.43	41.94%	0.00	4.65
MD	38.83	31.88	17.90%	0.00	6.95
ME	1.90	5.06	0.00%	3.15	-3.15
NH	4.93	7.33	0.00%	2.40	-2.40
NJ	23.40	19.46	16.86%	0.00	3.95
NY	56.11	54.66	2.58%	0.00	1.45
VT	0.03	1.04	0.00%	1.01	-1.01
MA	24.97	22.66	9.26%	0.00	2.31
RI	1.78	2.26	0.00%	0.48	-0.48
Total	176.30	159.87	9.32%	7.04	16.43

* The shaded states, ME, NH, VT, and RI, have allocated allowances higher than their projected 2020 BAU emission levels. As a result, these states have zero emission reduction targets in their power sector. In addition, they can sell the excess allowances in the market at zero mitigation cost.

Sources: 1. RGGI States GHG Caps by Year from 2009 to 2018 are provided by Jeff Wennberg from CCS. Numbers for year 2019 and year 2020 are estimated by extrapolating 2014 to 2018 numbers.
2. RGGI states 2020 BAU emission projections are obtained from RGGI website http://www.rggi.org/documents.htm, the Reference Case projections. The 2020 values are computed by interpolating 2018 and 2021 projections.

Table 2. Determination of Allowances Purchasing and Selling States

	Reduction Target (%)	In-state Reduction Potential with MC<= $7 (%)	Whether an Allowance Buyer	The Amount of Allowances to Buy
CT	31.45%	5.78%	Yes	3.40
DE	41.94%	44.05%	No	
MD	17.90%	42.90%	No	
ME	0.00%	39.92%	No	
NH	0.00%	6.78%	No	
NJ	16.86%	8.49%	Yes	1.96
NY	2.58%	5.44%	No	
VT	0.00%	100.00%	No	
MA	9.26%	47.72%	No	
RI	0.00%	62.95%	No	
Total	9.32%	23.54%	—	5.36

Note: If the percentage in the third column is less than the reduction target in percentage terms in the second column, the state would be an allowance buyer.

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Table 3. Power Sector Cap and Trade Simulation among 10 RGGI States in Year 2020
Scenario 1: Allowance Price = $7/tCO2

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Saving	Allowances Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Cost	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
CT	1,200.05	-49.64	23.83	-25.81	1,225.86	3.40	0.77	5.78	31.45
DE	-171.89	-170.83	-1.61	-172.43	0.55	-0.23	4.88	44.05	41.94
MD	-407.91	-439.20	-5.13	-444.33	36.43	-0.73	7.68	19.79	17.90
ME	0.00	-41.49	-5.13	-46.62	46.62	-0.73	0.72	38.00	0.00
NH	0.00	-25.72	-5.13	-30.85	30.85	-0.73	0.32	6.50	0.00
NJ	38.45	-313.93	13.71	-300.22	338.67	1.96	1.99	8.49	16.86
NY	-418.66	-530.22	-5.13	-535.36	116.70	-0.73	2.18	3.89	2.58
VT	0.00	-2.34	-5.13	-7.48	7.48	-0.73	0.03	100.00	0.00
MA	-235.68	-301.68	-5.13	-306.81	71.13	-0.73	3.05	12.20	9.26
RI	0.00	-61.48	-5.13	-66.61	66.61	-0.73	1.07	60.45	0.00
Total	4.37	-1,936.53	0.00	-1,936.53	1,940.89	5.36[a]	22.69	12.87	13.31

[a] Represents number of allowances bought or sold.

