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Agriculture, Forestry, and Waste Management Technical Work Group

Introduction:

Forests and trees. Their benefits are extensive, complex, and beyond measure. Trees remove carbon dioxide from the air and store carbon in their trunks and branches; trees absorb and filter nitrogen dioxide, sulfur dioxide, ozone, carbon monoxide, and particulate matter less than 10 microns in size; trees release oxygen and intercept rainwater and dust. The process of evapotranspiration and shade from trees lowers summertime air and surface temperatures.

Shade and lower surface temperatures reduce the need for air conditioning in buildings thereby reducing the need for the production and transmission of electricity. Reduced energy production reduces emissions of green house gases and carbon from power plants. Shade and lower surface temperatures reduce maintenance needs of infrastructure which, in turn, reduces the conversion of raw materials to asphalt and concrete which reduces the production of green house gases from manufacturing plants and transportation and heavy equipment. Shade and lower surface temperatures reduce the evaporation of chemicals from car engines and reduces the need for air conditioning in cars. This reduces the amount of fuel burned and reduces the emissions from cars. And these are but a few examples.

Sustainable forest and urban forest management is essential to healthy, productive forests and trees that maximize mitigation for green house gases and carbon sequestration. In the face of climate change, it is critical that we do everything within our power to increase the amount and enhance the condition of forests and trees everywhere. Their benefits span arenas making them our single most cost effective tool for mitigating for climate change.

Summary List of Draft Priorities for Analysis

	Policy Option	GHG Reductions (MMtCO ₂ e)			Net Present Value 2008–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Level of Support	
		2015	2020	Total 2008–2020				
AFW-1	Forest Management for Enhanced Carbon Sequestration (with Mitigation of Forest Loss Due to Insects, Disease, Pests and Invasive Species)	TBD	TBD	TBD	TBD	TBD	Pending	
AFW-2	Managing Urban Trees and Forests for Greenhouse Gas Benefits (with Mitigation of Forest Loss Due to Insects, Disease, Pests and Invasive Species)	1.17	1.90	13.27	-2,017	-251	Pending	
AFW-3	Afforestation, Reforestation and Restoration of Forests and Wetlands	0.4	0.6	3.9	112.7	28.88	Pending	
AFW-4	Protection & Conservation of Agricultural Land, Coastal Wetlands and Forested Land a. Agricultural land b. Forested land c. Coastal Wetlands	a. 0.170 b. 2.4 c. NQ	a. 0.276 b. 2.7 c. NQ	a. 1.93 b. 30.5 c. NQ	a. 168.6 b. 1,128.7 c. NQ	a. 87 b. 37 c. NQ	Pending	
AFW-5	“Buy Local” Programs for Sustainable Agriculture, Wood and Wood Products	a. Farmer’s Market	0.016	0.032	0.198	TBD	TBD	Pending
		b. Local Produce	NQ	NQ	NQ	NQ	NQ	
		c. Locally Grown and Processed Lumber	TBD	TBD	TBD	TBD	TBD	
AFW-6	Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production	Biomass (inc Ag Residue, Forest Feedstocks and Energy Crops)	0.193	0.440	2.50	33.1	13	Pending
		Methane utilization from livestock manure:	0.022	0.036	0.254	57.0	0.22	
AFW-7	In-State Liquid Biofuels Production	Ethanol	2.17	2.51	12.2	1,020	83.85	Pending
		Biodiesel	0.36	0.81	4.8	86.8	18.04	
AFW-8	Nutrient Trading with Carbon Benefits	0.087	0.141	0.987	29.7	30.1	Pending	
AFW-9	Waste Management through Source Reduction & Advanced Recycling	17.0	29.2	187	-1,118	-6	Pending	
	Sector Total After Adjusting for Overlaps ^a							
	Reductions From Recent Actions							
	Sector Total Plus Recent Actions							

AFW-1 Forest Management for Enhanced Carbon Sequestration

Policy Description

Healthy, sustainable and productive forests provide a vast array of benefits. Sustainable forest management enhances environmental benefits and increases social and economical benefits, as well. This policy enhances productivity of healthy sustainable forests. Benefits from this option include: increased rates of carbon dioxide (CO₂) sequestration in forest biomass through healthier forests, increased amounts of carbon stored in harvested, durable wood products, and the availability of renewable biomass for energy production.

Practices may include: supplemental planting on poorly stocked lands, age extension of managed stands, thinning and density management, fertilization and wood waste recycling, expanded use of short-rotation woody crops (for fiber and energy), expanded use of genetically preferred species, modified biomass removal practices, and/or fire management and risk reduction.

Programs that reduce populations of invasive and damaging insects, diseases, plants and other pests enhance forest health and long-term sustainability. Reducing pressure from invasive species increases benefits from forests, helps mitigate for GHG emissions and sequester more carbon. Threats from invasive species are increasing in number and severity, especially since forestlands are more vulnerable due cumulative effects of other stressors. Some native species populations exceed the carrying capacity of the habitat, undermining regeneration efforts, and therefore sustainability. For example, the over-abundance of white-tailed deer places excessive browse pressure on regeneration and understory plants in all forests. *(difficult to quantify effects on emissions and costs as implementation mechanisms and efficacy vary widely)*

Policy Design

Education and outreach especially for citizens and land managers will be an important part of this goal both to underscore importance of forests and to teach best management practices for forests.

Goals:

- Improve sustainable forest management on 25,000 acres of private land by 2020
- Manage XX% of public lands using sustainable management practices by 2020
- As markets are developed, biomass removed through forest management will be used first for long-term storage in durable wood products then for beneficial uses such as bio-fuels and energy. NOTE: The biomass generated from improved management practices is quantified in AFW-1, and the GHG implications of using the increased biomass for durable wood products and energy production is quantification in AFW-5 and AFW-6, respectively.
- (Possible goal) Implement forest certification on XX% of public and private lands by 2020?

Parties Involved: DNR, MDE, MDA, DNR, counties, SHA, Chesapeake Bay Program, NRCS, USFS, private land owners, public land owners, private sawmills, landscaping industry, nursery industry, MD Cooperative Extension and Master Gardeners, and artisan community.

Implementation Mechanisms

- Outreach and education
- Revise FCA
- Support Sustainable Forestry Act
- Legislation restricting sale of priority non-native invasive species
- Outreach and education about invasive species and control methods
- Use offset funds to enhance forest management on private lands and reduce conversion to other land uses
- Develop prioritization of invasive species and identify species of high priority
- Shift decision making efforts to plan ahead for invasive species problems—move towards prevention or proactive management rather than control and reactive treatment
- Develop mechanism to aggregate smaller land holdings to compete in meaningful markets
- Include sustainable forest management in the RGGI Carbon Rule

Related Policies/Programs in Place

Forest Conservation Act

Sustainable Forestry Act

Types(s) of GHG Reductions

CO₂: Enhancement of annual carbon sequestration from forest growth and reforestation through forestry management programs. Removal of fuels that contribute to wildfire emissions. Maintain carbon sequestration through the production of durable wood products. Reduce emissions by reducing use of fossil fuels replaced by energy from woody biomass. Reduce emissions by preventing the release of carbon from dead and dying trees. Reduce wildfire emissions by maintaining healthy forests.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

- **Data Sources:** [TBD by CCS on TWG approval]
- **Quantification Methods:** [e.g. Full life-cycle analysis with supply/demand equilibrium adjustments on TWG approval]
- **Key Assumptions:** [TBD, as needed on TWG approval]

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MWG meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the MWG]

AFW-2 Managing Urban Trees and Forests for Greenhouse Gas Benefits

Policy Description

Healthy, sustainable urban forests are essential to our social, economic, and environmental welfare. This policy option maintains and improves the health and longevity of trees in urban and residential areas. Trees in urban areas avoid emissions from power production and maintenance of built structures and infrastructure. Further, urban trees contribute to lower summertime temperatures in urban areas, reducing and the formation of ground-level ozone and the evaporation and volatilization of organic compounds from vehicles. They can also store carbon in their biomass, and reduce ambient concentrations of VOCs, NO_x, fine PM, and other air and water pollutants.

Statewide, urban canopy cover in Maryland is 40.1% (Nowak, USFS). This option seeks to increase canopy cover of urban trees. It will also increase the utilization of wood recovered from urban trees for energy production or in value-added products for long-term carbon storage, encourage species diversity while extending survival and longevity rates, and address insects, invasive species and disease in urban forest settings.

Policy Design

Educate the public and legislators on the importance of urban forests for ozone & temperature regulation leading to reduced energy use.

Goals:

- Enhance green infrastructure planning including tying green areas together (non-quantified goal).
- Develop incentives to better use urban wood recovery highest order wood product (non quantified goal).
- Achieve urban tree canopy goal of 50% (averaged over all urban land use types) by 2020.

Goals related to Forest Pests and Invasive Species (non quantified goals):

- Develop prioritization of invasive species and identify species of high priority
- Shift decision making efforts to plan ahead for invasive species problems—move towards prevention or proactive management rather than control and reactive treatment

Timing: See goals, above.

Parties Involved: DNR, MDE, MDA, DNR, counties, municipalities, SHA, Chesapeake Bay Program, NRCS, USFS, private land owners, public land owners, private sawmills, artisan community, landscaping industry, nursery industry, MD Cooperative Extension and Master Gardeners, arborist industry

Other: TBD.

Implementation Mechanisms

PLACE HOLDER:

- Outreach and education
- Monitor and report plantings at local level
- Provide enhanced funding from conservation programs like Program Open Space to local jurisdictions to implement policies (like wood recovery and canopy goals) and/or plant trees
- Legislation restricting sale of priority non-native invasive species
- Outreach and education about invasive species and control methods

Related Policies/Programs in Place

Strengthen, fund, and support the Urban Community Forestry Act: Add urban tree canopy goals to Act

Types(s) of GHG Reductions

- **CO₂:** Avoidance of emission of carbon dioxide and associated GHGs through the reduction of heating and cooling needs in urban areas. Carbon sequestration due to tree growth.
- **CO₂:** (not quantified) Reduction of surface temperatures reducing volatilization of gasses from vehicles. Maintaining carbon sequestration by creating durable wood products. Reduce use of fossil fuels by using wood waste for energy.

Estimated GHG Reductions and Net Costs or Cost Savings

• Data Sources:

- Data about existing and potential urban tree canopy cover for Maryland from: Galvin et al. 2006a: A Report on Baltimore City's present and potential Urban Tree Canopy. Galvin et al. 2006b: A Report on Annapolis' present and potential Urban Tree Canopy. Galvin et al. 2008: A Report on the City of Frederick's Existing and Possible Urban Tree Canopy. Maryland Department of Natural Resources – Forest Service.
- Information about current numbers of trees in urban forest and annual C storage in urban trees in MD from Nowak et al., USFS, Northern Research Station, Urban Forest Effects on Environmental Quality State Summary data for Maryland (http://www.fs.fed.us/ne/syracuse/Data/State/data_MD.htm).
- Fossil fuel reductions through reduced demand for cooling and protection from wind from: McPherson and Simpson (1999). Carbon Dioxide Reduction Through Urban Forestry, USFS PSW-GTR-171.
- Data on costs and benefits of tree planting from McPherson, E.G. et al. 2006. Piedmont Community Tree Guide: Benefits, Costs, and Strategic Planting. USDA Forest Service Pacific Southwest Research Station General Technical Report PSW-GTR-200.
- Additional data on benefits of tree canopy in MD are from Galvin, M. 2007. A Report on Hyattsville's Street Trees. Maryland Department of Natural Resources – Forest Service.

• Quantification Methods:

This option quantifies the cumulative impact on carbon sequestration and avoided fossil fuel emissions of incrementally increasing existing canopy cover in MD. Specifically, AFW-2 seeks to achieve a 50% urban canopy cover goal by 2020. Currently, Maryland's urban areas are 40.1% forested (Nowak, USFS), so this goal recommends a 25% increase over the existing canopy cover by 2020. The goal of 50% is based on recent assessments of existing and potential urban tree canopy (UTC) in Maryland. For example, Baltimore currently has a canopy cover of 20% and a goal of 46.3% is recommended as feasible within the 2030-2036 timeframe (Galvin et al. 2006a). Annapolis' urban areas are currently 41% forested, and a 50% goal is recommended within the same timeframe (Galvin et al. 2006b). Frederick is currently only 12% forested (Galvin et al. 2008), but there appear to be no obvious barriers to increasing its UTC. While the UTC analyses cited above recommend a longer timeframe to reach the UTC targets, this analysis seeks to quantify the effects of policy implementation within the 2008-2020 timeframe described by the MWG.

Currently MD contains 89.4 million urban trees: thus this option quantifies the effect of adding 2.2 million new trees total by 2020. The number of trees planted each year is constant at roughly 1.7 million per year, with the target number of trees planted by 2020.

GHG benefits are twofold: direct C sequestration by planted trees and avoided GHG emissions from strategic tree planting to reduce energy demand due to heating and cooling.

A. Direct C Sequestration in Urban Trees

Annual C sequestration per urban tree is calculated as 0.006 tC/tree/year, based on statewide average data reported by the USFS. This is the average annual per-tree C sequestration value when the total estimated urban forest C accumulation in MD (544,000 tC/year) is divided by the total number of urban trees in MD (89.4 million). Since trees planted in one year continue to accumulate C in subsequent years, annual C sequestration in any given year is calculated as the sum of C stored in trees planted in that year, plus the sequestration by trees that were planted in prior years.

B. Avoided Fossil Fuel Emissions

Offsets from avoided fossil fuel use for heating and cooling are the sum of three different types of savings: avoided emissions from reduced cooling demand, avoided emissions from reduced demand for heating due to wind reduction (this benefit is only available for evergreen trees), and enhanced fossil fuel emissions needed for heat due to wintertime shading. Calculations for avoided fossil fuel offsets are based on calculations presented by McPherson et al. in GTR-PSW-171 (Table AFW2-1). For this analysis, it was assumed that half of the trees would be planted in residential settings, or close enough to buildings to result in avoided emissions. For the trees where this avoided emissions benefit is available, it was further assumed that the trees planted would be evenly split among residential settings with pre-1950, 1950–1980, and post-1980 homes, and that all planted are medium-sized evergreens. These avoided emission factors assume average tree distribution around buildings (i.e. these fossil fuel reduction factors are average for existing buildings, but do not necessarily assume that trees are optimally placed around buildings to maximize energy efficiency). These factors are also dependent on the fuel mix (coal, hydroelectric, nuclear, etc.) in the region, and are thus likely to change if the electricity mix changes from its 1999 distribution.

Table AFW2-1. Factors Used To Calculate CO₂e Savings (MMtCO₂e/Tree/Year) From Reduced Need for Fossil Fuel for Heating and Cooling, and From Windbreak Effect of Evergreen Trees

Fossil Fuel Offsets: Evergreen Trees (Mid-Atlantic Climate Region)				
Housing vintage	shade-cooling	shade-heating	wind-heating	net effect
pre-1950	0.0168	-0.0315	0.1294	0.1147
1950-1980	0.0275	-0.0403	0.1555	0.1427
post-1980	0.0232	-0.0324	0.133	0.1238
Average	0.0225	-0.0347	0.1393	0.1271
Average (MMtCO ₂ e)				1.2707E-07

Source: McPherson et al., 1999.

C. Overall GHG Benefit of Urban Tree Planting

Total GHG benefits are calculated as the sum of direct C sequestration plus fossil fuel offset from reduced cooling demand and wind reduction (Table AFW2-2).

Table AFW2-2. Overall GHG Benefit (MMtCO₂e/year) of Implementing AFW-2.

	Trees planted this year	Trees planted in previous years	GHG sequestered (MMtCO ₂ e/ yr)	GHG avoided (MMtCO ₂ e/ yr)
2008	1,698,440	0		0.0379
2009	1,698,440	1,698,440		0.0758
2010	1,698,440	3,396,879		0.1136
2011	1,698,440	5,095,319		0.1515
2012	1,698,440	6,793,759		0.1894
2013	1,698,440	8,492,198		0.2273
2014	1,698,440	10,190,638		0.2652
2015	1,698,440	11,889,078		0.3030
2016	1,698,440	13,587,517		0.3409
2017	1,698,440	15,285,957		0.3788
2018	1,698,440	16,984,397		0.4167
2019	1,698,440	18,682,836		0.4546
2020	1,698,440	20,381,276		0.4924
cumulative totals		22,079,716		3.4471

D. Cost Analysis

Economic costs of tree planting are calculated as the sum of tree planting and annual maintenance, including the costs of program administration and waste disposal. Economic benefits of tree planting include the cost offset from reduced energy use, as well as the estimated economic benefits of services such as provision of clean air, hydrologic benefits such as storm water control, and aesthetic enhancement.

The cost of tree planting in MD was assumed to be \$275/ tree.¹ This is a one-time cost incurred in the year of planting. Annual maintenance costs include pruning, pest management, administration, removal, and infrastructure repair due to damage from trees. Over a 40-year period, these costs were estimated at \$22/tree/year, based on McPherson et al. (2006). This value assumes a medium-sized evergreen tree, and is an average of trees under public and private management. This value is consistent with per-tree annualized maintenance costs published for other states and regions.

The economic benefit of planting urban trees includes the value of aesthetic improvement, air and water quality improvements, stormwater management, and energy savings. Annual economic benefit per tree was estimated at -\$96.30/ tree/ year, using information from Galvin et al. (2007) on the economic value of Hyattsville, Maryland’s urban forest.

Net economic costs for this option are calculated as the difference between costs of planting + maintenance and economic benefit realized by urban trees. Negative costs therefore refer to net economic benefits, where estimated benefits exceed overall costs. For this analysis, net economic benefit per tree was estimated at -\$74.30/tree/year. Discounted costs were calculated assuming a 5% discount rate (Table AFW2-3). AFW-2 has a net economic benefit of -\$251.52/tCO₂e mitigated.

AFW2-3. Economic benefits and costs of implementing AFW2.

	Trees planted this year	Trees planted in previous years	Total \$\$ benefit	Net benefit (costs minus benefits)	Discounted net benefits
2008	1698440	0	\$0	\$467,070,909	\$467,070,909
2009	1698440	1698440	\$163,559,740	\$340,876,842	\$324,644,611
2010	1698440	3396879	\$327,119,480	\$214,682,774	\$194,723,605
2011	1698440	5095319	\$490,679,221	\$88,488,707	\$76,439,872
2012	1698440	6793759	\$654,238,961	-\$37,705,361	-\$31,020,294
2013	1698440	8492198	\$817,798,701	-\$163,899,428	-\$128,419,491
2014	1698440	10190638	\$981,358,441	-\$290,093,496	-\$216,472,233
2015	1698440	11889078	\$1,144,918,182	-\$416,287,563	-\$295,847,799
2016	1698440	13587517	\$1,308,477,922	-\$542,481,631	-\$367,172,921
2017	1698440	15285957	\$1,472,037,662	-\$668,675,698	-\$431,034,317
2018	1698440	16984397	\$1,635,597,402	-\$794,869,766	-\$487,981,084
2019	1698440	18682836	\$1,799,157,142	-\$921,063,833	-\$538,526,947
2020	1698440	20381276	\$1,962,716,883	-\$1,047,257,901	-\$583,152,386
Cumulative totals		22079716	\$12,757,659,738	-\$3,771,215,443	-\$2,016,748,473

¹ Mike Galvin, Supervisor, Urban and Community Forestry, MD-DNR. Personal communication with J. Jenkins, January 2008. Range of costs estimated at \$250-300.

- **Key Assumptions:** Economic costs and benefits of urban tree cover. Feasibility of accelerated implementation of UTC recommendations.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MWG meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the MWG]

AFW-3 Afforestation, Reforestation and Restoration of Forests and Wetlands

Policy Description

Increasing forest and tree cover provides additional benefits for mitigation of GHG. This policy option promotes forest cover and associated carbon stocks by regenerating or establishing healthy, functional forests through afforestation (on lands that have not, in recent history, been forested including agricultural lands) and reforestation (on lands with little or no present forest cover) where current beneficial practices are not displaced. Successful establishment requires commitment for as much as 20 years. Forest patches should be sufficient in size to function as a community of trees.

In addition, this policy promotes the implementation of practices such as soil preparation, erosion control, and supplemental planting to ensure conditions that support forest growth. Identify areas, including all wetlands, that are in need of physical intervention to return forest habitats to full vigor. Additional areas of concern are linking islands of fragmented forests to restore function, recovering severely disturbed lands and reversing the effects of continued toxicity.

Policy Design

Carbon sequestration via afforestation is important, but other ancillary benefits provided by forests, in terms of greenspace, quality of life, and avoided emissions are also critical and add to the value of forest land for the community (see Introduction).

