MINNESOTA
Climate Change
Advisory Group

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Agriculture, Forestry, and Waste Management Technical Work Group

Summary List of Draft Priorities for Analysis

	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/t$CO_2$e)	Level of Support
		2015	2025	Total 2008 2020			
AFW-1	Agricultural Crop Management	1.6	2.7	31	-546	-18	Pending
AFW-2	Land Use Management Approaches for Protection and Enrichment of Soil Carbon	0.14	0.43	3.6	2,320	420	Pending
AFW-3	In-State Liquid Biofuels Production	6.8	17	150	-143	-1	Pending
AFW-4	Expanded Use of Biomass Feedstocks for Electricity, Heat, or Steam Production	1.3	3.8	32	292	9	Pending
AFW-5	Forestry Management Programs to Enhance GHG Benefits						Pending
AFW-6	Forest Protection—Reduced Clearing and Conversion to Non-Forest Cover	5.4	5.7	59	TBD	TBD	Pending
AFW-7	Integrated Waste Management A. Source Reduction B. Recycling C. Composting	 0 0.83 0.15	 1.3 1.8 0.55	 6.1 16 4.1	TBD	TBD	Pending
AFW-8	End of Use Waste Management Practices A. Landfilled Waste Methane B. Organics Recovery & WTE C. WTE Preprocessing	 0.03 0.11 0.002	 0.34 0.07 0.005	 2.1 1.8 0.04	 2.1 TBD nq	 1 TBD nq	Pending
	Sector Total After Adjusting for Overlaps[a]						
	Reductions From Recent Actions						
	Sector Total Plus Recent Actions						

[a] Excludes benefits and costs for AFW-4 due to overlap with Option ES-?.

AFW-1. Agricultural Crop Management

Policy Description

This option addresses both agricultural soil carbon management as well as nutrient management to achieve greenhouse gas (GHG) benefits. For soil carbon management, conservation-oriented management of agricultural lands, cropping systems, crop management, and agricultural practices can regulate the net flux of carbon dioxide (CO_2) from soil. Each farm operation and each field management unit has unique traits that allow management practices to influence nutrient, water and carbon cycling and sequestration. Defining GHG outcomes based upon management indices will allow farmers to incorporate management practices within their specific operational needs to meet desired GHG goals. Providing cropping and management flexibility within each field or tract management unit allows both production goals and [carbon] resource management goals to be transparent and readily-valued.

The efficient use of agricultural fertilizer, both commercial and animal-based, can be improved through certain management practices and systems. An example is over application of nitrogen that can result in nitrogen not being fully metabolized by plants. This is important because free nitrogen can leach into groundwater and/or be emitted to the atmosphere as nitrous oxide (N_2O). Better nutrient utilization can lead to lower nitrous oxide emissions from run-off. An example is tile drainage systems that use the latest technology and design models to reduce nitrates leaching into surface water and groundwater.

Policy Design

Goals:

Soil Carbon Management: No-till, strip till, other conservation farming practices, or other cropping management practices that achieve similar soil carbon benefits will account for 33% of all annual crop production in Minnesota.

Nutrient Management: Increase fertilizer application efficiency by 50% by 2025.

Timing:

Soil Carbon Management: By 2015, no-till, strip till or other conservation farming practices that reduce GHG emissions and increase soil carbon sequestration will account for 15% of all annual crop production in Minnesota or manage cropping systems to achieve similar outcomes. By 2025, the full goal will be achieved.

Nutrient Management: By 2015, increase fertilizer application efficiency by 25% and achieve the full goal by 2025.

Parties Involved: SWCD, NRCS, MDA, University of Minnesota, FSA, and agriculture organizations

Other: Research and incentives will be needed to help farmers convert current farming practices over to no-till, strip till or other conservation farming practices. These practices will reduce GHG emissions and increase soil carbon sequestration. Research will be used to develop methods to efficiently and effectively determine outcomes.

Research and incentives will be needed to speed adoption of GPS based technologies and to develop outcome-based and performance-based methods. Research will be needed to determine the best management practices of animal and commercial based fertilizer. Encouraging incorporation of livestock manure to reduce GHG emissions and possible run-off issues is an example of best management practices for livestock produces.

More information about MDA's BMPs can be found at: http://www.mda.state.mn.us/chemicals/fertilizers/nitroch4.htm

In relation to other conservation farming practices, or other cropping management practices that achieve similar soil carbon benefits in the quantification, it will be considered as another conservation farming practices, or other cropping management practices that achieves similar soil carbon benefits to conservation tillage. So while it won't be calculated as a separate component, it will be a possible practice encouraged by this policy (the type of conservation practice adopted under the goal is not prescriptive). Land use crop cover quantification will be considered under AFW-2.

Implementation Mechanisms

- Encourage farmers to adopt voluntary best management practices (BMPs) as prescribed by the Minnesota Department of Agriculture.
- Develop GHG outcome-based indices to identify the greatest sequestration capacity by individual management field or tract.
- Fund research and development of farming practices and cropping systems that increase carbon input (e.g., reversion to native vegetation, setting agricultural land aside as grassland, improved crop rotations, yield enhancement measures, organic amendments, cover crops, improved irrigation practice) or decrease carbon output (e.g., proper tillage methods) while maintaining crop yield so that GHG emissions are reduced.
- Evaluate and implement economical agricultural practices that maintain a primary income source from crop production or that might become a primary income source from land set-asides.
- Evaluate and implement economical mechanisms that might affect crop choice (support payments, crop insurance, disaster relief) and farmland preservation (conservation easement, use value taxation, agricultural zoning) as incentives to increase carbon stock of agricultural soil.
- Document environmental co-benefits of carbon sequestration practices such as soil fertility, soil buffering capacity, pesticide immobilization, reduced energy for field operation, enhanced water infiltration, prevention of wind and water erosion, and improved fertilizer management.

TWG comments: Flexible outcome-based measures will give farmers the ability to use various management methods and practices.

Recommend a strong research and development component.

Suggestion from TWG: Management outcomes could be used with indices rather than practice-based approaches (i.e. energy consumption indices and nutrient indices related to carbon).

Related Policies/Programs in Place

Blue Earth River Basin Initiative ran a project called the Third Crop Initiative. This initiative aims to replace annual crops with perennial crops.

Type(s) of GHG Reductions

N_2O: reductions occur when nitrogen run-off and leaching are reduced, which leads to the formation and emission of N_2O.

CO_2: reductions occur as soil carbon levels in crop soils are increased above business as usual levels. Increasing the levels of carbon in soils indirectly sequesters carbon from the atmosphere.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG reduction potential in 2015, 2025 (MMtCO_2e): TBD, TBD

Net Cost per MtCO_2e: TBD

Data Sources:

1. Reference abstract: Tristram O. West and Gregg Marland. "Net Carbon Flux From Agriculture: Carbon Emissions, Carbon Sequestration, Crop Yield, and Land-Use Change," *Biogeochemistry*, 63(1), April 2003.
2. Reference: Draft Document. "The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle, Synthesis and Assessment Product 2.2," Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Edited by the Scientific Coordination Team: Anthony W. King (Lead), Lisa Dilling (Co-Lead), Gregory P. Zimmerman (Project Coordinator), David M. Fairman, Richard A. Houghton, Gregg H. Marland, Adam Z. Rose, and Thomas J. Wilbanks, March 2007.
3. Minnesota Draft Inventory and Forecast. Appendix F. Agriculture, Minnesota Pollution Control Agency and Center for Climate Strategies, July 2007.
4. Quantification of the no-till portion of this option is based upon 19,108,901 acres of harvested cropland in Minnesota[1].
5. The historical quantity of fertilizer used is consistent with the Agriculture module of the Minnesota Draft Inventory & Forecast. This forecast also provides the resulting N_2O emissions and carbon equivalent emissions. Data regarding the cost savings associated with an increase in the efficiency of fertilizer use is taken from an average of the cost of common fertilizers in the spring of 2004.

Quantification Methods:

Soil Carbon Management (No-till Cultivation)

Harvested cropland in Minnesota is estimated at 19,108,901 acres[1]. For the purposes of this analysis, conservation tillage is defined as any system that leaves 50% or more of the soil covered with residue[2].

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[1] From Conservation Technology Information Center

Based on the policy design parameters, the schedule for acres to be put into conservation tillage/no-till cultivation are shown in Table 7-1. These areas are the percentage of cropland required by the policy less the area currently implementing conservation tillage. For the first two years of the analysis (2008-2010) the mid-point sequestration rate from of the range provided by the national farmers union for the carbon credit program was used to estimate the amount of carbon to be sequestered – 0.5 MtC/acre (MN range 0.4 - 0.6)[3]. This program runs until 2010. While it is likely that the program will be extended, at this stage it is unknown. For the remainder of the policy period, the mid-point of the estimated range for carbon sequestration, 1 metric tons carbon per acre (MtC/ac), in agricultural soils was used to estimate the amount of carbon to be sequestered[4]. Based on the Naderman et al. study[5], it was further assumed that this additional carbon would be sequestered in the soil over a period of 10 years (after 10 years, the crop acres that entered the program were assumed to not store additional carbon). The resulting annual carbon accumulation rate was converted into its CO_2 equivalent yielding 0.333Mt CO2/acre-yr. To estimate carbon stored each year, the annual accumulation rate was multiplied by the number of acres in the policy program each year.