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Table 4. Power Sector Cap and Trade Simulation among 10 RGGI States in Year 2020
Scenario 2: Allowance Price = $1/tCO2

(million dollars or otherwise specified)

State	Before Trading	After Trading			Cost Saving	Allowances Traded	Emission Reduction w/ Trading		Emission Reduction Goal
	Mitigation Cost	Mitigation Cost	Trading Cost	Net Cost		(million tCO_2)	(million tCO_2)	(percent from BAU)	(percent from BAU)
CT	1,200.05	-49.77	3.44	-46.33	1,246.38	3.44	0.73	5.54	31.45
DE	-171.89	-171.97	0.06	-171.91	0.03	0.06	4.59	41.45	41.94
MD	-407.91	-441.27	-0.78	-442.06	34.15	-0.78	7.73	19.92	17.90
ME	0.00	-41.49	-0.78	-42.27	42.27	-0.78	0.72	38.00	0.00
NH	0.00	-25.72	-0.78	-26.50	26.50	-0.78	0.32	6.50	0.00
NJ	38.45	-314.07	1.99	-312.07	350.52	1.99	1.95	8.34	16.86
NY	-418.66	-535.40	-0.78	-536.18	117.52	-0.78	2.23	3.98	2.58
VT	0.00	-2.34	-0.78	-3.13	3.13	-0.78	0.03	100.00	0.00
MA	-235.68	-306.07	-0.78	-306.85	71.17	-0.78	3.10	12.40	9.26
RI	0.00	-61.48	-0.78	-62.26	62.26	-0.78	1.07	60.45	0.00
Total	4.37	-1,949.58	0.00	-1,949.58	1,953.94	5.49[a]	22.49	12.76	13.31

[a] Represents number of allowances bought or sold.

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B. Auction of Allowances

In the case where allowances are auctioned, we assume the 2020 emission caps for CT, DE, MD, NJ, NY, and MA are the same as in the free granting case. For ME, NH, VT, and RI, which have excess allowances in the free granting case, we assume their caps in the auction case would equal the state BAU 2020 emission levels (i.e., there is no reason to purchase any excess allowances at auction). Table 5 shows the emission caps for the 10 RGGI states in the auction case.

Table 5. RGGI States 2020 Emission Projections and Caps (Auction Case)

	2020 BAU Emissions (MMtCO2)	Cap/Budget (MMtCO2)
CT	13.26	9.09
DE	1.07	6.43
MD	8.83	31.88
ME	1.90	1.90
NH	4.93	4.93
NJ	23.40	19.46
NY	56.11	54.66
VT	0.03	0.03
MA	24.97	22.66
RI	1.78	1.78
Total	176.30	152.82

In the auction case, there would be no trading among states. According to the Coase Theorem, in equilibrium, each state would choose to mitigate emissions as long as its marginal abatement cost is lower than or equal to the price of allowances, and purchase the remaining allowance (the difference between the state's BAU level and the amount mitigated by autarkic actions) from the auctioneer. Table 6 presents the amount of emissions that can be reduced by each state's autarkic mitigation actions associated with marginal cost of $7/tCO2e. The simulation results of the auction case with allowance price equal to $7/tCO2e are presented in Table 7. A second simulation with the auction price assumed to be at $1/tCO2e is presented in Table 8.

In usual C&T cases, where the equilibrium point corresponds to a positive allowance price, auction and free granting would reach the same cost-effectiveness level, i.e., the auction price would be at the same level as the equilibrium price in the allowance trading market, and the collaborative CO2 reductions achieved by the partner states in these two allocation cases would be the same and equal to the overall emission reduction target of the region. The only difference between these two allocation cases would be that the auction can generate revenues to the state government, which in turn can be recycled to fund R&D in clean energy technologies, end-use energy efficiencies, etc., and thus lower the impacts to the electricity ratepayers.

However, as indicated in Section A, the supply of allowances would exceed the demand for allowances at all positive allowance prices in RGGI's case. Therefore, in the case of C&T with a grandfathering allocation strategy and with the assumed market price at $7/tCO2, to ensure the balance of trade in the market (supply equalizing demand), many states such as MD, NY, and MA would not use up all their mitigation potentials with marginal cost less than $7/tCO2. Collaboratively, the emission reductions achieved by the 10 states in the free granting case with allowance price equal to $7/tCO2 are 22.69 MMtCO2. In the auction case, each state would utilize all its mitigation potential with marginal cost less than $7/tCO2 before purchasing allowances from the auctioneer. As a result, the total emission reductions achieved by the 10 states in this case are 41.50 MMtCO2. Since considerable amounts of un-used mitigation potentials of some states such as MD and MA in the free granting case are associated with cost savings, the total cost savings of mitigation in the auction case (2.53 billion) are higher than the total mitigation cost savings in the free granting case (1.94 billion). In addition, in the auction case, many states would reduce more emissions than required by the state mitigation target. The additional reductions achieved by these states can be saved for future use.

