



www.mdclimatechange.us

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 greenhouse 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 greenhouse gases from manufacturing plants, 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 greenhouse 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 – 2012 and 2020

Option No.	Policy Option	GHG Reductions (MMtCO ₂ e)			Net Present Value 2008–2020 (Million \$)	Cost-Effectiveness (\$/tCO ₂ e)	Level of Support	
		2012	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)	0.04	0.09	0.66	89.1	135	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)	0.73	1.90	13.3	-2,017	-251	Pending	
AFW-3	Afforestation, Reforestation, and Restoration of Forests and Wetlands a. Afforestation b. Riparian areas	a. 0.21	a. 0.6	a. 3.9	a. 112.7	a. 29	Pending	
		b. 0.02	b. 0.1	b. 0.6	b. 27.6	b. 44		
AFW-4	Protection and Conservation of Agricultural Land, Coastal Wetlands, and Forested Land a. Agricultural land b. Forested land c. Coastal Wetlands	a. 0.11	a. 0.28	a. 1.93	a. 168.6	a. 87	Pending	
		b. 2.2	b. 2.7	b. 30.5	b. 1,128.7	b. 37		
		c. NQ	c. NQ	c. NQ	c. NQ	c. NQ		
AFW-5	"Buy Local" Programs for Sustainable Agriculture, Wood, and Wood Products	a. Farmer's Market	0.010	0.032	0.198	-33.1	-167	Pending
		b. Local Produce	NQ	NQ	NQ	NQ	NQ	
		c. Locally Grown and Processed Lumber	NQ	NQ	NQ	NQ	NQ	
AFW-6	Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production	Biomass (Inc. Ag. Residue, Forest Feedstocks, and Energy Crops)	0.116	0.50	2.83	34.1	12	Pending
		Methane Utilization From Livestock Manure and Poultry Litter	0.014	0.04	0.25	0.06	0.2	
AFW-7	In-State Liquid Biofuels Production	Ethanol	0.36	0.91	2.73	219	80	Pending
		Biodiesel	0.10	0.18	1.41	10.5	7	
AFW-8	Nutrient Trading With Carbon Benefits	0.054	0.14	0.99	-29.7	-30	Pending	
AFW-9	Waste Management Through Source Reduction and Advanced Recycling	9.3	29.2	184	-1,118	-6	Pending	
	Sector Total After Adjusting for Overlaps^a							
	Reductions From Recent Actions							
	Sector Total Plus Recent Actions							

NQ = not quantified; TBD = to be determined; MMt = million metric tons; CO₂e = carbon dioxide equivalent.

Note that negative costs represent a monetary savings.

Summary List of Draft Priorities for Analysis: 2015 and 2020

Option No.	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)	0.06	0.09	0.66	89.1	135	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	13.3	-2,017	-251	Pending	
AFW-3	Afforestation, Reforestation, and Restoration of Forests and Wetlands a. Afforestation b. Riparian areas	a. 0.4 b. 0.05	a. 0.6 b. 0.1	a. 3.9 b. 0.6	a. 112.7 b. 27.6	a. 29 b. 44	Pending	
AFW-4	Protection and Conservation of Agricultural Land, Coastal Wetlands, and Forested Land d. Agricultural land e. Forested land f. Coastal Wetlands	a. 0.170 b. 2.4 c. NQ	a. 0.28 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	-33.1	-167	Pending
		b. Local Produce	NQ	NQ	NQ	NQ	NQ	
		c. Locally Grown and Processed Lumber	NQ	NQ	NQ	NQ	NQ	
AFW-6	Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production	Biomass (Inc. Ag. Residue, Forest Feedstocks, and Energy Crops)	0.22	0.50	2.83	34.1	12	Pending
		Methane Utilization From Livestock Manure and Poultry Litter	0.02	0.04	0.25	0.06	0.2	
AFW-7	In-State Liquid Biofuels Production	Ethanol	0.85	0.91	2.73	219	80	Pending
		Biodiesel	0.14	0.18	1.41	10.5	7	
AFW-8	Nutrient Trading With Carbon Benefits	0.09	0.14	0.9	-29.7	-30	Pending	
AFW-9	Waste Management Through Source Reduction and 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							

NQ = not quantified; TBD = to be determined; MMt = million metric tons; CO₂e = carbon dioxide equivalent.

Note that negative costs represent a monetary savings.

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.

Healthy and vigorous forests provide direct benefits to greenhouse gas (GHG) reductions as noted above but also serve as the preferred land-use for avoiding emissions and capturing airborne GHGs. Yet, upon protecting forest for reducing GHGs, it is incumbent upon the owner of those forests to attend to the necessary stewardship activities needed to keep these forests healthy and vigorous such that they most able to meet the desired GHG objectives.

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 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. It is difficult to quantify the effects of invasive species growth on emissions as the costs of implementation and the efficacy of management strategies can 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.
- Improve sustainable forest management on 100% of state-owned resource 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, Maryland Cooperative Extension and Master Gardeners, and artisan community.

Implementation Mechanisms

- Outreach and education.
- Revise the Forest Conservation Act.
- Support a Sustainable Forestry Act that encourages enhanced carbon storage in forests, use of durable wood products, and use of wood biomass for energy while maintaining healthy forest ecosystems.
- 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 toward 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 Regional Greenhouse Gas Initiative (RGGI) Model Rule.

Related Policies/Programs in Place

Forest Conservation Act.

Types(s) of GHG Reductions

CO₂ (quantified): Enhancement of annual carbon sequestration from forest growth and reforestation through forestry management programs.

CO₂ (not quantified): Remove 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

- **Data Sources:**

Forest type distribution in Maryland and land ownership statistics are from USDA Forest Inventory and Analysis (FIA), <http://fia.fs.fed.us>.

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 U.S. Department of Energy (DOE) Voluntary GHG Reporting Program).

- **Quantification Methods:**

While experts largely agree that sustainably managed forests can probably store substantially more carbon on an annual basis than forests that are not managed sustainably, few data are currently available to quantify exactly what kinds of sites can store exactly how much additional carbon, and under what silvicultural regimes. Furthermore, some existing forests are undoubtedly already being managed sustainably, such that determining the amount of acreage available for improved forest management can be difficult.

To calculate the effect of improved forest management on carbon sequestration in Maryland, the additional carbon stored as a result of improved forest management was indexed using data on rates of carbon storage in average loblolly-shortleaf pine stands compared with carbon storage rates in high-productivity intensively managed loblolly-shortleaf pine stands in the Southeast (NE-GTR-343, Tables A39 and A40). The index of incremental carbon storage was calculated over a 90-year time period to capture the slowdown in forest carbon sequestration that typically occurs in maturing forest stands. Soil carbon was assumed to remain constant with time because there is no change in estimates of soil carbon pools over time in the 1605(b) guidelines. The incremental rate of carbon (C) storage due to intensive management in loblolly-shortleaf pine stands, relative to average loblolly-shortleaf pine stands in the Southeast is roughly 5% (Table 1-1).

Table 1-1. Carbon sequestration rates under average and intensive management scenarios for loblolly-shortleaf pine forests in the Southeast U.S. following clear-cut harvest

Forest Type	MtC/ac (0 yr)	MtC/ac (90 yr)	MtC/ac/yr	Increment in MtC/ac/ yr Due to Management
Loblolly-shortleaf pine stands (NE-GTR-343 Table A39)	10.7	60.5	0.553	
Loblolly-shortleaf pine on high productivity sites under intensive management (NE-GTR-343 Table A40)	14.9	67.0	0.579	5%

Forests in Maryland are 63% oak-hickory, with 10% oak-pine and 11% loblolly-shortleaf pine.¹ A mixture of forest types comprises the remaining 16% of forest land area. Co-efficients for improved productivity in oak-hickory and oak-pine stands were not available. The rate of carbon sequestration due to improved forest management in these forest types was thus calculated as a proportion of average carbon sequestration in forests under typical management, using the 5% value calculated for incremental carbon storage in loblolly-shortleaf pine stands (Table 1-2).

¹ USDA Forest Service Northern Global Change Program, <http://www.fs.fed.us/ne/global/pubs/books/epa/states/MD.htm>

Table 1-2. Estimated carbon sequestration rates on forestland under intensive management

Forest Type	MtC/ac (0 yr)	MtC/ac (65 yr)	MtC/ac/yr	MtC/ac/yr Under Intensive Management
Oak-Hickory (GTR NE 343 Table A3)	23.0	72.7	0.765	0.800
Oak-Pine (GTR NE 343 Table A4)	25.9	63.4	0.577	0.604
Loblolly-shortleaf pine (GTR NE343 Table A39)	10.7	51.8	0.632	0.662

Forest carbon sequestration rates under baseline conditions (no improved forest management) were based on published carbon stocks (tons carbon per acre in forest biomass) for oak-hickory and oak-pine in the Northeast and for loblolly-shortleaf pine stands in U.S. Southeast (USFS GTR-343). Annual rates of carbon sequestration (tons carbon sequestered per acre per year) were calculated by subtracting total carbon stocks in forest biomass of 65-year-old stands from total carbon stocks in forest biomass of new stands and dividing by 65. An average for 65-year-old stands was used to reflect the typical stand age of forests in the Northeast region.

Quantification for this option was based on a combined goal of achieving enhanced forest management on 25,000 acres of private land and 100% of state-owned forestland by 2020. Based on 2004 Forest Inventory and Analysis (FIA) data, state-owned forests total 749,975 acres² in Maryland, roughly 31.2% of the 2.4 million forested acres statewide. Other forest land ownership entities in the State include the US Fish and Wildlife Service (42,561 acres), county and municipal government (41,148 acres) and privately-owned forests (1,567,846 acres). This acreage includes all land that is both classified as forest by FIA and owned by the State of Maryland, regardless of which branch of State government is currently responsible for managing that forest.

A linear ramp-up in implementation is assumed. Thus, each year from 2008 to 2020, the analysis assumes that 1,923 acres of private land and 57,690 acres of public land are added to the land base practicing sustainable forest management. The effect of policy implementation is thus the incremental carbon stored on these lands, over and above that which would be expected if enhanced forest management were not implemented. Both baseline and policy implementation scenarios assume that the distribution of forests affected by the program will reflect the distribution of forests statewide: 70% oak-hickory, 15% oak-pine and 15% loblolly-shortleaf pine. Acreage enrolled in the program in one year is assumed to continue sequestering additional carbon in subsequent years. Table 1-3 summarizes the total carbon storage resulting from enhanced forest management.