The estimated cost savings ($2.75/acre) related to the adoption of no-till farming was derived from the low end of the range provided in Economic Comparison of Three Cotton Tillage Systems in Three NC Regions by S. Walton and G. Bullen[6]. The reduction in fossil diesel fuel use from the adoption of conservation tillage methods is 3.5 gallons/acre[7]. The life cycle fossil diesel GHG emission factor 12.31 $MtCO_2e$/1,000 gallons was used[8].

Additional GHG savings from reduced fossil fuel consumption were estimated by multiplying the fossil diesel emission factor and diesel fuel reduction per acre estimate provided above. Results are shown in Table 7-1 along with a total estimated benefit from both carbon sequestration and fossil fuel reductions.

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[2] The definitions of tillage practices from Conservation Technology Information Center were used under this policy. However, only No-till/strip-till and Ridge till were considered “conservation tillage” practices. No-till means leaving the residue from last year’s crop undisturbed until planting. Strip-till means no more than a third of the row width is disturbed with a coulter, residue manager or specialized shank that creates a strip. If shanks are used, nutrients may be injected at the same time.Ridge-till. 4-6” high ridges are formed at cultivation. Planters using specialized attachments scrape off the top two inches of the ridge before placing the seed in the ground

[3] From national farmers union website. from http://www.nfu.org/issues/environment/carbon-credits

[4] Mid-point of the range provided by - Naderman, G., B.G. Brock, G.B. Reddy, C.W. Raczkowski, Long Term No-Tillage: Effects on Soil Carbon and Soil Density Within the Prime Crop Root Zone, Project Report, January 2006.

[5] G. Naderman, B.G. Brock, G.B. Reddy, and C.W. Raczkowski, “Long Term No-Tillage: Effects on Soil Carbon and Soil Density Within the Prime Crop Root Zone,” Project Report, January 2006.

[6] www.ces.ncsu.edu/depts/agecon/Cotton_Econ/production/Economic_Comparison.ppt, accessed February 2007.

[7] Reduction associated with conservation tillage compared with conventional tillage, at http://www.ctic.purdue.edu/Core4/CT/CRM/Benefits.html, accessed August 2006.

[8] Life cycle emissions factor for fossil diesel From: Hill, J., et. al., Proceedings of the National Academy of Sciences, vol. 103, no. 30, 11206-11210. from the assessment used to evaluate U.S. soybean-based biodiesel lifecycle impacts.

Table 7-1. GHG benefits for no-till cultivation

Year	Percent of total cropland in program	Acres in Program	Acres Still Accumulating Carbon	$MMtCO_2e$ Sequestered	Diesel Saved (1,000 gal)	$MMtCO_2e$ From Diesel Avoided	Total $MMtCO_2e$ Saved
2008	2%	268,470	268,470	0.492	940	0.0116	0.5038
2009	4%	536,941	536,941	0.984	1,879	0.0231	1.0075
2010	6%	805,411	805,411	1.477	2,819	0.0347	1.5113
2011	8%	1,073,881	1,073,881	0.357	3,759	0.0463	0.4035
2012	9%	1,342,351	1,342,351	0.447	4,698	0.0578	0.5044
2013	11%	1,610,822	1,610,822	0.536	5,638	0.0694	0.6052
2014	13%	1,879,292	1,879,292	0.625	6,578	0.0810	0.7061
2015	15%	2,147,762	2,147,762	0.714	7,517	0.0925	0.8070
2016	17%	2,491,722	2,491,722	0.829	8,721	0.1074	0.9362
2017	19%	2,835,683	2,835,683	0.943	9,925	0.1222	1.0654
2018	20%	3,179,643	2,911,173	0.968	11,129	0.1370	1.1054
2019	22%	3,523,603	2,986,662	0.993	12,333	0.1518	1.1453
2020	24%	3,867,563	3,062,152	1.019	13,536	0.1666	1.1852
2021	26%	4,211,523	3,137,642	1.044	14,740	0.1815	1.2252
2022	28%	4,555,484	3,213,132	1.069	15,944	0.1963	1.2651
2023	29%	4,899,444	3,288,622	1.094	17,148	0.2111	1.3050
2024	31%	5,243,404	3,364,112	1.119	18,352	0.2259	1.3450
2025	33%	5,587,364	3,439,602	1.144	19,556	0.2407	1.3849

Costs savings were estimated by multiplying the estimated savings per acre cited above ($2.75) by the number of acres in the program each year. This savings estimate takes into account budget changes for the cost of fuel, labor, chemicals, and equipment. Two studies that cited the need to provide a financial incentive to generate more widespread adoption of no-till cultivation—despite the expected cost savings of the practice—were consulted. The midpoint of the incentive needed for wheat ($4/acre)[9] and corn ($2.4/acre)[10] was multiplied by the total quantity of land entering the cultivation program each year. The resulting discounted cost-effectiveness of no-till cultivation is a cost savings of $9.74/$MtCO_2e$. The result is a net cost savings for the no-till cultivation program with a net present value of $8 million.

Costs for adoption of conservation tillage/no-till practices are estimated to be $0 based on averaging costs from two studies. The first study from North Carolina State University on applying these practices to cotton growing in NC resulted in a range of cost savings from about $3 to $14 per acre per year.[11] CCS used the low end of the range as a conservative estimate of cost savings. The second study from Iowa found that subsidy of $3 would be required to get non-

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[9] S. Brooks and R.N. Elliot. “Agricultural Energy Efficiency Infrastructure: Leveraging the 2002 Farm Bill and Steps for the Future. *American Council for an Energy Efficient Economy*. Report No. IE072. July 2007.

[10] L. Kurkavola, C. Kling, and J. Zhao. “Green Subsidies in Agriculture: Estimating the Adoption Costs of Conservation Tillage From Observed Behavior.” *Center for Agricultural and Rural Development; Iowa State University*. Working Paper 01-WP 286. April 2003.

[11] $3–$14/acre savings dependent on comparison of no-till with either strip till or conventional tillage. From “Economic Comparison of Three Cotton Tillage Systems in Three NC Regions,” S. Walton and G. Bullen, NCSU, at www.ces.ncsu.edu/depts/agecon/Cotton_Econ/production/Economic_Comparison.ppt, accessed February 2007.

adopters to switch to no-till.[12] It was further assumed that carbon credits would be available through future programs similar to the National Farmers Union Carbon Credit Program[13].

Nutrient Management

A nitrous oxide emission factor for fertilizer use was calculated by dividing the carbon equivalent emissions from fertilizer use in the Minnesota inventory and forecast by the fertilizer use for each year. Then, the CO_2e emission factors for the years 1990–2002 are averaged to provide an estimated emission factor (5.41×10^{-9} $MMtCO_2e/kg$ N), which is used to calculate the avoided GHG emissions from the proposed increase in fertilizer efficiency. The results of the calculations detailed in the preceding discussion are displayed in Table 7-2. Note that this approach does not capture the avoided life cycle GHG reductions that would occur through fertilizer efficiency programs (emissions associated with the production, transport, and energy consumption during application).

Table 7-2. Fertilizer reduction targets and avoided emissions

Year	Total BAU Fertilizer Use (short tons N)	Policy Target Efficiency Improvements	Target Fertilizer Reduction (short tons N)	Avoided GHG Emissions (MMtCO2e)
2007				
2008	661801	3%	20,055	0.12
2009	663598	6%	39,035	0.23
2010	665395	9%	57,034	0.33
2011	667192	13%	74,132	0.43
2012	668990	16%	90,404	0.53
2013	670787	19%	105,914	0.62
2014	672584	22%	120,720	0.70
2015	674381	25%	134,876	0.79
2016	676178	28%	145,842	0.85
2017	677975	30%	156,456	0.91
2018	679773	33%	166,737	0.97
2019	681570	35%	176,703	1.03
2020	683367	38%	186,373	1.09
2021	685164	40%	195,761	1.14
2022	686961	43%	204,883	1.19
2023	688758	45%	213,753	1.25
2024	690555	48%	222,382	1.30
2025	692353	50%	230,784	1.35

Historical fertilizer use for Minnesota was obtained from the USDA.[14] This was extrapolated to obtained BAU fertilizer use figures for the policy period. The target fertilizer efficiency improvements were applied to the inferred fertilizer application rate and multiplied by the

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[12] “Costs and Environmental Effects From Conservation Tillage Adoption in Iowa,” Lyubov Kurkalova, Catherine Kling, and Jinhua Zhao.

[13] Price of $2.10 per metric ton of CO2-e sourced from CCX website on November 13 2007.

[14] http://www.ers.usda.gov/Data/FertilizerUse/

number of acres to obtain the fertilizer applied under the policy. The difference between BAU fertilizer applied and fertilizer applied under the policy is the target fertilizer reduction, displayed in table 7.2.

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 the April of 2007.[15] The program costs of nutrient management 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 \$1,577/year for soil testing (assuming \$10 per 75 acre field size). Costs for 2 full-time equivalents (FTEs) of additional staff, overhead, travel, lab, and associated costs was estimated at \$250,000/year, and preparation of guidance documents was assumed to be \$75,000 in the first year.[16]

The total net cost of AFW-1 is a cost/savings of \$24/MtCO$_2$e with a net present value of \$358 million. Table 7-3 provides a summary of the data used to calculate the program discounted levelized cost-effectiveness.