Comparing the two auction cases with auction prices at $7 and $1, the amount the states choose to reduce by mitigation options (41.50 MMtCO2 vs. 39.62 MMtCO2) and the amount to be bought from the auctioneer (134.79 MMtCO2 vs. 136.68 MMtCO2) differ slightly. The big difference in total auction cost between these two cases is due primarily to the difference of the two auction price levels.

Table 6. Mitigation Potential Associated with MC=$7/tCO2e

	Cap/Budget (MMtCO2)	In-state Reduction Potential with MC<= $7 (%)	In-state Reduction Potential with MC<= $7 (MMtCO2)
CT	9.09	5.78%	0.77
DE	6.43	44.05%	4.88
MD	31.88	42.90%	16.66
ME	1.90	39.92%	0.76
NH	4.93	6.78%	0.33
NJ	19.46	8.49%	1.99
NY	54.66	5.44%	3.05
VT	0.03	100.00%	0.03
MA	22.66	47.72%	11.92
RI	1.78	62.95%	1.12
Total	152.82	23.54%	41.50

Table 7. Simulation Results of an Auction Case among RGGI States (with assumed auction price at $7/tCO2)

State	Total BAU Emissions in 2020 (million tCO2)	2020 Emissions Cap/Budget (million tCO2)	Emission Reduction Undertaken by the State[a]		Mitigation Cost (million dollars)	Emission Allowances Bought from Auctioneer (million tCO2)	Auction Cost (million dollars)[b]	Net Cost (million dollars)[c]
			(percent from BAU)	(million tCO_2)				
CT	13.26	9.09	5.78	0.77	-49.64	12.50	87.47	37.83
DE	11.07	6.43	44.05	4.88	-170.83	6.20	43.37	-127.45
MD	38.83	31.88	42.90	16.66	-604.01	22.17	155.20	-448.81
ME	1.90	1.90	39.92	0.76	-41.36	1.14	8.00	-33.36
NH	4.93	4.93	6.78	0.33	-25.67	4.59	32.16	6.48
NJ	23.40	19.46	8.49	1.99	-313.93	21.42	149.92	-164.01
NY	56.11	54.66	5.44	3.05	-573.12	53.06	371.43	-201.69
VT	0.03	0.03	100.00	0.03	-2.34	0.00	0.00	-2.34
MA	24.97	22.66	47.72	11.92	-692.28	13.06	91.40	-600.88
RI	1.78	1.78	62.95	1.12	-61.32	0.66	4.61	-56.71
Total	176.30	152.82	23.54	41.50	-2,534.51	134.79	943.56	-1,590.95

[a] In equilibrium, each state will choose to mitigate to the level that its marginal abatement cost equals the auction price.
[b] We assume the auction price is $7/tCO2 in this case.
[c] Sum of Mitigation Cost and Auction Cost.

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Table 8. Simulation Results of an Auction Case among RGGI States (with assumed auction price at $1/tCO2)

State	Total BAU Emissions in 2020 (million tCO2)	2020 Emissions Cap/Budget (million tCO2)	Emission Reduction Undertaken by the State[a]		Mitigation Cost (million dollars)	Emission Allowances Bought from Auctioneer (million tCO2)	Auction Cost (million dollars)[b]	Net Cost (million dollars)[c]
			(percent from BAU)	(million tCO_2)				
CT	13.26	9.09	5.54	0.73	-49.77	12.53	12.53	-37.24
DE	11.07	6.43	41.45	4.59	-171.97	6.48	6.48	-165.49
MD	38.83	31.88	40.42	15.70	-607.83	23.13	23.13	-584.70
ME	1.90	1.90	38.28	0.73	-41.49	1.17	1.17	-40.31
NH	4.93	4.93	6.54	0.32	-25.72	4.61	4.61	-21.11
NJ	23.40	19.46	8.34	1.95	-314.07	21.45	21.45	-292.62
NY	56.11	54.66	5.35	3.00	-573.31	53.11	53.11	-520.20
VT	0.03	0.03	100.00	0.03	-2.34	0.00	0.00	-2.34
MA	24.97	22.66	45.96	11.48	-694.03	13.50	13.50	-680.54
RI	1.78	1.78	60.81	1.08	-61.47	0.70	0.70	-60.78
Total	176.30	152.82	22.47	39.62	-2,542.01	136.68	136.68	-2,405.33