² FIA EVALIDator version 1.0, <http://fiatools.fs.fed.us/>

Table 1-3. Additional acreage and carbon sequestration resulting from expanded land base participating in sustainable forest management

Year	Private Land Added to Sustainable Forest Management This Year	Public Land		Additional Carbon Storage (MMtCO ₂ e/yr)
		Added in Prior Years	Added This Year	
2008	1923	0	57,690	0.007
2009	1923	1,923	57,690	0.014
2010	1923	3,846	57,690	0.022
2011	1923	5,769	57,690	0.029
2012	1923	7,692	57,690	0.036
2013	1923	9,615	57,690	0.043
2014	1923	11,538	57,690	0.051
2015	1923	13,462	57,690	0.058
2016	1923	15,385	57,690	0.065
2017	1923	17,308	57,690	0.072
2018	1923	19,231	57,690	0.080
2019	1923	21,154	57,690	0.087
2020	1923	23,077	57,690	0.094
Total	25,000		749,975	0.658

The economic cost of implementing enhanced forest management on forest acreage is a one-time cost (over and above the cost to implement standard management techniques) of improved forest management practices, and is estimated to be \$151.50/acre. This value is an average of values from other states where similar policy options have been quantified: Vermont, where a value of \$3 per acre was used,³ and Montana, where a value of \$300 per acre was used.⁴ Clearly, there is little consensus about what is required to implement an enhanced forest management program, and as a result the estimates of how much it will cost to implement these policies varies widely. State-specific data would substantially improve the validity of the estimate of economic costs for this option in Maryland. At \$151.50/acre, and using a discount rate of 5%, the net present value (NPV) of this option is \$89.1 million (Table 1-4), with an overall cost-effectiveness of \$135.31 per tCO₂e stored.

Table 1-4. Total economic costs for implementing improved forest management on combined private and public acreage in Maryland

Year	Carbon Sequestered (MMtCO ₂ e/ yr)	Total Cost	Discounted Cost
2008	0.007	\$9,031,439	\$9,031,439
2009	0.014	\$9,031,439	\$8,601,371
2010	0.022	\$9,031,439	\$8,191,782
2011	0.029	\$9,031,439	\$7,801,697
2012	0.036	\$9,031,439	\$7,430,188
2013	0.043	\$9,031,439	\$7,076,369

³ <http://www.vtclimatechange.us>

⁴ <http://www.mtclimatechange.us>

2014	0.051	\$9,031,439	\$6,739,399
2015	0.058	\$9,031,439	\$6,418,475
2016	0.065	\$9,031,439	\$6,112,834
2017	0.072	\$9,031,439	\$5,821,746
2018	0.080	\$9,031,439	\$5,544,520
2019	0.087	\$9,031,439	\$5,280,496
2020	0.094	\$9,031,439	\$5,029,043
Total	0.658	\$117,408,713	\$89,079,360

• **Key Assumptions:**

- Carbon storage resulting from sustainable management of oak-hickory and oak-pine types is indexed to incremental carbon storage in loblolly-shortleaf-pine forests, as quantified using methods in NE-GTR-343.
- One-time costs to implement enhanced forest management are \$151.50/acre, and include costs over and above standard costs for forest management operations.
- Forest types added to the pool of sustainably managed forests will reflect the distribution of forests statewide.

Key Uncertainties

GHG emissions from management activities such as harvest are not included in this analysis. To provide clarity about the effects of policy implementation, it would be important to quantify the changes in emissions resulting from changes in management practices due to policy implementation.

Additional Benefits and Costs

As markets are developed, additional biomass generated via enhanced forest management will be used first for long-term storage in durable wood products then for beneficial uses such as biofuels and energy. The biomass generated from improved management practices could be used for durable wood products and energy production. The quantification described above assumes that additional carbon is stored in the forest.

Forest certification will likely be necessary for participation in RGGI market, but effects of certification is not quantified here because its effects on carbon storage are uncertain and because the costs are difficult to quantify.

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 help avoid emissions from power production and from the operation and maintenance of built structures and infrastructure. Further, urban trees contribute to lower summertime temperatures at street level. Reduced heat slows the formation of ground-level ozone as well as the evaporation and volatilization of organic compounds from vehicles. Trees also take in CO₂ for photosynthesis, storing carbon in their biomass through growth. Trees likewise reduce ambient concentrations of volatile organic compounds, nitrous oxide, fine particulate matter and other air and water pollutants.

Statewide, urban canopy cover in Maryland is 40.1% (Nowak, USFS). This option seeks to increase the canopy cover of urban trees throughout the state. Planting additional trees in-state may 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 through the creation of amenable microclimates, and address insects, invasive species and disease in urban forest settings, though these impacts are not quantified here.

Policy Design

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

Goals:

- Enhance green infrastructure planning including tying green areas together (not quantified).
- Develop incentives to better use urban wood recovery directed towards the highest order wood product (not quantified).with the remainder recovered for biomass to energy conversion (see AFW-6).
- Achieve urban tree canopy goal of 50% (averaged over all urban land use types) by 2020.

Goals Related to Forest Pests and Invasive Species (not quantified):

- Develop prioritization process of invasive species, identifying species of high priority for targeted action.
- Shift decision-making efforts to plan ahead for invasive species problems—move towards prevention or proactive management rather than control and reactive treatments.

Timing: See quantified goal above.

Parties Involved: Maryland Department of Natural Resources (DNR), Maryland Department of the Environment (MDE), Maryland Department of Agriculture, Maryland State Highway

Administration (SHA), counties, municipalities, Chesapeake Bay Program, Natural Resource Conservation Service (NRCS), United States Forest Service (USFS), private land owners, private sawmills, the artisan community, landscaping industry, nursery industry, arborist industry, Maryland Cooperative Extension and Master Gardeners.

Implementation Mechanisms

- Encourage planting programs in all communities, including a replacement program for dead trees where a tree with equal potential is planted in as good or better site to maximize longevity and efficacy
- Insert urban tree planting strategy and objectives in all comprehensive plans
- Encourage local counties to identify, maintain and augment street tree populations
- Outreach and education on the significance of trees and their role in our built environment.
- 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 to plant trees.
- Legislation restricting sale of priority non-native invasive species.
- Outreach and education about invasive species and control methods.
- To strengthen, fund, and support this act, add urban tree canopy (UTC) goals to the Urban Community Forest Act.

Related Policies/Programs in Place

Urban Community Forestry Act

Types(s) of GHG Reductions

- **CO₂** (quantified): 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 carbon storage in urban trees in Maryland 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 Maryland are from Galvin, M. 2007. A Report on Hyattsville's Street Trees. Maryland Department of Natural Resources – Forest Service.

- **Quantification Methods:**

The following quantifies the cumulative impact on carbon sequestration and avoided fossil fuel emissions of incrementally increasing existing tree canopy cover in Maryland. 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 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 time frame (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 Mitigation Working Group (MWG).

Currently Maryland contains 89.4 million urban trees; this option quantifies the effect of adding 22 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 carbon sequestration by planted trees and avoided GHG emissions from strategic tree planting to reduce energy demand due to heating and cooling.

A. Direct Carbon Sequestration in Urban Trees

Annual carbon sequestration per urban tree is calculated as 0.006 tCO₂/tree/year, based on statewide average data reported by the USFS. This is the average annual per-tree carbon sequestration value when the total estimated urban forest carbon accumulation in Maryland (544,000 tCO₂/year) is divided by the total number of urban trees in Maryland (89.4 million). Since trees planted in one year continue to accumulate carbon in subsequent years, annual carbon sequestration in any given year is calculated as the sum of carbon stored in trees planted in that year, plus the sequestration by trees that were planted in prior years. Because it simply takes the difference between total live C stocks at two points in time, this stock change approach accounts for normal tree mortality.

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 2-1). 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 2-1. 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)			Wind–Heating	Net Effect
Housing Vintage	Shade–Cooling	Shade–Heating		
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 (MMtCO₂e)				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 carbon sequestration plus fossil fuel offset from reduced cooling demand and wind reduction (Table 2-2).

Table 2-2. Overall GHG benefit (MMtCO₂e/year) of implementing AFW-2

Year	Trees Planted This Year	Trees Planted in Previous Years	GHG Sequestered (MMtCO ₂ e/yr)	GHG Avoided (MMtCO ₂ e/yr)	Overall GHG Savings (MMtCO ₂ e/yr)
2008	1,698,440	0	0.0379	0.1079	0.1458
2009	1,698,440	1,698,440	0.0758	0.2158	0.2916
2010	1,698,440	3,396,879	0.1136	0.3237	0.4374
2011	1,698,440	5,095,319	0.1515	0.4316	0.5832
2012	1,698,440	6,793,759	0.1894	0.5395	0.7289

2013	1,698,440	8,492,198	0.2273	0.6474	0.8747
2014	1,698,440	10,190,638	0.2652	0.7554	1.0205
2015	1,698,440	11,889,078	0.3030	0.8633	1.1663
2016	1,698,440	13,587,517	0.3409	0.9712	1.3121
2017	1,698,440	15,285,957	0.3788	1.0791	1.4579
2018	1,698,440	16,984,397	0.4167	1.1870	1.6037
2019	1,698,440	18,682,836	0.4546	1.2949	1.7495
2020	1,698,440	20,381,276	0.4924	1.4028	1.8952
Total		22,079,716	3.4471	9.8196	13.2667

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 Maryland was assumed to be \$275/ tree.⁵ 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. It was assumed that trees planted in the first year of policy implementation would still be living at the end of the policy implementation period; in other words, the effects of tree mortality are not explicitly accounted for in the analysis of the numbers of trees planted to achieve the canopy goals described above.

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. Consistent with convention, the economic benefit per tree planted is a negative number since the economic benefit outweighs the cost of the option. When the economic benefit of an option outweighs its cost, then the resulting net economic cost is negative.

⁵ Mike Galvin, Supervisor, Urban and Community Forestry, Maryland DNR. Personal communication with J. Jenkins, January 2008. Range of costs estimated at \$250-300.

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 2-3). AFW-2 has a net economic benefit of -\$251.52/tCO_{2e} mitigated.

Table 2-3. Economic benefits and costs of implementing AFW-2

Year	Trees Planted This Year	Trees Planted in Previous Years	Total Economic Benefit	Net Benefit (Costs Minus Benefits)	Discounted Net Benefits
2008	1,698,440	0	\$0	\$467,070,909	\$467,070,909
2009	1,698,440	1,698,440	\$163,559,740	\$340,876,842	\$324,644,611
2010	1,698,440	3,396,879	\$327,119,480	\$214,682,774	\$194,723,605
2011	1,698,440	5,095,319	\$490,679,221	\$88,488,707	\$76,439,872
2012	1,698,440	6,793,759	\$654,238,961	-\$37,705,361	-\$31,020,294
2013	1,698,440	8,492,198	\$817,798,701	-\$163,899,428	-\$128,419,491
2014	1,698,440	10,190,638	\$981,358,441	-\$290,093,496	-\$216,472,233
2015	1,698,440	11,889,078	\$1,144,918,182	-\$416,287,563	-\$295,847,799
2016	1,698,440	13,587,517	\$1,308,477,922	-\$542,481,631	-\$367,172,921
2017	1,698,440	15,285,957	\$1,472,037,662	-\$668,675,698	-\$431,034,317
2018	1,698,440	16,984,397	\$1,635,597,402	-\$794,869,766	-\$487,981,084
2019	1,698,440	18,682,836	\$1,799,157,142	-\$921,063,833	-\$538,526,947
2020	1,698,440	20,381,276	\$1,962,716,883	-\$1,047,257,901	-\$583,152,386
Total		22,079,716	\$12,757,659,738	-\$3,771,215,443	-\$2,016,748,473

- **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 GHGs in addition to sequestration. 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 long as 20 years. Forest patches should be sufficient in size to function as a community of trees and related species.