Maryland is a member of the Regional Greenhouse Gas Initiative (RGGI) (<http://www.rggi.org>), which mandates the existence of an inter-state CO₂ Budget Trading Program to reduce emissions from the power sector (RGGI applies to fossil fuel-burning plants larger than 25MW). Beginning with implementation of the CO₂ Budget Trading Program on January 1, 2009, emissions entities are permitted to use offset projects to meet up to 3.3% of their emissions limitations (this could increase to 5% and 10% in later years). Specific uses of revenues from sale of carbon credits is at the discretion of states.

To be eligible to participate in the Program, an offset project must submit to specific reporting requirements as documented in the RGGI Model Rule (http://www.rggi.org/docs/model_rule_corrected_1_5_07.pdf). In addition, a forest offset project must:

- Be an afforestation project (i.e. land must have been in a non-forested condition for at least ten years prior to commencement of the offset project);
- Be protected in perpetuity via a conservation easement;
- Commit to management in accordance with widely accepted environmentally sustainable forestry practices, designed to promote the restoration of native forests by using mainly native species and avoiding the introduction of invasive nonnative species; and
- (if commercial timber harvest is planned) Enroll in a certification program such as those offered by the Forest Stewardship Council (FSC), Sustainable Forestry Institute (SFI), American Tree Farm System (ATFS), or such other similar organizations.

Additional categories for offset projects may be added to the list of eligible projects, at the discretion of individual states. For example, reforestation projects or forest management projects may be eligible to participate in the CO2 Budget Trading Program at some future point.

While the above requirements are prerequisites for participation in the RGGI offset program, all categories of afforestation and reforestation projects will reduce the atmospheric GHG burden. Thus AFW-3 is not limited to projects that are eligible for RGGI participation, and the associated costs of easement purchase and certification have been excluded from the quantification.

Goals:

- Establish sufficient acreage in forests to offset loss of 900 acres each month to development, beginning in June 2008 and continuing through December 2020.
- Establish riparian buffers at a rate of 900 miles/year (50-foot width either side of stream) from 2008 to 2020, and continue until 70% of all stream miles in the State are buffered (Chesapeake Bay Forest Conservation Initiative, December 2007).
- Increase wetland area (Non quantified goal).

Timing: See goals, above.

Parties Involved: DNR, counties, SHA, MDA, MDE, Chesapeake Bay Program, NRCS, private land owners

Implementation Mechanisms

PLACE HOLDER:

- Outreach and education
- Green infrastructure plans
- FCMA – tax law program
- Economic incentive to private landowners including promotion of non-traditional products such as hunting leases and passive recreation
- Review fee-in-lieu dollars (amount and use) within the Forest Conservation Act. Fees should be available for easements and set at fair market values. Fee-in-lieu should be used as a last resort and in amounts that make it.
- Allowances from RGGI auctions should be available to for reforestation and restoration.
- Also property and inheritance tax incentives

Related Policies/Programs in Place

PLACE HOLDER: FCA;

Recommend that the Commission for Climate Change and RGGI increase acknowledgment and importance of forests as significant in climate change mitigation

See example from Washington County in implementation of the Forest Conservation Act.

Types(s) of GHG Reductions

CO₂: Increasing annual carbon sequestration from establishing forest and riparian cover.

Estimated GHG Reductions and Net Costs or Cost Savings

- **Data Sources:**

- USDA Forest Service (USFS) Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the US, General Technical Report NE-343 (also published as part of the Department of Energy Voluntary GHG Reporting Program).
- USFS Forest Inventory Analysis data, provided by the USFS for the MD Forestry Inventory and Forecast (Jim Smith, USFS).
- Walker et al. 2007. Terrestrial carbon sequestration in the Northeast: Opportunities and Costs, Part 3A: Opportunities for Improving Carbon Storage through Afforestation of Agricultural Lands.

- **Quantification Methods:**

A. *GHG benefit*

Forests planted on land not currently in forest cover will likely accumulate carbon at a rate consistent with accumulation rates of average forest cover in the region. Therefore, C sequestered by afforestation activities was assumed to occur at the same rate as C sequestration in average MD forest. Average C storage was found based on USFS GTR-NE-343 assuming afforestation activity with a forest type distribution of 70% Oak-Pine, 15% Oak-Pine and 15% Loblolly-Shortleaf Pine. This distribution is reflective of the average forest composition in MD, and is based on USDA Forest Service Forest Inventory and Analysis statistics.² A 45-year project period was assumed, such that the rate of forest C sequestration under afforestation projects for an average acre in MD was estimated at 1.2 t C acre⁻¹ year⁻¹ (Table AFW3-1). Forests planted in one year continue to sequester carbon in subsequent years. Thus C storage in a given year is calculated as the sum of annual C sequestration on cumulative planted acreage.

Table AFW3-1. Forest Carbon Sequestration Rates for Afforestation Activity

	MtC/ac (0 yr)	MtC/ac (45 yr)	MtC/ac/yr
Oak-Hickory	0.8	56.2	1.2
Oak-Pine	1.7	48.5	1.0
Loblolly-shortleaf pine	1.7	41.9	0.9
Weighted average			1.2

The rate of afforestation was estimated at 900 acres/ month, for a total of 10,800 acres afforested annually. In 2008, it was assume that policy implementation would only occur over 7 months (beginning June 2008), so 6,300 acres would be afforested in that year. Between 2008 and 2020, a total of 135,900 acres would be afforested under AFW-3, for a total of 3.9 MMTCO₂e stored (Table AFW3-2).

² <http://www.fs.fed.us/ne/global/pubs/books/epa/states/MD.htm>

Table AFW3-2. Acreage planted each year under AFW-3, and total C sequestered.

	acres planted this year	acres planted in prior years	C sequestered (MtC/ yr)	C sequestered (MMtCO ₂ e/yr)
2008	6300	0	7256	0.027
2009	10800	6300	19695	0.072
2010	10800	17100	32135	0.118
2011	10800	27900	44574	0.163
2012	10800	38700	57013	0.209
2013	10800	49500	69452	0.255
2014	10800	60300	81891	0.300
2015	10800	71100	94331	0.346
2016	10800	81900	106770	0.391
2017	10800	92700	119209	0.437
2018	10800	103500	131648	0.483
2019	10800	114300	144087	0.528
2020	10800	125100	156527	0.574
Total		135900		3.903

B. Economic Costs

Estimated per acre costs for afforestation in Maryland were obtained from Walker et al. (2007), who surveyed state foresters, regional foresters, or other foresters and related specialists in the US Forest Service, universities, and forest companies and reported results on a state-by-state basis. Costs include site preparation, labor, seedlings, and herbivore protection (Walker et al. 2007). Per acre afforestation costs in Maryland were estimated to be \$1,180 and \$980 for hardwoods and softwoods, respectively. Following the distribution of forest types used to calculate the GHG benefit of forest planting (see above), it was assumed that 70% of the planted forests would be hardwoods with the remainder in softwoods. Thus the weighted average cost to plant an acre of forest in MD was estimated at \$1,105. This is a one-time cost incurred in the year of planting. Based on this information, the net present value (NPV) for this option is \$112.7 million, with a levelized cost effectiveness of \$28.88/ ton C sequestered (Table AFW3-3).

AFW3-3. Economic costs of afforestation.

	Acres planted	Total cost	Discounted cost
2008	6300	\$6,961,500	\$6,961,500
2009	10800	\$11,934,000	\$11,365,714
2010	10800	\$11,934,000	\$10,824,490
2011	10800	\$11,934,000	\$10,309,038
2012	10800	\$11,934,000	\$9,818,131
2013	10800	\$11,934,000	\$9,350,601
2014	10800	\$11,934,000	\$8,905,335
2015	10800	\$11,934,000	\$8,481,271
2016	10800	\$11,934,000	\$8,077,401
2017	10800	\$11,934,000	\$7,692,763
2018	10800	\$11,934,000	\$7,326,441
2019	10800	\$11,934,000	\$6,977,563
2020	10800	\$11,934,000	\$6,645,298
total	135900		\$112,735,545

- **Key Assumptions:** See analysis, above.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

Timing of implementation depends on funds and policy changes; once trees are planted it could take 6 to 18 years before measurable carbon sequestration is achieved. (moved from Timing section)

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MWG meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the MWG]

AFW-4 Protection and Conservation of Agricultural Land, Coastal Wetlands and Forested Land

Policy Description

Land conservation offers an important mechanism to mitigate and adapt to climate change. Deforestation and other land-use changes account for as much as 25 percent of global greenhouse gas emissions. In addition, the increasing rate of sea level rise and associated erosion threaten Maryland's shoreline and associated coastal wetlands, removing another natural sink for greenhouse gases. For these reasons and more, we should protect Maryland's green infrastructure and coastal lands.

The State of Maryland and its partners should map, designate, prioritize and purchase areas/property interests that provide potential retreat for wetlands and wildlife, address shoreline erosion issues and provide ancillary carbon sequestration benefits.

Policy Design

Green infrastructure is our natural life-support system – an interconnected network of natural areas and other open spaces that maintains fully functioning ecosystems, sequesters carbon dioxide, sustains clean air and water, and provides a wide array of benefits to people and wildlife. Green infrastructure planning is a systematic and strategic approach to land conservation (similar to watershed-based planning) used to develop a guide to an open space system.

Implementation for green infrastructure plans include such elements as land acquisition, conservation easements, purchase and transfer of development rights, tax credits and structures, and zoning. The toolbox also includes refining land use planning policies and funding programs to allow users of these tools – governments, non-governmental organizations and private citizens – to more effectively protect Maryland's green infrastructure network.

Goals: Using green infrastructure plans as a guide, leverage funds to protect agricultural lands, forest lands, wetlands and coastal areas.

Agriculture lands: Decrease the conversion of agriculture land to developed land through the protection of 1.2 million acres of productive agricultural lands, to ensure no net loss by 2020.

Forest lands: Retain existing levels of forest cover in Maryland, estimated at 2.6 million acres, past 2020 and protect an additional 250,000 acres of forest by 2020 through legal mechanisms, with more than half in areas of high value to water quality (MD Forest Service). The acreage protected under AFW-4 is additional to acreage already slated for protection under other programs, and thus seeks to target upland forest areas, which are at greatest risk of conversion to developed use.

Wetlands: Assess the capacity of wetland types to sequester or release carbon, then focus protection and restoration efforts on wetland types with the greatest capacity for CO₂ sequestration. Next using GIS analysis, predict losses due to climate change and set regional

goal for restoration based upon predicted losses and funding availability. (Progress un-quantified)

Coastal lands: Protect priority areas designated for coastal wetland retreat and coastal forest lands using nonstructural shore erosion controls (i.e. living shoreline) – keeping pace with wetland, forest and critical habitat loss due to sea level rise. (Progress un-quantified)

[Goal?]

Timing: Next legislative session. *Are there interim goals before 2020 that could be set?*

Parties Involved: State and quasi-state government agencies including Maryland Department of Planning, non-profit organizations, foundations and individuals.

Other: Before colonization by Europeans, Maryland was 95% forested, the other 5% being marsh around Chesapeake Bay (Besley, 1916 and Powell and Kingsley, 1980). By 2000, forest had decreased to 42.8% of land cover. Similarly, Maryland has lost 50% of its pre-settlement wetlands (Tiner and Burke, 1995). Developed land use reached 509,200 ha in 2000. The Maryland Department of Planning has projected that by 2020 urban land use will increase by more than 25% from 1997 levels, and that forest cover will decrease a further 9% by 2020 from 1997 levels. Agriculture has also been projected to decrease by 9% during the same period. Approximately 31 percent of Maryland's 4,360 mile coastline, which encompasses the Chesapeake Bay, the Coastal Bays, and the Atlantic coast, is currently experiencing some degree of erosion. Maryland loses ~260 acres of tidal shoreline to erosion each year. Accelerating rates of sea level rise combined with increased development along Maryland's coastline tend to prolong and exacerbate shore erosion problems.

Implementation Mechanisms

Watershed-based planning is an important tool to accomplishing the goals below.

Possibly rank POS (Project Open Space) money by GHG benefit. There should be no diversion of land conservation funds from the open space program.

Increase the transfer tax on agriculture/forestry land transfers to non-ag/forestry uses. MD Land Preservation Taskforce suggests doubling that tax on conversion of agricultural lands to development.

Reduce or eliminate transfer taxes for continued ag/forestry uses.

- **Land Preservation Tax Credit – Modify Existing Income Tax Credit for Preservation and Conservation Easements (Md. Code Ann §10-723)**
 - Individuals *and corporations* would be allowed to take a *larger* conservation credit for conveying land located in Maryland for such purposes as historical or conservation preservation, agricultural use, forest use, open space, and natural resource conservation. The credit pool would be capped at \$100million per year and prioritized to first accept tax credits in coastal hazard areas.
 - A conservation credit is an income tax credit available to landowners who voluntarily preserve their land through the donation of a conservation easement and or fee title.

- Landowners with little or no taxable income derive fewer benefits from tax credits than do wealthier landowners with high incomes. To address this issue the credit should be made transferable (not the case under existing law) to other taxpayers for use on Maryland State income tax returns.
- The maximum credit would be raised to \$100,000 per year with an unlimited amount eligible for transfer and use by third parties and could be carried forward for 15 years (as is the case under current law).
- The transfer of the credit must be completed before the end of the tax year in order to use the credit for that year and must be registered with the Department of Assessment and Taxation to be valid.
- A cap of \$100 million will be placed on the first year of implementation, and will be increased each year by the percentage that the consumer price index (CPI-U) exceeds the previous years CPI-U.
- A fee of 3% of the appraised value of the donated interest will be charged on the sale of land preservation credits.
- Funds derived from this program will cover the cost of program management up to 2% with residual monies used for shoreline restoration/conservation fund.
- **CO2 Budget Trading Program**
 - Prioritize the sequestration of carbon through land conservation or restoration by making a fixed percent of CO2 emissions proceeds from future Maryland carbon markets exclusively available to land conservation projects.
 - Approve Subtitle 26.09 Maryland CO2 Budget Trading Program, with above modification.
- **Blanket Authorization for Local Bond Initiatives**
 - Authorize all County governments (some are presently restricted) to approve local bond initiatives specifically for land conservation and climate change adaptation.
- **Program Open Space (POS) Targeting**
 - One of the State's key implementation tools is Program Open Space (POS), which provides dedicated funds for Maryland's state and local parks and conservation areas. Since the program began in 1969, POS funds have never distributed based upon a project's greenhouse gas benefit. Nevertheless, this should now be a prominent consideration when determining the use of these funds. In addition, given the importance of this program, there should be no diversion of funding from the POS program.
- **Extend the Next Generation Farmland Acquisition Program to Maryland Forest Landowners**
 - Through the Maryland Agriculture and Resource Based Industry Development Corp. (MARBIDCO), provide eligible forest landowners up to 70 percent of the easement value of a property, giving the forester equity for a loan to purchase the property.

- The forester then has the option of finding a land preservation program to buy the development rights at a higher price within three years, paying back MARBIDCO and pocketing the difference. Otherwise, the state pays back MARBIDCO's investment (POS funds) and takes over the easement (Maryland Environmental Trust).
- **Others**
 - Statutory and regulatory changes to cited laws.
 - Modify income tax policy regarding land conservation credits, cap credit pool to \$100mm. Maximum credit suggested is \$100m/year. (*Concept: update Tax Credit program to be more similar to VA to incentivize land conservation.*)
 - Generate pool of money from industry off-set allowances; earmark a certain amount specifically for land conservation.
 - Encourage local bond initiatives – allow through state authorization.
 - Encourage and support right of local governments to hold taxes specifically for conservation.
 - Increase the transfer tax on ag/forestry land transfers to non-ag/forestry uses. MD Land Preservation Taskforce suggests doubling that tax on conversion of ag lands to development. Reduce or eliminate transfer taxes for continued ag/forestry uses.

Related Policies/Programs in Place

DNR's Greenprint Program
Program Open Space (POS)
Rural Legacy Program (RLP)
Maryland Agricultural Land Preservation Foundation (MALPF)
Maryland Environmental Trust (MET)
Maryland Historical Trust (MHT)

Types(s) of GHG Reductions

CO₂: Preventing release of carbon from conversion of forests, wetlands, and agricultural lands to development. Maintain annual carbon sequestration from forest growth, thriving wetlands and productive agricultural lands. Reduce urban sprawl thus avoiding additional emissions from vehicle miles traveled.

Estimated GHG Reductions and Net Costs or Cost Savings

- **Data Sources:**

National Resource Inventory (NRI) data for Maryland
The Maryland Agricultural Land Preservation Foundation
Farm and Ranch Land Protection Program

US Forest Service Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the US, General Technical Report NE-343 (also published as part of the Department of Energy 1605(b) Voluntary GHG Reporting Program)

USDA Forest Service Forest Inventory data statistics for Maryland,
<http://www.fs.fed.us/ne/global/pubs/books/epa/states/MD.htm>

- **Quantification Methods:**

Agriculture Lands GHG benefit

Studies are lacking on the changes in below and above-ground carbon stocks when agricultural land is converted to developed uses. For some land use changes, carbon stocks could be higher in the developed use relative to the agricultural use (e.g., parks). In other instances, carbon stocks are likely to be lower (graded and paved surfaces). CCS assumed that the agricultural land would be developed into typical tract-style suburban development. It was further assumed that 50% of the land would be graded and covered with roads, driveways, parking lots, and building pads. The final assumption was that 75% of the soil carbon in the top eight inches of soil for these graded and covered surfaces would be lost and not replaced. CCS assumed no change in the levels of above-ground carbon stocks.

The benefit in each year was determined by:

1. determining the amount of land protected in each year by estimating the annual rate of agricultural land lost (11,813 acres per year, determined from NRI Maryland data³) and assuming that agricultural land protected at an increasing rate up to 2020, where it is assumed there is no net loss of agricultural land.
2. multiplying the soil carbon content (assumed to be 0.017 MMtC per 1000 acres) on the protected land by 50% (representing graded and covered areas) and by 75% (fraction of soil carbon lost);
3. converting the soil carbon lost to CO₂ by multiplying by 44/12.

The greenhouse gas benefits are indicated in table 4-1.

Agriculture Lands cost

To estimate program costs in each year, CCS multiplied the estimated agricultural acres protected from development by the conservation cost. The conservation costs were assumed to be the average easement acquisition cost per acre by MALPF (\$5,952/acre)⁴. This cost of conservation is assumed to remain constant across the policy period. It is further assumed that subsidies are available through the Farm and Ranch Land Protection Program (FRPP)⁵ for a 50% cost share. While the administrative structure between MALPF and FRPP has changed, it is assumed that the cost share will continue and reduce the conservation costs by 50%⁶. The

³ The most recent NRI data available at the detailed state level is for 1982 to 1997. It is expected that data up to 2003 will be available in 2008.

⁴ Average easement acquisition cost per acre FY 2007 Easements Purchased by MALPF from The Maryland Agricultural Land Preservation Foundation five-year Annual Report for FY 2003-2007 (11 January 2008), available at <http://www.malpf.info/reports/AR2007Distn.pdf>.

⁵ The FRPP provides matching funds (up to 50%) to keep productive farm and rangeland in agricultural uses. Working through existing programs, USDA partners with State, tribal, or local governments and non-governmental organizations to acquire conservation easements or other interests in land from landowners.

⁶ Until December 31, 2005, FRPP matched up to 50% of MALPF's easement value. FRPP now requires a "before-and-after" appraisal incorporating a new definition of fair market value that adjusts values for the impact of the easement on adjacent parcels owned by the seller to calculate the value of the federal match. The FRPP easement valuation system creates administrative problems for MALPF because the amount of the federal match cannot be determined at the time of the offer, but only after a third appraisal is completed close to the time of settlement,

resulting cost effectiveness is \$87/Mt. This estimate only accounts for the direct reductions associated with soil carbon losses estimated above and does not include potentially much larger indirect benefits associated with reductions in vehicle miles traveled. The greenhouse gas benefits and program costs are summarized in table 4-1.

Table 4-1 Acreage protected annually and associated avoided emissions and costs under policy implementation.