[a] In equilibrium, each state will choose to mitigate to the level that its marginal abatement cost equals the auction price.
[b] We assume the auction price is $1/tCO2 in this case.
[c] Sum of Mitigation Cost and Auction Cost.

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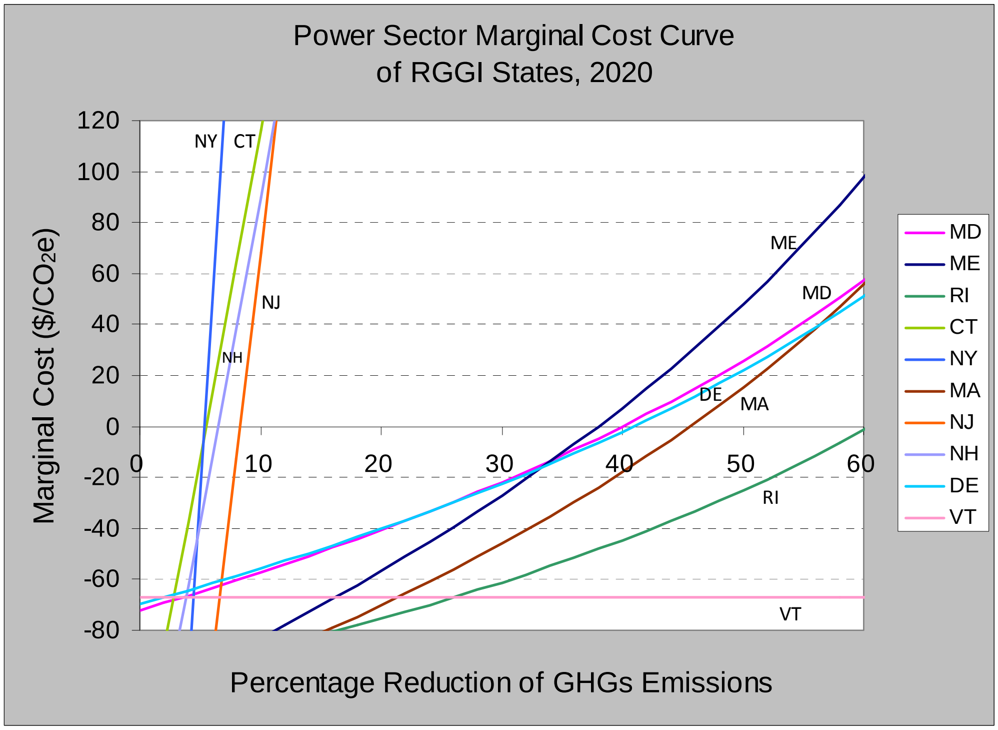

Figure 1. State Marginal Cost Curves of Power Sector, 2020

Notes: 1. There are no direct data for MA, NJ, NH, and DE. Marginal cost curves for these four states are developed based on cost curves of RI, NY, CT, and MD, respectively.
2. The marginal cost curves of the states are developed based on the reduction potential and mitigation cost/saving data of individual options that contribute to the emission reductions from power sector. These options not only include those designed directly for the electricity supply sector (such as promotion of renewable energy utilization, repowering existing plants, generation performance standards, etc.), but also include options in RCI sectors that contribute to the reduction of electricity consumption (e.g., demand-side management, energy efficiency appliances, building codes, etc.). The emission reduction potentials of these options are adjusted by multiplying the percentage of electricity consumption to total energy consumption in the RCI sector. RCI options that relate entirely to reduction of other fossil fuels consumption (such as gas, oil) are not included in the cost curves above.