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, 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 on those disturbed lands.

Policy Design

Carbon sequestration via afforestation is important, but other ancillary benefits provided by forests, in terms of green space, quality of life, and avoided emissions are also critical and add to the value of forestland 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 the 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, to be eligible for RGGI as currently written a forest offset project must:

- Be an afforestation project (i.e. land must have been in a non-forested condition for at least 10 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, Sustainable Forestry Institute, American Tree Farm System, 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. In addition, all categories of easements (in perpetuity or long-term) will have GHG benefits. 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.

Wetlands and Marshes

Carbon storage and methane emissions from wetlands in Maryland (and North America more broadly) are highly uncertain in these complex ecosystems. In many cases, wetlands are a natural sink for carbon but can also be a source of methane when conditions support anaerobic decomposition. Other wetlands, such as salt water marshes, are different as they support carbon sequestration but emit negligible amounts of methane emissions due to saline water suppressing the development of anaerobic organisms.

The complexities of these ecosystems make the net carbon equivalent balance (i.e. sinks less GHG outputs) for fresh water wetlands inherently difficult to measure. Salt water marshes are more straight forward and *The First State of the Carbon Cycle Report*⁶ identifies a carbon accumulation rate for conterminous United States tidal marshes as 2.2 million grams of carbon per hectare per year.

Research is necessary to reduce the uncertainties in carbon and methane fluxes in wetlands to provide better information on the appropriate management techniques and the potential for GHG emissions savings through effective management of wetlands.

Regardless of the type of wetland or the net carbon balance, there are potential risks that significant amounts of carbon stored could be released into the atmosphere if these areas are not appropriately maintained. This highlights the need to preserve and restore these ecosystems, from both a greenhouse and local environmental perspective.

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.

⁶ King, A.W., L. Dilling, G.P. Zimmerman, D.M. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.) *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, USA, See <http://www.climatechange.gov/Library/sap/sap2-2/final-report/default.htm>

- Establish riparian buffers at a rate of 900 miles/year (50-foot width either side of stream) 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). ADDITIONAL INFORMATION PENDING.

Timing: See goals, above.

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

Implementation Mechanisms

- Outreach and education
- Green infrastructure plans
- Forest Conservation Act
- Forest Conservation Management Act (FCMA) – provides landowners a reduction in property taxes on lands actively managed for forest conservation including newly planted areas
- Also other property and inheritance tax incentives
- 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 for reforestation and restoration.
- Recommend that the Commission for Climate Change and RGGI increase acknowledgment and importance of forests as significant in climate change mitigation

Related Policies/Programs in Place

Forest Conservation Act: See example from Washington County in implementation of the Forest Conservation Act (Forest Conservation Ordinance, adopted in 1993).⁷

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 GTR-NE-343 (also published as part of the DOE Voluntary GHG Reporting Program).

⁷ http://www.washco-md.net/washco_2/pdf_files/legal/forestcn.pdf

- USFS Forest Inventory Analysis data, provided by the USFS for the Maryland 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. Afforestation

1. 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, carbon sequestered by afforestation activities was assumed to occur at the same rate as carbon sequestration in average Maryland forest. Average carbon storage was found based on USFS GTR-NE-343 assuming afforestation activity with a forest type distribution of 70% Oak-hickory, 15% Oak-Pine and 15% Loblolly-Shortleaf Pine. This distribution is reflective of the average forest composition in Maryland, and is based on USDA Forest Service Forest Inventory and Analysis statistics.⁸ A 45-year project period was assumed, such that the rate of forest carbon sequestration under afforestation projects for an average acre in Maryland was estimated at 1.2 tC/acre⁻¹/year⁻¹ (Table 3-1). Forests planted in one year continue to sequester carbon in subsequent years. Thus, carbon storage in a given year is calculated as the sum of annual carbon sequestration on cumulative planted acreage.

Table 3-1. Forest carbon sequestration rates for afforestation activity

Forest Type	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 3-2).

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

Year	Acreage Planted This Year	Acreage Planted in Prior Years	Carbon Sequestered (MtC/yr)	Carbon Sequestered (MMt CO ₂ e/yr)
2008	6,300	0	7,256	0.027
2009	10,800	6,300	19,695	0.072
2010	10,800	17,100	32,135	0.118
2011	10,800	27,900	44,574	0.163
2012	10,800	38,700	57,013	0.209
2013	10,800	49,500	69,452	0.255

⁸ <http://www.fs.fed.us/ne/global/pubs/books/epa/states/MD.htm>

2014	10,800	60,300	81,891	0.300
2015	10,800	71,100	94,331	0.346
2016	10,800	81,900	106,770	0.391
2017	10,800	92,700	119,209	0.437
2018	10,800	103,500	131,648	0.483
2019	10,800	114,300	144,087	0.528
2020	10,800	125,100	156,527	0.574
Total		135,900		3.903

2. 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 Maryland 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 CO₂e (Table 3-3). This analysis ignores the likely economic benefits of afforestation, in terms of services such as clean air and clean water, reduced flooding, aesthetic effects, and other benefits. These benefits are typically more difficult to quantify than the tangible costs of tree planting, but they should be considered in the analysis of economic costs and benefits of afforestation activity.

Table 3-3. Economic costs of afforestation

Year	Acres Planted	Total Cost	Discounted Cost
2008	6,300	\$6,961,500	\$6,961,500
2009	10,800	\$11,934,000	\$11,365,714
2010	10,800	\$11,934,000	\$10,824,490
2011	10,800	\$11,934,000	\$10,309,038
2012	10,800	\$11,934,000	\$9,818,131
2013	10,800	\$11,934,000	\$9,350,601
2014	10,800	\$11,934,000	\$8,905,335
2015	10,800	\$11,934,000	\$8,481,271
2016	10,800	\$11,934,000	\$8,077,401
2017	10,800	\$11,934,000	\$7,692,763
2018	10,800	\$11,934,000	\$7,326,441
2019	10,800	\$11,934,000	\$6,977,563
2020	10,800	\$11,934,000	\$6,645,298
Total	135,900		\$112,735,545

B. Riparian forest

1. GHG benefit

The annual rate of riparian forest establishment was calculated from the goals as established by the Chesapeake Bay Forest Conservation Initiative (2007),⁹ which describe a goal of establishing 900 miles/ year of 50-foot-wide buffers by 2020, continuing until 70% of all stream miles are buffered. This goal corresponds to establishing 5455 acres/ year of riparian forest by 2020. A linear ramp-up toward the goal was assumed (Table 3-4).

The most common species in riparian buffers statewide are loblolly pine (21% of total stocking), green ash (10%) and sweet gum (8%). Other species in smaller proportions make up the remainder of the trees found in riparian buffers.¹⁰ Thus statewide, it was assumed that riparian forests would be 50% elm-ash-cottonwood and 50% loblolly-pine forest types (Table 3-5). A 45-year project period was assumed, such that the rate of forest carbon sequestration in riparian projects for an average acre in Maryland was estimated at 0.9 tC/acre⁻¹/year⁻¹. Forests planted in one year continue to sequester carbon in subsequent years. Thus, carbon storage in a given year is calculated as the sum of annual carbon sequestration on cumulative planted acreage (Table 3-4).

Table 3-4. Acres planted and C stored in riparian forests in Maryland.

	acres planted this year	acres planted in prior years	C sequestered (MMtCO ₂ e/yr)
2008	420	0	0.001
2009	839	420	0.004
2010	1259	1259	0.008
2011	1678	2517	0.014
2012	2098	4196	0.021
2013	2517	6294	0.029
2014	2937	8811	0.038
2015	3357	11748	0.049
2016	3776	15105	0.062
2017	4196	18881	0.075
2018	4615	23077	0.091
2019	5035	27692	0.107
2020	5455	32727	0.125
cumulative totals	38182		0.625

Table 3-5. Forest carbon sequestration rates for riparian forest establishment.

	MtC/ac (0 yr)	MtC/ac (45 yr)	MtC/ac/y r
Loblolly pine (Southeast) (NE-GTR Table B39)	1.7	41.9	0.9
Elm-ash-cottonwood (South Central) (NE-GTR Table B46)	1.7	41.8	0.9

⁹ http://www.chesapeakebay.net/press_ec2007forests.aspx

¹⁰ Riparian Forest Buffer Survival and Success in Maryland, April 2001. Maryland DNR Forest Service Research Report DNR/FS-01-01, http://dnrweb.dnr.state.md.us/download/forests/rfb_survival.pdf.

2. Economic Costs

Estimated per acre costs for riparian forest establishment in Maryland were assumed to be the same as for afforestation, and were obtained from Walker et al. (2007). 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. Since riparian forests were assumed to be softwoods and hardwoods in equal proportions, the weighted average cost to plant an acre of forest in Maryland was estimated at \$1,055. 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 \$27.6 million, with a levelized cost-effectiveness of \$44.19/ ton CO₂e (Table 3-6). As with the afforestation option above, this analysis ignores the likely economic benefits of riparian forest establishment, in terms of services such as clean air and clean water, reduced flooding, aesthetic effects, and other benefits. These benefits are typically more difficult to quantify than the tangible costs of tree planting, but they should be considered in the analysis of economic costs and benefits of riparian afforestation activity.

Table 3-6. Economic costs of riparian forest establishment

	Acres planted	Total cost	Discounted cost
2008	420	\$442,660	\$442,660
2009	839	\$885,321	\$843,163
2010	1259	\$1,327,981	\$1,204,518
2011	1678	\$1,770,642	\$1,529,547
2012	2098	\$2,213,302	\$1,820,889
2013	2517	\$2,655,962	\$2,081,016
2014	2937	\$3,098,623	\$2,312,240
2015	3357	\$3,541,283	\$2,516,724
2016	3776	\$3,983,944	\$2,696,490
2017	4196	\$4,426,604	\$2,853,428
2018	4615	\$4,869,264	\$2,989,306
2019	5035	\$5,311,925	\$3,105,772
2020	5455	\$5,754,585	\$3,204,368
total	38182		\$27,600,122

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

Key Uncertainties

Economic benefits of afforestation, in terms of ecosystems services such as clear water, clean air, flooding mitigation, aesthetic value, tourism, etc.

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 6–18 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% of global GHG 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 GHGs. For these reasons and more, we should protect Maryland's green infrastructure and coastal lands.

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, nongovernmental organizations and private citizens—to more effectively protect Maryland's green infrastructure network.

Wetlands and Marshes (*this information is repeated in AFW 3*)

Carbon storage and methane emissions from wetlands in Maryland (and North America more broadly) are highly uncertain in these complex ecosystems. In many cases, wetlands are a natural sink for carbon but can also be a source of methane when conditions support anaerobic decomposition. Other wetlands, such as salt water marshes, are different as they support carbon sequestration but emit negligible amounts of methane emissions due to saline water suppressing the development of anaerobic organisms.