Table 7-3. Fertilizer efficiency program costs and cost-effectiveness

Year	Total Savings ($MM)	Total Avoided GHG Emissions (MMtCO2e)	Cost of Programs ($MM)	Discounted cost ($MM)	D/L CE
2008	$ (8.76)	0.26	$ 2.79	$ (5.69)	
2009	$ (17.10)	0.52	$ 3.60	$ (12.25)	
2010	$ (25.07)	0.77	$ 4.48	$ (17.78)	
2011	$ (32.31)	0.84	$ 5.37	$ (22.16)	
2012	$ (39.52)	1.03	$ 6.26	$ (26.06)	
2013	$ (46.44)	1.22	$ 7.14	$ (29.32)	
2014	$ (53.08)	1.41	$ 8.03	$ (32.02)	
2015	$ (59.47)	1.59	$ 8.91	$ (34.22)	
2016	$ (64.91)	1.79	$ 10.05	$ (35.36)	
2017	$ (70.21)	1.98	$ 11.18	$ (36.24)	
2018	$ (75.19)	2.08	$ 12.32	$ (36.76)	
2019	$ (80.06)	2.18	$ 13.45	$ (37.09)	
2020	$ (84.80)	2.27	$ 14.59	$ (37.24)	
2021	$ (89.44)	2.37	$ 15.72	$ (37.23)	
2022	$ (93.98)	2.46	$ 16.86	$ (37.10)	
2023	$ (98.42)	2.55	$ 17.99	$ (36.85)	
2024	$ (102.77)	2.64	$ 19.13	$ (36.49)	
2025	$ (107.03)	2.73	$ 20.26	$ (36.05)	
Total		30.68		$ (545.91)	(17.79)

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[15] 2007 Fertilizer Use and Cost. www.ers.usda.gov/Data/FertilizerUse/Tables/Fert%20Use%20Table%207.xls

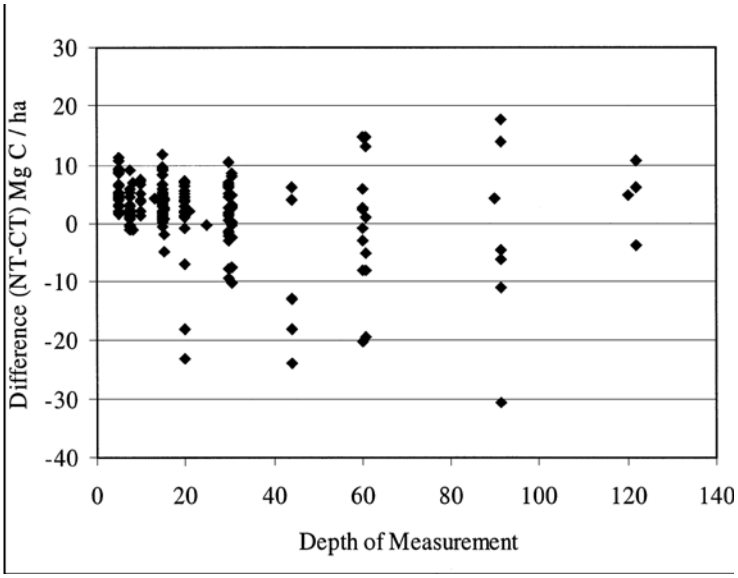
[16] Brian Hurd, NMSU Agricultural Economics, personal communication with H. Lindquist, CCS, June 2006.

Key Assumptions:

Assumed carbon sequestration potential is representative across all of the crop systems to which the policy is applied; a 10-year period for accumulating the soil carbon; no additional significant accumulation of soil carbon after 10 years; any potential increase in N_2O emissions is not large enough to significantly effect the estimated CO_2 benefits; cost savings is a representative average of savings to be achieved across all crop systems.

Key Uncertainties

There are key uncertainties surrounding the potential greenhouse benefits associated with no-till and conservation till practices compared to conventional tillage practices. The soil sequestration rates associated with land management practices, including conservation tillage, remain extremely uncertain and studies including those by Manley et al highlight this uncertainty. The chart below, taken from Manley et al[17]. Manley suggests that it is difficult to determine the level of carbon (if any) being sequestered and that further research is required to clarify this issue.



An additional uncertainty surrounds the current uptake of conservation tillage within Minnesota. While states elsewhere in the United States have been adopting no-till, the trend in Minnesota has been away from no-till practices. This raises questions on the potential of increasing the uptake of conservation tillage practices, as required by this policy.

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

TWG Suggestion: IPCC prioritizes N_2O management as high, with important water quality benefits.

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[17] Manley etal, Creating Carbon Offsets In Agriculture Through No-Till Cultivation: a Meta-Analysis Of Costs and Carbon Benefits. Climatic Change 2004.

Feasibility Issues

1. If changes in management result in decreased crop yields, the net carbon flux can be greater under the new system, assuming that crop demand remains the same and additional lands are brought into production. Conversely, if increasing crop yields lead to land abandonment, the overall carbon savings from changes in management will be greater than when soil carbon sequestration alone is considered.
2. Options to increase carbon can be implemented in the short-term, but the amount of carbon sequestered typically is low initially then rising for a number of years before tapering off again as the total potential is achieved. There is also a significant risk that the carbon sequestered may be released again by natural phenomena or human activities.

   Practices for conserving carbon affect emissions of other GHGs. Of particular importance is the interaction of carbon sequestration with N_2O emission because N_2O is such a potent GHG. In some environs, carbon-sequestration practices, such as reduced tillage, can stimulate N_2O emissions thereby offsetting part of the benefit. Elsewhere, carbon-conserving practices may suppress N_2O emissions, amplifying the net benefit. Similarly, carbon-sequestration practices might affect emissions of CH_4 if the practice, such as increased use of forages in rotations, leads to higher livestock numbers. Policies designed to suppress emission of one GHG need to also consider complex interactions to ensure that net emissions of total GHGs are reduced.

Status of Group Approval

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

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]

AFW-2. Land Use Management Approaches for Protection and Enrichment of Soil Carbon

Policy Description

Convert marginal or sensitive agricultural land with an immediate history of use for annual crop production to permanent cover such as grassland/rangeland, orchard, or forest on land that was formerly forested, where the soil carbon and/or carbon in biomass is substantially higher under the new land use. Includes opportunities to keep CRP, CREP and RIM lands in well-managed, continual cover, while also providing opportunities for working lands to increase carbon sequestration through biomass production that can provide feedstocks for in-state bioenergy production.

Incentives need to be created to convert annual row crop acres to perennial crops that prevent these acres from either returning to conventionally tilled production or to suburban/urban development. Incentives also need to be created for promoting carbon sequestration goals on public lands and lands enrolled in existing conservation programs. Finally, research should be conducted and programs adopted to identify and eliminate threats to the vast carbon pools currently stored in lands that hold high levels of soil organic carbon, such as peatlands and wetlands.

Finally, research and increased management of the vast carbon pools stored in wetlands and peatlands is critical. A high percentage of all carbon stored in Minnesota is in wetlands and peatlands. Efforts are needed to protect these carbon reservoirs from the impacts of warmer and drier conditions and increased fire risk. Efforts should include identification of wetlands and peatlands at risk of re-emitting sequestered carbon dioxide and methane. Additional study is needed to understand GHG dynamics in the full range of wetland types in Minnesota and to apply this understanding to the state’s wetlands conservation policies.

Policy Design

Goals:

Natural Coverage Protection—Protect 10% by 2015 and 30% by 2025 of lands in natural cover and/or existing conservation programs that would have been converted to intensive agricultural production or urban/suburban development.

Perennial Production on Working Lands—By 2025, expand the Reinvest in Minnesota–Clean Energy (RIM-CE) program land to 200,000 acres.

Protection of Peatlands & Wetlands—Protect or restore northern peatlands and other wetlands to prevent releases of GHGs and fire and to allow existing peatlands to continue to sequester carbon. The TWG is not comfortable presenting numeric goals at this time. Please see alternative goals under “Protection of Peatlands & Wetlands” below.

Timing:

Natural Coverage Protection—Protect 10% by 2015 and 30% by 2025 of lands in natural cover and/or existing conservation programs that would have been converted to intensive agricultural production by 2015. Achieve the full goal by 2025. The goal could be met in whole or in part by:

increasing the amount of privately held high carbon value lands in land protection programs by 10% by 2015, and by 25% by 2025; and making carbon sequestration an additional management priority for 25% of publicly held and managed lands in Minnesota by 2025.

Perennial Production on Working Lands—By 2015, 20,000 acres of land should be established and/or producing low-carbon perennial energy crops in Minnesota. Achieve the full goal by 2025.

Protection of Peatlands & Wetlands—By 2015, identify peatlands at risk of releasing GHGs because of lowered water tables, fire potential, or industrial uses (horticulture, sod-farming, or mining). By 2015, initiate research program on fire potential and management in peatlands. By 2015, develop carbon management standards for wetlands and peatlands. By 2025, raise water table elevations as high as practicable on degraded peatlands and/or plant with appropriate forest species.

Parties Involved: Board of Soil and Water Resources, Department of Natural Resources, University researchers, Rural Advantage, AURI, Minnesota Waterfowl Association, Delta Waterfowl, Ducks Unlimited, Izaak Walton League of America, Institute for Agriculture and Trade Policy, Land Stewardship Project, Minnesota Project, Farmers Union.

Other:

Agricultural Land Protection—This policy would create a program to provide additional tax incentives for landowners donating development rights as part of an easement transaction for the carbon storage value of their land. These programs need to be assessed for their carbon sequestration benefit. Management strategies need to assure that the original goals and public values (water quality, soil conservation, and wildlife habitat) are not diminished as carbon sequestration goals are met.