Sources: 1. Connecticut Governor's Steering Committee on Climate Change. 2005. *2005 CT Climate Change Action Plan*. http://www.ctclimatechange.com/StateActionPlan.html.
2. Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options*. http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.
3. Maine Department of Environmental Protection. 2004. *Final Maine Climate Action Plan 2004*. http://www.maine.gov/dep/air/greenhouse/.
4. Center for Clean Air Policy and New York GHG Task Force. 2003. *Recommendations to Governor Pataki for Reducing New York State Greenhouse Gas Emissions*. http://www.ccap.org/pdf/04-2003_NYGHG_Recommendations.pdf
5. Rhode Island Greenhouse Gas Process. 2002. *Rhode Island Greenhouse Gas Action Plan*. http://righg.raabassociates.org/.
6. Vermont Governor's Commission on Climate Change. 2007. *Final Report and Recommendations of the Governor's Commission on Climate Change*. http://www.anr.state.vt.us/air/Planning/htm/ClimateChange.htm.

C. Carbon Tax

In this simulation, we will estimate the level of carbon tax to the non-C&T sectors to yield the Maryland state reduction target in year 2020 — 25% below 2006 levels.

Table 9. Emission Reduction Target by Sector to Achieve the Maryland State Goal

	2006 (MMtCO2)	2020 (MMtCO2)	Emission Cap in 2020 (25% below 2006) (MMtCO2)	Emission Reduction Target	
				(MMtCO2)	Percentage
Emissions from Electricity -- Production Based	28.2	38.8	21.2	17.7	45.5%
Emissions from Electricity -- Consumption Based	43.3	52.8	32.5	20.3	38.4%
Emissions from Non-electricity Sector	63.4	76.9	47.6	29.4	38.2%
Total Gross Emissions (Consumption Based)	106.8	129.7	80.1	49.6	38.3%

According to the analyses in Sections A and B, the Power Sector in Maryland can reach the state mitigation goal by implementing in-state policies and measures affecting the power sector and by purchasing allowances from the RGGI C&T system. The power sector would implement in-state mitigation options as long as the marginal abatement cost is less than or equal to the price of the allowance, and purchase the remaining allowances from power sector in other states (in the free granting case) or the auctioneer (in the auction case).

Next, we need to look at the mitigation options list of the non-C&T sectors in Maryland in order to evaluate:

A. whether the contributions of mitigation options from all the non-C&T sectors would meet the state goal and,
B. if not, what would be the carbon tax level to non-C&T sectors to achieve the goal;
C. if the mitigation options meet the state goal, how many incremental tons of CO_2 will be abated for each increasing $ of carbon tax.

Table 10 shows the options list of non-C&T sectors in Maryland. Note that some RCI sector options that entirely or partially contribute to electricity consumption reduction are included in the options list to develop the MD power sector mitigation cost curve in Figure 1. To avoid double-counting, the part of emission mitigation potentials related to electricity consumption reduction of those options are not included in the list in Table 10. Please also note that only options with quantified reduction potentials and costs/savings estimated by the TWGs are included in Table 10. Column 3 of the table presents the estimated 2020 annual GHG reduction potential for each option, with reduction potentials translated into percentages of the 2020 BAU emissions level in Column 5. The estimated cost or cost saving per ton of GHG removed by each option in 2020 is presented in Column 4. The options are ordered in ascending sequence in terms of cost, beginning with the cheapest option. Column 6 calculates the cumulative GHG reduction potentials of the first *n* policy options listed in the table. The last column presents the proportion of GHG mitigation contributed by each option.