The complexities of these ecosystems make the net carbon equivalent balance (i.e. sinks less GHG outputs) for fresh water wetlands inherently difficult to measure. Salt water marshes are more straight forward and *The First State of the Carbon Cycle Report*¹¹ identifies a carbon

¹¹ King, A.W., L. Dilling, G.P. Zimmerman, D.M. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.) *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle. A Report by the U.S. Climate Change Science Program and the*

accumulation rate for conterminous United States tidal marshes as 2.2 million grams of carbon per hectare per year.

Research is necessary to reduce the uncertainties in carbon and methane fluxes in wetlands to provide better information on the appropriate management techniques and the potential for GHG emissions savings through effective management of wetlands.

Regardless of the type of wetland or the net carbon balance, there are potential risks that significant amounts of carbon stored could be released into the atmosphere if these areas are not appropriately maintained. This highlights the need to preserve and restore these ecosystems, from both a greenhouse and local environmental perspective.

Goals: Using green infrastructure plans as a guide, leverage funds to protect agricultural lands, forestlands, 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 (Maryland 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 not 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)

Timing: As described above.

Parties Involved: State and quasi-state government agencies including the Maryland Department of Planning, nonprofit 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

Subcommittee on Global Change Research. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, USA, See <http://www.climate-science.gov/Library/sap/sap2-2/final-report/default.htm>

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% 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- agriculture/forestry uses. Maryland Land Preservation Taskforce suggests doubling that tax on conversion of agricultural lands to development.

Reduce or eliminate transfer taxes for continued agriculture/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 for all urban consumers (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 GHG 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% 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 3 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 agriculture/forestry land transfers to non- agriculture /forestry uses. Maryland Land Preservation Taskforce suggests doubling that tax on conversion of

agriculture lands to development. Reduce or eliminate transfer taxes for continued agriculture/forestry uses.

Related Policies/Programs in Place

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

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

MALPF

Farm and Ranch Land Protection Program (FRPP)

U.S. 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 DOE 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 aboveground 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. The Center for Climate Strategies (CCS) assumed no change in the levels of aboveground carbon stocks.

The benefit in each year was determined by:

- 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 data¹²) 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.
- multiplying the soil carbon content (assumed to be 0.017 MMtC per 1,000 acres) on the protected land by 50% (representing graded and covered areas) and by 75% (fraction of soil carbon lost);
- converting the soil carbon lost to CO₂ by multiplying by 44/12.

The GHG benefits are indicated in table 4-1. Note that the GHG benefits only include changes to below ground soil carbon and the quantification does not include emissions caused by activities associated with the various land uses (e.g., emissions from tractor activities on agriculture land or urban vehicle activity on developed land).

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 the average easement acquisition cost per acre by MALPF (\$5,952/acre).¹³ This cost of conservation is assumed to remain constant across the policy period. It is further assumed that subsidies are available through the FRPP¹⁴ 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%.¹⁵ The 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 GHG benefits and program costs are summarized in Table 4-1.

¹² 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.

¹³ 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>.

¹⁴ The FRPP provides matching funds (up to 50%) to keep productive farm and ranchland 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.

¹⁵ 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, increasing the difficulty of allocating funds among funding sources (MALPF five-year Annual Report for FY 2003-2007, 11 January 2008)

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	\$ 8,930,412	\$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 carbon may be lost on forest conversion to developed use, soil carbon loss was excluded from this analysis because soil carbon 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 carbon densities from the USDA Forest Service Forest Inventory and Analysis (FIA) for Maryland results, roughly 27.9 tons carbon emissions are avoided for every acre of forest preserved in Maryland.

The best currently-available data on transition into and out of the forest land category are from the FIA dataset. Based on these data, between 1986 and 1999, roughly 9,643 acres of forest were lost in Maryland annually (FIA statistics). The most recent FIA data on forestland use transition in Maryland are not reliable because an adequate number of plots have not yet been sampled to provide a statistically robust sample of forestland area. Still, the most recent inventory cycle (in 2006) does suggest a continued loss of forestland in Maryland.

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 4-2 shows the annual and total acreage targeted by the program and associated avoided emissions that would be generated between 2008 and 2020.

Table 4-2. Acreage protected annually and associated avoided emissions under policy implementation

Year	Acres Protected	Avoided Emissions (MMtCO ₂ e)
2008	19,200	1.962
2009	19,200	1.962
2010	19,200	1.962
2011	19,200	1.962
2012	19,200	1.962
2013	19,200	1.967
2014	19,200	1.967
2015	19,200	1.967
2016	19,200	1.967
2017	19,200	1.967
2018	19,200	1.967
2019	19,200	1.967
2020	19,200	1.967
Total	250,000	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 4-3). Soil carbon density was assumed constant and is not included in the calculation.

Table 4-3. Forest carbon sequestration rates in protected forests

Forest Type	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 4-4. 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.

Year	Cumulative Acreage Protected	Annual Sequestration (MMtCO ₂ e)
2008	19,200	0.055
2009	38,400	0.110
2010	57,600	0.165
2011	76,800	0.220
2012	96,000	0.274
2013	115,250	0.329
2014	134,500	0.384
2015	153,750	0.439
2016	173,000	0.495
2017	192,250	0.550
2018	211,500	0.605
2019	230,750	0.660
2020	250,000	0.715
Total	250,000	5.000

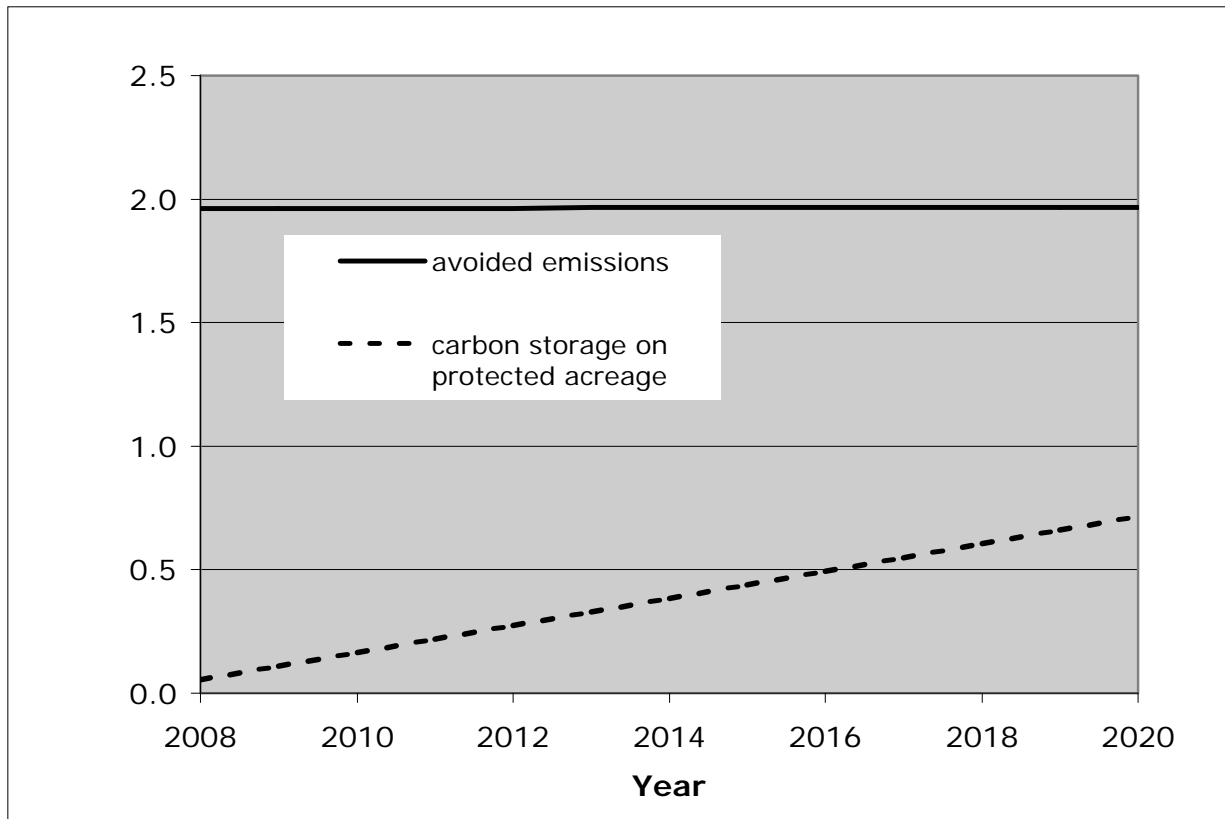
3. Overall GHG Benefit of Avoided Land Conversion

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 4-5). Figure 4-1 shows the relative impact of avoided emissions and sequestration in protected acreage.

Table 4-5. Combined effect of avoided land conversion and C storage on protected acreage

Year	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 4-1. Relative impact of forest protection and carbon 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 MALPF (see Agriculture Land Costs, above).

Net economic costs of protecting forestland are presented in Table 4-6. Discounted costs were calculated using a 5% discount rate, with a total NPV of \$1128.7 million. The cost-effectiveness of this option is \$36.95/Mt CO₂e avoided.

Table 4-6. Economic costs of protecting forestland under AFW-4

Year	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

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: Increase 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, MDA, DNR, 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.
- Maryland has been a LEED (a rating and certification 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. Maryland should push for LEED to include points for the use of wood, particularly local sustainably grown wood.
- Encourage the creation of value-added products from local woods in lieu of shipping raw materials from long distances.

Related Policies/Programs in Place

MDA has recently been revitalized and is actively promoting a Buy Local program.

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

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 University¹⁶ which compared miles traveled, fossil fuel used, and CO₂ emitted in the transport sector of several food systems. The study estimated the fuel use and the CO₂ emissions for 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

¹⁶ Food, Fuel, and Freeways: An Iowa perspective on how far food travels, fuel usage, and GHG emissions. Leopold Center for Sustainable Agriculture, 209 Curtis Hall Iowa State University Ames, Iowa 50011-1050 Website: <http://www.leopold.iastate.edu/>

summarized in Table 5-1. The 2006 population estimates were based on U.S. Census Bureau data for Iowa and Maryland¹⁷—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)	CO ₂ Emissions (metric tons/year)
Iowa conventional semi-trailer	368,102	3,807
Iowa local—CSA farmers market small truck (gas)	49,359	439
Maryland conventional semi-trailer	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 presents the GHG savings from increasing the proportion of produce sold at farmer's markets.

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 CO ₂ e
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
Cumulative		198,205

Farmer's Market Costs

Costs to administer this program and the possible incentives required to increase the number of farmer's markets in Maryland are difficult to determine and further work in this area is required. For the purposes of quantification, it was assumed that the program costs will be similar to those required to implement the Farm-to-School Program¹⁸. The breakdown of the expenditures for the first year is presented in Table 5-3.

¹⁷ see <http://quickfacts.census.gov/qfd/states/19000.html> and <http://quickfacts.census.gov/qfd/states/24000.html>

¹⁸ A fiscal and policy note on this program has recently been submitted to the Maryland General Assembly (HB 696).