This option can assist with the promotion of the goals of AFW-3 and AFW-4, by providing some incidental biomass for bioenergy and biofuel production, but these lands should not be viewed as primary biomass sources. Federal and state managed and contracted lands (including federal wildlife refuges, DNR wildlife management areas, state forest lands, national and state park areas, BLM lands, national forests and grasslands, and CRP, CREP, and RIM acres) are managed for a variety of purposes and under many state and federal laws, and in many instances these purposes could include carbon sequestration. Most public lands, and all CRP, CREP, and RIM lands, are managed at least in part to preserve the public's interest in their non-commodity values, mainly water quality improvement, soil conservation, and wildlife habitat.

At present, the carbon storage value of lands protected is an uncompensated additional benefit that comes with the open space and wildlife habitat protection values of protecting lands. Moreover, there are clear examples of public lands being managed in ways that are counterproductive or simply squander natural carbon sequestration and detention potentials of the land. Additional incentives that monetize stored carbon and changes in carbon storage on the land, over and above existing compensation for retiring development and production rights, would increase acreage of high carbon value lands that are managed for carbon sequestration, and compensate landowners for the additional societal benefit of avoided carbon emissions.

Perennial Production on Working Lands—While protection of existing perennial production on conservation and public lands is necessary, the vast majority of agricultural land is currently used intensively to produce annual crops that have minimal ability to sequester carbon over the long term. Programs to encourage production of perennial crops on acres currently in agricultural production must be funded and expanded quickly.

The RIM-CE program should be fully funded in 2008. This program is a working lands program for bioenergy production that was established in the 2007 Minnesota legislative session. It provides long-terms easements and training to farmers who want to begin growing next generation energy crops, such as diverse native prairie or monocultures of native species such as switchgrass, for sale to facilities needing the crops for heat, power and transportation fuel production. Tiered payments are made based on increased levels of public benefits, specifically carbon sequestration in the deep root systems of diverse native perennial grassland plantings, improvements to water quality, and improved wildlife habitat. After a short lead time for establishment of the crops, we will begin reaping the benefits as each acre sequesters carbon below ground while producing harvestable biomass fuels above ground. This will jumpstart the production of energy crops in the state, providing some of the feedstocks to meet the goals outlined in AFW-3 and AFW-4.

Protection of Peatlands & Wetlands—Wetlands have among the highest potential carbon sequestration capacities for any type of land use in Minnesota. Peatlands are likely Minnesota's largest single carbon sink containing 37% of all carbon stored in the state compared to 3% stored in the state's forests. Protecting these enormous carbon reservoirs from the impacts of warmer and drier conditions and increased fire risk is critical. Early attention should be given to identifying degraded peatlands at risk of re-emitting sequestered carbon dioxide and methane. Additional study is needed to understand GHG dynamics in the full range of wetland types in Minnesota and management options to reduce the risk of catastrophic releases of stored GHGs from these systems.

Policies need to be designed that ensure protection of peatland and wetlands from drainage and other carbon-releasing land uses. Additional research must be done to evaluate their contribution to carbon sequestration and long-term storage. In particular, policies should

- Identify areas where significant peatland carbon stocks are in danger of being oxidized by drainage infrastructure. Evaluate and conduct hydrologic or vegetation management, including afforestation with appropriate forest species.
- Evaluate GHG impacts of horticulture, sod farming, and energy production on peatlands and develop standards to protect carbon stocks.
- Protect carbon stocks in freshwater mineral wetlands. Support development of scientific understanding and management options for GHGs associated with mineral wetlands.
- Initiate serious research program of the fire potential and management in peatlands.

Implementation Mechanisms

Protection of Peatlands & Wetlands

- Identify peatlands that are in danger ceasing their present carbon sequestration or releasing their stored carbon.
- Expand existing databases to provide baselines for future evaluations of carbon sequestration or carbon release by Minnesota peatlands.
- Fund restoration of water tables and flows necessary to restore degraded peatlands and preserve existing ones.

- Support research aimed at the past, present, and future of carbon sequestration in Minnesota peatlands.
- Maintain or expand funding for existing or past peatland management programs within state agencies.
- Educate landowners about the role of peatlands in reducing carbon in the air.
- Encourage peatland owners to adopt voluntary best management practices for maintaining peatlands. This includes, for example, protecting peatlands from exogenous nutrients from nearby fertilized fields.

Related Policies/Programs in Place

Minnesota has invested significantly in preservation and restoration of significant conservation lands -including forests, prairies, and wetlands. The Minnesota DNR owns and manages more than 1.1 million acres of public conservation lands in addition to the state forestland. In addition, the State of Minnesota holds long term conservation easements on nearly 200,000 acres of privately owned lands. Restoration and management strategies for these lands focus on restoring diverse native plant communities, which are shown to be very productive in the sequestration of carbon.

In 1991, Minnesota established one of the most sweeping wetlands protection laws in the country: the Wetland Conservation act. With a goal of no-net-loss of wetlands, the Wetland Conservation Act requires anyone proposing to drain, fill, or excavate a wetland first try to avoid disturbing the wetland; second, to try to minimize any impact on the wetland; and, finally, to replace any lost wetland acres, functions, and values.

Type(s) of GHG Reductions

CO_2: Conservation of agricultural lands retains the ability of the land to sequester carbon in soil and biomass. Also, emissions are indirectly reduced to the extent that development patterns are influenced and vehicle miles traveled (VMT) are reduced (see TLU Options).

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2015, 2025 (MMtCO$_2$e): TBD, TBD

Net Cost per MtCO$_2$e: TBD

Data Sources:

Natural Resources Conservation Service data on CRP acres expiring during the policy period, NRI data on agricultural/range/forest land lost to urban development and data on above and below ground soil carbon levels from USDA study.

Quantification Methods:

Natural Coverage Protection GHG Benefits

The amount of lands in natural cover and/or existing conservation programs which is potentially available for conversion was obtained from NRI data[18] and USDA FSA data on active and

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[18] The most recent NRI data available is for the period 1982 to 1997.

expiring CRP cropland acres[19]. Over the NRI data period the average loss of land to developed use was estimated at 3,400 acres/year. These conversion estimates are multiplied by the targets (10% by 2015 and 30% by 2025) to yield the averted conversion in the target years. Land enrolled in the CRP has remained relatively constant over the last decade. However, there are expectations that the re-enrollment rate will begin to decrease as the price of agriculture crops (e.g. corn) increase, making other (non-CRP) land uses more attractive. While the amount of land coming off the CRP program is easily identifiable, the extent to which these contracts will be re-enrolled or extended is unknown. A flat re-enrollment rate of 84% was assumed based on historical re-enrollment and extension offers. The lands not re-enrolled into the CRP program are assumed to enter intensive agriculture. The carbon value of grasslands that is lost due to conversion is 0.023 MMtC/1,000 acres and for land moving from CRP to cropland 2.2 MtCO2-e per acre[20]. The cost of easements is assumed to be $2,500 /acre[21]. The benefits and costs for agricultural land conversion are presented in Table 7.4.

Table 7-4. Benefits and costs for agricultural land conversion

Year	Acres Saved from developed use	Acres saved from Agriculture	MMtCO2e Saved (from developed)	MMtCO2e Saved (from Agriculture)	Costs	Discounted Costs
2008	424	552	0.018	0.001	$ 1,093,006	$1,040,958
2009	794	1,036	0.033	0.002	$ 2,049,385	$1,858,853
2010	1,165	1,588	0.049	0.003	$ 3,010,021	$2,600,170
2011	1,535	2,141	0.064	0.005	$ 3,970,657	$3,266,669
2012	1,906	2,693	0.080	0.006	$ 4,931,293	$3,863,797
2013	2,277	3,246	0.095	0.007	$ 5,891,929	$4,396,648
2014	2,647	3,798	0.111	0.008	$ 6,852,564	$4,869,990
2015	3,389	4,420	0.142	0.010	$ 8,744,045	$5,918,314
2016	4,066	5,304	0.170	0.012	$ 10,492,854	$6,763,787
2017	4,744	6,187	0.199	0.014	$ 12,241,662	$7,515,319
2018	5,422	7,071	0.227	0.016	$ 13,990,471	$8,179,939
2019	6,100	7,955	0.255	0.018	$ 15,739,280	$8,764,220
2020	6,777	8,839	0.284	0.019	$ 17,488,089	$9,274,307
2021	7,455	9,723	0.312	0.021	$ 19,236,898	$9,715,941
2022	8,133	10,607	0.340	0.023	$ 20,985,707	$10,094,484
2023	8,811	11,491	0.369	0.025	$ 22,734,516	$10,414,944
2024	9,488	12,375	0.397	0.027	$ 24,483,325	$10,681,994
2025	10,166	13,259	0.426	0.029	$ 26,232,134	$10,899,993

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[19] http://content.fsa.usda.gov/crpstorpt/rmepegg/MEPEGGR1.HTM

[20] USDA study, shows change of about -3 tons/acre over 10 years for land under crop production and +3 tons/acre over 10 years for CRP. Assuming that these are additive (loss of continued sequestration potential in CRP acres, plus losses occurring from cultivated lands, yields 3 tons C/acre + 3 tons C/acre over 10 years. Annual average loss from conservation to cultivation would be 0.6 Mt/yr (2.2 MtCO2/yr). http://www.fapri.missouri.edu/outreach/publications/2007/FAPRI_UMC_Report_01_07.pdf. Figure

[21] Based on NRCS 2003 fact sheets. Range of Farmland Protection Program costs for easements, range $1,943/acre in Wisconsin and $3,630 in Michigan; Farmland Protection Program, NRCS Fact Sheets; www.nrcs.usda.gov/programs/frpp

			3.571	0.247		**$120,120,325**

Studies are lacking on the changes in below and above-ground carbon stocks when agricultural land is converted to developed uses. For some land use changes, carbon stocks could be higher in the developed use relative to the agricultural use (e.g., parks). In other instances, carbon stocks are likely to be lower (graded and paved surfaces). CCS assumed that the agricultural land would be developed into typical tract-style suburban development with no soil sequestration benefits. CCS assumed no change in the levels of aboveground carbon stocks.