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Table 10. Mitigation Options List of Non-C&T Sectors in Maryland

Sector	Climate Mitigation Actions	Estimated 2020 Annual GHG Reduction Potential (MMtCO2e)	Estimated Cost or Cost Savings per ton GHG Removed	GHG Reduction Potential as Percentage of 2020 Baseline Emissions[1]	Cumulative GHG Reduction Potential	Weights (add-up to 100)
TLU-3	Transit	2.80	-$917.00	3.64%	3.64%	5.39
TLU-9[2]	Commuter Choice and other Pricing Measures	2.20	-$322.00	2.86%	6.50%	4.24
AFW-2	Managing Urban Trees and Forests for Greenhouse Gas Benefits (With Mitigation of Forest Loss Due to Insects, Disease, Pests, and Invasive Species)	1.90	-$251.00	2.47%	8.97%	3.66
AFW-5	"Buy Local" Programs for Sustainable Agriculture, Wood, and Wood Products--a. Farmer's Market	0.03	-$167.00	0.04%	9.01%	0.06
RCI -4	Improved design, construction, appliances, and lighting in new and existing state and local government buildings, "Government Lead-by-example"	0.44	-$60.00	0.58%	9.59%	0.85
RCI -7	More Stringent Appliance/Equipment Efficiency Standards *(state-level, or advocate for regional or federal-level standards)*	0.06	-$54.00	0.08%	9.67%	0.13
RCI -10	Energy Efficiency Resource Standard (EERS)	3.83	-$52.00	4.98%	14.65%	7.38
RCI -1	Improved Building and Trade Codes and Beyond-Code Building Design and Construction	0.73	-$39.00	0.95%	15.61%	1.41
AFW-8	Nutrient Trading With Carbon Benefits	0.14	-$30.00	0.18%	15.79%	0.27
AFW-9	Waste Management Through Source Reduction and Advanced Recycling	29.20	-$6.00	37.96%	53.75%	56.26
AFW-6	Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production--Methane Utilization From Livestock Manure and Poultry Litter	0.04	$0.20	0.05%	53.80%	0.08
AFW-7	In-State Liquid Biofuels Production-Biodiesel	0.18	$7.00	0.23%	54.04%	0.35
AFW-6	Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production--Biomass (Inc. Ag. Residue, Forest Feedstocks, and Energy Crops)	0.50	$12.00	0.65%	54.69%	0.96
AFW-3	Afforestation, Reforestation, and Restoration of Forests and Wetlands--a. Afforestation	0.60	$29.00	0.78%	55.47%	1.16

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AFW-4	Forested Land--b. Forested land	2.70	$37.00	3.51%	58.98%	5.20
AFW-3	Afforestation, Reforestation, and Restoration of Forests and Wetlands--b. Riparian areas	0.10	$44.00	0.13%	59.11%	0.19
TLU-4[2]	Low Greenhouse Gas Fuel Standard	1.90	$60.00	2.47%	61.58%	3.66
AFW-7	In-State Liquid Biofuels Production-Ethanol	0.91	$80.00	1.18%	62.76%	1.75
AFW-4	Forested Land--a. Agricultural Land	0.28	$87.00	0.36%	63.12%	0.54
RCI -8	Rate structures and Technologies to Promote Reduced GHG Emissions (including inverted block rates)	0.06	$115.00	0.08%	63.20%	0.12
AFW-1	Forest Management for Enhanced Carbon Sequestration (With Mitigation of Forest Loss Due to Insects, Disease, Pests, and Invasive Species)	0.09	$135.00	0.12%	63.32%	0.17
TLU-10[2]	Transportation Technologies	3.20	$650.00	4.16%	67.48%	6.17

[1] 2020 projected gross CO2 emissions from non-C&T sectors are 76.92 MMtCO2e.
[2] Numbers presented in the column of "Estimated Cost or Cost Savings per ton GHG Removed" are the average of the high and low estimates by the TLU TWG.

From Column 6 of Table 10, we see that the cumulative mitigation potential of options with cost savings is around 53.7% of the non-C&T sectors' 2020 BAU emissions level. As shown in Table 9, the reduction goal of 25% below the 2006 level translates to 38.2% below 2020 BAU level for the non-C&T sectors. Therefore, the state goal can be over-achieved by implementing only the cost-saving mitigation options.