Table 5-3. Farm-to-school program future year expenditure estimates

Type of Expenditure	Costs
Positions	1.5
Salaries and Fringe Benefits	\$82,288
Contractual Services	\$27,500
Equipment	\$4,200
Operating Expenses	\$9,246
Total State Expenditures	\$123,234

The above estimates are based on one full-time position within the Maryland State Department of Education and one and a half position within MDA to coordinate the Farmer’s Market program, based on the costs required to implement the Farm-to-School program.¹⁹ While the Farm-to-School Program is not identical to the Farmer’s Market program, it serves as a good proxy for estimating the program costs—noting that other costs such as additional costs to incentivize local year-round production of agricultural products, as well as regional storage, processing, packaging, and distribution have not been included in this analysis.

In addition to these program costs and incentives required, there are also likely to be cost savings associated with the reduced fuel use in the transportation of non-local produce. The price of gasoline was assumed to be \$3.00 per gallon. Table 5-4 summarizes the potential costs and costs savings of the farmer’s market component.

Table 5-4. Costs and savings from farmer’s market expansion under AFW-5

Year	Fuel Saved (gal/yr)	Program Costs ²⁰	Fuel Savings	Net Costs	Discounted Costs
2008	187,576	\$123,234	\$562,727	-\$439,493	-\$398,633
2009	375,151	\$134,000	\$1,125,454	-\$991,454	-\$856,456
2010	562,727	\$140,000	\$1,688,182	-\$1,548,182	-\$1,273,693
2011	750,303	\$146,200	\$2,250,909	-\$2,104,709	-\$1,649,094
2012	937,879	\$152,800	\$2,813,636	-\$2,660,836	-\$1,985,557
2013	1,125,454	\$159,676	\$3,376,363	-\$3,216,687	-\$2,286,040
2014	1,313,030	\$166,861	\$3,939,090	-\$3,772,229	-\$2,553,193
2015	1,500,606	\$174,370	\$4,501,818	-\$4,327,447	-\$2,789,511
2016	1,800,727	\$182,217	\$5,402,181	-\$5,219,964	-\$3,204,605
2017	2,100,848	\$190,417	\$6,302,545	-\$6,112,128	-\$3,573,635
2018	2,400,969	\$198,985	\$7,202,908	-\$7,003,923	-\$3,900,046
2019	2,701,091	\$207,940	\$8,103,272	-\$7,895,332	-\$4,187,063
2020	3,001,212	\$217,297	\$9,003,635	-\$8,786,338	-\$4,437,698
Total					-\$33,095,223

¹⁹ Costs include salaries, fringe benefits, one-time start-up costs and on-going operating expenses. Future years (2010-2013) reflect 4.4% annual increases in salaries, 3% employee turnover and 2% annual increases in ongoing operating expenses.

²⁰ After 2013, the program costs were assumed to increase at a rate of 4.5% p.a. to account for increases to salary expenses and operating expenses.

Note: Other costs such as additional costs to incentivize local year-round production of agricultural products, as well as regional storage, processing, packaging, and distribution have not been included in this analysis.

Locally Grown and Processed Lumber: GHG benefits and economic costs (to be expanded)

If the amount of lumber used in-state remains constant, and if there is no increase in lumber produced from in-state sources, then a switch from imported to domestic lumber would result in GHG benefits due only to the transportation of the domestic lumber that would otherwise have been imported. Because these benefits are likely to be both very difficult to quantify and also quite negligible, GHG benefits from this component of AFW-5 are not quantified.

• **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.

Additional costs to incentivize local year-round production of agricultural products, as well as regional storage, processing, packaging, and distribution have not been included in this analysis.

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]

Barriers to Consensus

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

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

Policy Description

Sustainable forest and farm practices produce by-products and feedstocks (for example, chicken litter, methane, slash, switchgrass, corn stalks, etc.) which before were considered unsuitable for further use. These can be sources of renewable energy. This policy option should increase the utilization of biomass from urban and rural feedstocks 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 feedstocks and by-products are used to create heat or power, which offsets fossil fuel-based energy production and associated GHG emissions.

Note: This option also has significant overlap with AFW-7. AFW-6 calculates the utilization of 25% of crop residues and 50% of forestry residues by 2020 as a biomass energy source but AFW-7 assumes 100% utilization of sustainable biomass residue available within the state of Maryland, including crop and forestry residue. If those residues are assumed to be used for AFW-7 instead of AFW-6 then final AFW-6 emissions savings and costs would need to be decreased by a total of 1.82 MMTCO_{2e} at a cost of \$22.5 million.

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, dairy and poultry 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 and Poultry Litter: By 2020, utilize 50% of available methane from livestock manure and Poultry Litter for renewable electricity, heat and steam generation.

- **Timing:** As described above.
- **Parties Involved:** Maryland Energy Administration (MEA), DNR, MDE, MDA, municipalities, power producers (such as Mirant and Constellation), local electric utilities (and distributors), Board of Education, energy consumers in rural communities (hospitals, community colleges, and universities), Soil Conservation Districts.

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.
- Maryland Department of General Services (DGS) could provide equal credit to efficient design, energy efficiently loan programs, etc.
- Wood-based systems should be afforded equal treatment by DGS.
- Establish incentives for utilizing renewable heating fuels (such as tax credits similar to those afforded electric producers in the Maryland Clean Energy Act).
- Acknowledge that Maryland energy policy is devoid of any discussion regarding thermal loads, which happen to represent 40% of Maryland's total energy budget.

Related Policies/Programs in Place

Modify the Renewable Portfolio Standards requiring local sources of renewable energy

Types(s) of GHG Reductions

- **CO₂, Nitrous Oxide (N₂O), Methane (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 biomass will be used to replace coal in the RCI and electricity sector (where coal represents the majority of electricity generated).²¹ While co-firing was used as a technology to provide an estimate of possible capital costs required to enable the utilization of biomass, it is recognized that other technologies, such as gasification, potentially offer more significant opportunities.

²¹ Based on eGRID data: Coal 56%, Nuclear 28%, Oil 6.3%, Natural Gas 2.2%, Biomass 1.3%.

With the exception of available urban wood waste, the amount of biomass available is taken from the Maryland Department of Natural Resources Document *The Potential for Biomass Co-firing in Maryland*.²² 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 Potential for Biomass Co-firing in Maryland* assumed that 25% 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 (MMBtu/ton) ²³	Estimated Heat input (MMBtu)
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

Forestry Feedstocks	Dry Tons	Heat Content (MMBtu/ton)	Estimated Heat input (MMBtu)
Forest Residue	136,878	9.6	1,314,029
Mill Residue	148,754	14	2,082,556
Urban Residue ²⁴	526,713	10	5,267,132
Total Forest Feedstocks	812,345		8,663,717

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*.²⁵

²² 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

²³ 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.

²⁴ Available urban wood waste is based on analysis by Daniel Rider, Maryland DNR Forest Service. Mr. Rider's analysis indicated that urban wood sourced from Refuse (e.g., construction and demolition, pallets, landfill segregates), Arborists, and Land clearing totaled approximately 810,328 tons of fresh "natural" wood each year. A moisture content of 35% was assumed to derive the estimate of 526,713 dry tons p.a.

²⁵ 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 \$/MMBtu 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 is calculated using the costs indicated in Table 6-3. The difference in costs (dollars per million British thermal units [\$/MMBtu]) is multiplied by the amount of coal energy (MMBtu) 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 per kilowatt [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 biomass.²⁶

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).

Table 6-4 displays GHG benefits and fuel costs for agricultural residue, Table 6-5 displays the same for energy crops and likewise, Table 6-6 addresses benefits and costs for forestry feedstocks. A summary of avoided emissions and cost for all the biomass components is presented in Table 6-7.

²⁶ 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	Agriculture Residue Biomass (MMBtu)	Avoided Emissions Agriculture Residue (MMtCO ₂ e)	Agriculture 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
Cumulative Total			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(MMtCO 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 Total			1.010		\$11,527,205

Table 6-6. GHG benefits and fuel costs for forestry feedstocks

Year	Percentage of Utilization	Forest Feedstocks (Includes Forest & Mill Residue & Urban Wood Waste) (MMBtu)	Avoided Emissions All Forest Feedstocks (MMtCO ₂ e)	Forest Feedstock (Includes Forest & Mill Residue & Urban Wood Waste) Cost/Savings	Discounted Cost/Savings
2008	1%	108,296	0.010	\$69,423	\$62,969
2009	3%	216,593	0.020	\$138,846	\$119,940
2010	4%	324,889	0.031	\$208,268	\$171,343
2011	5%	433,186	0.041	\$277,691	\$217,578
2012	6%	541,482	0.051	\$347,114	\$259,022
2013	8%	649,779	0.061	\$416,537	\$296,025
2014	9%	758,075	0.071	\$485,959	\$328,916
2015	10%	866,372	0.081	\$555,382	\$358,004
2016	13%	1,126,283	0.106	\$721,997	\$443,243
2017	16%	1,386,195	0.130	\$888,612	\$519,553
2018	19%	1,646,106	0.155	\$1,055,226	\$587,589
2019	22%	1,906,018	0.179	\$1,221,841	\$647,968
2020	25%	2,165,929	0.204	\$1,388,455	\$701,264
Cumulative Total			1.038		\$4,713,415

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

Year	Total Biomass Use (Ag Residue, Forest Feed-stocks and Energy Crops) (MMBtu)	Annualized Capital Costs	Fuel Costs (Ag Residue, Forest Feed-stocks and Energy Crops)	Total Costs	Discounted Cost/Savings	Total GHG Emissions Avoided (MMtCO ₂ e)
2008	246,720	\$37,031	\$423,831	\$460,861	\$418,015	0.023
2009	493,440	\$74,061	\$847,661	\$921,723	\$796,219	0.046
2010	740,160	\$111,092	\$1,271,492	\$1,382,584	\$1,137,455	0.070
2011	986,880	\$148,123	\$1,695,322	\$1,843,445	\$1,444,387	0.093
2012	1,233,600	\$185,153	\$2,119,153	\$2,304,306	\$1,719,509	0.116
2013	1,591,020	\$238,799	\$2,741,136	\$2,979,935	\$2,117,784	0.150
2014	1,948,439	\$292,445	\$3,363,118	\$3,655,563	\$2,474,229	0.183
2015	2,305,859	\$346,090	\$3,985,101	\$4,331,191	\$2,791,924	0.217
2016	2,905,367	\$436,072	\$5,015,504	\$5,451,576	\$3,346,795	0.273
2017	3,504,875	\$526,053	\$6,045,908	\$6,571,961	\$3,842,489	0.329
2018	4,104,383	\$616,034	\$7,076,311	\$7,692,346	\$4,283,386	0.386
2019	4,703,891	\$706,016	\$8,106,715	\$8,812,731	\$4,673,579	0.442
2020	5,303,399	\$795,997	\$9,137,119	\$9,933,115	\$5,016,898	0.499
Cumulative Total					\$34,062,670	2.83