Year	Assumed percentage of goal achievement	Agriculture Acres protected	MMtCO ₂ e Saved	Costs	Discounted Costs
2008	8%	909	0.021	\$ 2,704,345	\$2,704,345
2009	15%	1,817	0.042	\$ 5,408,689	\$5,151,133
2010	23%	2,726	0.064	\$ 8,113,034	\$7,358,761
2011	31%	3,635	0.085	\$ 10,817,378	\$9,344,458
2012	38%	4,544	0.106	\$ 13,521,723	\$11,124,355
2013	46%	5,452	0.127	\$ 16,226,068	\$12,713,549
2014	54%	6,361	0.149	\$ 18,930,412	\$14,126,165
2015	62%	7,270	0.170	\$ 21,634,757	\$15,375,418
2016	69%	8,178	0.191	\$ 24,339,102	\$16,473,662
2017	77%	9,087	0.212	\$ 27,043,446	\$17,432,447
2018	85%	9,996	0.234	\$ 29,747,791	\$18,262,563
2019	92%	10,905	0.255	\$ 32,452,135	\$18,974,091
2020	100%	11,813	0.276	\$ 35,156,480	\$19,576,444
	Total	82,693	1.93		\$168,617,389

Forest Lands GHG Benefit

Carbon savings from this option were estimated from two sources: 1) the amount of carbon that would be lost as a result of forest conversion to developed uses (i.e., “avoided emissions”) and 2) the amount of annual carbon sequestration potential that is maintained by protecting the forest area.

1. Avoided Emissions

Carbon savings from avoided emissions were calculated using statewide average estimates of total standing forest carbon stocks in Maryland, provided by the USFS as part of the Forest Inventory and Forecast for Maryland (Appendix XX).

Loss of forests to development results in a large one-time surge of carbon emissions. In this case, it was assumed that 100% of the vegetation carbon stocks would be lost in the event of forest conversion to developed uses, with no appreciable carbon sequestration in soils or biomass following development. While soil C may be lost on forest conversion to developed use, soil C

increasing the difficulty of allocating funds among funding sources (MALPF five-year Annual Report for FY 2003-2007, 11 January 2008)

loss was excluded from this analysis because soil C dynamics are not included in the baseline calculations for the Inventory and Forecast. A comparison of data from the American Housing Survey with land use conversion data from the Natural Resources Inventory (NRI) suggests that, on average, two thirds of the land area in residential lots is cleared during land conversion. Thus, it was assumed that, during forest conversion to developed use, 100% of the forest vegetation would be lost on 67% of the converted acreage. Using the statewide average C densities from the Maryland FIA results, roughly 27.9 tons C emissions are avoided for every acre of forest preserved in Maryland.

Between 1986 and 1999, roughly 9,643 acres of forest were lost in Maryland annually (FIA statistics). Between 1999 and 2005, there was a net gain in forestland annually of roughly 15,000 acres per year (FIA statistics). Overall, between 1986 and 2005 there was a net forest loss of 2,602 acres annually.

To reach the goal of protecting 250,000 acres by 2020 (with 96,000 acres protected by 2012), an additional 19,200 acres would need to be protected each year between 2008 and 2012, and 19,250 acres would need to be protected between 2013 and 2020.

Table AFW4-1 shows the annual and total acreage targeted by the program and associated avoided emissions that would be generated between 2008 and 2020.

Table AFW4-2. Acreage protected annually and associated avoided emissions under policy implementation.

	Acres protected	Avoided emissions (MMTCO ₂ e)
2008	19200	1.962
2009	19200	1.962
2010	19200	1.962
2011	19200	1.962
2012	19200	1.962
2013	19250	1.967
2014	19250	1.967
2015	19250	1.967
2016	19250	1.967
2017	19250	1.967
2018	19250	1.967
2019	19250	1.967
2020	19250	1.967
total	250000	25.545

2. Annual Sequestration Potential in Protected Forests

A majority of the forests in Maryland are oak-hickory types (63%), with 11% in oak-pine and 10% in natural loblolly-shortleaf pine stands (USDA Forest Service, Forest Inventory and Analysis). The remaining forest land is a mix of elm-ash-cottonwood, oak-gum-cypress, maple beech-birch, and white-red-jack pine. This analysis assumed protected forests would occur in the three predominant forest types, following the proportions in the existing inventory: oak-hickory (70%), oak-pine (15%) and loblolly-shortleaf pine (15%). The calculations in this

section of the analysis thus used default carbon sequestration values for these forest types (USFS GTR-343, Tables A3, A4, and A39). Average annual carbon sequestration was calculated for stand ages between 25 and 75 years, assuming that protected forests would span this age range. Average annual sequestration rate was calculated by subtracting non-soil carbon stocks in 75-year-old stands from non-soil carbon stocks in 25-year-old stands and dividing by 50 (Table AFW4-2). Soil carbon density was assumed constant and is not included in the calculation.

Table AFW4-3. Forest carbon sequestration rates in protected forests.

	MtC/ac (25 yr)	MtC/ac (75 yr)	MtC/ac/yr
Oak-Hickory (GTR NE 343 Table A3)	37.7	80.1	0.8
Oak-Pine (GTR NE 343 Table A4)	33.3	68.8	0.7
Loblolly-shortleaf pine (GTR NE 343 Table A39)	29.1	55.6	0.5

The results for annual sequestration potential under policy implementation are given in Table AFW4-3. Forests preserved in one year continue to sequester carbon in subsequent years. Thus, annual sequestration potential includes benefits from acres preserved cumulatively under the program.

Table AFW4-4. Cumulative protected acreage and annual sequestration on protected acreage under policy implementation.

	Cumulative acreage protected	Annual Sequestration (MMtCO ₂ e)
2008	19200	0.055
2009	38400	0.110
2010	57600	0.165
2011	76800	0.220
2012	96000	0.274
2013	115250	0.329
2014	134500	0.384
2015	153750	0.439
2016	173000	0.495
2017	192250	0.550
2018	211500	0.605
2019	230750	0.660
2020	250000	0.715
total	250,000	5.000

3. Overall GHG Benefit of Avoided Land Conversion

The cumulative GHG benefit of avoided forest land conversion (including avoided emissions from reduced conversion as well as annual sequestration in protected forest) was calculated in units of MMtCO₂e (Table AFW4-4). Figure AFW4-1 shows the relative impact of avoided emissions and sequestration in protected acreage.

AFW4-5. Combined effect of avoided land conversion and C storage on protected acreage.

	MMtCO ₂ e/yr
2008	2.017
2009	2.072
2010	2.126
2011	2.181
2012	2.236
2013	2.296
2014	2.351
2015	2.406
2016	2.461
2017	2.517
2018	2.572
2019	2.627
2020	2.682
Total	30.544

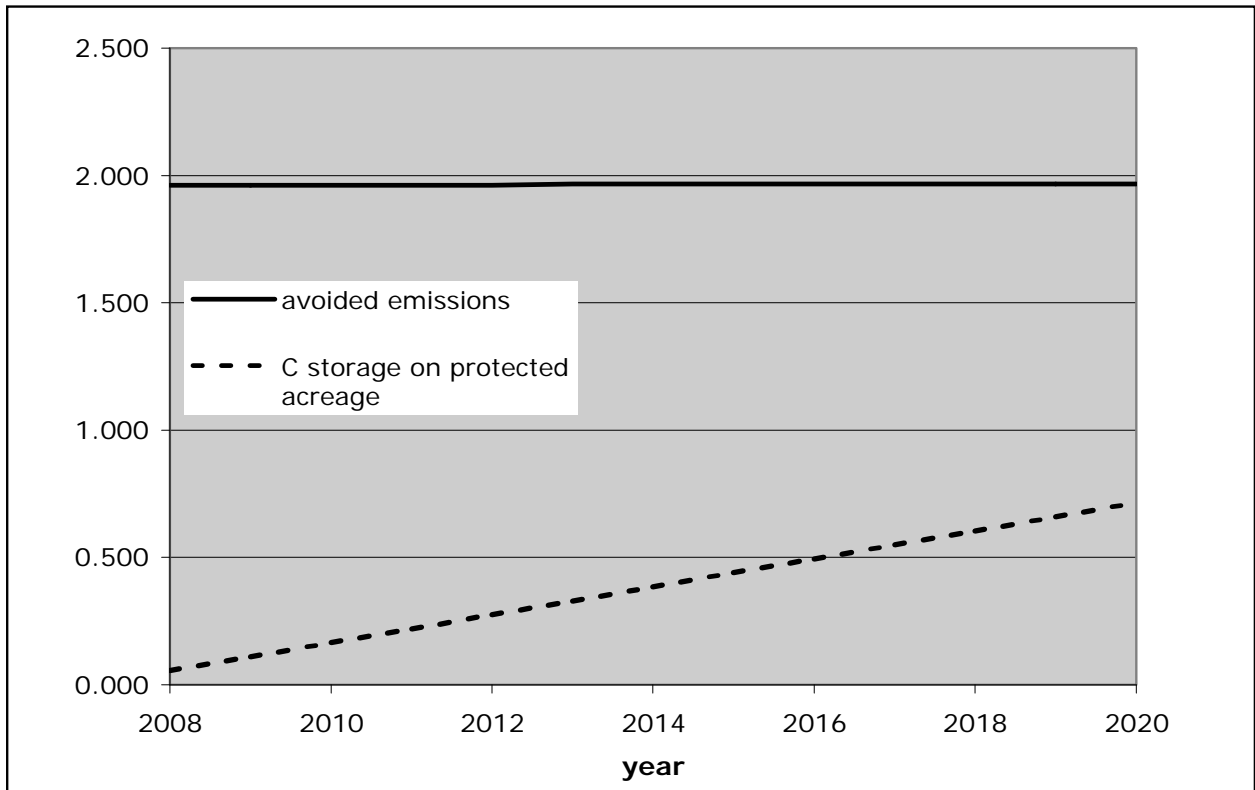


Figure AFW4-1. Relative impact of forest protection and C sequestration on protected acreage.

Forest Lands Cost

Economic costs of protecting forest land were assumed to be the per-acre one-time cost of purchasing conservation easements, at \$5,952/acre. This estimate is the recorded average “acquisition cost” in 2007 for easements obtained in Maryland via the Maryland Agricultural Land Protection Foundation (see Agriculture Land Costs, above).

Net economic costs of protecting forest land are presented in Table AFW4-5. Discounted costs were calculated using a 5% discount rate, with a total Net Present Value of \$1128.7 million. The cost effectiveness of this option is \$36.95/Mt CO₂e avoided.

Table AFW4-6. Economic costs of protecting forest land under Option AFW-4.

	Total cost	Discounted costs
2008	\$114,278,400	\$114,278,400
2009	\$114,278,400	\$108,836,571
2010	\$114,278,400	\$103,653,878
2011	\$114,278,400	\$98,717,979
2012	\$114,278,400	\$94,017,122
2013	\$114,576,000	\$89,773,294
2014	\$114,576,000	\$85,498,375
2015	\$114,576,000	\$81,427,024
2016	\$114,576,000	\$77,549,547
2017	\$114,576,000	\$73,856,711
2018	\$114,576,000	\$70,339,725
2019	\$114,576,000	\$66,990,214
2020	\$114,576,000	\$63,800,204

- **Key Assumptions:**

The cost of conservation is assumed to remain constant across the policy period.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

AFW-5 “Buy Local” Programs for Sustainable Agriculture, Wood and Wood Products

Policy Description

Promote the sustainable production and consumption of locally produced agricultural goods, which displace the consumption of those transported from other states or countries. GHG reductions occur from reduced transportation-related emissions, reduced production-related emissions and enhanced forest health.

Using local wood for construction, furniture or other value-added wood products will enhance local economies while reducing carbon emissions by lowering transportation distances and sequestering carbon in those products.

The use of wood products displaces GHG emissions associated with processing high-energy input materials such as steel, plastic and concrete.

Increased demand for local wood products increases opportunities for forest management treatments that improve forest health and sustainability, thereby improving sequestration and nutrient absorption.

Policy Design

Use definition for sustainable biomass in RPS.

Put leverage on local governments to be part of the solution by ensuring that zoning does not preclude intelligent, sustainable uses that support this objective, such as constraining local value-added mills or limit location/participation in local markets.

Goals:

Farmer’s Market: Several projects are being proposed in Maryland that would result in the increase of local farmer’s markets in Maryland by 25% by 2015 and 50% by 2020.

Local Produce: Of the food Marylanders consume, 80% would be grown or produced locally by 2050.

Locally Grown and Processed Lumber: The amount of locally grown and processed lumber would displace imported wood by 20% by 2015 and 50% by 2050.

Timing: Startup in 2009 and ramp up to higher levels in 2015 and 2020, consistent with goals.

Parties Involved: Agricultural and wood product primary producers such as Maryland farmers, lumber mills, farmer’s market associations and promoters; value-added producers such as Maryland caterers, producers of packaged food for retail, furniture makers, construction businesses, wholesalers and retailers of construction and do-it-yourself products, architects and designers; applicable trade associations, Dept. of Agriculture, Dept. of Natural Resources, LEED certification entities.

- **Other:** As needed, identify incentives that encourage the sustainable growing and harvesting of local agricultural and wood products.

Implementation Mechanisms

Specific incentives recommended:

Care must be taken to ensure that the wood and agricultural products are sustainably harvested and produced to create a net carbon sequestration and reduction in emissions.

The following will be included in further discussions:

Maryland has been a LEED (rating system for green building) leader, but hasn't been given credit for wood products, especially local woods as contributing to energy efficiency and carbon emission reductions. This is an issue in several states. TWG needs to put removing that obstacle into Policy Implementation design. MWG is aware of this problem and supports resolution.

Encourage the creation of value-added products from local woods in lieu of shipping raw materials.

Related Policies/Programs in Place

The Maryland Dept. of Agriculture has recently been revitalized and is actively promoting a Buy Local program by (list specific actions and incentives here).

Types(s) of GHG Reductions

CO₂: Extending carbon sequestration in durable wood products and wood construction. Maintaining carbon sequestration in healthy forests. Avoidance of emissions through reduced transportation miles. Avoidance of emissions through reduced use of high-energy input construction materials.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

- **Data Sources:**

All data sources, methods and assumptions are based on the Iowa study cited below, and were scaled to Maryland using state population adjustments. The study analyzed the feasibility and effects of shifting transportation distance and mode.

- **Quantification Methods:**

Farmer's Market GHG Benefits

The GHG benefits for the Maryland option are based on a study from Iowa State University⁷ which compared miles traveled, fossil fuel used, and carbon dioxide emitted in the transport sector of several food systems. The study estimated the fuel use and the CO₂ emissions for

⁷ Food, Fuel, and Freeways: An Iowa perspective on how far food travels, fuel usage, and greenhouse gas emissions. Leopold Center for Sustainable Agriculture
209 Curtis Hall Iowa State University Ames, Iowa 50011-1050 Website:
<http://www.leopold.iastate.edu/>

transporting (from farm to point of sale) 10% of 28 different fresh produce items using three different food systems: conventional, regional, and local (which includes farmer’s markets)

This study was scaled to Maryland using state population adjustments and the relevant percentage of produce to be sourced locally (as determined by the policy goals). This scaling is summarized in Table 5-1. 2006 population estimates were based on U.S. Census Bureau data for Iowa and Maryland⁸ – 2,982,085 for Iowa and 5,615,727 for Maryland.

Table 5-1: Fuel consumption and emissions from the Iowa study and the assumed scaling for Maryland.

Food system and type of truck	Fuel Consumption (gal/year)	CO2 emissions (metric tons/year)
Iowa Conventional semitrailer	368,102	3,807
Iowa local -CSA farmers market small truck (gas)	49,359	439
Maryland Conventional semitrailer	693,193	7,169
Maryland local -CSA farmers market small truck (gas)	92,951	826
Estimated benefit of sourcing 10% locally grown fresh produce	600,242	6,343

Table 5-2: GHG Savings from increasing the proportion of produce sold at farmer’s markets

Year	Increase in local farmer's market	Metric tons CO2e
2008	3%	1,982
2009	6%	3,964
2010	9%	5,946
2011	13%	7,928
2012	16%	9,910
2013	19%	11,892
2014	22%	13,874
2015	25%	15,856
2016	30%	19,028
2017	35%	22,199
2018	40%	25,370
2019	45%	28,542
2020	50%	31,713
		198,205

Farmer’s Market Costs

Costs of the program or incentives required to address the envisioned regional approach to increase consumption of local products are yet to be determined. Costs could include the additional costs to incentivize local year-round production of agricultural products, as well as

⁸ see <http://quickfacts.census.gov/qfd/states/19000.html> and <http://quickfacts.census.gov/qfd/states/24000.html>

regional storage, processing, packaging, and distribution. There are also likely to be cost savings associated with the reduced fuel use in the transportation of non-local produce.

• **Key Assumptions:**

The assumptions and data inputs for the Iowa analysis are assumed to be the same for Maryland, including the distance of food under present (conventional) circumstances and the relative mix of food categories.

Key Uncertainties

- The largest source of uncertainty is whether the region can supply the amount and variety of agricultural products needed to meet the required goals. Significant work will be needed to identify and promote products that can be regionally produced to meet the goals of this policy.
- The relative mix of food categories in Maryland compared to Iowa are not included in this analysis.
- The differences in cost of growing food locally vs. elsewhere (as determined by market) have not been incorporated.
- Incentive system required to make producer and consumer shifts viable

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

This analysis only has addressed the farmer’s market aspect of the buy local option. Other components of this option are addressing the food system more broadly (i.e. 80% of all food consumed in Maryland). At this stage the information and resources available are not sufficient to capture these benefits and costs. However, it is noted that the potential benefits are significantly greater. The Iowa study notes that the analysis of 10% of 28 produce items “represents less than 1 percent of total food and beverage per capita consumption by weight (not including water) in Iowa”. With this in mind, a higher percentage of meats, processed foods, and beverages grown and/or processed locally would result in significantly higher GHG emissions reductions from transport.

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MWG meeting #5]

AFW-6 Expanded Use of Forest and Farm Feedstocks and Bi-Products for Energy Production

Policy Description

Sustainable forest and farm practices produce bi-products and feed stocks. These are renewable sources of energy. This policy option should increase the utilization of biomass from urban and rural feed stocks including processing byproducts for generation of electricity, thermal energy, and transportation fuels. Additionally, this option should reduce the amount of methane emissions from livestock manure by installing manure digesters and energy recovery projects.

All sources will be considered and implementation strategies will ensure the sustainability of supply. Energy from forest and farm feed stocks and bi-products are used to create heat or power, which offsets fossil fuel-based energy production and associated greenhouse gas (GHG) emissions.

[Note: Need to add reductions from municipal sources of methane.]

Policy Design

All biomass products will be sustainably harvested without depriving soils of important organic components for reducing erosion and maintaining soil nutrients and structure, nor depleting wildlife habitat or jeopardizing future feedstocks in quantity and quality.

Install manure digesters and energy recovery projects in hog and dairy operations.

The lifecycle energy costs and carbon emissions for each feedstock will be evaluated.

Goals:

Agricultural Residues: Increase agricultural residues use for electricity, steam, and heat generation to utilize 10% of available in-state agricultural residue biomass by 2015, 25% of available biomass by 2020.

Forest Residues: Increase forest residues use for electricity, steam, and heat generation to utilize 10% of available biomass by 2015, 25% of available in-state forest residue by 2020.

Energy Crop: Increase the use of energy crop to utilize 50% of available in-state energy crop biomass for electricity, steam, and heat generation by 2020.

Methane from Livestock Manure: By 2020, utilize 50% of available methane from livestock manure for renewable electricity, heat and steam generation.

- Establish certain acreage target for energy crops
- Ensure wood-based energy is given weight equal to wind and solar-based energy in renewable energy credits. (Look at Energy Act and recommend changes if necessary.)
- Many questions about biomass supply remain making projections that drive technology and policy difficult to estimate. Given the current information, it may be too early in the development process to predict goals. Therefore preliminary goals should include
 - Develop benchmarks to implement mechanisms for improvements

- Developing processes and identifying resources to capture data
- Develop metrics and methodology of data collection and analysis
- **Timing:**
- **Parties Involved:** Maryland Energy Administration, DNR, MDE, municipalities, power producers (Mirant and Constellation), local electric utilities (distributors), Board of Education, rural community entities (hospitals, community colleges, and universities), Department of Agriculture, Soil Conservation Districts
- **Other:**

Implementation Mechanisms

- Outreach and education
- Change present laws to add incentives (such as Maryland Clean Energy Act)
- Increase incentives through programs such as Fuels for Schools, tax-forgiveness
- Department of General Service could provide equal credit to efficient design, energy efficiently loan programs, etc.

Related Policies/Programs in Place

Modify the Renewable Portfolio Standards requiring local sources of renewable energy

Types(s) of GHG Reductions

- **CO₂, N₂O, CH₄:** Savings occur as a result of reducing methane emissions and the displacement of fossil fuel use in the production of electricity or steam..

Estimated GHG Reductions and Net Costs or Cost Savings

- **Data Sources:**

As indicated and referenced below.