Natural Coverage Protection Costs

To estimate program costs in each year, CCS used multiplied the estimated agricultural acres protected from development by the conservation cost ($2,500 /acre). The resulting cost-effectiveness is $31.46/MtCO$_2$e. 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.

RIM-CE expansion GHG benefits

The GHG benefits of expanding RIM-CE program were quantified by assuming a constant rate of carbon accumulation of 1 tCO2-e/acre per year[22]. Based on the CCX guidelines and the Naderman et al. study[23], it was further assumed that this additional carbon would be sequestered in the soil over a period of 10 years (after 10 years, the crop acres that entered the program were assumed to not store additional carbon). The sequestration rate was applied to acres in the program as indicated in Table 7-5

Table 7-5. Benefits and costs of expanding the RIM-CE program

Year	Additional acres in Program	MMtCO2e Sequestered	Costs	Savings (revenue generated through carbon credits)	net cost	Discounted Cost
2008	10,000	0.010	$ 23,000,000	$ (21,000)	$ 22,979,000	$ 21,884,762
2009	20,000	0.020	$ 46,000,000	$ (42,000)	$ 45,958,000	$ 41,685,261
2010	30,000	0.030	$ 69,000,000	$ (63,000)	$ 68,937,000	$ 59,550,373
2011	40,000	0.040	$ 92,000,000	$ (84,000)	$ 91,916,000	$ 75,619,521
2012	50,000	0.050	$ 115,000,000	$ (105,000)	$114,895,000	$ 90,023,239
2013	60,000	0.060	$ 138,000,000	$ (126,000)	$137,874,000	$ 102,883,702

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[22]. Taken from CCX agricultural grass soil carbon sequestration offset project guidelines. MN is in zone A.

[23] G. Naderman, B.G. Brock, G.B. Reddy, and C.W. Raczkowski, “Long Term No-Tillage: Effects on Soil Carbon and Soil Density Within the Prime Crop Root Zone,” Project Report, January 2006.

2014	70,000	0.070	$ 161,000,000	$ (147,000)	$160,853,000	$ 114,315,224
2015	80,000	0.080	$ 184,000,000	$ (168,000)	$183,832,000	$ 124,424,734
2016	90,000	0.090	$ 207,000,000	$ (189,000)	$206,811,000	$ 133,312,215
2017	100,000	0.100	$ 230,000,000	$ (210,000)	$229,790,000	$ 141,071,127
2018	110,000	0.110	$ 253,000,000	$ (231,000)	$252,769,000	$ 147,788,799
2019	120,000	0.120	$ 276,000,000	$ (252,000)	$275,748,000	$ 153,546,804
2020	130,000	0.130	$ 299,000,000	$ (273,000)	$298,727,000	$ 158,421,306
2021	140,000	0.140	$ 322,000,000	$ (294,000)	$321,706,000	$ 162,483,391
2022	150,000	0.150	$ 345,000,000	$ (315,000)	$344,685,000	$ 165,799,378
2023	160,000	0.160	$ 368,000,000	$ (336,000)	$367,664,000	$ 168,431,115
2024	170,000	0.170	$ 391,000,000	$ (357,000)	$390,643,000	$ 170,436,247
2025	180,000	0.180	$ 414,000,000	$ (378,000)	$413,622,000	$ 171,868,484
	Cumulative	1.710		$ (3,591,000)		$2,203,545,680

RIM-CE expansion costs

The cost of the program was assumed to be constant over the period at $2,300 per acre[24]. It was assumed that carbon credits would be generated through the Chicago Climate Exchange, or similar future program ($2.10/tCO2)[25]. Costs for each year are indicated in table 7-5.

Key Assumptions:

No change in above-ground carbon stocks. No appreciable carbon sequestration occurs post-development.

While the amount of land coming off the CRP program is easily identifiable, it is unknown the extent to which these contracts will be re-enrolled or extended. A flat re-enrollment rate of 84% was assumed based on historical re-enrollment and extension offers. However, there are expectations that the re-enrollment rate will begin to decrease as the price of agriculture crops (e.g. corn) increase, making other (non-CRP) land uses more attractive.

Key Uncertainties

The soil sequestration rates associated with land management practices, remain extremely uncertain and studies including those by Manley et al highlight this uncertainty[26].

The RIM-CE program is in a very early stage of development. The program was authorized by the legislature last year but design details along with funding are currently being developed.

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[24] Based on the funding request of $46 million for 20,000 acres.

[25] Assume that carbon credits can be obtained through future programs. Price sourced from CCX website on November 13 2007.

[26] Manley etal, Creating Carbon Offsets In Agriculture Through No-Till Cultivation: a Meta-Analysis Of Costs and Carbon Benefits. Climatic Change 2004.

Currently $46 million in funding is being considered by the Governors office. It is anticipated that funding decisions and design details will be finalized by early next year.

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 MCCAG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]

AFW-3. In-State Liquid Biofuels Production

Policy Description

Promote sustainable in-state production and consumption of transportation biofuels from agriculture and/or agroforestry feedstocks to displace the use of gasoline and diesel. 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. Sustainability standards also need to be developed for low-carbon biofuels, so that producers are rewarded accordingly.

Promote the in-state development of feedstocks, such as cellulosic material and perennials that are able to be utilized. Realize that conversion technologies, such as thermo-chemical Fischer-Tropsch processes and enzymatic conversion, are developing fast in this sector, so facilitate their development but not be prescriptive.

Promote multiple biofuel (ethanol, biodiesel, biobutanol) production systems that improve the embedded energy content, life cycle, and carbon profile of biofuels. Focus on plant material feedstocks that favor energy production and are carbon neutral or negative and have multiple other positive environmental benefits, such as maintaining carbon sequestration potential and soil productivity, and decreasing water and fossil fuel inputs in their production.

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, Minnesota consumption of biofuels produced in-state will produce better GHG benefits than these same fuels obtained from a national market due to lower embedded CO_2 (due to out of state fuels produced using feedstocks/production methods with lower GHG benefits; and transportation of biodiesel, ethanol, other fuels, or their feedstocks from distant sources).

Note: This option is linked with TLU-3 on Biofuels and the ES-2 on a Low Carbon Fuels Standard. This option seeks to achieve incremental GHG benefits beyond the TLU option by promoting in-state production of biofuels using feedstocks with greater GHG benefits than the likely business as usual national production methods..

Policy Design

Goals:

Lower the carbon footprint of ethanol produced from existing plants—By 2015, 80% of the thermal heat used in ethanol facilities will be produced from biomass or other renewable energy; by 2017, 80% the electrical power consumed by ethanol facilities will produced from biomass or other renewable energy. The goal of this policy design is to decrease the use of fossil fuel in the existing production of Minnesota biofuels by using low-GHG life cycle biomass for the heat and power inputs into biofuel production facilities. A technology that could achieve this goal is biomass gasification, which is currently available.

Gasoline displacement goals—By 2025, achieve in-state production volume equivalent to offsetting gasoline consumption in the state by 50% of the gasoline consumed in the state (ie replace gasoline with biofuels using GHG superior feedstocks and conversion processes).*

Fossil diesel displacement goals—Increase in-state biodiesel production to offset 10% of fossil diesel consumption by 2025 (i.e. the fossil diesel consumed in the state will by replaced by biodiesel produced using feedstocks and conversion processes that are superior to today's conventional sources).

Timing:

Lower the carbon footprint of ethanol produced from existing plants—See above.

Gasoline displacement goals—Incremental increases, up to achieving the full goal by 2025.

Fossil diesel displacement goals—Incremental increases, up to achieving the full goal by 2025.

Parties Involved: Ethanol facilities, Department of Commerce, Department of Agriculture, Next Generation Energy Board, sustainable agriculture groups, conservation and renewable energy nonprofits, those currently developing standards (e.g., Forest Resource Council, Board of Water and Soil Resources), engineering firms, forest products industry, agriculture production groups.

Other: Current State policy for fossil diesel displacement is 2% biodiesel blend. For gasoline displacement, current policy is 20% ethanol displacement by 2013; with a carve-out goal for 5% derived from cellulosic material. Current petroleum displacement goal is 20% of the liquid fuel sold in the State will come from renewable sources by the year 2015 and 25% by 2025. This new policy would need to be coupled with strong reductions in fossil gasoline/diesel consumption demand out to 2025 and high biofuels content (i.e. E85) vehicle/infrastructure.

Money related to capital conversion for certain near-term technologies, such as gasifiers, may need to be allotted. A certification process to acknowledge that Minnesota-produced biofuels have lower carbon footprints (i.e. for future Minnesota, California and potentially national LCFS markets) is needed. Incentives for planting crops that have a low carbon profile that can be used as boiler fuel should be enacted (i.e. RIM-CE program).