Methane Utilization from Livestock Manure and Poultry Litter GHG Benefits

Methane emissions (in MMtCO₂e) 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 and poultry litter. An assumed collection efficiency of 75%²⁷ was applied to methane emissions from manure and poultry litter 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 captured in each year to its heat content (in BTUs) and then multiplying by an energy recovery factor of 17,100 Btu per kilowatt-hour (kWh) 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 kWh to megawatt hours (MWh) 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 (MMtCO ₂ e)	Million Metric Tons of Methane	Methane (MBtu)	CO ₂ e Offset as Electricity (Metric Tons)	Total Emission Reductions (MMtCO ₂ e)
2008	0.090	4%	0.003	0.000	6547	225	0.003
2009	0.090	8%	0.005	0.000	13,050	448	0.006
2010	0.090	12%	0.008	0.000	19,515	669	0.008
2011	0.090	15%	0.010	0.000	25,977	891	0.011
2012	0.090	19%	0.013	0.001	32,417	1,112	0.014
2013	0.089	23%	0.015	0.001	38,837	1,332	0.017
2014	0.089	27%	0.018	0.001	45,236	1,552	0.020
2015	0.089	31%	0.021	0.001	51,613	1,770	0.022
2016	0.089	35%	0.023	0.001	57,957	1,988	0.025
2017	0.089	38%	0.026	0.001	64,276	2,205	0.028
2018	0.089	42%	0.028	0.001	70,573	2,421	0.031
2019	0.088	46%	0.031	0.001	76,846	2,636	0.033
2020	0.088	50%	0.033	0.002	83,095	2,850	0.036

²⁷ 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*.²⁸ The production costs were assumed to be \$0.11 per kWh for swine anaerobic digesters and \$0.05 per kWh for dairy anaerobic digesters²⁹. 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 costs³⁰. 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).³¹ The value of electricity produced was taken from the all sector average projected electricity price for the Southeastern Electric Reliability Council from the DOE Energy Information Administration (EIA) *2007 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.

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
Total				\$57,041

²⁸ 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.

²⁹ 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.

³⁰ 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.

³¹ *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 energy production from 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-megawatt (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. Similar issues also surround the production of energy from livestock manure and poultry litter.

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

The expansion of crops as an energy feedstock needs to ensure that the energy crops are grown on appropriate land and in ways that do not damage terrestrial or aquatic resources nor displace food and fiber production.

Feasibility Issues

The feasibility of installing digesters on a small-scale farm is uncertain and the costs may make this unattractive. Digester facilities tend to require a critical number of animals before the projects are feasible. As such, implementation at the community or cooperative scale may be more feasible and realistic.

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).

Note: This option is linked with Transportation and Land Use policy recommendation TLU-4, which focuses on the demand-side aspects of a Low Carbon Fuels Standard. This AFW option seeks to achieve incremental GHG benefits from the supply-side by promoting in-state production of biofuels using feedstocks with greater GHG benefits than the likely business-as-usual (BAU) national production methods.

This option also has significant overlap with AFW-6. AFW-6 calculates the utilization of 25% of crop residues and 50% of forestry residues by 2020 as a biomass energy source but AFW-7 assumes 100% utilization of sustainable biomass residue, including crop and forestry residue. If those residues are assumed to be used for AFW-7 instead of AFW-6 then final AFW-6 emissions savings and costs would need to be decreased by a total of 1.82 MMTCO₂e at a cost of \$22.5 million.

Policy Design

Goals:

Gasoline displacement goals—Achieve in-state cellulosic ethanol production equivalent to offsetting gasoline consumption in the state by 3.0% in 2015 and 3.0% in 2020.

Fossil diesel displacement goals—Increase in-state biodiesel production from Maryland non-food feedstocks to offset diesel consumption in the state by 2% in 2015 and 2.2% in 2020.

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.

The timeline needs to allow time for permitting and construction of sufficient production facilities to meet the goals.

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, MEA, MDA, Maryland Department of Business and Economic Development, MDE, etc.

Other:

Currently there is one small commercial cellulosic ethanol plants in the United States located in Upton, Wyoming. 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, but not in Maryland. The only ethanol plants proposed in Maryland are corn-based plants.

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

Impact studies on effects of gas specification changes including vapor pressure and ozone emissions needed.

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; and
 - Change existing gasoline specifications in Maryland so that ethanol can be blended into conventional fuel (which represents only 15% of the Maryland fuel supply; most is reformulated gasoline with E10).
- 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—beginning in FY 2007 and lasting 10 years—offers a \$0.20/gal credit for ethanol made from small grains and a \$0.05/gal credit for ethanol from other agricultural sources; offers a \$0.20/gal credit for biodiesel made after 2005 from soy and a \$0.05/gal credit for biodiesel made before 2005 from any feedstock including soy. MDE reports that of the two facilities in Maryland that have shown interest in ethanol credits, only one has been permitted and has to produce within 18 months or will lose the permit.
- Cellulosic feedstock and value-added by-product study (MEA)—e.g., feasibility studies.
- Renewable Fuels Task Force (created by statute) – a one-time task force with a single report as a deliverable.
- Grants for E85 refueling stations (MEA- but very limited funds- \$50,000 total).
- Increase E85 use in State Government.
- US DOE construction grants (for biofuels plants?).
- Federal loan guarantees (for biofuels plants?).
- Potential 2007 Farm Bill programs (need some specifics on this).
- Requirements for State Use of Diesel – required Maryland to purchase state equipment for biodiesel; 50% of state fleet diesel vehicles use at least a B5 blend beginning July 1, 2007; 50% of state off road and heating (generators) heavy equipment use at least a B5 blending beginning July 1, 2008.

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 CO₂e 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),³² biodiesel from soybeans contains 91% of the usable energy of 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 life-cycle GHG emissions further downward as they are developed as biodiesel sources. Local production of biodiesel also decreases the embedded CO₂e of biodiesel compared to the import of out of state supplies. In this policy only non-food biodiesel feedstocks will be considered.

Estimated GHG Reductions and Net Costs or Cost Savings

Ethanol

- GHG reduction potential in 2015, 2020 (MMtCO₂e) 0.85, 0.91
- Net cost per MtCO₂e: \$80.08

This section will focus exclusively on ethanol production from cellulosic feedstocks. Maryland is a corn deficit state, meaning that it has to import corn to meet its current food/feed needs. Because of that, there is insufficient corn to consider policy incentives to promote in-state production of corn- or starch-based ethanol.

According to studies conducted by DOE's Argonne National Laboratory one of the benefits of cellulosic ethanol is that it reduces GHG emissions 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 Maryland 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 (under business as usual) are presented in Table 7-1.

Table 7-1. BAU gasoline consumption

Year	Gasoline Consumption (million gal/yr)
2015	2,989
2020	3,190

³² 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.

The policy design calls for displacement of 3.0% of BAU gasoline consumption with cellulosic ethanol by 2015 and maintain displacement of 3.0% BAU consumption by 2020 as gasoline consumption increases. Ethanol has approximately 67% the heat content of gasoline.³³ Therefore, incremental in-state ethanol production targets are presented in Table 7-2.

Table 7-2. Cellulosic ethanol production needed to meet policy goals

Year	BAU Gasoline consumption (Million gal/year)	Percentage to be displaced	Ethanol Production Needed (Million gal/year)
2015	2,989	3%	135
2020	3,190	3%	144

In-state cellulose supply was estimated from residual biomass residues. No land conversion for cultivation of fuel crops is assumed. The conversion factors in Table 7-3 were used to estimate ethanol from cellulose based on DOE and NREL data.³⁴ DOE and NREL assume that by 2012 the ethanol yield per ton biomass will have improved. Estimates of biomass from crop residues, forest residues, primary and secondary mill residues, and urban wood were obtained from a Maryland Department of Natural Resources study.³⁵ This study assumes that 50% crop residue will be left in the fields to maintain soil or be set aside for livestock feed. Only excess residue that is sustainable will be used for conversion to fuel. Conservation Reserve Program land is also not assumed to be used for fuel production. This policy assumes that 100% of the rest of the biomass can be converted to fuel.

Table 7-3. Cellulose feedstock conversion factors

Year	Ethanol yield from cellulose (gal/ton biomass)
2008	70
2012	90
2020	100

It was assumed that it would take seven years for production to ramp up to its maximum based on feedstock supplies. Table 7-4 shows the in-state cellulosic ethanol targets based on available in-state feedstock supplies. It is assumed that 100% of biomass residue is converted to cellulosic ethanol.

³³ DOE/EIA, <http://www.eia.doe.gov/oiaf/analysispaper/biomass.html>, accessed January 9, 2008

³⁴ http://genomicsgtl.energy.gov/biofuels/2005workshop/2005low_intro.pdf, accessed December 28, 2008; J. Ashworth, NREL, personal communication, 4/06/07.

³⁵ The Potential for Biomass Cofiring in Maryland, Maryland Power Plant Research Program, Maryland, Department of Natural Resources, March 2006

Table 7-4. Cellulosic ethanol annual production based on upper bound of feedstock supplies

Year	Cellulosic ethanol (Million gal)	% of BAU Consumption
2008	0	0%
2009	10	0.2%
2010	19	0.5%
2011	38	0.9%
2012	58	1.4%
2013	77	1.8%
2014	96	2.2%
2015	135	3.0%
2016	136	3.0%
2017	138	3.0%
2018	140	3.0%
2019	142	3.0%
2020	144	3.0%

Emission factors from gasoline, starch-based ethanol and cellulosic ethanol are based on the ANL GREET Model.³⁶ 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.³⁷ The production cost differential for cellulosic versus starch-based ethanol was obtained from the National Renewable Energy Laboratory (NREL).³⁸

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 TLU 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.³⁹ This analysis does not take into account the benefits from transitioning from gasoline to corn-based ethanol.

GHG deductions in each year were estimated by multiplying production by the incremental benefit of cellulose over corn-based ethanol.

³⁶ Ibid.

³⁷ ANL GREET model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

³⁸ http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/19_forum/braemar_cellulosic.pdf, slide 21, accessed December 2007

³⁹ ANL GREET model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

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.⁴⁰ 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 \$0.51/gallon currently offered for ethanol production.⁴¹ If enacted, this \$0.255/gallon premium could cover the additional incentives that are assumed to be needed by the State of Maryland. However, the federal incentives do not assure that production facilities would locate in Maryland. These federal incentives have not been factored into the cost estimates for this option.

Biodiesel

- GHG reduction potential in 2015, 2020 (MMtCO₂e): 0.14, 0.18
- Net Cost per MtCO₂e: \$7.44

Fossil diesel consumption estimates (under business as usual) are presented in Table 7-5.

Table 7-5. BAU Diesel Consumption

Year	Diesel Consumption (million gal/yr)
2015	817
2020	941

The policy design calls for displacement of 2% of diesel consumption by 2015 and 2.2% by 2020 with biodiesel from non-food feedstocks such as animal fats, yellow grease (also called sewer grease or restaurant grease), and algal oil. Biodiesel has approximately 91% the heat content of fossil diesel.⁴² In-state biodiesel production targets are presented in Table 7-6.

⁴⁰ http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/19_forum/braemar_cellulosic.pdf, slide 21, accessed December 2007

⁴¹ 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.