- **Quantification Methods:**

Biomass GHG Benefits

This analysis focuses on the incremental GHG benefits associated with the utilization of additional biomass to offset the consumption of fossil fuels. The analysis assumes that biomass will replace coal. This is based on the assumption that a significant amount of biomass will be used to replace coal through co-firing opportunities in the RCI and electricity sector (where coal represents the majority of electricity generated⁹). The amount of biomass available is taken from the Maryland Department of Natural Resources Document *The Potential for Biomass Co-firing in Maryland*¹⁰. Available agriculture biomass is indicated in table 6-1 and available biomass from forests is indicated in table 6-2. The amount of available energy crop estimated in *The*

⁹ Based on eGRID data: Coal 56%, Nuclear 28%, Oil 6.3%, Natural Gas 2.2%, Biomass 1.3%.

¹⁰ Maryland DNR "The Potential for Biomass Cofiring in Maryland", March 2006. Prepared by Princeton Energy Resources International, LLC and Exeter Associates INC for the DNR Maryland Power Plant Research Program

Potential for Biomass Co-firing in Maryland assumed that 25 percent of idle cropland, approximately 51,307 acres in Maryland, is used to grow switchgrass (this translates to approximately 250,000 dry tons of switchgrass fuel).

Table 6-1: Available Biomass from Agriculture Feedstocks

Agriculture Feedstocks	Dry Tons	Heat content (Mbtu/Ton)¹¹	Estimated Heat input (Mbtu)
Corn	262,866	8.3	2,181,788
Wheat	148,723	8.3	1,234,401
Winter Wheat	185,903	8.3	1,542,995
Barley	25,390	8.3	210,737
Total Agriculture Residue	622,882		5,169,921
Switchgrass	251,019	14.7	3,689,979
Total Agriculture Biomass	873,901		8,859,900

Table 6-2: Available Biomass from Forestry Feedstocks

Forest Feedstocks	Dry Tons	Heat content (Mbtu/Ton)	Estimated Heat input (Mbtu)
Forest Residue	136,878	9.6	1,314,029
Mill Residue	148,754	14	2,082,556
Urban Residue	275,867	10	2,758,670
Total Forest Feedstocks	561,499		6,155,255

Biomass is assumed to have a reduction of 0.0940 tCO₂e/MMBTU when replacing coal combustion.

Biomass Costs

There are two main components to the cost calculation, the fuel costs and capital costs. The fuel component is based on the difference in costs between supply of biomass fuel and the assumed fossil fuel that it is replacing (i.e. coal). The assumed costs are identified in Table 6-3 below and have been taken from *The Potential for Biomass Co-firing in Maryland*.¹²

¹¹ Heat content of Agricultural byproducts sourced from above DNR report which references EIA (1999) Annual Electric Generator. Heat content for switchgrass is also sourced from the DNR report which references the Energy Information Administration, Annual Energy Outlook 2005, Table H1, February 2005.

¹² Maryland DNR "The Potential for Biomass Cofiring in Maryland", March 2006. Prepared by Princeton Energy Resources International, LLC and Exeter Associates INC for the DNR Maryland Power Plant Research Program.

Table 6-3: Assumed Costs of Feedstocks

Fuel Type	Cost \$/ton delivered	Cost \$/MBtu delivered
Agricultural Byproducts	\$ 40.00	\$ 4.85
Urban waste wood	\$ 17.00	\$ 1.70
SwitchGrass	\$ 47.00	\$ 3.20
Mill Residue (Dry)	\$ 27.00	\$ 1.93
Forest Residue	\$ 35.00	\$ 3.65
Bituminous Coal	\$ 33.84	\$ 1.41

The cost is calculated by assuming the replacement of coal with biomass. The difference in cost of supply between biomass and coal and biomass is calculated using the costs indicated in Table 6-3. The difference in costs (\$/MBtu) is multiplied by the amount of coal energy (MBtu) being replaced by biomass. The assumed incremental capital costs are based on the capital costs associated with retrofitting an existing 300-700 MW capacity coal-fired boiler. An average capital cost of \$180 per kW was assumed, based on the range (\$150-\$200/kW) provided in *The Potential for Biomass Co-firing in Maryland*. While use of biomass may be pursued through other technology types (e.g. gasification) or end uses (e.g. heat or steam), the capital costs of co-firing were used to provide an estimate of possible capital costs required to enable the utilization of biomass¹³. The capital infrastructure lifespan was assumed to be 30 years, and the interest rate of was assumed to be 5%, giving a Capital Recovery Factor of 0.065 (i.e. \$1 million plant is assumed to cost approximately \$65,000 per year over the life of the project). For the purposes of this analysis, it is assumed that biomass plants do not require additional operating and maintenance costs (e.g. no additional emission control measures and ash disposal required). A summary of avoided emissions and cost for all the biomass components is presented in Table 6-7.

¹³ The capital costs associated with using biomass as an alternative to fossil-based generation are dependent on many factors, including the end use (i.e. electricity, heat or steam), the design and size of the systems, the technology employed, and the configuration specifications of the system. Each system implemented under this policy would require a detailed analysis (incorporating specific engineering design and costs aspects) to provide a more accurate cost estimate of the system.

Table 6-4. GHG Benefits and Fuel Costs for Agriculture Residue

Year	Percent of Utilization	Ag Residue Biomass (MMBtu)	Avoided Emissions Ag Residue (MtCO ₂ -e)	Ag Residue Cost/Savings	Discounted Cost/Savings
2008	1%	64,624	0.006	\$ 222,307	\$201,639
2009	3%	129,248	0.012	\$ 444,613	\$384,074
2010	4%	193,872	0.018	\$ 666,920	\$548,677
2011	5%	258,496	0.024	\$ 889,226	\$696,732
2012	6%	323,120	0.030	\$ 1,111,533	\$829,443
2013	8%	387,744	0.036	\$ 1,333,840	\$947,935
2014	9%	452,368	0.043	\$ 1,556,146	\$1,053,261
2015	10%	516,992	0.049	\$ 1,778,453	\$1,146,406
2016	13%	672,090	0.063	\$ 2,311,988	\$1,419,360
2017	16%	827,187	0.078	\$ 2,845,524	\$1,663,719
2018	19%	982,285	0.092	\$ 3,379,060	\$1,881,587
2019	22%	1,137,383	0.107	\$ 3,912,596	\$2,074,933
2020	25%	1,292,480	0.122	\$ 4,446,132	\$2,245,599
			0.620		\$15,093,364

Table 6-5. GHG benefits and fuel costs for Energy Crops

Year	Percent of Utilization	Total Energy Crops (MMBtu)	Avoided Emissions, Energy Crops(MtCO ₂ e)	Ag Residue Cost/Savings	Discounted Cost/Savings
2008	2%	73,800	0.007	\$ 132,101	\$119,820
2009	4%	147,599	0.014	\$ 264,203	\$228,228
2010	6%	221,399	0.021	\$ 396,304	\$326,040
2011	8%	295,198	0.028	\$ 528,405	\$414,019
2012	10%	368,998	0.035	\$ 660,506	\$492,880
2013	15%	553,497	0.052	\$ 990,759	\$704,114
2014	20%	737,996	0.069	\$ 1,321,013	\$894,113
2015	25%	922,495	0.087	\$ 1,651,266	\$1,064,421
2016	30%	1,106,994	0.104	\$ 1,981,519	\$1,216,481
2017	35%	1,291,493	0.121	\$ 2,311,772	\$1,351,645
2018	40%	1,475,992	0.139	\$ 2,642,025	\$1,471,178
2019	45%	1,660,491	0.156	\$ 2,972,278	\$1,576,263
2020	50%	1,844,990	0.173	\$ 3,302,531	\$1,668,003
Cumulative			1.01		\$11,527,205

Table 6-6. GHG benefits and fuel costs for Forestry Feedstocks

Year	Percent of Utilization	Forest Feedstocks (includes forest residue, Mill Residue and Urban woodwaste) (MMBTU)	Avoided Emissions All Forest Feedstocks (MtCO ₂ -e)	Forest Feedstock (includes forest residue, Mill Residue and Urban woodwaste) Cost/Savings	Discounted Cost/Savings
2008	1%	76,941	0.007	\$ 60,330	\$54,721
2009	3%	153,881	0.014	\$ 120,659	\$104,230
2010	4%	230,822	0.022	\$ 180,989	\$148,900
2011	5%	307,763	0.029	\$ 241,318	\$189,079
2012	6%	384,703	0.036	\$ 301,648	\$225,094
2013	8%	461,644	0.043	\$ 361,978	\$257,251
2014	9%	538,585	0.051	\$ 422,307	\$285,834
2015	10%	615,525	0.058	\$ 482,637	\$311,112
2016	13%	800,183	0.075	\$ 627,428	\$385,186
2017	16%	984,841	0.093	\$ 772,219	\$451,500
2018	19%	1,169,498	0.110	\$ 917,010	\$510,625
2019	22%	1,354,156	0.127	\$ 1,061,801	\$563,096
2020	25%	1,538,814	0.145	\$ 1,206,592	\$609,411
			0.738		\$4,096,040

Table 6-7. Summary of GHG benefits and costs for Biomass

Year	Total Biomass utilization (Ag Residue, Forest Feedstocks and Energy Crops) MMBTU	Annualized capital costs	Fuel costs (Ag Residue, Forest Feedstocks and Energy Crops)	Total Costs	Discounted Cost/Savings	Total GHG emissions avoided (MMt CO ₂ -e)
2008	215,364	\$ 32,324	\$ 414,737	\$447,062	\$405,498	0.020
2009	430,729	\$ 64,649	\$ 829,475	\$ 894,124	\$772,378	0.040
2010	646,093	\$ 96,973	\$1,244,212	\$1,341,186	\$1,103,397	0.061
2011	861,457	\$ 129,298	\$ 1,658,950	\$1,788,247	\$1,401,139	0.081
2012	1,076,821	\$ 161,622	\$ 2,073,687	\$2,235,309	\$1,668,022	0.101
2013	1,402,885	\$ 210,562	\$ 2,686,577	\$ 2,897,138	\$2,058,942	0.132
2014	1,728,949	\$ 259,501	\$ 3,299,466	\$ 3,558,967	\$2,408,849	0.163
2015	2,055,012	\$ 308,441	\$ 3,912,355	\$ 4,220,796	\$2,720,763	0.193
2016	2,579,267	\$ 387,127	\$ 4,920,935	\$ 5,308,062	\$3,258,690	0.242
2017	3,103,521	\$ 465,813	\$ 5,929,515	\$ 6,395,328	\$3,739,216	0.292
2018	3,627,775	\$ 544,499	\$ 6,938,095	\$ 7,482,595	\$4,166,589	0.341
2019	4,152,029	\$ 623,186	\$ 7,946,675	\$ 8,569,861	\$4,544,780	0.390
2020	4,676,284	\$ 701,872	\$ 8,955,255	\$ 9,657,127	\$4,877,505	0.440

Methane Utilization from Livestock Manure GHG Benefits

Methane emissions (in MMt CO₂-e) data from the I&F was used as the starting point to estimate the GHG benefits of capturing and controlling the volumes of methane targeted by the policy and to add in the additional benefit of electricity generation using this captured methane (through offsetting fossil-based generation). The first portion of GHG benefit is obtained through reduced methane emissions through the capture of emissions from manure. An assumed collection efficiency of 75%¹⁴ was applied to methane emissions from animal manure which was then multiplied by the assumed policy target ramping up to achieve 50% collection by 2020.

The second portion of the GHG benefit is through the offsetting of fossil-based electricity generation. This was estimated by converting the methane to captured in each year to its heat content (in BTUs) and then multiplying by an energy recovery factor of 17,100 BTU/kW-hr to estimate the electricity produced (assumes a 25% efficiency for conversion to electricity in an engine and generator set). The CO₂e associated with this amount of electricity in each year was estimated by converting the kW-hrs to MW-hrs and then multiplying this value by the Maryland-specific emission factor for electricity production from eGRID (0.587 Mt/MWh).

The total GHG benefit was estimated as the sum of both portions of the benefit described above and indicated in Table 6-8.

Table 6-8. GHG benefits for methane utilization from livestock manure

Year	Methane Emissions From Dairy, Swine and Poultry (MMt CO ₂ -e)	Policy Utilization objective	Methane Captured and Utilized under policy (MMt CO ₂ -e)	Million Metric Tons of Methane	Methane (million BTUs)	CO ₂ e Offset as Electricity (Metric Tons)	Total Emission Reductions (MMt CO ₂ -e)
2008	0.090	4%	0.003	0.000	6547	225	0.003
2009	0.090	8%	0.005	0.000	13050	448	0.006
2010	0.090	12%	0.008	0.000	19515	669	0.008
2011	0.090	15%	0.010	0.000	25977	891	0.011
2012	0.090	19%	0.013	0.001	32417	1,112	0.014
2013	0.089	23%	0.015	0.001	38837	1,332	0.017
2014	0.089	27%	0.018	0.001	45236	1,552	0.020
2015	0.089	31%	0.021	0.001	51613	1,770	0.022
2016	0.089	35%	0.023	0.001	57957	1,988	0.025
2017	0.089	38%	0.026	0.001	64276	2,205	0.028
2018	0.089	42%	0.028	0.001	70573	2,421	0.031
2019	0.088	46%	0.031	0.001	76846	2,636	0.033
2020	0.088	50%	0.033	0.002	83095	2,850	0.036

¹⁴ The collection efficiency is an assumed value based on engineering judgment. No applicable studies were identified that provided information on methane collection efficiencies achieved using manure digesters (as it relates to collection of entire farm-level emissions).

Methane Utilization from Livestock Manure Costs

The costs for the dairy and swine components were estimated using an analysis by Natural Resources Conservation Service (NRCS), *An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities*¹⁵. The production costs were assumed to be \$0.11 per kWh for swine anaerobic digesters and \$0.05 per kWh for dairy anaerobic digesters¹⁶. These costs are in 2006 dollars and assume a 30% thermal efficiency. The costs include annualized capital costs for the digester, generator, and Operation and Maintenance costs¹⁷. The assumed costs for the poultry component were taken from *Availability of Poultry Manure as a Potential Bio-Fuel Feedstock for Energy Production* by Joseph R.V. Flora, Ph.D., P.E. and Cyrus Riahi-Nezhad (\$0.103 per kWh in 2005 dollars using of Anaerobic Digestion).¹⁸ The value of electricity produced was taken from the all sector average projected electricity price for the Southeastern Electric Reliability Council from the EIA Annual Energy Outlook (see <http://www.eia.doe.gov/oiaf/aeo/supplement/index.html>). This price represents the value to the farmer for the electricity produced (to offset on-farm use) and is netted out from the production costs to estimate net costs. Total costs are indicated in Table 6-9 below.

Table 6-9. Costs for methane utilization from livestock manure

Year	Cost of Dairy Technology (2006 dollars)	Cost of Swine Technology (2006 dollars)	Cost of Poultry Technology (2006 dollars)	Total Costs (2006 dollars)
2008	-\$5,718	\$1,270	\$3,841	-\$607
2009	-\$11,469	\$2,509	\$7,717	-\$1,243
2010	-\$17,271	\$3,714	\$11,615	-\$1,942
2011	-\$21,892	\$5,122	\$16,059	-\$710
2012	-\$25,637	\$6,667	\$20,958	\$1,988
2013	-\$29,373	\$8,209	\$25,854	\$4,690
2014	-\$33,475	\$9,689	\$30,546	\$6,759
2015	-\$37,722	\$11,141	\$35,150	\$8,568
2016	-\$43,003	\$12,421	\$39,158	\$8,577
2017	-\$48,803	\$13,611	\$42,866	\$7,675
2018	-\$54,643	\$14,789	\$46,530	\$6,677
2019	-\$59,150	\$16,180	\$50,898	\$7,928
2020	-\$63,936	\$17,520	\$55,096	\$8,680
				\$57,041

¹⁵ Beddoes, Bracmort, Burns and Lazarus (2007) *An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities*, NRCS, Technical Note No. 1, October 2007.

¹⁶ It was assumed that the technology employed for both swine and dairy anaerobic digesters was covered anaerobic lagoon. Cost were obtained from table 1 of the NRCS paper cited above.

¹⁷ The economic analysis conducted by Beddoes et al does not include feedstock and digester effluent transportation costs. The technical note does not address the economics of centralized digesters where biomass is collected from several farms and then processed in a single unit.

¹⁸ *Availability Of Poultry Manure As A Potential Bio-Fuel Feedstock For Energy Production* By Joseph R.V. Flora, Ph.D., P.E. and Cyrus Riahi-Nezhad Department of Civil and Environmental Engineering University of South Carolina, August 2006.

- **Key Assumptions:**

The fuel mix being replaced by biomass is assumed to be 100% coal. Biomass is assumed to have a reduction of 0.0940 tCO₂e/MMBTU when replacing coal combustion. Methane utilization is assumed to replace electricity.

While use of biomass may be pursued through other technology types (e.g. gasification) or end uses (e.g. heat or steam), the capital costs of co-firing were used to provide an estimate of possible capital costs required to enable the utilization of biomass. This analysis assumes that on average the capital costs will be similar to those of a 300-700 MW capacity retrofitted co-fired boiler system. The capital costs associated with using biomass as an alternative to fossil-based generation are dependent on many factors, including the end use (i.e. electricity, heat or steam), the design and size of the systems, the technology employed, and the configuration specifications of the system. Each system implemented under this policy would require a detailed analysis (incorporating specific engineering design and costs aspects) to provide a more accurate cost estimate of the system.

Key Uncertainties

Energy crops are not widely produced in the Maryland, due to the opportunity cost involved in switching higher value agriculture products such as corn, wheat and barley. The Potential for Biomass Co-firing in Maryland notes that “it is unlikely that a large percentage of local farmers will switch to bioenergy crops absent a subsidy or incentive to encourage the production of energy crops”.

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

The economical and technical feasibility of using biomass energy as a replacement to conventional energy was not considered as a part of this analysis.

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MWG meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the MWG/MCCC]

AFW-7 In-State Liquid Biofuels Production

Policy Description

Promote sustainable in-state production and consumption of transportation biofuels including ethanol and/or biodiesel from agriculture and/or agroforestry feedstocks to displace the use of fossil fuels. Decrease the use of fossil fuel in the production of these biofuels, which will improve the GHG profile of in-state liquid biofuels production and consumption. Favor the use of cellulosic and non-food source starches in ethanol production and monitor to ensure the sustainability of feedstocks and soil health.

It is understood that promoting biofuel production must be coupled with strong policies to reduce overall transportation fuel consumption if true gains in reducing GHGs is to be achieved. Upon successful implementation of this policy, Maryland consumption of biofuels produced in-state will produce better GHG benefits than these same fuels obtained from a national market due to lower embedded CO₂ (due to transportation of biodiesel, ethanol, other fuels, or their feedstocks from distant sources).

NEED TO CHECK WITH TLU Note: This option is linked with TLU-X on a Low Carbon Fuels Standard. This AFW option seeks to achieve incremental GHG benefits beyond the TLU option by promoting in-state production of biofuels using feedstocks with greater GHG benefits than the likely BAU national production methods.

Policy Design

Goals:

Develop specific policies based on cellulosic feedstock and value-added by-product study due in December 2007 with production volumes and percent supply use. In the interim, these goals will be used:

Gasoline displacement goals—Achieve in-state cellulosic ethanol production equivalent to offsetting gasoline consumption in the state by 10% in 2015 and 20% in 2020.

Fossil diesel displacement goals—Increase in-state biodiesel production from Maryland feedstocks to offset 10% and 20% of 2005 Maryland petroleum diesel consumption by 2015 and 2020, respectively.

Timing:

Gasoline displacement goals—Incremental increases, up to achieving the full goal by 2020.

Fossil diesel displacement goals—Incremental increases, up to achieving the full goal by 2020.

Parties Involved:

Suppliers of feedstocks, ethanol producers, distributors, communities adjacent to potential facilities, environmental groups, etc. Associated agencies would include: Maryland Department of Natural Resources, MD Energy Administration, Department of Agriculture, Department of Business and Economic Development, etc.

Other:

Currently there are no commercial cellulosic ethanol plants in the United States. One large plant is under construction in Georgia, one has just broken ground in Montana and a few others are being planned across the country. The only ethanol plants proposed in MD are corn-based plants.

There are two biodiesel plants in the state with production totaling 5 million gallons per year.