Note the linkage to the TLU option for establishing a low carbon fuel standard (LCFS) that will stimulate the biofuels production envisioned by this option, as well as innovation and investment in biofuel production technologies. Promote efficiency and low carbon feedstocks/fuel inputs in biofuels production facilities, and increase demand for biofuels blending in transportation fuel production processes. Within AFW or TLU, policies should address labeling and certification to verify low and zero-carbon biofuel players should be implemented, which will allow for a sound low-carbon fuels market to be developed locally and nationally. Any Minnesota based fuel standard/certification process should be able to easily integrate into the emerging California, federal (EPA) and European LCFS as well as any tax or cap regimes established for Minnesota and the Upper Midwest.

Note the linkage to AFW-2 on funding the Reinvest in Minnesota–Clean Energy (RIM-CE) program (200,000 acres growing low-carbon energy crops by 2025). This program is a working lands program for bioenergy production that was established in the 2007 legislature. It provides long-term easements and training to farmers who want to begin growing next generation energy crops such as switchgrass and other diverse prairie grasses for sale to facilities needing the crops for heat and power (gasifiers). Tiered payments are made based on increased levels of public benefits such as carbon storage in the roots, improvements to water quality/use and wildlife habitat. We need to begin getting these energy crops in the ground and farmers trained on how to grow them, especially since there is a lead time for establishment of the crops. Getting started on that now will set the stage for utilizing the energy crops for biofuels in the coming years as well as link to goals outlined in AFW-1 and AFW-2.

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

TWG Suggestion: *A low-carbon index or biofuels production should be incorporated, along with feedstock sustainability standards.* By 2015, a life cycle certification/labeling process for low-carbon fuels should be implemented (either through Minnesota-specific or adoption of regional/national standards) that credits biofuels for varying reductions in their carbon intensity, ranging from 25-100%.

Related Policies/Programs in Place

Ethanol: Minnesota established an ethanol production incentive to provide payment to producers to help develop a new market for Minnesota's agricultural products. On the market side, Minnesota requires that all gasoline sold in the state be blended with a 20% ethanol mix by 2013. Of this, there is a state goal that a quarter of the RFS will come from cellulosic derived biofuel by 2015, or when 60,000,000 gallons comes online, whichever is first. In addition, Minnesota began efforts in 1997 to develop a network of fueling stations for flex fuel vehicles that could run on an 85% ethanol blend.

Biodiesel: According the U.S. Department of Energy (US DOE), biodiesel has the most favorable energy balance of any currently commercially viable transportation fuel. For every unit of energy needed to produce a gallon of biodiesel, 3.2 units of energy are gained. As of September 29, 2005, Minnesota requires nearly all diesel fuel sold in the state to contain at least a 2% biodiesel blend.

Petroleum Replacement Goal: There exists a state goal that 20% of the liquid fuel sold in the state will come from renewable sources by the year 2015, and 25% will by 2025. There are many grants available for bioenergy facilities, through the Department of Commerce and the Department of Agriculture.

RIM-Clean Energy: a reinvest in Minnesota program within the Board of Soil and Water Resources. RIM-CE is a working lands program that allows for growing and harvesting of bioenergy crops with added payments for increased conservation, water quality benefits. The program still needs funds for granting easements for bioenergy crops.

Type(s) of GHG Reductions

CO_2: Life cycle 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).

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2015, 2025 (MMtCO_2e): 6.8, 17

Net Cost per MtCO_2e: -1

Data Sources: These are cited within the quantification methods section below.

Quantification Methods:

GHG reductions from lowering the carbon footprint of ethanol produced from existing plants

80% of energy (both thermal and electricity) consumed by ethanol facilities should come from biomass or other renewable sources. 80% thermal by 2015 and 80% of electricity by 2017.

Energy use in typical ethanol plant type were taken from from Wang et al[27]. This paper estimated the energy intensity of existing ethanol production per gallon of ethanol produced using the GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model developed at Argonne National Laboratory. It was assumed that the BAU ethanol plant utilized natural gas as a heat input and grid-sourced electricity. The energy required to produce one gallon of ethanol is indicated in Table 7-6 below.

Table 7-6. BAU Ethanol Plant Energy Use per Gallon of Ethanol[27]

Ethanol plant type	Natural gas (Btu)	Coal (Btu)	Renewable process fuel (Btu)	Electricity (kW h)
Existing Plant with NG	33330	None	None	0.75

Full production from existing ethanol plants is assumed. Currently, there are 16 ethanol plants in Minnesota with an annual production capacity of approximately 620 million gallons[28]. That is approximately 13 percent of the total U.S. output. As of August 2007, there were five Minnesota facilities under construction with an operational capacity of more than 450 million gallons per year. Once construction of these facilities is complete, Minnesota's total ethanol production capacity will be over one billion gallons of ethanol per year. From 2010, an the ethanol production capacity is assumed to grow at 3% per year. The emissions from an ethanol facility using conventional sources for heat and electricity was calculated by multiplying the energy input (both natural gas and electricity) by their respective emission factors. The emission factor for natural gas was assumed to be 0.0539 tCO2-e/mbtu[29] and 0.720 tCO2-e/MWh[30].

The GHG emissions from ethanol plants incorporating renewable energy were calculated with similar methodology but the fossil based energy inputs were reduced by the policy design requirements. The emissions from the renewable energy inputs were assumed to be zero. The emissions associated with the production of ethanol from BAU and Policy plants are indicated in table 7-7 below.

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[27] Michael Wang, MayWu and Hong Huo, *Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types*, Center for Transportation Research, Argonne National Laboratory, (2007).

[28] From Planning and Constructing an ethanol plant (http://www.pca.state.mn.us/publications/ethanol-guidancedoc.pdf)

[29] Taken from Minnesota I&F Energy Supply projections.

[30] Minnesota State annual CO2 output emission rate from eGRID

Table 7-7. GHG Benefits of Sourcing Renewable Energy for Ethanol Production

Year	BAU Production Gallons of ethanol (1000 gallons)	Renewable energy input goal	Renewable Electricity Goal	BAU emissions Million Mt CO2-e	Emissions under the new policy	GHG emissions saved (MMtCO2-e)
2008	620,000.0	10%	8%	1.449	1.310	0.138
2009	1,000,000.0	20%	16%	2.336	1.891	0.446
2010	1,030,000.0	30%	24%	2.406	1.718	0.689
2011	1,060,900.0	40%	32%	2.479	1.533	0.946
2012	1,092,727.0	50%	40%	2.553	1.335	1.217
2013	1,125,508.8	60%	48%	2.630	1.125	1.505
2014	1,159,274.1	70%	56%	2.708	0.900	1.808
2015	1,194,052.3	80%	64%	2.790	0.661	2.129
2016	1,229,873.9	80%	72%	2.873	0.628	2.246
2017	1,266,770.1	80%	80%	2.960	0.592	2.368
2018	1,304,773.2	80%	80%	3.048	0.610	2.439
2019	1,343,916.4	80%	80%	3.140	0.628	2.512
2020	1,384,233.9	80%	80%	3.234	0.647	2.587
2021	1,425,760.9	80%	80%	3.331	0.666	2.665
2022	1,468,533.7	80%	80%	3.431	0.686	2.745
2023	1,512,589.7	80%	80%	3.534	0.707	2.827
2024	1,557,967.4	80%	80%	3.640	0.728	2.912
2025	1,604,706.4	80%	80%	3.749	0.750	2.999
					cumulative	35.176

It should be noted that this policy may overlap with AFW-3 particularly in relation to the available supply of biomass both as a source of energy and as a feedstock in the production process.

Cost of lowering the carbon footprint of ethanol produced from existing plants

The cost of this policy was estimated using a similar methodology to the quantification of GHG benefits. The energy input required was multiplied by the cost of energy for each of the energy inputs. The cost of each energy input is in table 7-8 and is based on EIA DOE (AEO2007) using the National Energy Modeling System, a computer-based model which produces annual projections of energy markets for 2005 to 2030. Renewable electricity was assumed to cost 15% above conventional electricity in the period 2008-2015 (5% 2015-2020 and equal from 2020). The renewable energy component is assumed to be a combination of biomass and other non-biomass energy and is assumed to decline at a 3% rate due to technological advances in the non-biomass technology system.