⁴² Biomass Energy Data Book, Oak Ridge National Laboratory, http://cta.ornl.gov/bedb/appendix_a.shtml, accessed December 28, 2008.

Table 7-6. Biodiesel production needed to meet policy goals

Year	Biodiesel Production Goals (Million gallons)	Fraction of 2005 consumption
2008	4	0.5%
2009	4	0.5%
2010	8	1.0%
2011	10	1.3%
2012	14	1.7%
2013	15	1.8%
2014	16	1.9%
2015	18	2.0%
2016	19	2.0%
2017	20	2.1%
2018	21	2.1%
2019	22	2.2%
2020	23	2.2%

Table 7-7 presents the existing and planned facilities and capacity in Maryland.⁴³ Production of biodiesel from soybean oil will not be considered under this policy, which is designed to incentivize production from non-food sources.

Table 7-7. Existing and planned biodiesel facilities in Maryland

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

Table 7-8 summarizes the upper limit of biodiesel that could be produced from in-state feedstock by 2015 and 2020. 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 BioPower

⁴³ <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

Evaluation Tool (BioPET) that identifies locations, types, and volumes of biomass fuels.⁴⁴ Yellow grease was projected based on industry estimates of 14 pounds restaurant grease per capita and 7.6 pounds of grease per gallon using U.S. Census projections for Maryland.⁴⁵ It was assumed that by 2020 algal biodiesel technology will have progressed enough to be available to provide ~20% of biodiesel production. Table 7-8 summarizes the upper limit of biodiesel that could be produced from in-state feedstock by 2015 and 2020.

Table 7-8. Biodiesel potential from available feedstock

Feedstock	Biodiesel equivalent (1000 gal)
Animal fats	5,791
Yellow grease 2015	11,780
Yellow grease 2020	12,329
Algal 2020 - estimated at 20% of feedstock	5,000
total 2015	17,571
total 2020	23,120

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.⁴⁶

Quantification Methods:

GHG Reductions

For biodiesel production a new study on lifecycle GHG benefits was used to estimate the CO₂e reductions for this option.⁴⁷ 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. Life-cycle 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.

⁴⁴ <http://www.mncee.org/pdf/biomassreport.pdf>, accessed January 8, 2008.

⁴⁵ <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.

⁴⁶ From: Hill, J., et al., Proceedings of the National Academy of Sciences, vol. 103, no. 30, 11206-11210. U.S. soybean-based biodiesel.

⁴⁷ Ibid.

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 20% 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 assumed to average 100 miles,⁴⁸ yielding a benefit of 7,207 MtCO₂e/MMgal biodiesel over soy-based.

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

GHG estimates for this scenario were calculated by multiplying new production of each oil feedstock by the applicable incremental benefit. Total reductions in each year were estimated by summing the incremental benefit for each oil type.

Costs

For biodiesel, costs were estimated using information from an analysis of biodiesel production costs from the US DOE.⁴⁹ The value of incentives needed is assumed to be \$0.30/gallon—the value of incentives offered in a State of Missouri incentives program.⁵⁰ 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.⁵¹ 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.

⁴⁸ Max dimension of Maryland is ~200 miles, 100 miles is distance from center of the state to border.

⁴⁹ See www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html; accessed January 2007.

⁵⁰ Information on the Missouri Program from www.newrules.org/agri/mobiofuels.html#biodiesel, accessed January 2007.

⁵¹ <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 Assumptions:

All available feedstock (that does not serve as a food source) will be used for fuel production.
(This will be adjusted to balance with the feedstock use in AFW-6)

Key Uncertainties

Cost competitiveness of biofuels will depend on cost of oil. This analysis did not account for the cost of oil, which is currently \$95.15 per barrel crude oil,⁵² the cost of gasoline, which is currently \$3.16 per gallon, nor the cost of diesel, which is currently \$3.66 per gallon.⁵³ However, if the price of oil drops substantially alternative biofuels become less cost competitive and any incentives outlined here may be insufficient to encourage production.

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.”⁵⁴

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, DOE 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 U.S. \$1.07/gal (U.S. \$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.

⁵² As of February 29, 2008, EIA, Weekly Petroleum Status report,
http://www.eia.doe.gov/oil_gas/petroleum/data_publications/weekly_petroleum_status_report/wpsr.html

⁵³ As of March 3, 2008, EIA, Weekly Petroleum Status report,
http://www.eia.doe.gov/oil_gas/petroleum/data_publications/weekly_petroleum_status_report/wpsr.html

⁵⁴ <http://www.eia.doe.gov/oiaf/analysispaper/biomass.html>, accessed December 2007.

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 U.S. 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.

Changes in gasoline specifications due to blending may raise vapor pressure and increase ozone. Additional information on the impacts of this type of policy is needed.

Feasibility Issues

Currently gasoline and diesel specifications are set by federal law and EPA regulations. Any fuels used in the state of Maryland would need to conform to federal laws.

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.

If algal oils become commercialized there is a possibility that they could be used to meet production goals that are much higher than currently outlined in this policy.

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 global positioning system technology 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 GHG 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 N_2O , which has 310 times the effect as one unit of CO_2 . Better nutrient utilization can lead to lower nitrous oxide emissions from runoff.

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.

Goals:

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

- **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, MDE, and MDA.
- **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.
- 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.

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 runoff 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”, DOE’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 Agricultural Research Service in Fort Collins, Colorado, which included analysis on deep core soil samples for baseline data under NLEAP (Nitrate Leaching and Economic Analysis Package) and CEQUESTER [what do these letters stand for?] 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 MDA (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)⁵⁵. 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 MMtCO₂e 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 Cowie⁵⁶. The estimate provided for the U.S. (taken from West and Marland, 2001⁵⁷) was 857.5 grams (g) CO₂e per kilogram of nitrogen (kgN)⁵⁸ or 0.778 MtCO₂e per ton of nitrogen (tN). This estimate was significantly lower than the estimates for European fertilizers (ranging from 5,339.9 to 7,615.9 gCO₂e/kgN). Wood and Cowie recognize that the estimate for the U.S. is low and suggested that

⁵⁵ There was no data for the 2002-03 FY period.

⁵⁶ 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

⁵⁷ 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.

⁵⁸ These emission factors provide an estimate of the typical life cycle GHG emissions (including resource extraction, the transport of raw materials and products, and the fertilizer production processes) per unit weight of fertilizer produced (i.e., gCO₂e/kg fertilizer).

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 2007 (Table 8-1).⁵⁹ 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 two full-time equivalents 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.⁶⁰ The cost estimates do not include any financial benefit that may result through the generation of carbon credits.

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
Total			1.0				-\$29.7

- **Key Assumptions:**

⁵⁹ April 2007 data from ERS/USDA see <http://www.ers.usda.gov/Data/fertilizeruse/>.

⁶⁰ Brian Hurd, New Mexico State University, Agricultural Economics, personal communication with H. Lindquist, CCS, June 2006.

Key Uncertainties

Due to weather and drought conditions there may be a discrepancy between estimated and actual nutrient and GHG reductions. This poses some uncertainties in certifying credits in advance of project construction.

This analysis 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.

Other uncertainties surround baseline issues (what are the minimum standards below which credits will be generated), timing of trading (now or in the future after implementation of certain regulatory standards?) and the duration of trade (e.g., 10 years or life of best management practice?).

Additional Benefits and Costs

Ancillary conservation benefits; wildlife corridors; enhanced biodiversity, and leveraged private capital in ecosystem restoration projects.

Feasibility Issues

Pending –

Status of Group Approval

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

Level of Group Support

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

Barriers to Consensus

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

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 GHG 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 up-cycling (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 suggested as policy elements, but not included in the quantification of this option.

Policy Design

- **Goals:** Waste stream, including diverted waste, 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%.⁶¹ This recycling rate includes composted organics. The overall diversion rate includes recycling, compostable organics, and source reduction credits. Source reduction credits are allocated by MDE, based on approved source reduction programs implemented by municipalities. It is assumed, therefore, that these programs reduce

⁶¹ 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>.

the overall amount of waste that must be managed. Table 9-1 displays diversion data in Maryland from 2001 through 2005. 2005, the most recent year for which reliable data are available, will be used as the base year, rather than 2006.

Table 9-1. Data from Maryland Recycling Act Annual Reports (Calendar Years 2001–2005)⁶²

Item	2001	2002	2003	2004	2005
MRA Rate	37.0%	37.0%	36.8%	35.8%	39.2%
Waste Diversion Rate	39.0%	39.5%	39.6%	38.8%	42.6%
Source Reduction Credit	2.0%	2.5%	2.8%	3.0%	3.4%
Compostables (tons)	617,390	645,230	892,250	853,094	944,358
Glass (tons)	47,764	55,481	64,894	71,558	57,889
Metals (tons)	220,631	251,703	271,646	302,904	535,195
Paper (tons)	948,513	909,447	821,652	861,927	840,644
Plastic (tons)	23,149	35,930	24,483	30,663	36,858
Miscellaneous (tons)	547,586	558,050	518,599	561,829	518,935
Total MRA Diversion (Including Organics) (tons)	2,405,033	2,455,841	2,593,524	2,681,975	2,933,879
Recycling (Excluding Organics) (tons)	1,787,643	1,810,611	1,701,274	1,828,881	1,989,521
Total MRA Waste Disposed in Landfills and Incinerators* (tons)	4,095,056	4,181,567	4,454,096	4,809,575	4,550,506
Total MRA Waste, Including Recycling (tons)*	6,500,089	6,637,408	7,047,620	7,491,550	7,484,385
Total Source Reduction (tons)*	132,655	170,190	203,018	231,697	263,426
Total Generation, Including Recycling, Composting, and Source Reduction (tons)*	6,632,744	6,807,598	7,250,637	7,723,248	7,747,811
% Change*		2.6%	6.5%	6.5%	0.3%
Annual Generation Change*	3.4%				
Average Annual Recycling Rate*	37.2%				

*Calculated from report data. MRA = Maryland Recycling Act.

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,

⁶² 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.

West Virginia, and the District of Columbia.⁶³ Considering the net exports of landfill MSW in Maryland, the baseline recycling rate in Maryland was 31.2% (including organics), lower than the rate reported by the 2005 Maryland Recycling Act Report.⁶⁴ As Table 9-2 shows, the BAU composting level is projected by assuming that 32% of total diversion is composted.⁶⁵ For this analysis, all waste generated in Maryland will be included, but not the waste imported from elsewhere.

Table 9-2. Business-as-usual waste management projection for Maryland

Item	2005	2010	2012	2015	2020
Total MD Waste Generation (Including Net Exports) (tons)	9,242,389	10,904,236	11,649,832	12,864,895	15,178,095
MSW Managed in-state (3.4%/yr Growth 2001–2005) (tons)	7,747,811	9,140,922	9,765,948	10,784,525	12,723,659
Net MSW Exports (tons)	1,494,578	1,763,314	1,883,883	2,080,370	2,454,435
MD Population (From I&F) (tons)	5,561,214	5,907,575	5,989,170	6,113,680	6,326,975
MSW Generation per Capita (tons/person)	1.7	1.9	2.0	2.1	2.4
MSW Diverted (Including Recycling and Organics, 39.2% MSW Managed in State; 2005 Baseline) (tons)	2,933,879	3,583,242	3,828,252	4,227,534	4,987,674
MSW Composting (32% of MSW Recycled) (tons)	938,841	1,146,637	1,225,041	1,352,811	1,596,056
MSW Disposed (In-State Landfills Only) (tons)	3,169,045	3,617,031	3,864,352	4,267,399	5,034,708
MSW Disposed in All Landfills (tons)	4,949,634	5,717,783	6,108,746	6,745,881	7,958,838
Waste to Energy (incinerators) (18% of waste generated) (tons)	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.