Implementation Mechanisms

- Develop a state strategy for increasing production of biofuels
 - Based on the MEA/Salisbury University study results of statewide feedstock supply (December 2007), determine opportunities for appropriately-scaled, cellulose-based biofuels facilities
 - Policy options could include:
 - Ensure wood-based energy is given weight equal to wind and solar-based energy in renewable energy credits
 - Change current Renewable Fuels Incentive to include cellulosic ethanol production specifically and give a larger incentive to it
 - Establish tax credit and grant program for E85 filling stations
 - Change existing gasoline specifications in Maryland so that ethanol can be blended into conventional fuel
- Integrate state strategy with regional activities to serve as a market for Maryland supply
- Promote the development of technologies to fractionate black liquor (from paper mills) which can be refined into valuable products using a thermo-chemical or other processes
- Provide financial incentive to research the production of bio-oils from algae grown in wastewater effluents
- Provide “bonus” renewable energy credits for fuels generated in-state or from fuels derived from in-state sources
- Provide access to long-term, low-interest financing for new cellulosic ethanol facilities and supporting infrastructure
- Tax credits and grant programs designed to reduce capital costs of new cellulosic ethanol facilities and supporting infrastructure
- Foster partnerships between users, suppliers, corporations, and adjacent communities
- Provide incentives to communities that provide supply (e.g. woody debris) to biofuels industries

- Provide reliable and predictable supply of cellulose from state lands while ensuring sustainable management
- Incentivize local production of biofuels

Related Policies/Programs in Place

- Renewable Fuels Incentive Act
- Cellulosic feedstock and value-added by-product study (MEA)
 - Feasibility studies
- Renewable Fuels Task Force (created by statute)
- Grants for E85 refueling stations (MEA- but very limited funds- \$50,000 total)
- Increase E85 use in State Government
- US DOE construction grants (for bio-fuels plants?)
- Federal loan guarantees (for bio-fuels plants?)
- Potential 2007 Farm Bill programs (need some specifics on this)

Types(s) of GHG Reductions

CO₂: Lifecycle emissions are reduced to the extent that biofuels are produced with lower embedded fossil-based carbon than conventional (fossil) fuel. Feedstocks used for producing biofuels can be made from crops or other biomass, which contain carbon sequestered during photosynthesis (e.g., biogenic or short-term carbon).

There are two different methods for producing ethanol based on two different feedstocks. Starch-based ethanol is derived from corn or other starch/sugar crops. Cellulosic ethanol is made from the cellulose contained in a wide variety of biomass feedstocks, including agricultural residue (e.g., corn stover), forestry waste, purpose grown crops (e.g., switchgrass), and municipal solid waste. Local production of ethanol also decreases the embedded CO_{2e} of ethanol compared to importation from the current U.S. primary ethanol producing regions. Current research indicates cellulose-based ethanol production provides up to 72%–85% reduction in GHGs compared to gasoline, whereas an 18%–29% reduction is measured from starch-based ethanol production compared to gasoline.

The primary feedstocks for biodiesel are vegetable oils (soy, canola, sunflower, algal, etc.) and alcohols (either methanol or ethanol). From a recent report (Hill et al., 2006),¹⁹ biodiesel from soybeans contains 93% more useable energy than its petroleum equivalent and reduces lifecycle GHG emissions by as much as 41%. Higher oil production potential of different feedstocks (e.g., other oil crops, algae) will likely adjust the lifecycle GHG emissions further downward as they are developed as biodiesel sources. Local production of biodiesel also decreases the embedded CO_{2e} of biodiesel compared to importation of out of state vegetable oil supplies.

¹⁹ Hill et al., 2006, “Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels,” *Proceedings of the National Academy of Sciences*, 103:11206–11210, July 25, 2006.

Estimated GHG Reductions and Net Costs or Cost Savings

Ethanol

Scenario A – Based on TWG production goals

- GHG reduction potential in 2015, 2020 (MMtCO_{2e}): 2.8, 6.0
- Net Cost per MtCO_{2e}: \$82.57

Scenario B – Based on upper bound limits of in-state feedstock supply

- GHG reduction potential in 2015, 2020 (MMtCO_{2e}) 2.17, 2.51
- Net Cost per MtCO_{2e}: \$83.85

Biodiesel

Scenario A – Based on TWG production goals

- GHG reduction potential in 2012, 2020 (MMtCO_{2e}): 0.17, 0.41
- Net Cost per MtCO_{2e}: \$8.54

Scenario B – Based on upper bound limits of in-state feedstock supply

- GHG reduction potential in 2012, 2020 (MMtCO_{2e}): 0.14, 0.16
- Net Cost per MtCO_{2e}: \$16.66

Scenario C – For biodiesel alone: Based on TWG production goals with new technologies meeting in-state feedstock supply shortfall; phase out of food-based feedstock by 2015

- GHG reduction potential in 2012, 2020 (MMtCO_{2e}): 0.36, 0.81
- Net Cost per MtCO_{2e}: \$18.04

Ethanol

According to studies conducted by the U.S. Department of Energy’s Argonne National Laboratory one of the benefits of cellulosic ethanol is that it reduces greenhouse gas emissions (GHG) by 85% over reformulated gasoline. By contrast, starch ethanol (e.g., from corn), which most frequently uses natural gas to provide energy for the process, reduces GHG emissions by 18% to 29% over gasoline.

Data Sources: Data from the MD Draft Inventory & Forecast were the starting point for quantifying the benefits of offsetting fossil diesel and gasoline consumption with biodiesel and ethanol produced within the state (these do not incorporate future reductions in consumption due to TLU options). Gasoline consumption estimates are (under business as usual):

BAU Gasoline Consumption

Year	Gasoline consumption (Mmgal/year)
2015	2,989
2020	3,190

The policy design calls for 10% of gasoline consumption to be offset by 2015 from in-state cellulosic ethanol production and 20% offset by 2020. Ethanol has approximately 67% the heat content of gasoline.²⁰ Therefore, incremental in-state biodiesel production targets are:

Ethanol production needed to meet policy goals

Year	Gasoline consumption to be displaced (Mmgal/year)	Ethanol Production Needed (MMgal/year)
2015	2,989	444
2020	3,190	947

Emission factors from gasoline, starch-based ethanol and cellulosic ethanol are based on the ANL Greet Model.²¹ The lifecycle CO₂e emission factor used for gasoline used is 11.74 Mt/1,000 gallons, for starch-based ethanol is 9.60 Mt/1,000 gallons, and for cellulosic ethanol is 3.28 Mt/1,000 gallons.²² The production cost differential for cellulosic versus starch-based ethanol was obtained from the National Renewable Energy Laboratory (NREL).²³

Quantification Methods:

GHG Reductions

The benefits for this option are dependent on developing in-state production capacity that achieves benefits above the levels of using ethanol from starch-based production, which may already be accounted for under the Transportation and Land Use policy recommendations. (Need to check with TLU).

Based on the emission factors listed above, the incremental benefit of the production targeted by this policy over conventional starch-based ethanol is 6.32 Mt/1,000 gallons, or a 66%. This value was used along with the production in each year to estimate GHG reductions.²⁴ This analysis does not take into account the benefits from transitioning from gasoline to corn-based ethanol.

Scenario A

In Scenario A the GHG emissions benefits and cost were calculated as if the TWG goals could be met. For ethanol, it was assumed that there would be enough in-state feedstock requirements. Ethanol production needed was assumed to ramp up from replacing 0% of BAU gasoline consumption in 2007 to 10% in 2015. GHG reductions were estimated by multiplying the cellulosic ethanol by the incremental benefit of using cellulose over corn.

Scenario B

In Scenario B the upper limit of potential in-state feedstock supplies were estimated and GHG emissions were calculated accordingly.

²⁰ DOE/EIA, <http://www.eia.doe.gov/oiaf/analysispaper/biomass.html>, accessed January 9, 2008

²¹ Ibid.

²² ANLGreet model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

²³ http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/19_forum/braemar_cellulosic.pdf, slide 21, accessed December 2007

²⁴ ANLGreet model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

In-state cellulose supply was estimated from non-harvested cropland and residual biomass residues. The Maryland non-harvested cropland from 2002 was estimated by subtracting harvested cropland from total cropland.²⁵ The conversion factors below were used to estimate dry mass from cropland and ethanol from cellulose based on DOE and NREL data.²⁶ Additional estimates of biomass from crop residues, switchgrass on Conservation Reserve Program (CRP) land, forest residues, primary and secondary mill residues, and urban wood were obtained from an NREL study.²⁷

Cellulose feedstock conversion factors

Year	Cellulose yield per acre (tons)	Ethanol yield from cellulose (gal/ton biomass)
2008	5	70
2012	7.5	90
2020	10	100

It was assumed that it would take five years for production to ramp up to its maximum based on feedstock supplies. This ramp-up is faster than that assumed for Scenario A resulting in higher production and higher emissions savings earlier in the policy period. Consequently, the total emissions reduction and cost effectiveness are very similar for ethanol Scenarios A and B. The following table shows calculated cellulosic ethanol annual production maxima based on the upper bound of feedstock supplies.

²⁵ 2002 production, http://www.nass.usda.gov/census/census02/volume1/sc/st45_1_001_001.pdf, Table 1

²⁶ http://genomicsgtl.energy.gov/biofuels/2005workshop/2005low_intro.pdf, accessed December 28, 2008; J. Ashworth, NREL, personal communication, 4/06/07.

²⁷ A Geographic Perspective on the Current Biomass Resource Availability in the United States, A. Milbrandt, NREL, December 2005

Cellulosic ethanol annual production based on upper bound of feedstock supplies

Year	Cellulosic ethanol (1,000 gal)
2007	0
2008	62,138
2009	124,276
2010	186,414
2011	248,552
2012	310,689
2013	321,418
2014	332,146
2015	342,874
2016	353,602
2017	364,330
2018	375,058
2019	385,786
2020	396,514

Total ethanol production needed to meet TWG goals surpasses the upper bound of in-state potential feedstock by 2012. For scenario B, cellulosic ethanol production was assumed to equal the production maximum based on in-state feedstock resources. GHG deductions in each year were estimated by multiplying production by the incremental benefit of cellulose over corn-based ethanol.

Costs

For ethanol, costs for the incentives needed by this policy option are based on the difference in estimated production costs between conventional starch-based ethanol and cellulosic ethanol. Estimates taken from an NREL-sponsored industry forum estimate a production cost of \$1.31 per gallon for corn-based ethanol and \$1.97 per gallon for cellulose-based, resulting in a differential of \$0.66 per gallon.²⁸ These estimates include capitals costs so additional incentives for capital and R&D are not included in this analysis. These incentives are considered necessary in the near term to help commercialize technologies that produce ethanol from cellulose. The incentives should also help to establish the infrastructure to deliver biomass to biorefineries, since producers will seek the local feedstocks or renewable fuels for their operations.

By 2015, it is assumed that advances in cellulosic ethanol production (e.g., enzyme costs, production processes) will make cellulosic ethanol production cost competitive with starch-based production. Hence, the incentives are discontinued beginning in 2015. Note that federal legislation has been proposed to offer cellulose an incentive of \$0.765/gallon compared to the

²⁸ http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/19_forum/braemar_cellulosic.pdf, slide 21, accessed December 2007

\$0.51/gallon currently offered for ethanol production.²⁹ If enacted, this \$0.255/gallon premium could cover the additional incentives that are assumed to be needed by the State of Maryland. Obviously, the federal incentives do not assure that production facilities would locate in MD. These federal incentives have not been factored into the cost estimates for this option.

Biodiesel

Fossil diesel consumption estimates are (under business as usual):

BAU Diesel Consumption

Year	Diesel consumption (Mmgal/year)
2015	817
2020	941

The policy design calls for 10% of the 2005 fossil diesel consumption to be offset by 2015 from in-state production and 20% offset by 2020. In-state BAU production is estimated to be 16 Mmgal/yr in 2015 and 21 Mmgal/yr in 2020 (see below). Biodiesel has approximately 90% the heat content of fossil diesel.³⁰ Therefore, incremental in-state biodiesel production targets are:

Biodiesel production needed to meet policy goals

Year	Diesel consumption to be displaced (Mmgal/year)	New Biodiesel Production Needed (MMgal/year)
2015	61	51
2020	126	113

The BAU biodiesel production is based upon the current and planned biodiesel capacity of Maryland and assumed 5% growth rate after 2012. See the table below for the existing and planned facilities and capacity in MD:³¹

Facility Name	Status	Capacity (1000 gal)	Feedstock	Misc.
Maryland Biodiesel	In-production	500	Soy	Planned expansion will add 0.5-1 Mmgal/year capacity; goal of 5 Mmgal/year by 2008
Greenlight Biofuels	In-production	4,000	Animal fat with multi-feedstock capacity	Potential to be expanded to 8MMgal/year

²⁹ D. Morris, *Making Cellulosic Ethanol Happen: Good and Not So Good Public Policy*, Institute for Local Self-Reliance, January 2007, at www.newrules.org/agri/cellulosicethanol.pdf, accessed January 2007.

³⁰ Biomass Energy Data Book, Oak Ridge National Laboratory, http://cta.ornl.gov/bedb/appendix_a.shtml, accessed December 28, 2008.

³¹ <http://www.biodieselmagazine.com/plant-list.jsp>, accessed January 9, 2008;
http://biodieselmagazine.com/article.jsp?article_id=1027, accessed January 9, 2008;
http://biodieselmagazine.com/article.jsp?article_id=1508&q=greenlight%20biofuels&category_id=19, accessed January 9, 2008

The CO₂e emission factor for fossil diesel used in the inventory and forecast is 10.07 Mt/1,000 gallons. The lifecycle fossil diesel emission factor is 12.3 Mt/1,000 gallons.³²

Quantification Methods:

GHG Reductions

For biodiesel production a new study on lifecycle GHG benefits was used to estimate the CO₂e reductions for this option.³³ This study covered biodiesel production from soybean production, which is currently the predominant feedstock source for biodiesel production in the US and is assumed to remain that way for the purposes of this analysis. Lifecycle CO₂e reductions (via displacement of fossil diesel with soybean-derived biodiesel) were estimated by Hill et al. to be 41%. This value is being used by the TLU TWG to estimate the benefit of the biodiesel component of the TLU biofuels option. Hence, this analysis focuses on incremental benefits of in-state feedstocks. It does not include the benefits from transitioning from fossil to standard imported soy.

For this option, the incremental benefit of in-state production is derived from the carbon avoided from having to transport the feedstocks from their likely source region. For this assessment, the likely source region for soybean is the U.S. mid-west. Using the Iowa/Illinois border as a potential source region, rail transport would require shipments to central Maryland of about 855 miles.³⁴ Rail fuel consumption is about 423 ton-miles/gallon.³⁵ From these inputs, a GHG emission rate of 506 MtCO₂/MMgal biodiesel produced was calculated.

In addition to soybean oil, other oil feedstocks included in this analysis include animal oils (yellow grease, poultry fat, lard, and tallow) and algal oils. Maryland has virtually no production of other oilseed such as cottonseed, canola, or sunflower. Under Scenario A, it is assumed that technology advances will occur during the policy period that will allow for commercial scale production of algal oil to make up approximately 5% of biodiesel production by 2020. With sufficient technology advancement, another option could be Fischer-Tropsch biodiesel from cellulose.

For oil sources other than soybean oil, the benefit for substituting in-state biodiesel for fossil diesel is estimated starting with the lifecycle soybean emission factor (7,261 MtCO₂e/MMgal from the Hill et al. study). As mentioned previously, the benefits of the biodiesel component of the TLU biofuels option is based on displacement with soybean-based biodiesel. Hence, this analysis was designed to only account for the incremental benefit of in-state feedstock (oil) production using GHG preferential feedstocks. For animal fats, algal oils, and yellow grease CCS assumes that these have negligible embedded energy. So the incremental benefit over soy equals the soybean based EF (7,261 MtCO₂e/MMgal) minus transportation costs, which are

³² From: Hill, J., et. al., Proceedings of the National Academy of Sciences, vol. 103, no. 30, 11206-11210. U.S. soybean-based biodiesel.

³³ Hill, J., et. al., Proceedings of the National Academy of Sciences, vol. 103, no. 30, 11206-11210. U.S. soybean-based biodiesel.

³⁴ Google Maps directions, Davenport, Iowa to Maryland; www.maps.google.com.

³⁵ Association of American Railroads, http://www.aar.org/getFile.asp?File_id=466.

assumed to average 100 miles³⁶, yielding a benefit of 7,207 MtCO₂e/MMgal biodiesel over soy-based.

Scenario A

For biodiesel, the table below provides the mix of oil feedstocks assumed in this analysis based on relative proportions of available feedstocks to meet the TWG goals.

Assumed mix of oil feedstocks

Year	Oil Feedstock	Fraction of New Production	MMgal/yr Needed
2015	Soy	0.57	29
2015	Yellow grease	0.29	15
2015	Animal fats	0.14	7
2015	Algal	0.00	0
2015 Total			51
2020	Soy	0.54	61
2020	Yellow grease	0.28	32
2020	Animal fats	0.13	15
2020	Algal	0.05	6
2020 Total			113

GHG reductions were estimated by multiplying the production of each oil feedstock by the applicable incremental benefit (e.g., by oil type). Total reductions in each year were estimated by summing the incremental benefit for each oil type.

Scenario B

In Scenario B the upper limit of potential in-state feedstock supplies were estimated and GHG emissions were calculated accordingly.

For biodiesel, in-state oilseed feedstock supplies were estimated by measuring the average 2003-2005 Maryland production yields of soybean assuming that 100% of production would go towards biodiesel.³⁷ Animal fats available were estimated based on the ratio of Maryland livestock/poultry slaughter/production to that of Minnesota, given that detailed amounts of grease, lard, poultry fat, and tallow available in Minnesota are known from their Bio-Power Evaluation Tool (BioPET) that identifies locations, types, and volumes of biomass fuels.³⁸ Yellow grease was projected based on industry estimates of 14 pounds restaurant grease per capita and 7.6 pounds of grease per gallon using US Census projections for Maryland.³⁹ It was

³⁶ Max dimension of MD is ~200 miles, 100 miles is distance from center of the state to border.

³⁷ http://www.nass.usda.gov/Publications/Ag_Statistics/2007/index.asp, accessed January 9, 2008.

³⁸ <http://www.mncee.org/pdf/biomassreport.pdf>, accessed January 8, 2008.

³⁹ <http://media.cleantech.com/node/376>, accessed January 8, 2008; <http://www.cgfa.org/news.html>, under Evaluate The Cost And Usage Of Various Fuels, accessed January 8, 2008; <http://www.census.gov/population/www/projections/projectionsagesex.html>, table 6, accessed December 28, 2007.

assumed that by 2020 algal biodiesel technology will have progressed enough to be available to provide 5% of biodiesel needs.

Available biodiesel feedstock potential

Feedstock	Biodiesel equivalent (1000 gal)
Soybean oil	23,688
Animal fats	5,791
Yellow grease 2015	11,780
Yellow grease 2020	12,329
Algal 2020 - estimated at 5% of feedstock	2,090
total 2015	41,259
total 2020	43,898

The mix of feedstocks assumed was based on respective proportion of each feedstock of the upper-bound of in-state supply as in Scenario A.

Total biodiesel production needed to meet TWG goals surpasses the upper bound of in-state potential feedstock by 2012 and new biodiesel production above BAU needed surpasses in-state potential feedstock by 2014. GHG estimates for this scenario were calculated by multiplying new production of each oil feedstock by the applicable incremental benefit after subtracting BAU production. After 2012, production is assumed to be capped based on the upper bound of potential feedstock supply. Total reductions in each year were estimated by summing the incremental benefit for each oil type.

Scenario C

Scenario C assumes that new technology – in this case, algal – makes up the shortfall between the upper bound of potential in-state feedstock supply and the TWG in-state production goals. It also assumes that the use of soybean oil as a feedstock is phased out by 2015 in favor of non-food feedstocks. To meet the in-state production goals the table below provides the mix of oil feedstocks assumed in this analysis based on transitioning from current feedstock supply proportions to future proportions based on new technology.

Assumed mix of feedstocks with new technology meeting goal shortfall

Year	Oil Feedstock	Fraction of New Production	MMgal/yr Needed
2015	Soy	0.00	0
2015	Yellow grease	0.23	12
2015	Animal fats	0.11	6
2015	Algal	0.65	33
2015 Total			51
2020	Soy	0.00	0
2020	Yellow grease	0.11	12
2020	Animal fats	0.05	6
2020	Algal	0.84	95
2020 Total			113

Costs

For biodiesel, costs were estimated using information from an analysis of biodiesel production costs from the US DOE.⁴⁰ The value of incentives needed is assumed to be \$0.30/gallon - the value of incentives offered in a State of Missouri incentives program.⁴¹ In Oct 2004 when the \$0.30 Missouri biodiesel incentive passed, there was only 1 biodiesel plant under construction in Missouri; by the end of 2007, Biodiesel magazine lists 8 plants in operation or under construction in the state.⁴² This program offers production incentives to producers up to 15 million gallons of production/yr. The incentive grants last for five years. Hence, CCS only applied the incentives costs to the first five years of the policy period, except in Scenario C where a 10-year incentive is applied to encourage new technology.