Table 7-8. Cost of Energy Inputs

Year	Natural Gas ($/Mbtu)	Coal ($/Mbtu)	Renewable (Biomass) $/Mbtu	Renewable energy input (Price declining at 3% pa)	Electricity - Industry prices (cents per KWh)	Renewable electricity (cents per KWh)
2008	6.23	1.63	1.76	4.88	5.94	6.83
2009	5.66	1.59	1.89	4.74	5.91	6.80
2010	5.35	1.77	1.92	4.60	5.68	6.54
2011	4.93	1.93	1.87	4.47	5.36	6.16
2012	4.77	1.90	1.89	4.34	5.13	5.90
2013	4.58	1.97	1.86	4.21	5.03	5.79
2014	4.61	1.83	1.87	4.09	4.97	5.72
2015	4.55	1.84	1.95	3.97	4.96	5.71
2016	4.68	1.81	1.93	3.85	5.01	5.26
2017	4.86	1.80	2.04	3.74	5.10	5.35
2018	4.83	1.73	2.06	3.63	5.13	5.39
2019	4.82	1.67	2.02	3.53	5.15	5.40
2020	4.94	1.75	1.98	3.42	5.19	5.45
2021	4.91	1.69	1.96	3.32	5.24	5.24
2022	5.06	1.62	2.03	3.23	5.32	5.32
2023	5.20	1.58	2.09	3.13	5.46	5.46
2024	5.30	1.61	2.11	3.04	5.55	5.55
2025	5.26	1.62	2.13	2.95	5.51	5.51

The costs associated with the BAU and Policy plants are indicated in Table 7-9

Table 7-9. BAU and Policy Costs

Year	BAU costs	Costs Under the policy	Cost/savings	Discounted Cost ($MM)
2008	$156,319,572.26	$154,715,067.45	-$1,604,504.81	-$1.53
2009	$232,927,645.03	$230,583,825.05	-$2,343,819.97	-$2.23
2010	$227,422,496.21	$225,360,872.21	-$2,061,624.00	-$1.96
2011	$216,843,283.07	$217,603,703.42	$760,420.35	$0.72
2012	$215,846,069.83	$216,863,284.62	$1,017,214.79	$0.97
2013	$214,211,983.03	$216,786,372.65	$2,574,389.62	$2.45
2014	$221,266,497.04	$220,091,608.78	-$1,174,888.26	-$1.12
2015	$225,706,308.36	$222,199,718.42	-$3,506,589.94	-$3.34
2016	$238,006,115.74	$224,223,730.45	-$13,782,385.29	-$13.12
2017	$253,771,288.09	$231,344,355.57	-$22,426,932.52	-$21.35
2018	$260,237,317.48	$234,641,229.96	-$25,596,087.52	-$24.37
2019	$267,709,274.55	$237,960,093.45	-$29,749,181.10	-$28.32

2020	$281,635,067.10	$243,056,531.27	-$38,578,535.83	-$36.73
2021	$289,446,663.79	$243,955,942.97	-$45,490,720.82	-$43.31
2022	$306,439,087.77	$250,158,361.65	-$56,280,726.12	-$53.58
2023	$323,870,390.26	$257,171,748.21	-$66,698,642.04	-$63.50
2024	$340,009,487.11	$263,555,088.57	-$76,454,398.54	-$72.78
2025	$347,797,475.68	$266,666,166.31	-$81,131,309.37	-$77.23
				-$440

Note that the economical and technical feasibility of using renewable energy as a replacement to conventional energy was not considered as a part of this analysis.

GHG reductions through gasoline and fossil diesel displacement with superior feedstocks and processes.

A study on life cycle GHG benefits for biodiesel production and use was used to estimate the CO_2e reductions for this option (Hill et al., 2006).[31] 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 CO_2e reductions (via displacement of fossil diesel with soybean-derived biodiesel) were estimated by Hill et al. to be 41%.

For this option, the additional incremental benefit of in-state production is derived from the lower embedded GHG footprint of biodiesel feedstocks (vegetable oil) avoided from having to transport the feedstocks from their likely source region. While Minnesota has a significant in-state domestic soybean industry, for this assessment the potential alternative source regions for soybean or canola oil are the U.S. mid-west or northern plains regions with rail transport shipments to central Minnesota estimated at about 350 miles.[32] Rail fuel consumption is about 400 ton-miles/gallon.[33] The density of vegetable oil is about 3,700 tons/MMgal. From these inputs, a GHG emission rate of 33 $MtCO_2$/MMgal oil was calculated.

When combined with the other feedstocks needed to produce biodiesel (e.g., either methanol or ethanol),[34] a gallon of vegetable oil will produce slightly more than one gallon of biodiesel. For the purposes of this estimate, each gallon is assumed to produce one gallon of biodiesel.

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[31] 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.

[32] U.S. National Atlas at http://nationalatlas.gov/natlas/Natlasstart.asp

[33] U.S. National Atlas at http://nationalatlas.gov/articles/transportation/a_freightrr.html

[34] While the analysis here focuses on the primary feedstock for biodiesel, vegetable oil, the policy should also promote the production and use of alcohol feedstocks produced from renewable resources (e.g., starch or cellulosic ethanol, renewable methane to methanol).

For oil sources other than soybean oil, the benefit for substituting in-state biodiesel for fossil diesel is estimated starting with the life cycle soybean emission factor (7,261 MtCO$_2$e/MMgal from the Hill et al. study).

The benefits of the biodiesel component will be considered by TLU/ES low carbon fuel option and is based on displacement with soybean-based biodiesel. Additional benefits occur through the development of in-state feedstock (oil) production using GHG preferential feedstocks. These include vegetable oils that produce greater volumes of oil per unit of energy input (e.g., canola), animal fats, and, in the future, algal oils.

Canola produces 127 gallons of oil per acre compared to soybeans at 48 gallons/acre. Assuming canola production energy inputs are not significantly greater than soy, the life cycle emission rate for canola would be 7,261 × 48/127 or 2,744 MtCO$_2$e/MMgal. So the additional benefit of canola over soy is 7,261 – 2,744 = 4,517 MtCO$_2$e/MMgal.

For animal fats and algal oils, CCS assumes that these have negligible embedded energy. So the incremental benefit over soy equals the life cycle fossil diesel emission factor (EF) (12,306 MtCO$_2$e/MMgal) minus the soybean based EF (7,261 MtCO$_2$e/MMgal), which is 5,045 MtCO$_2$e/MMgal.

To meet the in-state production goals for 2025, Table 7-10 provides the mix of oil feedstocks assumed in this analysis. The assumed mix relies on new technologies (e.g., algal oil) to produce feedstocks in the post-2015 period. The new production data summarized below excludes BAU production, which is currently approximately 63 million gallons per year of which only about 3 millino gallons is from animal oil feedstocks[35]. The 2015 and 2025 totals are based on existing production capabilities and available feedstocks obtained from the Center for Energy and Environment's BioPET tool.

BAU production is further assumed to be soybean-based with little incremental benefit above the option developed by the TLU TWG.

Table 7-10. Biodiesel Feedstocks and Shares of Production

Year	Oil Feedstock	Fraction of New Production	MMgal/year Needed*
2015	Soy	85%	32
2015	Canola	0%	0
2015	Animal	15%	6
2015	Algal	0%	0
2015 Total			**37**
2025	Soy	60%	57
2025	Canola	5%	5
2025	Animal	30%	28

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[35] Based on *Economic Impact Of Soy Diesel In Minnesota* by Su Ye Agricultural Marketing Services Division Minnesota Department of Agriculture

2025	Algal	5%	5
2025 Total			**94**

* 2015 and 2025 totals calculated using policy design goals[36].

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

For gasoline displacement, the benefits for this option are dependent on developing in-state production capacity that achieves benefits above the levels of existing and planned (BAU) starch-based production in the U.S. Emission factors for reformulated gasoline, starch-based ethanol, and cellulosic ethanol were taken from a General Motors/ANL study.[37] These emission factors incorporate the GHG emissions during the entire life cycle of fuel production (e.g., for gasoline: extraction, transport, refining, distribution, and consumption; for ethanol: crop production, feedstock transport, processing, distribution, and consumption). These life cycle emission factors are referred to as “well-to-wheels” emission factors:

Table 7-11. Life cycle emission factors for gasoline and ethanol

Fuel	**Emission Factor (grams CO_2e/mi)**
Reformulated gasoline	552
Starch-based ethanol	451
Cellulosic ethanol	154

In addition to cellulosic ethanol production, the other types of ethanol production processes targeted by this option include starch-based processes that achieve similar levels of life cycle GHG reductions to cellulosic ethanol. These would be starch-based plants that use renewable fuels, such as biomass, biogas, landfill gas, or other renewable fuels. While CCS is not aware of any lifecycle emission factors for these types of plants (although several have been proposed in the United States), CCS assumes that reductions similar to cellulosic ethanol can be achieved.

Based on the emission factors shown in Table 7-11, the incremental benefit of the production targeted by this policy over conventional starch-based ethanol is 66% (reduction of CO_2e by offsetting gasoline consumption). This value was used along with the life cycle emission factor for gasoline[38] and the production in each year to estimate GHG reductions.

Currently, there is significant ethanol production in Minnesota with 16 ethanol plants and an annual production capacity of approximately 620 million gallons[39]. That is approximately 13 percent of the total U.S. output. An additional four plants are under construction with another

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[36] Assumes production needed is additional to existing in-state production.

[37] Brinkman, Wang and Weber, *Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems - A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions*. 2005.

[38] In the GM/ANL study, the average fuel economy used was 21.3 miles/gallon or 100 miles/4.7 gallons. Multiplying this value by the emission factor of 552 grams/mile yields 11,745 grams/gallon.

[39] From Planning and Constructing an ethanol plant http://www.pca.state.mn.us/publications/ethanol-guidancedoc.pdf

400 million gallons of capacity[40]. Three plants under construction are expected to start-up by March 2008 and the forth in October 2008. Once construction of these facilities is complete, Minnesota's total ethanol production capacity will be over one billion gallons of ethanol per year. About half of the state's total annual ethanol production is exported. The GHG benefit quantification assumes that additional cellulosic ethanol production is required to meet the policy's goals. Cellulosic ethanol production required by existing policies has been incorporated into the analysis and assists the state meet the targets under this option[41].