⁶³ 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.

⁶⁴ 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).

⁶⁵ 32% = 944,358 tons composted / 2,933,879 tons diverted.

- Increase quality as a means to enhance product longevity with innovative programs to reward manufacturers for quality.
- Identify and phase out any subsidies that discourage waste reduction, reuse of components, or improved quality and longevity of products.
- Work with the Cross-Cutting Issues TWG to include education regarding the wisdom of these policies to all segments of the population including the public.
- 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. Diverting compostables from landfills offers a tremendous opportunity for reducing GHG emissions due to the higher global warming potential of methane. Therefore, these types of programs should be included in the overall plan. Care will be given, however, to making sure the composting programs of organic waste do not create additional problems such as foul odors, groundwater pollution, or increasing rodent populations.
- 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. Although this type of program would be challenging for Maryland to implement as a sole state, it should be considered. At a minimum, Maryland should recommend to our national policy makers that similar legislation be passed at the national level.
- Implement “Resource Management (RM) Contracting.”⁶⁶ RM contracting rationalizes incentives such that the contracting waste hauler receives revenue from the sorting and selling of recyclable materials. This could include the cost transfer of tipping fees to the contracting waste hauler to provide a disincentive for the disposal of waste to a landfill or incinerator. This provides a financial incentive to the contracting waste hauler to maintain effective collection programs and to ensure appropriate sorting and recycling.

Related Policies/Programs in Place

There are no cradle-to-cradle programs in place but MDE does have an aggressive e-cycling program to deal with electronic waste.

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.

⁶⁶ See the following webpage and article for more information on RM contracting:

<http://www.epa.gov/wastewise/wrr/rm.htm>.

http://www.epa.gov/wastewise/pubs/rr_rm.pdf

- **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. The energy saved and resource reduction gained by using less packaging, for example, or by eliminating single-use containers is also substantial.

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.⁶⁷ The breakdown of the waste disposed in Maryland by type was derived from U.S.-level data provided in the EPA 2005 Waste Characteristics Report.⁶⁸ The breakdown of baseline recycled waste in Maryland was derived from the 2006 Maryland Recycling Act Annual Report⁶⁹ and the EPA 2005 Waste Characteristics Report. The GHG emission reductions modeled using EPA's Waste Reduction Model (WARM).⁷⁰

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 Report⁷¹ and a case study from Montgomery County.⁷²

- **Quantification Methods:**

GHG Reductions

⁶⁷ 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.

⁶⁸ *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>.

⁶⁹ 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>.

⁷⁰ Version 8, May 2006. From http://www.epa.gov/climatechange/wyacd/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/wyacd/waste/SWMGHGreport.html>

⁷¹ 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.

⁷² Montgomery County, Maryland. 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>.

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.⁷³ 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 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 WARM (see Tables 9-12 and 9-13 for accepted inputs).

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 BAU—projections for waste generation, recycling, landfilling, exports, imports, and incineration are displayed in Table 9-2, 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.

⁷³ Waste captured by the Maryland Recycling Act diversion rate is determined on a county level. However, the MRA excludes scrap metal, land-clearing 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 %)

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) (tons)	9,242,389	10,359,024	9,902,357	9,648,671	9,865,762
MSW Generation per Capita (tons/person)	1.7	1.8	1.7	1.6	1.6
MSW Source Reduced (tons)	–	545,212	1,747,475	3,216,224	5,312,333
MSW Diverted (tons)	2,933,879	3,702,683	4,211,077	5,073,041	6,483,977
MSW Disposed (In-State Landfills Only) (tons)	3,455,056	3,503,273	2,876,482	2,120,698	1,256,376
Net MSW Exports (to Out-of-State Landfills) (tons)	1,494,578	1,675,148	1,601,301	1,560,278	1,595,383
Total MSW Landfill Disposal (tons)	4,949,634	5,178,421	4,477,783	3,680,975	2,851,759
Waste to Energy (29.7% of Waste Disposed) (tons)	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.⁷⁴

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% (Table 9-5). 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 9-6).

Table 9-5. Waste generation characteristics⁷⁵

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 waste to energy)⁷⁶

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>	

⁷⁴ 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.

⁷⁵ *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>.

⁷⁶ *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).⁷⁷ The further characterization of waste recycled in Maryland is estimated based on national data from the 2005 EPA Waste Characteristics report (Table 9-8).⁷⁸

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%

⁷⁷ 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.

⁷⁸ *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>.

Table 9-8. Baseline and policy recycling characterization

Waste Type	BAU	2015 Policy	2020 Policy
<i>% of Discarded Paper</i>			
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%
<i>% of Discarded Organics</i>			
Food Waste	70.0%	70.0%	70.0%
Yard Trimmings	30.0%	30.0%	30.0%
<i>% of Recycled Plastics</i>			
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%
<i>% of Recycled Metals</i>			
Aluminum Cans	31.5%	31.5%	31.5%
Steel Cans	68.5%	68.5%	68.5%

The limitations of WARM preclude one from applying the 35% reduction in generation by 2020 (henceforth, source reduction) across all waste types – WARM does not accept source reduction as an input for mixed paper, food waste, yard trimmings, mixed plastics, or mixed recyclables. 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. 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, which is not a plausible result. Thus, additional “recycling” quantities are allocated to the “mixed” waste types in order to assure that the total quantity of diversion instructed by the policy option goal is entered into the model. 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%
Textbooks	1.4%
Aluminum Cans	11.9%
Steel Cans	15.3%

The waste generated for each waste type under the baseline scenario is estimated 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).

The tons source reduced for each waste type are calculated for each waste type where source reduction is a valid WARM input. This is accomplished by using a multiplier (see Table 9-10) that is derived from the total quantity of source reduction divided by the total waste generation. This multiplier is used to estimate the source reduction for each waste type, allocating the quantity of waste source reduced proportionally amongst recycling, landfilling, and incineration.

Table 9-10. Source reduction multiplier

Source Reduction Multiplier	2010	2012	2015	2020
Source Reduction as a % of WARM SR Categories' BAU Generation	12.3%	37.0%	61.7%	86.3%

The total tons of waste diverted for each category under the policy scenario are calculated using a diversion multiplier (see Table 9-11), which is derived in the same manner as the source reduction multiplier. This multiplier is applied to the waste remaining after source reduction. The diversion is allocated proportionally amongst waste that would have been headed to landfills and incinerators.

Table 9-11. Diversion multiplier

Diversion Multiplier	2010	2012	2015	2020
Incremental Recycling as a % of All Categories' BAU Generation	1.1%	3.3%	6.6%	9.9%

The BAU and policy scenario waste management projections for each waste type are entered into WARM for the years 2015 and 2020. GHG reductions are assumed to increase linearly from 2010 - 2015 and from 2015 - 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, Residential		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

HDPE = high-density polyethylene; LDPE = low-density polyethylene; PET = polyethylene terephthalate.

WARM 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 Waste-to-Energy 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
Total	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.⁷⁹ 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.⁸⁰ 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 net present value of -\$1,174 million.

⁷⁹ Not a Maryland-specific estimate. 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.

⁸⁰ 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	
Total				–\$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.⁸¹ Dividing this number by the incremental recycling per capita in 2020⁸² times the average household size of 2.61⁸³ yields the maximum collection cost of \$51/ton. The capital cost of additional recycling facilities in Maryland is \$255 million.⁸⁴ 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.⁸⁵ CCS also factored in the commodity value of recycled materials with a value of \$35/ton.⁸⁶ 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

⁸¹ Not a Maryland-specific estimate. 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.

⁸² Population projection for 2020 from the Maryland Inventory and Forecast.

⁸³ US Census Bureau. State & County QuickFacts – Maryland. Accessed on January 11, 2008 from: <http://quickfacts.census.gov/qfd/states/24000.html>.

⁸⁴ Not a Maryland -specific estimate. Based upon ratio of Capital Cost per household used in Vermont Analysis. VT capital cost a result of Personal Communication with P. Calabrese.

⁸⁵ 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.

⁸⁶ Not a Maryland-specific estimate. 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 14 MMtCO₂e, and the estimated cost-effectiveness is -\$2.5/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	
Total						-\$67.15	-\$35.15	14.00	-\$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.⁸⁷ 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

⁸⁷P. Calabrese, Cassella Waste Management, personal communication with S. Roe, CCS, June 5, 2007. Not a Maryland-specific estimate.

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,⁸⁸ 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,⁸⁹ and a compost value of \$10/ton.⁹⁰

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 MMtCO₂e. 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 ₂ e)	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	
Total									\$91.47	0.50	\$183.81

⁸⁸ 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.

⁸⁹ Montgomery County, Maryland. 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/>.

⁹⁰ *Ibid.*

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 MMtCO₂e.

Table 9-19. 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 ₂ e)
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 WARM 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 WARM (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 waste-to-energy plants.

In some cases, Maryland-specific information was not available and alternative data was used as a default, including:

- The breakdown of the waste disposed in Maryland by type was derived from US-level data provided in the EPA 2005 Waste Characteristics Report.
- 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 alternate information.
 - A net cost for the State to implement source reduction programs of \$1 per capita is assumed.⁹¹
 - The additional cost to separate curbside collection of recyclables was assumed to be \$2.50/household/month, or \$30/household/year.⁹²
 - The capital cost of additional recycling facilities in Maryland was assumed to be \$255 million.⁹³
 - Commodity value of recycled materials was assumed to be \$35/ton.⁹⁴
 - Information on the capital and operating costs of composting facilities was received from Cassella Waste Management during the analysis of a similar option in Vermont.⁹⁵

Key Uncertainties

Biomass derived from landfilled waste may be diverted for use in electricity, heat, and steam generation facilities (see AFW-6). Such a diversion would not reduce total carbon emissions, as the carbon in the waste biomass is biogenic. However, more of this biogenic carbon is emitted as methane in landfill emissions than biomass combustion emissions. Such a diversion would likely reduce the overall GHG emissions from landfills in Maryland.

⁹¹ The source reduction program cost is a preliminary estimate that is consistent with costs assumed in similar options considered by CCS projects in Washington and Colorado.

⁹² T. Brownell, Eureka Recycling, personal communication with S. Roe, CCS, December 17, 2007.

⁹³ Based upon ratio of Capital Cost per household used in Vermont Analysis. VT capital cost a result of Personal Communication with P. Calabrese.

⁹⁴ 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.

⁹⁵ P. Calabrese, Cassella Waste Management, personal communication with S. Roe, CCS, June 5, 2007.

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]