CCS assumed a similar incentive structure and that these would cover the costs of all grants or tax incentives associated with this policy (all other implementation mechanisms are assumed to be achieved within existing programs). The cost estimates are based on multiplying the amount of biodiesel produced in each year above BAU by the production incentive. This assumes that all production occurs at production facilities of less than 15 million gallons/yr. The production incentive runs out after five years of production, except in Scenario C.

Key Assumptions: [TBD, as needed on TWG approval]

⁴⁰ See www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html; accessed January 2007.

⁴¹ Information on the Missouri Program from www.newrules.org/agri/mobiofuels.html#biodiesel, accessed January 2007.

⁴² <http://www.renewableenergyaccess.com/rea/news/story?id=21253>, accessed January 9, 2008; <http://www.biodieselmagazine.com/plant-list.jsp?view=production&sort=state&sortdir=asc&country=USA>, accessed January 9, 2008.

Key Uncertainties

Cost competitiveness of biofuels will depend on cost of oil

We are awaiting additional studies on Maryland feedstock estimates that may help refine projections.

The Energy Information Administration (EIA) has stated “Capital costs for a first-of-a-kind cellulosic ethanol plant with a capacity of 50 million gallon per year are estimated by one leading producer to be \$375 million (2005 dollars), as compared with \$67 million for a corn-based plant of similar size, and investment risk is high for a large-scale cellulosic ethanol production facility. Other studies have provided lower cost estimates. A detailed study by the National Renewable Energy Laboratory in 2002 estimated total capital costs for a cellulosic ethanol plant with a capacity of 69.3 million gallons per year at \$200 million.”⁴³

In June 2006, a U.S. Senate hearing was told that the current cost of producing cellulosic ethanol is US \$2.25 per US gallon (US \$0.59/litre). This is primarily due to the current poor conversion efficiency. At that price it would cost about \$120 to substitute a barrel of oil (42 gallons), taking into account the lower energy content of ethanol. However, the Department of Energy is optimistic and has requested a doubling of research funding. The same Senate hearing was told that the research target was to reduce the cost of production to US \$1.07 per US gallon (US \$0.28/litre) by 2012.

Transitioning to large amounts of energy crop cultivation for biofuels has the potential for a negatively impact on biodiversity.

A key uncertainty with this option is in estimating the incremental benefit above what is achieved with the low carbon fuel standard. To estimate benefits for in-state production of ethanol using GHG-superior technologies and feedstocks, one must make critical assumptions about what types of fuels will supply the low carbon fuel standard within the policy period. For the purposes of this analysis, CCS has assumed that the primary low carbon fuel that will be used to lower the carbon content of gasoline-powered vehicles will be starch-based ethanol. The incremental benefit is based on the higher GHG benefits associated with producing ethanol in-state using cellulosic ethanol technology and feedstocks. To the extent that this technology is widely employed within the policy period and acts as a significant supplier of fuel to meet the low carbon standard, the incremental benefits estimated here could be overstated.

Additional Benefits and Costs

Potential for competition with the production of food; less impact by cellulosic ethanol than corn ethanol on water quality and could actually reduce nutrient loads in some circumstances; permanent new sources of income for farmers and foresters; using current waste streams to replace US fuel consumption; environmental benefits or costs; recycling money in local economies; stimulation of potential markets for other biomass feedstocks (forest treatment biomass, municipal solid waste fiber); increased transportation energy security with shorter transport distances and on-farm use of fuel produced; reduced reliance on imported petroleum.

⁴³ <http://www.eia.doe.gov/oiaf/analysispaper/biomass.html>, accessed December 2007

Feasibility Issues

Implementation of this option requires additional research and development in cellulosic ethanol production methods, development of feedstock collection and delivery infrastructure, successful negotiations with cellulosic technology leaders to establish pilot and commercial-scale plants in the state. Sourcing of feedstocks and the size and location of facilities (both crushing and biodiesel production) must be addressed for optimization and planning. Trade-offs between food and fuel crops will be an important issue. Full implementation of biodiesel goals require quick research advancement in algal oil harvesting.

There may be an overlap among agricultural options that seek to increase/maintain crop acreage in no-till production or in conservation management programs. This could be in conflict with the higher levels of crop production proposed in this option.

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MWG meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the MWG]

AFW-8 Nutrient Trading with Carbon Benefits

Policy Description

Nutrient trading, particularly trading between point sources (such as waste water treatment plants) and non-point sources (such as agricultural operations), provides the opportunity to create significant carbon sequestration benefits in Maryland.

Nutrient trading is a flexible and cost-effective means to achieve water quality improvements while also providing significant carbon benefits. Nutrient trading is the transfer of credits created through nutrient reduction from one source, specifically nitrogen and phosphorus. For example, buyers who need to apply or release more nutrients than currently permitted under state-law could obtain credits from sellers who have produced excess nutrient credits. Opportunities exist to apply this policy to also promote and register any carbon reductions associated with nutrient reduction practices. These policies would apply to agriculture, wastewater treatment plants, industrial dischargers, highway contractors and developers.

Besides creating economic benefits, nutrient trading encourages improved efficiency of fertilizer use and other nitrogen-based soil amendments through best management practices and advanced technologies. Advanced technologies such as GPS and GreenSeeker can assist in precision application of nitrogen on crops.

Many of the best management practices that would be incentivized under the nutrient trading program would also result in significant greenhouse gas reductions, such as no-till, conservation tillage, improved irrigation management, conservation buffers, grassland plantings, green infrastructure, afforestation, reforestation and restoration of wetlands.

Note: Excess nitrogen not metabolized by plants can leach into groundwater and/or be emitted to the atmosphere as N₂O which has 310 times the effect as one unit of CO₂. Better nutrient utilization can lead to lower nitrous oxide emissions from run-off.

Policy Design

A cap is currently under development. This is important so as not to overpromise and under-deliver. A cap will also keep costs under control and stay focused on the real goal of reducing GHG rather than just trading for economic gain.

Include acreage benefits and ancillary benefits.

Quantify as best as possible what the saving might be in nutrient reductions.

Goals:

By 2020, increase nitrogen fertilizer efficiency by 20% through the implementation of a nutrient trading scheme.

Have a 2010 target – perhaps that should be the cap?

Further goals could be amount of acreage in program or number of participants or expressed in terms of carbon, such as, carbon will be reduced by xx % by 2020 through sequestration.

The Chesapeake Bay Program has specific reduction goals. Those could be incorporated. Work with MDA to put together some state-wide scenarios and come up with some goals.

Build on existing point source nutrient trading policy document being developed by the Maryland Department of the Environment and develop a complimentary agricultural non-point source policy to include carbon and nutrients. This can be accomplished through regulation and guidance.

- **Work Group:** Agricultural Nutrient Trading Advisory Committee formed and convened November 20, 2007. A draft policy on the non-point source policy is slated for public review by February, 2008.
- **Timing:** Adopt policy by first quarter 2008, stakeholder meetings in spring, and finalize by June, 2008.
- **Parties Involved:** Agricultural and urban non-point sources; municipal wastewater treatment plants; industrial and commercial dischargers; Soil Conservation Districts, Maryland Department of the Environment and Maryland Department of Agriculture.
- **Other:** Septic system owners; other non-point sources; Chesapeake Bay Foundation; University of Maryland; World Resources Institute; Maryland Association of Municipal Wastewater Agencies; Soil Conservation Service.

Implementation Mechanisms

A nutrient/carbon trading policy could be implemented through watershed-based MDE general permit that authorizes trading to occur. A point and non-point source trading policy would be developed and finalized by the MDE and MDA. Any credits produced would be certified and the carbon sequestered could be placed on the state registry and eligible for sale in the event such credits meet applicable standards under emerging state and federal laws/policies on greenhouse gasses.

Consider placing nutrient trading options in permits.

Related Policies/Programs in Place

- Chesapeake Bay Program, Nutrient Trading, Fundamental Principles and Guidance, March, 2001.
- MDE point source trading document, to be issued by end of 2007.
- EPA Water Quality Trading Policy, 2003.
- EPA, Water Quality Trading Took Kit for Permit Writers, 2007.
- Maryland Nutrient Management Act of 1998.
- Virginia Chesapeake Bay Watershed Nutrient Credit Exchange Program, 2005

- Pennsylvania Policy and Guidelines on Trading of Nutrient and Sediment Reduction Credits, 2006.

Types(s) of GHG Reductions

- **N₂O**: reductions occur when nitrogen run-off and leaching are reduced, which leads to the formation and emission of N₂O.
- **CO₂**: Carbon is sequestered through riparian buffers; soil sequestration; and constructed wetlands.
- **CH₄**: Methane is reduced through agricultural best management practices or captured for renewable energy.

Estimated GHG Reductions and Net Costs or Cost Savings

- **Data Sources:** See reference documents regarding carbon sequestration rates from reforestation. For example, see the USDA Forestry Inventory and Analysis “look up tables”, USDOE’s 1605 (b) look up table; Winrock carbon uptake model; Chapman – Richards growth model. See reference documents regarding carbon sequestration rates from no-till practices, such as Va. Tech Rainfall Simulate Research. Also, see research analysis from USDA/ARS in Fort Collins, Colorado, which included analysis on deep core soil samples for baseline data under NLEAP and CEQUESTER models.

- **Quantification Methods:**

A nitrous oxide emission factor for fertilizer use was calculated by dividing the carbon equivalent emissions from fertilizer use (obtained from the Maryland inventory and forecast) by the fertilizer use for each year. Historical fertilizer use for Maryland was obtained from the Maryland Department of Agriculture (1999-2000 to 2005-06). Based on this historical data it was assumed that BAU fertilizer use for the policy period would remain constant at 108,000 tons per year (this was the average of all years available)⁴⁴. The target fertilizer efficiency improvements brought about through the implementation of the nutrient trading program were applied to the assumed fertilizer use over the policy period. The difference between BAU fertilizer applied and fertilizer applied under the policy is the target fertilizer reduction, displayed in Table 8-1.

The average CO₂e emission factor (in MMtCO₂-e per ton of fertilizer applied) for the years 1990–2006 was used to calculate the avoided GHG emissions from the proposed increase in fertilizer efficiency resulting from the implementation of the nutrient trading program. The avoided life cycle GHG emissions (i.e. emissions associated with the production, transport, and energy consumption during application) were taken from Wood and Cowie⁴⁵. The estimate provided for the U.S. (taken from West and Marland, 2001⁴⁶) was 857.5 g CO₂-e per Kg N⁴⁷ or

⁴⁴ There was no data for the 2002-03 FY period.

⁴⁵ Sam Wood and Annette Cowie (2004) *A Review of Greenhouse Gas Emission Factors for Fertiliser Production* Research and Development Division, State Forests of New South Wales, Cooperative Research Centre for Greenhouse Accounting

⁴⁶ West, T. O. and Marland, G. 2001. *A Synthesis of Carbon Sequestration, Carbon Emissions and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States*. Agriculture, Ecosystems and Environment 1812, 1-16.

0.778 Mt CO₂-e per Ton N. This estimate was significantly lower than the estimates for European fertilizers (ranging from 5,339.9 to 7,615.9 g CO₂-e per Kg N). Wood and Cowie recognize that the estimate for the U.S. is low and suggested that part of this discrepancy could be explained by the exclusion of N₂O emissions from the US estimate, which are significant component of GHG emissions.

The results of the calculations detailed in the preceding discussion are displayed in Table 8-1. Note that this approach does not capture other GHG benefits associated with nutrient trading including enhanced soil carbon sequestration, possible forest sequestration or other land use practices that may be incorporated under a nutrient trading program.

The cost savings associated with using less fertilizer was calculated by multiplying the total fertilizer reduction in each year by the average cost of fertilizer in 2007⁴⁸. The program costs of nutrient trading were estimated as the sum of fertilizer savings (negative cost); costs for soil testing; costs for staff, overhead, and travel; and guidance document preparation costs. Soil testing would be required for each crop field once every 4 years. The cost for each soil test was estimated to be \$10, for a total cost of \$683/year for soil testing (assuming \$10 per 75 acre field size). Costs for 2 full-time equivalents (FTEs) of additional staff, overhead, travel, lab, and associated costs was estimated at \$250,000/year, and preparation of guidance documents was assumed to be \$75,000 in the first year.⁴⁹

Table 8-1: Fertilizer Reduction, GHG Benefits and Costs of a Nutrient Trading Program

Year	Policy Target Efficiency Improvements	Target Fertilizer Reduction (short tons N)	Avoided GHG Emissions (MMtCO ₂ e)	Annual Cost of Fertilizer Programs (\$MM)	Avoided Cost of Fertilizer (\$MM)	Net Cost (savings as negative)	Discounted Cost/savings (\$MM)
2008	2%	1,662	0.01	\$ 1.01	-\$0.639	\$0.37	\$0.33
2009	3%	3,324	0.02	\$0.683	-\$1.28	-\$0.60	-\$0.51
2010	5%	4,986	0.03	\$0.683	-\$1.92	-\$1.23	-\$1.02
2011	6%	6,647	0.04	\$0.683	-\$2.56	-\$1.87	-\$1.47
2012	8%	8,309	0.05	\$0.683	-\$3.20	-\$2.51	-\$1.88
2013	9%	9,971	0.07	\$0.683	-\$3.83	-\$3.15	-\$2.24
2014	11%	11,633	0.08	\$0.683	-\$4.47	-\$3.79	-\$2.57
2015	12%	13,295	0.09	\$0.683	-\$5.11	-\$4.43	-\$2.86
2016	14%	14,957	0.10	\$0.683	-\$5.75	-\$5.07	-\$3.11
2017	15%	16,618	0.11	\$0.683	-\$6.39	-\$5.71	-\$3.34
2018	17%	18,280	0.12	\$0.683	-\$7.03	-\$6.35	-\$3.53
2019	18%	19,942	0.13	\$0.683	-\$7.67	-\$6.99	-\$3.71
2020	20%	21,604	0.14	\$0.683	-\$8.31	-\$7.63	-\$3.85

⁴⁷ These emission factors provide an estimate of the typical life cycle greenhouse gas emissions (including resource extraction, the transport of raw materials and products, and the fertilizer production processes) per unit weight of fertilizer produced (i.e. g CO₂-e / kg fertilizer).

⁴⁸ April 2007 data from ERS/USDA see <http://www.ers.usda.gov/Data/fertilizeruse/>.

⁴⁹ Brian Hurd, NMSU Agricultural Economics, personal communication with H. Lindquist, CCS, June 2006.

AFW-9 Waste Management through Source Reduction & Advanced Recycling

Policy Description

Reduce the volume of waste from residential, commercial, and government sectors through programs that reduce the generation of wastes and enhance reuse of product components and manufacturer's lifetime product responsibility. Reduction of generation at the source reduces both landfill emissions as well as upstream production emissions. Increase recycling and reduce waste generation in order to limit greenhouse gas emissions associated with the production of raw materials.

Reduce methane emissions associated with landfilling by reducing and recycling the biodegradable fraction of waste emplaced.

For products that cannot be reused, increase recycling programs, create new recycling programs, provide incentives for the recycling of construction materials, develop markets for recycled materials, and increase average participation/recovery rates for all existing recycling programs to enhance and encourage upcycling (where the remanufactured product is equal to or higher in quality than the original product).

Electronics recycling and recovery of industrial gases from foam products are included.

Policy Design

- **Goals:** Waste stream will be reduced by 15% in 2012, 25% by 2015, 35% by 2020, and 80% by 2050. Recycling stream will increase by 10% by 2012, 20% by 2015, 30% by 2020, then gradually decrease to 10% by 2050 as more products and their components are reused and new source use also decreases.
- **Timing:** Startup in 2010 and ramp up to higher levels in 2012 and 2015, consistent with goals
- **Parties Involved:** Manufacturers, relevant trade associations, consumer's associations, all state and local agencies, consumers, retail outlets
- **Other:** According to the "2006 Maryland Waste Diversion Activities Report," which provides information on the state's recycling and source reduction activities for the 2005 calendar year, Maryland achieved a recycling rate of 39.2% (including organics) and an overall diversion rate of 42.6%.⁵⁰ Table 9-1 displays diversion data in Maryland from 2001 through 2005. Although the standard baseline year for the MD process is 2006, the baseline for this recycling option is assumed to be 2005, as this is the year data was last available.

⁵⁰ Maryland Department of the Environment. 2006. "Maryland Waste Diversion Activities Report: 2006." Accessed on December 20, 2007 from: <http://www.mde.state.md.us/assets/document/recycling/2006MWDAR.pdf>.

Table 9-1: Data from Maryland Recycling Act Annual Reports (Calendar Years 2001-2005)⁵¹

Item	2001	2002	2003	2004	2005
MRA Rate	37.00%	37.00%	36.80%	35.80%	39.20%
Waste Diversion Rate	39.00%	39.50%	39.60%	38.80%	42.60%
Source Reduction Credit	2.00%	2.50%	2.80%	3.00%	3.40%
Compostables	617,390	645,230	892,250	853,094	944,358
Glass	47,764	55,481	64,894	71,558	57,889
Metals	220,631	251,703	271,646	302,904	535,195
Paper	948,513	909,447	821,652	861,927	840,644
Plastic	23,149	35,930	24,483	30,663	36,858
Misc.	547,586	558,050	518,599	561,829	518,935
Total MRA Recycling (including organics)	2,405,033	2,455,841	2,593,524	2,681,975	2,933,879
Recycling (excluding organics)	1,787,643	1,810,611	1,701,274	1,828,881	1,989,521
Total MRA Waste Disposed in Landfills and Incinerators*	4,095,056	4,181,567	4,454,096	4,809,575	4,550,506
Total MRA Waste, Including Recycling*	6,500,089	6,637,408	7,047,620	7,491,550	7,484,385
Total Source Reduction*	132,655	170,190	203,018	231,697	263,426
Total Generation, Including Recycling and Source Reduction*	6,632,744	6,807,598	7,250,637	7,723,248	7,747,811
% Change*		2.64%	6.51%	6.52%	0.32%
Annual generation change*	3.36%				
Average annual recycling rate*	37.17%				

*Calculated from Report Data

These rates are specific to what is referred to as “MRA (Maryland Recycling Act) waste” – the definition of which aligns with the EPA definition of municipal solid waste (MSW). This diversion rate does not take into account waste exported to landfills in neighboring states. The “Annual Report of Solid Waste Management in Maryland – Calendar Year 2005” reports that nearly 1.8 million tons of waste were exported to landfills in Pennsylvania and Virginia, while Maryland landfills received almost 0.3 million tons of waste from New York, Pennsylvania, West Virginia, and the District of Columbia.⁵² Considering the net exports of landfill MSW in Maryland, the baseline recycling rate in Maryland was 31.74% (including

⁵¹ Maryland Department of the Environment. “Maryland Waste Diversion Activities Report.” Reports for 2002-2006, reporting data from 2001-2005 all available at: http://www.mde.state.md.us/Land/land_publications/index.asp.

⁵² Maryland Department of the Environment. 2006. “Annual Report: Solid Waste Management in Maryland – Calendar Year 2005.” September 2006. Accessed on December 20, 2007 from: http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

organics), lower than the rate reported by the 2005 Maryland Recycling Act Report.⁵³ As Table 9-2 shows, the business-as-usual (BAU) composting level is projected by assuming that 32% of total recyclables are composted.