Thus, to achieve current 2020 goal, the carbon tax is not needed. However, we can examine the potential of a carbon tax for additional mitigation in the following way. We next fit a smooth curve through the points of options with unit mitigation cost higher than zero (see the smooth curve in Figure 2). Based on the curve, Table 11 presents the total reduction potentials of the non-C&T sectors with assumed carbon tax levels at $1 to $7. Approximately, for every $1 increase in the carbon tax, an additional 100 thousand tons of CO2 will be abated in the non-C&T sectors.

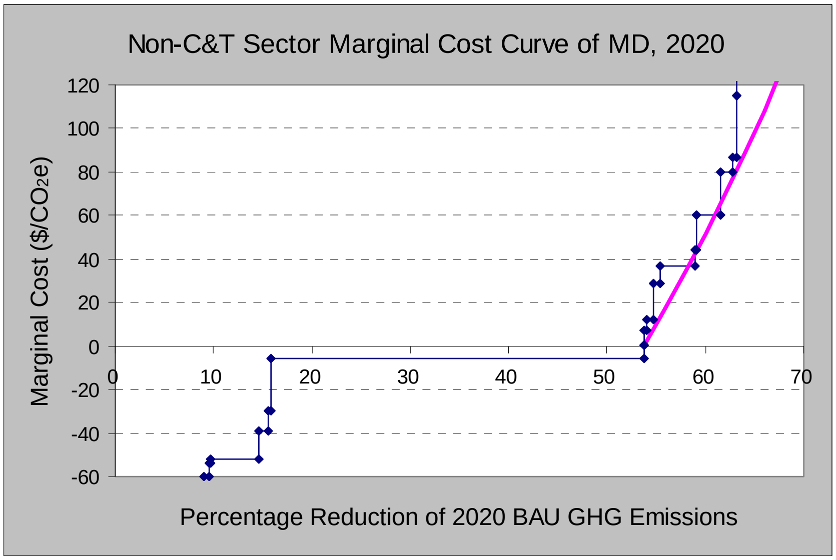

Figure 2. Marginal Cost Curve of Non-C&T Sectors in Maryland

Note: The step curve is developed based on the options data in Table 10. The horizontal axis represents the percentage of GHG emissions reduction, and the vertical axis represents the marginal cost or savings of mitigation. In the figure, each horizontal segment represents an individual mitigation option. The width of the segment indicates the GHG emission reduction potential of the option in percentage terms. The height of the segment relative to the x-axis shows the average cost (saving) of reducing one ton of GHG with the application of the option. The smooth curve is fitted through the points of options with unit mitigation cost higher than zero.

Table 11. Carbon Tax Level and Corresponding Total Reduction Potential in Non-C&T Sectors

Carbon Tax ($/tCO2)	Total Reduction Potential % 2020 BAU level	Total Reduction Potential in MMtCO2	Incremental Reduction per Dollar Increase in the Carbon Tax (thousand tCO2)
0	53.71%	41.31	
1	53.84%	41.41	101.07
2	53.97%	41.51	100.79
3	54.10%	41.62	100.50
4	54.23%	41.72	100.21
5	54.36%	41.82	99.93
6	54.49%	41.92	99.65
7	54.62%	42.01	99.36

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3) Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options*. http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.
4) Maryland Power Plant Research Program. 2006. *The Potential for Biomass Cofiring in Maryland*. http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

Quantification Methods:

Emissions of GHG from coal were compared to emissions from co-fired biomass with the same heating potential. Additionally, coal GHG emissions were compared to GHG emissions from equivalent NGCC power units for the repower portion of this policy option. The difference in emissions from coal to biomass and NGCC is the net GHG reduction for this policy option. Total costs are calculated from levelized NPV costs of power production, adjusted for Maryland construction and fuel costs.

Key Assumptions:

Biomass co-firing initiates in 2010 and increases linearly over a 5 year period to a maximum of 8% of energy input at converted plants.
Estimated 'Warrior Run' conversion costs are representative of future conversion costs.
Increased demand for biomass does not alter fuel costs.
Conversion from coal to NGCC occurs at a rate of 3% per year, starting in 2010.
Existing coal power is displaced by both biomass and NGCC.