Table 9-2: Business-as-Usual Waste Management Projection for Maryland

Item	2005	2010	2012	2015	2020
Total MD Waste Generation (Including Net Exports)	9,242,389	10,904,236	11,649,832	12,864,895	15,178,095
MSW Managed in-state (3.36%/yr growth 2001-2005)	7,747,811	9,140,922	9,765,948	10,784,525	12,723,659
MSW Imported	286,011	337,438	360,511	398,112	469,695
MSW Exported	1,780,589	2,100,752	2,244,394	2,478,482	2,924,130
MD Population (from I&F)	5,561,214	5,907,575	5,989,170	6,113,680	6,326,975
MSW Generation per capita (tons/person)	1.66	1.85	1.95	2.10	2.40
MSW Recycled (Including organics, 39.2% MSW managed in-state; 2005 Baseline)	2,933,879	3,583,242	3,828,252	4,227,534	4,987,674
MSW Composting (32% of MSW Recycled)	938,841	1,146,637	1,225,041	1,352,811	1,596,056
MSW Disposed (in-state landfills only)	3,169,045	3,617,031	3,864,352	4,267,399	5,034,708
MSW Disposed in all landfills	4,949,634	5,717,783	6,108,746	6,745,881	7,958,838
Waste to Energy (incinerators) (18% of waste generated)	1,358,876	1,603,212	1,712,834	1,891,480	2,231,582

Implementation Mechanisms

- All government agencies would be required/encouraged to preferentially purchase goods made from reused and recycled materials and goods from manufacturers who take “cradle to cradle” responsibility for their products.
- As needed, identify incentives that encourage the reuse of materials and products, recycling of materials and products, and discourages the single-use waste of products.
- Identify incentives to reduce the amount of raw materials used.
- Increase quality as a means to enhance product longevity with innovative programs to reward manufacturers for quality.

⁵³ Calculation: (2,933,879 tons recycled)/(2,933,879 tons recycled + 1,358,876 tons incinerated + 4,949,636 tons landfilled + 1,780,589 tons exported – 286,011 tons imported).

- Identify and phase out any subsidies that discourage waste reduction, reuse of components, or improved quality and longevity of products.
- Work with cross-cutting TWG to include education regarding the wisdom of these policies to all segments of the population including the public.
- Add discussion of consumer's role in reducing overall consumption. Perhaps look at incentives or disincentives to reduce consumption.
- Recently, an area of focus in the solid waste industry has been in increase recycling of organic wastes (lawn & garden waste, food waste, wood, paper, etc.) using different conversion technologies, including composting, anaerobic digestion, or hybrids of these technologies. These tend to be problematic and can have negative impacts not only in smell but in groundwater pollution.
- The European Union has WEEE (Waste Electronic and Electrical Equipment) Directive. Manufacturers of all electronic and electrical equipment sold in Europe are required to take back all products when no longer useful or desired by the purchaser. This encourages interchangeable, reusable parts; elimination of toxins and heavy metals; and maximum recycling, significantly reducing waste.

Related Policies/Programs in Place

Recent Actions in MD: No cradle-to-cradle programs in place but MDE does have an aggressive e-cycling program.

Types(s) of GHG Reductions

- **CH₄:** Methane reductions because of reduced volumes in landfills. Diverting biodegradable wastes from landfills will result in a decrease in methane gas releases from landfills.
- **CO₂:** Upstream Energy Use Reductions – The energy and GHG intensity of manufacturing a product is generally less using recycled feedstocks than from using virgin feedstocks.

Estimated GHG Reductions and Net Costs or Cost Savings

- **GHG Reduction Potential in 2015, 2020 (MMtCO₂e):** 17.0, 29.2
- **Net Cost per MtCO₂e:** -\$6
- **Data Sources:** Baseline recycling and waste generation estimates and projections were generated from annual reports on the waste diversion activity and solid waste management in Maryland.⁵⁴ The breakdown of the waste disposed in Maryland by type was derived from

⁵⁴ Maryland Department of the Environment. 2006. "Maryland Waste Diversion Activities Report: 2006." Accessed on December 20, 2007 from: <http://www.mde.state.md.us/assets/document/recycling/2006MWDAR.pdf>.

Maryland Department of the Environment. 2006. "Annual Report: Solid Waste Management in Maryland – Calendar Year 2005." September 2006. Accessed on December 20, 2007 from: http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

US-level data provided in the EPA 2005 Waste Characteristics Report.⁵⁵ The breakdown of baseline recycled waste in Maryland was derived from the 2006 Maryland Recycling Act Annual Report⁵⁶ and the EPA 2005 Waste Characteristics Report. The GHG emission reductions modeled using EPA's Waste Reduction Model (WARM).⁵⁷

Information used to build the cost effectiveness estimates was compiled from several sources. Where available, Maryland-specific data were used. However, in many cases, the cost effectiveness quantification relies on information used in previous quantifications of similar options by CCS. Maryland-specific information is from the 2006 MRA Report⁵⁸ and a case study from Montgomery County.⁵⁹

- **Quantification Methods:**

GHG Reductions

The 2005 MRA recycling rate of 39.2%, along with the reported recycling tonnage of 2,933,879, was used to calculate the quantity of MRA waste disposed: 4,550,506 tons.⁶⁰ As the information regarding the net export of waste comes from a different document than the MRA recycling rate, the recycling rate of 39.2% will be applied to MSW managed in-state, for consistency purposes. Based on the total diversion rate (42.6% in 2005), the total estimated waste “generated” – including tons source reduced – is 7,747,881 tons (shown in Table 9-2 above). Data were collected from the MRA annual reports covering the calendar years 2001-2005. The average annual generation change over this time frame is 3.36%. This historic average is used to project future baseline generation.

Organic composting is assumed to consist of food and yard waste collected curbside and processed at a central composting facility. While this is a part of the MRA recycling figure, yard trimmings and food waste are treated as compostables by WARM. Therefore, this

⁵⁵ *Municipal Solid Waste in the United States, 2005 Facts and Figures*, US EPA, Office of Solid Waste, EPA530-R-06-011, October 2006. Accessed on December 30, 2007 from: <http://www.epa.gov/garbage/pubs/mswchar05.pdf>.

⁵⁶ Maryland Department of the Environment. 2006. “Maryland Waste Diversion Activities Report: 2006.” Accessed on December 20, 2007 from: <http://www.mde.state.md.us/assets/document/recycling/2006MWDAR.pdf>.

⁵⁷ Version 8, May 2006. From http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html. EPA created **WARM** to help solid waste planners and organizations track and voluntarily report GHG emissions reductions from several different waste management practices. **WARM** is available both as a Web-based calculator and as a Microsoft Excel spreadsheet. **WARM** calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in MtCe, MtCO₂e, and energy units (million Btu) across a wide range of material types commonly found in MSW. For explanation of methodology, see the EPA report “Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks,” EPA530-R-02-006, at <http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html>

⁵⁸ Maryland Department of the Environment. 2006. “Annual Report: Solid Waste Management in Maryland – Calendar Year 2005.” September 2006. Accessed on December 20, 2007 from: http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

⁵⁹ Montgomery County, MD. Department of Environmental Protection. “Composting/Grasscycling Program Summary.” Accessed on January 11, 2008 from: <http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/composting/summary.asp>.

⁶⁰ Waste captured by the Maryland Recycling Act diversion rate is determined on a county level. However, the MRA excludes scrap metal, landclearing debris, construction and demolition debris, sewage sludge, and hospital wastes. The waste that is captured by the MRA is assumed to align closely with the EPA definition of municipal solid waste. This calculation is performed utilizing the following equation: Waste Disposed = MRA Recycling * (1 – Recycling %)/(Recycling %)

analysis will separate organic composting from recycling. The cost analysis for organic composting will differ for that of recycling, as well. Source reduction is the process of reducing the amount of refuse that enters the front-end of the waste stream. For the purpose of this analysis, the only items that are “source reduced” are those for which source reduction is an accepted input for the WARM model.

The analysis of this policy option is performed on the incremental changes in waste diversion, based on the policy goals established by the TWG. Therefore, it is assumed that the baseline source reduction is captured by the projected baseline waste generation. Exports and imports are assumed to increase at the same rate as MSW managed in-state. The baseline - or business as usual (BAU) – projections for waste generation, recycling, landfilling, exports, imports, and incineration are displayed in Table XX in the “Policy Design” section above.

Table 9-3 shows the projected waste generation and diversion – including recycling and source reduction – through 2020. These projections are formulated by applying the goals set forth by the TWG to the baseline projections from Table 9-2. Table 9-4 displays the incremental changes in waste generation and diversion as a result of the policy goals; the difference between Tables 9-3 and 9-2.

Table 9-3: Waste Management Projection for Maryland – Including Policy Goals

Item	2005	2010	2012	2015	2020
Waste Stream Reduction	0%	5%	15%	25%	35%
Recycling Stream Increase	0%	3%	10%	20%	30%
Total MD Waste Generation (Including Net Exports)	9,242,389	10,359,024	9,902,357	9,648,671	9,865,762
MSW Generation per capita (tons/person)	1.66	1.75	1.65	1.58	1.56
MSW Source Reduced	-	545,212	1,747,475	3,216,224	5,312,333
MSW Recycled	2,933,879	3,702,683	4,211,077	5,073,041	6,483,977
MSW Disposed (in-state landfills only)	3,455,056	3,503,273	2,876,482	2,120,698	1,256,376
Net MSW Exports (to out-of-state landfills)	1,494,578	1,675,148	1,601,301	1,560,278	1,595,383
Total MSW Landfill disposal	4,949,634	5,178,421	4,477,783	3,680,975	2,851,759
Waste to Energy (29.7% of waste disposed)	1,358,876	1,477,920	1,213,497	894,655	530,025

Table 9-4: Incremental Diversion Under Policy Goals

Item	2005	2010	2012	2015	2020
MSW Recycled (Including Organic Composting)	-	119,441	382,825	845,507	1,496,302
MSW Recycled (Excluding Organic Composting)	-	86,834	278,313	614,681	1,087,808
MSW Composted	-	32,608	104,512	230,826	408,495
MSW Source Reduced	-	545,212	1,747,475	3,216,224	5,312,333
MSW Landfilled	-	-539,362	-1,630,963	-3,064,905	-5,107,079
MSW Incinerated (WTE)	-	-125,292	-499,337	-996,825	-1,701,557
Incremental Diversion (tons)	-	664,653	2,130,300	4,061,731	6,808,635
Total Diversion (%)	31.7%	39.0%	51.1%	64.4%	77.7%
Incremental Diversion (%)	-	6.1%	18.3%	31.6%	44.9%

The waste generated in Maryland is broken down into six major categories: paper, organics, mixed plastic, metals, glass, and other. Where further categorization information was available, the waste generated within each of these categories is broken down further. Table 9-5 shows the composition of waste generated in Maryland.

Of the six categories displayed in the breakout in Table 9-5; paper, organics, mixed plastic, and metals may be categorized further with the information currently available. Glass is considered to be its own category within WARM, and “other” is assumed to be represented by the WARM category, “mixed recyclables.” Table 9-6 shows the breakdown of waste that is disposed in landfills or incinerator facilities, both in the BAU and policy scenarios. The

baseline waste breakdown for each waste type is calculated from the amount of the waste type disposed and the total amount disposed in each category.⁶¹

The share of total waste generated for each category is multiplied by the total waste landfilled to determine the baseline quantity of waste landfilled for each category. The categories for which further categorization information is available (all except glass and other) are further broken out by multiplying the total quantity of waste landfilled for each category by the share of disposal for each waste type. For example: the baseline landfill disposal projection for 2020 is 7,958,838 tons. To estimate the tons of corrugated cardboard landfilled under the BAU scenario, multiply this number by 34.2% and multiply the result of this product by 21.0%. The result is the projected amount of corrugated cardboard landfilled in 2020 under the baseline scenario (571,604 tons). The process for estimating the characterization of waste incinerated is identical to the methodology used to estimate the characterization of waste landfilled.

Table 9-5: Waste Generation Characteristics⁶²

Category	Baseline Composition (BAU)
Paper	34.2%
Organics	25.0%
Mixed Plastic	11.8%
Metals	7.6%
Glass	5.5%
Other (assumed mixed reyclables)	15.9%

Table 9-6: Characterization of Waste Disposed (Landfill and WTE)⁶³

Waste Type	BAU
<i>% of Discarded Paper</i>	
Corrugated Cardboard	21.0%
Magazines/Third Class Mail	12.6%
Newspaper	3.2%
Office Paper	5.9%
Phonebooks	1.3%
Textbooks	2.0%
Other (assumed mixed paper, broad)	54.0%
<i>% of Discarded Organics</i>	

⁶¹ Maryland Department of the Environment. 2006. "Annual Report: Solid Waste Management in Maryland – Calendar Year 2005." September 2006. Accessed on December 20, 2007 from: http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

⁶² *Municipal Solid Waste in the United States, 2005 Facts and Figures*, US EPA, Office of Solid Waste, EPA530-R-06-011, October 2006. Accessed on December 30, 2007 from: <http://www.epa.gov/garbage/pubs/mswchar05.pdf>.

⁶³ *Ibid.*

Waste Type	BAU
Food Waste	70.0%
Yard Trimmings	30.0%
<i>% of Discarded Plastics</i>	
HDPE	24.9%
LDPE	29.0%
PET	9.7%
Other (assumed mixed plastics)	36.4%
<i>% of Discarded Metals</i>	
Aluminum Cans	58.2%
Steel Cans	41.8%

The baseline composition of recycled waste is derived from the data presented in the MRA report on diversion activities over the 2005 calendar year (seen in Table 9-7).⁶⁴ The further characterization of waste recycled in Maryland is estimated based on national data from the 2005 EPA Waste Characteristics report (Table 9-8).⁶⁵

The share of total waste for each category is multiplied by the total waste recycled to determine the baseline quantity of waste recycled for each category. The categories for which further categorization information is available (all except glass and other) are further broken out by multiplying the total quantity of recycling for each category by the share of recycling for each waste type. For example: the baseline recycling projection for 2020 is 4,733,201 tons. To estimate the tons of corrugated cardboard recycled under the BAU scenario, multiply this number by 29.0% and multiply the result of this product by 52.7%. The result is the projected amount of corrugated cardboard recycled in 2020 under the baseline scenario (762,226 tons).

Table 9-7: Recycled Waste Characteristics

Category	Baseline Recycling (BAU)
Paper	29.0%
Organics	32.0%
Mixed Plastic	1.0%
Metals	18.0%
Glass	2.0%
Other (assumed mixed recyclables)	18.0%

Table 9-8: Baseline and Policy Recycling Characterization

Waste Type	BAU	2015 Policy	2020 Policy
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⁶⁴ Maryland Department of the Environment. 2006. "Annual Report: Solid Waste Management in Maryland – Calendar Year 2005." September 2006. Accessed on December 20, 2007 from: http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

⁶⁵ *Municipal Solid Waste in the United States, 2005 Facts and Figures*, US EPA, Office of Solid Waste, EPA530-R-06-011, October 2006. Accessed on December 30, 2007 from: <http://www.epa.gov/garbage/pubs/mswchar05.pdf>.

Waste Type	BAU	2015 Policy	2020 Policy
% of Discarded Paper			
Corrugated Cardboard	52.7%	17.9%	7.3%
Magazines/Third Class Mail	7.3%	2.6%	1.1%
Newspaper	25.5%	9.1%	3.7%
Office Paper	9.8%	3.5%	1.4%
Phonebooks	1.0%	0.4%	0.1%
Textbooks	1.0%	0.4%	0.1%
Mixed Paper, Broad	2.7%	66.1%	86.2%
% of Discarded Organics			
Food Waste	70.0%	70.0%	70.0%
Yard Trimmings	30.0%	30.0%	30.0%
% of Recycled Plastics			
HDPE	40.6%	6.6%	2.2%
LDPE	10.8%	1.8%	0.6%
PET	42.2%	6.9%	2.3%
Other (assumed mixed plastics)	6.4%	84.7%	94.8%
% of Recycled Metals			
Aluminum Cans	31.5%	31.5%	31.5%
Steel Cans	68.5%	68.5%	68.5%

The limitations of the WARM model preclude one from applying the 35% reduction in generation by 2020 (henceforth, source reduction) across the board. WARM does not accept source reduction as an input for mixed paper, food waste, yard trimmings, mixed plastics, or mixed recyclables. The application of the source reduction goal to the remaining waste types results in a negative amount of waste landfilled and/or incinerated for many categories. Therefore, it is necessary to achieve the source reduction goal by assuming that only materials where source reduction is an acceptable WARM input are source reduced. This assumption explains why the shares of recycled waste for mixed paper, mixed plastics, mixed recyclables (other) increased over the policy period. This assumption also explains the decrease in the share of disposed (landfill and incinerator) waste over the policy period. The composition of waste that is source reduced is displayed in Table 9-9.

Table 9-9: Composition of Waste “Source Reduced”

Waste Type	% of Total SR
Glass	10.7%
HDPE	5.2%
LDPE	5.8%
PET	2.2%
Corrugated Cardboard	24.3%
Magazines/Third Class Mail	8.9%
Newspaper	7.8%
Office Paper	5.6%
Phonebooks	1.0%

Waste Type	% of Total SR
Textbooks	1.4%
Aluminum Cans	11.9%
Steel Cans	15.3%

The following list describes step-by-step the methods used to estimate the levels of recycling, source reduction, landfill disposal, and incineration disposal under the policy scenario:

1. Estimate the waste generated for each waste type under the baseline scenario. This may be accomplished by multiplying the total generation (including net exports) by the share of generation of each category and the share of each category's generation by the share of each waste type within the category (except for glass and other, which are single-type categories). The alternate method is to take the sum of the calculated baseline waste landfilled, incinerated, and recycled (methods for these calculations listed above).
2. Calculate the tons source reduced for each waste type where source reduction is a valid WARM input.
 - a. Determine the source reduction multiplier for each of these waste types. This is accomplished by dividing the total quantity of waste source reduced in each given year by the sum of the total baseline waste generation over all of these waste types.

Table 9-10: Source Reduction Multiplier

	2010	2012	2015	2020
Source Reduction as a % of WARM SR Categories' BAU Generation	12.33%	36.99%	61.65%	86.32%

- b. Take the product of the source reduction multiplier and the baseline waste generation for each waste type calculated in Step1.
 - c. Multiply the tons source reduced for each waste type by one plus the share of baseline tons disposed that is landfilled. This share is equal to the tons landfilled divided by the total tons disposed in incinerators or landfills. The result is the source reduction that diverts waste specifically from landfills.
 - d. Multiply the tons source reduced for each waste type by one plus the share of baseline tons disposed that is incinerated. This share is equal to the tons incinerated divided by the total tons disposed in incinerators or landfills. The result is the source reduction that diverts waste specifically from incinerators.
3. Calculate the total tons of recycling for each category under the policy scenario.
 - a. Determine the recycling multiplier for each waste type. This is accomplished by dividing the tons to be recycled under the policy scenario by the total BAU waste generation.

Table 9-11: Recycling Multiplier

	2010	2012	2015	2020
Incremental Recycling as a % of All Categories' BAU Generation	1.10%	3.29%	6.57%	9.86%

- b. Subtract the BAU generation of each waste type in each year from the amount of waste source reduced for each waste type in each year to determine the remainder of waste that must be managed through recycling, landfilling, or incineration.
 - c. For each of the waste types that are “source reduced,” multiply the remainder of waste to be managed after source reduction by the share of waste generation recycled under the BAU scenario (tons recycled, divided by the sum of tons recycled, landfilled, and incinerated). Multiply this product by one plus the recycling multiplier to determine the number of tons recycled each year under the policy scenario.
 - i. To calculate the policy recycling (composting) tonnage for organics, multiply the baseline generation for each waste type by the recycling multiplier and add the BAU recycling tonnage.
 - ii. To calculate the policy recycling for mixed paper and mixed plastic, first find the total amount of waste recycled in the paper and plastic categories under the policy scenario. This is done by multiplying the recycling multiplier by the tons generated for each of these categories, then adding the BAU tonnage recycled for each category. Next, subtract from this total the sum of the tons recycled for source reduced waste types within these categories.
 - iii. The policy scenario level of mixed recycling is equal to the total waste recycled under the policy scenario less the tons recycled under the policy scenario for all of the other categories.
 - d. Calculate the incremental recycling diversion from landfills by multiplying the difference between the policy scenario recycling and BAU scenario recycling for each waste type by the share of baseline tons disposed that are landfilled (see Step 2c).
 - e. Calculate the incremental recycling diversion from incinerators by multiplying the difference between the policy scenario recycling and BAU scenario recycling for each waste type by the share of baseline tons disposed that are incinerated (see Step 2d).
4. Subtract the results of Steps 3c and 4d from the BAU tons landfilled to determine the tons landfilled for each waste type under the policy scenario.
 5. Subtract the results of Steps 3d and 4e from the BAU tons incinerated to determine the tons incinerated for each waste type under the policy scenario.

The BAU and policy scenario waste management projections for each waste type are entered into EPA’s WASTE Reduction Model (WARM) for the years 2015 and 2020. WARM is a static model; so only one year’s inputs may be entered per run. Table 9-12 and 9-13 show the

WARM inputs for the 2020 baseline (BAU) and policy scenarios, as they would appear in the WARM workbook.

Table 9-12: 2020 Baseline WARM Inputs

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	733,544	282,801	352,035	98,707	NA
Steel Cans	938,710	614,980	252,836	70,893	NA
Copper Wire					NA
Glass	660,227	99,753	437,736	122,737	NA
HDPE	319,665	20,250	233,847	65,568	NA
LDPE	354,103	5,387	272,351	76,365	NA
PET	137,688	21,048	91,097	25,543	NA
Corrugated Cardboard	1,494,142	762,266	571,604	160,272	NA
Magazines/Third-class Mail	544,715	105,589	342,962	96,163	NA
Newspaper	480,362	368,839	87,102	24,422	NA
Office Paper	347,372	141,750	160,593	45,029	NA
Phonebooks	59,771	14,464	35,385	9,922	NA
Textbooks	84,167	14,464	54,438	15,264	NA
Dimensional Lumber					NA
Medium-density Fiberboard					NA
Food Scraps	2,900,563	NA	1,392,797	390,527	1,117,239
Yard Trimmings	1,243,098	NA	596,913	167,369	478,817
Grass		NA			
Leaves		NA			
Branches		NA			
Mixed Paper (general)	1,921,020	39,053	1,469,838	412,129	NA
Mixed Paper (primarily residential)					NA
Mixed Paper (primarily from offices)					NA
Mixed Metals					NA
Mixed Plastics	440,891	3,192	341,848	95,851	NA
Mixed Recyclables	2,518,058	897,781	1,265,455	354,822	NA
Mixed Organics		NA			
Mixed MSW		NA			NA
Carpet					NA
Personal Computers					NA
Clay Bricks		NA		NA	NA
Aggregate				NA	NA
Fly Ash				NA	NA

Table 9-13: 2020 Policy WARM Inputs

Material	Baseline Generation	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	733,544	633,171	42,511	45,190	12,671	NA
Steel Cans	938,710	810,264	92,445	28,117	7,884	NA
Copper Wire						NA
Glass	660,227	569,886	14,995	58,846	16,500	NA
HDPE	319,665	275,924	3,044	31,784	8,912	NA
LDPE	354,103	305,650	810	37,210	10,433	NA
PET	137,688	118,847	3,164	12,243	3,433	NA
Corrugated Cardboard	1,494,142	1,289,695	114,585	70,183	19,679	NA
Magazines/Third-class Mail	544,715	470,180	15,872	45,816	12,846	NA
Newspaper	480,362	414,633	55,445	8,032	2,252	NA
Office Paper	347,372	299,840	21,308	20,481	5,743	NA
Phonebooks	59,771	51,592	2,174	4,689	1,315	NA
Textbooks	84,167	72,650	2,174	7,297	2,046	NA
Dimensional Lumber						NA
Medium-density Fiberboard						NA
Food Scraps	2,900,563	NA	NA	1,169,469	327,908	1,403,185
Yard Trimmings	1,243,098	NA	NA	501,201	140,532	601,365
Grass		NA	NA			
Leaves		NA	NA			
Branches		NA	NA			
Mixed Paper, Broad	1,921,020	NA	1,721,034	156,192	43,795	NA
Mixed Paper, Resid.		NA				NA
Mixed Paper, Office		NA				NA
Mixed Metals		NA				NA
Mixed Plastics	440,891	NA	166,319	214,444	60,128	NA
Mixed Recyclables	2,518,058	NA	2,223,546	230,018	64,495	NA
Mixed Organics		NA	NA			
Mixed MSW		NA	NA			NA
Carpet						NA
Personal Computers						NA
Clay Bricks			NA		NA	NA
Aggregate		NA			NA	NA
Fly Ash		NA			NA	NA

The WARM model runs yielded the GHG benefits reported at the beginning of this section: 17.0 MMtCO₂e reduced in 2015 and 29.2 MMtCO₂e reduced in 2020. To estimate the cumulative emissions through 2020, the emissions reductions are assumed to increase linearly from 0 in 2009 to 17.0 MMtCO₂e in 2015 and from 17.0 MMtCO₂e in 2015 to 29.2 MMtCO₂e in 2020. Table 9-14 displays these results.

Table 9-14: Overall Policy Results – GHG Reductions

Year	Avoided Emissions (MMtCO ₂ e)	Incremental Waste Diversion (tons)	Incremental Source Reduction (tons)	Incremental Recycling (tons)	Avoided Landfill Emplacement (tons)	Avoided WTE Emplacement (tons)	Avoided Exported Waste (tons)
2009	-	-	-	-	-96,742	96,742	0
2010	2.93	658,559	545,212	113,347	-589,318	-69,241	-88,166
2011	5.86	1,361,404	1,127,087	234,317	-1,114,909	-246,495	-182,260
2012	8.80	2,110,768	1,747,475	363,293	-1,675,177	-435,591	-282,582
2013	11.73	2,708,292	2,207,615	500,678	-2,121,085	-587,207	-356,991
2014	14.66	3,343,612	2,696,722	646,890	-2,595,085	-748,527	-436,084
2015	17.59	4,018,592	3,216,224	802,369	-3,098,562	-920,031	-520,093
2016	20.15	4,502,594	3,590,312	912,281	-3,460,875	-1,041,719	-580,586
2017	22.71	5,014,599	3,985,921	1,028,678	-3,844,049	-1,170,550	-644,559
2018	25.27	5,555,945	4,404,073	1,151,871	-4,249,078	-1,306,867	-712,179
2019	27.83	6,128,024	4,845,839	1,282,185	-4,676,998	-1,451,027	-783,616
2020	29.27	6,732,294	5,312,333	1,419,960	-5,128,890	-1,603,404	-859,052
Totals	186.80	42,134,683	33,678,812	8,455,871	-32,650,768	-9,483,916	-5,446,169

Cost Effectiveness

Source Reduction. A net cost for the State to implement source reduction programs of \$1 per capita is assumed.⁶⁶ In addition to the program costs to the State, other cost elements include the avoided costs for collecting and transporting the waste to a landfill or other disposal site. For the purposes of this analysis, it was assumed that the waste would have been landfilled, so the landfill tipping fee, estimated at \$52/ton, is avoided.⁶⁷ CCS assumed that the cost for collecting the waste would not be avoided, since weekly collection of the remaining household/business waste would still be needed. Table 9-15 provides a summary of the costs estimated for the source reduction element of this policy. Cumulative reductions (estimated from WARM results) are about 164 MMtCO₂e through the policy period. A cost effectiveness of -\$7 MtCO₂e was calculated along with an NPV of -\$1,174 million.

⁶⁶ **Not a MD-specific estimate. Seek additional input from TWG.** The source reduction program cost is a preliminary estimate that is consistent with costs assumed in similar options considered by CCS projects in WA and CO.

⁶⁷ Maryland Department of the Environment. 2006. “Annual Report: Solid Waste Management in Maryland – Calendar Year 2005.” September 2006. Accessed on December 20, 2007 from: http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

Table 9-15: Cost analysis results for source reduction

Year	Tons Reduced	Avoided Landfill Tipping Fee (2006\$MM)	Program Costs (2006\$MM)	Net Source Reduction Costs (2006\$MM)	Discounted Costs (2006\$MM)	GHG Reductions (MMtCO _{2e})	Cost Effectiveness (\$/MtCO _{2e})
2009	-	\$0.00	\$0.00	\$0.00	\$0.00	0.00	
2010	545,212	\$28.35	\$5.91	-\$22.44	-\$21.37	2.55	
2011	1,127,087	\$58.61	\$5.95	-\$52.66	-\$47.76	5.10	
2012	1,747,475	\$90.87	\$5.99	-\$84.88	-\$73.32	7.65	
2013	2,207,615	\$114.80	\$6.03	-\$108.77	-\$89.48	10.20	
2014	2,696,722	\$140.23	\$6.07	-\$134.16	-\$105.12	12.75	
2015	3,216,224	\$167.24	\$6.11	-\$161.13	-\$120.24	15.30	
2016	3,590,312	\$186.70	\$6.16	-\$180.54	-\$128.31	17.62	
2017	3,985,921	\$207.27	\$6.20	-\$201.07	-\$136.09	19.95	
2018	4,404,073	\$229.01	\$6.24	-\$222.77	-\$143.60	22.27	
2019	4,845,839	\$251.98	\$6.28	-\$245.70	-\$150.84	24.59	
2020	5,312,333	\$276.24	\$6.33	-\$269.91	-\$157.81	26.24	
				-\$1,684.03	-\$1,173.95	164.2	-\$7.15

Recycling. The net cost of increased recycling rates in Maryland was estimated by adding the increased costs of collection for two-stream recycling, revenue obtained for the value of recycled materials, and avoided landfill tipping fees. The additional cost for separate curbside collection of recyclables is \$2.50/household/month, or \$30/household/year.⁶⁸ Dividing this number by the incremental recycling per capita in 2020⁶⁹ times the average household size of 2.61⁷⁰ yields the maximum collection cost of \$51/ton. The capital cost of additional recycling facilities in Maryland is \$255 million.⁷¹ Annualized over the 10 year policy period at 5% interest, the capital cost is \$16.5 million per year. The avoided cost for landfill tipping is \$52/ton.⁷² CCS also factored in the commodity value of recycled materials with a value of \$35/ton.⁷³ Table 9-16 provides the results of the cost analysis. The analysis assumes that costs begin to be incurred in 2010. The estimated cost savings result in an NPV of -\$35

⁶⁸ **Not a MD-specific estimate. Seek additional input from TWG.** T. Brownell, Eureka Recycling, personal communication with S. Roe, CCS, December 17, 2007. This value compares favorably with data provided to the AFW TWG (T. Troolin, St. Louis County) on recycling costs incurred by MN counties.

⁶⁹ Population projection for 2020 from the MD Inventory and Forecast.

⁷⁰ US Census Bureau. State & County QuickFacts – Maryland. Accessed on January 11, 2008 from: <http://quickfacts.census.gov/qfd/states/24000.html>.

⁷¹ **Not a MD-specific estimate. Seek additional input from TWG.** Based upon ratio of Capital Cost per household used in Vermont Analysis. VT capital cost a result of Personal Communication with P. Calabrese.

⁷² Maryland Department of the Environment. 2006. “Annual Report: Solid Waste Management in Maryland – Calendar Year 2005.” September 2006. Accessed on December 20, 2007 from: http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

⁷³ **Not a MD-specific estimate. Seek additional input from TWG.** T. Brownell, Eureka Recycling, personal communication with S. Roe, CCS, December 17, 2007. This value compares to a wide range of weighted commodity value provided by T. Troolin, St. Louis County. The weighted commodity value range is estimated to be about \$25 to \$70/ton with the higher end representing current values. CCS selected the value of \$35/ton as a conservative estimate for this analysis.

million. Cumulative reductions are almost 13 MMtCO₂e, and the estimated cost-effectiveness is -\$6/MtCO₂e.

Table 9-16: Cost analysis results for recycling

Year	Tons Recycled	Annual Collection Cost (2006\$MM)	Annual Capital Cost (2006\$MM)	Annual Recycled Material Revenue (2006\$MM)	Landfill Tip Fees Avoided (2006\$MM)	Net Policy Cost (Recycling) (2006\$MM)	Discounted Costs (MM\$)	GHG Reductions (MMt)	Cost Effectiveness (\$/Mt)
2009	-	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	0.00	
2010	86,834	\$4.22	\$16.51	\$3.04	\$4.52	\$13.17	\$12.55	0.22	
2011	179,506	\$8.72	\$16.51	\$6.28	\$9.33	\$9.62	\$8.72	0.44	
2012	278,313	\$13.53	\$16.51	\$9.74	\$14.47	\$5.82	\$5.03	0.66	
2013	383,561	\$18.64	\$16.51	\$13.42	\$19.95	\$1.78	\$1.46	0.88	
2014	495,572	\$24.09	\$16.51	\$17.35	\$25.77	-\$2.52	-\$1.98	1.10	
2015	614,681	\$29.87	\$16.51	\$21.51	\$31.96	-\$7.09	-\$5.29	1.32	
2016	698,883	\$33.97	\$16.51	\$24.46	\$36.34	-\$10.33	-\$7.34	1.51	
2017	788,053	\$38.30	\$16.51	\$27.58	\$40.98	-\$13.75	-\$9.31	1.71	
2018	882,429	\$42.89	\$16.51	\$30.89	\$45.89	-\$17.38	-\$11.20	1.90	
2019	982,261	\$47.74	\$16.51	\$34.38	\$51.08	-\$21.21	-\$13.02	2.09	
2020	1,087,808	\$52.87	\$16.51	\$38.07	\$56.57	-\$25.26	-\$14.77	2.20	
						-\$67.15	-\$35.15	14.0	-\$2.50

Composting. Composting is included in the total recycling volume by the Maryland Recycling Act report. However, as the WARM model considers the sole form of diversion for yard trimmings and food waste to be composting, the tons of these items that are “recycled” are assumed to be composted. The net costs for increased composting in Maryland were estimated by adding the additional costs for collection (same calculation as recycling) with the net costs for composting operations. The net cost for composting operations is the sum of the annualized capital and operating costs of composting, increased collection fees, revenue generated through the sale of compost, the avoided tipping fees for landfilling. Information on the capital and operating costs of composting facilities was received from Cassella Waste Management during 7th analysis of a similar option in Vermont.⁷⁴ These data are summarized in Table 9-17.

Table 9-17. Cost information for composting facilities

Annual Volume (tons)	Capital Cost (2007 \$,000)	Operating Cost (\$/ton)
<1,500	75	25
1,500–10,000	200	50
10,000–30,000	2,000	40
30,000–60,000+	8,000	30

⁷⁴ **Not a MD-specific estimate. Seek additional input from TWG.** P. Calabrese, Cassella Waste Management, personal communication with S. Roe, CCS, June 5, 2007.

CCS assumed that the composting facilities to be built within the policy period would tend to be from the largest category (achieving the most efficient operating costs) shown in Table 9-17. The composting volumes in 2015 and 2020 shown in Table 9-18 suggest the need for about 4 large composting operations by 2015 and another 4 large operations by 2020. To annualize the capital costs for these facilities, CCS assumed a 15-year operating life and a 5% interest rate. Other cost assumptions include an assumed landfill tipping fee of \$52/ton,⁷⁵ an additional source-separated organics collection fee of \$2.50/household (or \$51/ton, as used above in the recycling element), a compost facility tipping fee of \$24/ton,⁷⁶ and a compost value of \$10/ton.⁷⁷

Table 9-18 presents the results of the cost analysis for composting. GHG reductions were assumed not to begin until 2010, and the cumulative reductions estimated were 0.50 MMtCO_{2e}. An NPV of \$91 million was estimated along with a cost effectiveness of \$183/Mt.

Table 9-18: Cost analysis results for composting

Year	Annual Cost O&M (2006\$MM)	Capital Cost (2007\$MM)	Annualized Capital Cost (2006\$MM)	Annual Collection Cost (2006\$MM)	Avoided Landfill Tipping Fees (2006\$MM)	Value of Composted Material (2006\$MM)	Tons of Waste Composted	Total Annual Composting Cost (2006\$)	Discounted Costs (2007MM\$)	GHG Reductions (MMtCO _{2e})	Cost Effectiveness (\$/Mt)
2009	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	-	\$0.00	\$0.00	-	
2010	\$0.98	\$8.00	\$0.77	\$1.58	\$0.93	\$0.34	32,608	\$2.07	\$1.97	0.01	
2011	\$2.02	\$0.00	\$0.77	\$3.28	\$1.91	\$0.71	67,408	\$3.45	\$3.13	0.02	
2012	\$3.14	\$8.00	\$1.54	\$5.08	\$2.97	\$1.10	104,512	\$5.69	\$4.92	0.02	
2013	\$4.32	\$8.00	\$2.31	\$7.00	\$4.09	\$1.51	144,035	\$8.03	\$6.61	0.03	
2014	\$5.58	\$0.00	\$2.31	\$9.04	\$5.28	\$1.95	186,098	\$9.70	\$7.60	0.04	
2015	\$6.92	\$8.00	\$3.08	\$11.22	\$6.55	\$2.42	230,826	\$12.25	\$9.14	0.05	
2016	\$7.87	\$8.00	\$3.85	\$12.76	\$7.45	\$2.75	262,445	\$14.28	\$10.15	0.05	
2017	\$8.88	\$8.00	\$4.62	\$14.38	\$8.40	\$3.10	295,930	\$16.38	\$11.09	0.06	
2018	\$9.94	\$0.00	\$4.62	\$16.11	\$9.41	\$3.48	331,371	\$17.79	\$11.47	0.07	
2019	\$11.07	\$8.00	\$5.40	\$17.93	\$10.47	\$3.87	368,859	\$20.05	\$12.31	0.07	
2020	\$12.25	\$8.00	\$6.17	\$19.85	\$11.60	\$4.29	408,495	\$22.39	\$13.09	0.08	
									\$91.47	0.50	\$183.81

The overall cost analysis – as seen in Table 9-19 – yields a NPV of -\$1,117 and a cost effectiveness of -\$6, based on the cumulative emission reductions of 183 MMtCO_{2e}.

⁷⁵ Maryland Department of the Environment. 2006. “Annual Report: Solid Waste Management in Maryland – Calendar Year 2005.” September 2006. Accessed on December 20, 2007 from:

http://www.mde.state.md.us/assets/document/SW_Managed_in_MD_Report_CY_2005.pdf.

⁷⁶ Montgomery County, MD. Department of Environmental Protection. “Composting/Grasscycling Program Summary.” Accessed on January 11, 2008 from:

<http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/composting/summary.asp>.

[NOTE]: Figures originally presented in 1995\$. Converted to 2006\$ using conversion tool at <http://www.westegg.com/inflation/>.

⁷⁷ *Ibid.*

Table 19-9: Overall Policy Results – Cost Effectiveness

Year	Net Program Cost Recycling (\$MM)	Net Program Cost Composting (\$MM)	Net Program Cost Source Reduction (\$MM)	Total Net Program Cost (\$MM)	Discounted Cost (2006\$MM)	Cost Effectiveness (\$/MtCO _{2e})
2009	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	
2010	\$13.17	\$2.07	-\$22.44	-\$7.20	-\$6.86	
2011	\$9.62	\$3.45	-\$52.66	-\$39.60	-\$35.92	
2012	\$5.82	\$5.69	-\$84.88	-\$73.37	-\$63.38	
2013	\$1.78	\$8.03	-\$108.77	-\$98.95	-\$81.41	
2014	-\$2.52	\$9.70	-\$134.16	-\$126.97	-\$99.49	
2015	-\$7.09	\$12.25	-\$161.13	-\$155.97	-\$116.39	
2016	-\$10.33	\$14.28	-\$180.54	-\$176.59	-\$125.50	
2017	-\$13.75	\$16.38	-\$201.07	-\$198.44	-\$134.31	
2018	-\$17.38	\$17.79	-\$222.77	-\$222.36	-\$143.33	
2019	-\$21.21	\$20.05	-\$245.70	-\$246.86	-\$151.55	
2020	-\$25.26	\$22.39	-\$269.91	-\$272.78	-\$159.49	
					-\$1,117.63	-\$6.11

- Key Assumptions:** For the MSW management input data to WARM, the key assumption is that none of the goals would be achieved via existing programs in place. To the extent that those programs will achieve or partially achieve the goals of this policy, the GHG reductions estimated would be lower (no additional penetration from the current MDE recycling and composting campaigns has been incorporated into the BAU assumptions for this analysis). Therefore, the most important assumption relates to the assumed BAU projection for solid waste management. This BAU forecast is based on current practices and does not factor in the effects of further gains in recycling or composting rates during the policy period. The BAU assumptions are needed to tie into the assumptions used to develop the GHG forecast for the waste management sector, which does not factor in these changes in waste management practices during the policy period (2008–2020). To the extent that these gains in recycling and composting would occur without this policy, the benefits and costs are overstated.

The other key assumptions relate to the use of the WARM model in estimating lifecycle GHG benefits and the use of the stated assumptions regarding costs for increased source reduction, recycling, and organics recovery (composting in this example) programs.

Another important assumption is that under BAU, the waste directed to landfilling would include methane recovery (75% collection efficiency) and utilization. The need for this assumption is partly based on limitations of the WARM model (which doesn't allow for management of landfilled waste into both controlled and uncontrolled landfills), but also based on the overall direction of the policy recommendations of AFW-9.

Additionally, transportation emissions for WARM are taken as default. This analysis has not considered the impacts of reduced exports as a result of the goals in the Policy Design.

The cost estimates do not include cost savings that would be achieved through avoiding the need for additional WTE plants.

Quantification of carbon emissions of associated transportation of solid waste may be a useful figure.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until MWG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MWG meeting #5]

Barriers to Consensus

TBD – [blank until final vote until final MWG meeting]