Cost of gasoline and fossil diesel displacement with superior feedstocks and processes

For the biodiesel component, costs were estimated using information from an analysis of biodiesel production costs from the US DOE.[42] The value of incentives needed is assumed to be equivalent to the difference in the costs of producing fossil diesel and soy-based biodiesel ($0.34/gallon). This value is very close to the incentive offered in a State of Missouri incentives program.[43] This program offers production incentives of $0.30/gallon to producers up to 15 million gallons of production/year. The incentive grants last for 5 years.

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 by the production incentive. This assumes that all production occurs at production facilities of less than 15 million gallons/year. The production incentive runs out after 5 years of production.

For the gasoline component, 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. The DOE EIA estimated that the cost to produce starch-based ethanol is $1.10/gal compared to $1.29/gal, or a difference of $0.19/gal (in $1998).[44] In 2007 dollars, the difference is $0.24/gal. These incentives are considered necessary in the near term (up to 2015) to help commercialize technologies that produce ethanol from cellulose or produce starch-based ethanol using renewable fuels. 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 2016. Note that there is currently federal legislative proposal to offer cellulose an incentive of $0.765/gallon compared to the

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[40] From personal communications with Ralph Groschen Agriculture Marketing Specialist, MDA.

[41] Minnesota requires that all gasoline sold in the state be blended with a 20% ethanol mix by 2013. Of this, there is a state goal that a quarter of the RFS will come from cellulosic derived biofuel by 2015, or when 60,000,000 gallons comes online, whichever is first. For this analysis, the existing policy cellulosic requirements are assumed to be fulfilled from 2013.

[42] See www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html

[43] Information on the Missouri Program at www.newrules.org/agri/mobiofuels.html#biodiesel, accessed January 2007.

[44] DOE EIA analysis can be found at www.eia.doe.gov/oiaf/analysispaper/biomass.html.

$0.51/gallon currently offered for ethanol production.[45] If enacted, this $0.255/gallon premium could cover the additional incentives that are assumed to be needed by the State of Minnesota. Obviously, the federal incentives do not assure that production facilities would locate in Minnesota. These federal incentives have not been factored into the cost estimates for this option.

The costs for this option were estimated using the $0.24/gal incentive multiplied by the production needed in each year. By 2015, it is assumed that these incentives will no longer be needed as cellulosic ethanol technologies become fully commercialized. Below is the assumed schedule for these incentives and the emissions saved for each year.

Table 7-12. Costs and Benefits for Offsetting Gasoline with Ethanol

Year	MMGal EtOH Capacity Needed	Costs (MM$)	Discounted Cost (MM$)	Avoided Emissions MMT (cellulosic compared to corn)*
2008	88	$21.30	$20.30	0.56
2009	171	$41.30	$37.40	1.08
2010	248	$59.80	$51.70	1.57
2011	319	$77.00	$63.30	2.01
2012	420	$101.50	$79.50	2.66
2013	483	$116.70	$87.10	3.05
2014	606	$146.50	$104.10	3.83
2015	733	$177.00	$119.80	4.63
2016	862	$0.00	$0.00	5.45
2017	994	$0.00	$0.00	6.28
2018	1,130	$0.00	$0.00	7.14
2019	1,268	$0.00	$0.00	8.02
2020	1,411	$0.00	$0.00	8.91
2021	1,553	$0.00	$0.00	9.81
2022	1,698	$0.00	$0.00	10.73
2023	1,847	$0.00	$0.00	11.67
2024	1,998	$0.00	$0.00	12.63
2025	2,152	$0.00	$0.00	13.6
		cumulative	**$563.30**	**113.63**

*Note that the GHG benefits displayed here do not incorporate any overlap with the TLU Low Carbon Fuel Standard. This overlap will reduce the emission savings attributed to this option.

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[45] 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

Key Assumptions:

Life cycle GHG emission factors utilized/derived for this analysis are representative for each feedstock and for fossil diesel. Production incentives offered by this option are sufficient to drive production of GHG-superior feedstocks (e.g., superior to soybeans) and to increase the level of research and development needed for non-crop based feedstocks (e.g., algal biodiesel, Fischer-Tropsch biodiesel). Starch-based ethanol production using renewable fuels achieves equivalent GHG life cycle benefits as cellulosic ethanol; cellulosic production or starch-based production with renewable fuels can achieve the production levels in the near term required by this policy option; Federal tax incentives do not preclude the need for the additional state incentives assumed for the cost estimate

While Minnesota is a significant ethanol producer, for the purposes of quantification, the quantity of ethanol required by this policy assumes that additional cellulosic ethanol production is required to meet the policy's goals. Cellulosic ethanol production required by existing policies has been incorporated into the analysis and assists the state meet the targets under this option.

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 MCCAG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]

AFW-4. Expanded Use of Biomass Feedstocks for Electricity, Heat, or Steam Production

Policy Description

Dedicate a sustainable quantity of biomass from agricultural lands, land restoration activity, agricultural industry residues, wood industry process residues, those normally unused forestry residues, and agro forestry resources for efficient conversion to energy and economical production of heat, steam, or electricity. This biomass should be used in an environmentally-acceptable manner considering proper facility siting and feedstock use (e.g., proximity of users to biomass, impact on water supply and quality, control of air emissions, solid waste management, cropping management, nutrient management, soil and non-soil carbon management, and impact on biodiversity and wildlife habitat). The objective is to create concurrent reduction of carbon dioxide due to displacement of fossil fuel considering life cycle GHG emissions associated with viable collection, hauling, energy conversion, and energy distribution systems.

The potential feedstocks associated with this policy is biomass normally unused under any existing program, meaning:

(1) Any organic material grown for the purpose of being converted to energy;
(2) Any organic byproduct of agriculture that can be converted into energy; or
(3) Any material that can be converted into energy and is non-merchantable for other purposes, that is segregated from other non-merchantable material, and that is;
 (i) A forest-related organic resource, including mill residues, pre-commercial thinnings, slash, brush, or byproduct from conversion of trees to merchantable material; or
 (ii) A wood material, including pallets, crates, dunnage, manufacturing and construction materials (other than pressure-treated, chemically-treated, or painted wood products), and landscape or right- of-way tree trimmings.

Expanded biomass resources can be developed from agricultural industry process residues and agro forestry products as new industrial facilities are built and through conversion of existing facilities. Analyses project that there is theoretically enough residual biomass and energy crops in Minnesota that, if collected and fed to the most efficient conversion technologies available, could produce up to 99% of the total electricity currently used in Minnesota. Actual results are highly dependent on economically attractive methods for collection of materials, hauling, energy conversion and energy distribution systems, as well as sustainable harvest methods. Current research and increasing numbers of demonstration projects occurring nationally are available to determine which system components are most functional and cost-effective for given locations.

The policy will address the following needs:

- Provide resources to advance the rate of development of domestic biomass yield through research and development without compromising soil carbon stability and long-term viability of the production area, and to develop standards and methods to measure ecological sustainability and economical aspects of yield and harvest methods.

- Advance energy collection and conversion technologies for a range of applications from farm-scale point of use to larger industrial size units designed for specific use. Collection and conversion processes should be designed to maximize overall GHG reductions through life cycle analysis.
- Provide market incentives to develop a Minnesota biomass to energy conversion equipment industry and to enhance market infusion of biomass conversion products.
- Provide a focus on high potential, low cost actions that do not create an adverse effect on the forest industry, on existing forestry practices, or on existing agricultural practices.
- Ensure that the current raw material supplies of established forest product firms are sustained and the existing use of biomass by these firms for energy purposes is enhanced.
- Structure incentives to enable partnerships to develop between electric utilities and the forest products industry to increase the potential pool for investment capital and promote least cost compliance with the state's aggressive renewable electricity requirements.

Policy Design

Goals:

Energy Crop Production

By 2015 have 40,000 acres of land producing high MMBTU and ecologically sustainable energy crops near energy facilities. By 2025 have 120,000 acres of these crops in production. Energy in biomass from these acres is considered to be included in the biomass BTU utilization.

Biomass Utilization:

Increase beyond existing programs the usage of normally unused biomass for renewable energy (heat, steam or electricity) generation to 16,000 billion BTU per year by 2015 and 46,000 billion BTU per year by 2025.

Timing: See above.

Parties Involved: Review and analysis of power sector industry restructuring issues must consult with affected and interested parties, including representatives of: area land planners, rural and other energy consumers (commercial, industrial, small); investor-owned, cooperative, and municipal utilities; local units of government; Minnesota Pollution Control agency and local environmental agencies; renewable energy developers and providers; natural gas distribution utilities; community action agencies; and the public utilities commission; Agro-industries with waste products, Forest-product industries with waste products, conservation groups, Forest Resource Council, Board of Water and Soil Resources, Department of Natural Resources, Department of Agriculture.

Other:

Implementation Mechanisms

Focus on high potential, low cost actions that do not adversely effect existing agriculture and forestry practices.

Act on energy recommendations from the 2007 Governor's Task Force on the Competitiveness of Minnesota's Primary Forest Products Industry.[46] These include the following biomass energy recommendations for the NextGen Energy Board:

> a. Ensure that existing forest product industry facilities are a priority for state cellulosic biofuels and bioenergy policies, incentives, and research;
>
> b. Ensure that the current raw material supplies of established forest product firms are sustained and the existing use of biomass by these firms for energy purposes is enhanced;
> c. Provide capital incentives for high-value biomass utilization, including gasification equipment to produce bio-gas, as an offset for the use of natural gas and propane, and as a first step toward the next generation of biofuels;
> d. Structure incentives to enable partnerships to develop between electric utilities and the forest products industry, in order to increase the potential pool for investment capital and promote least cost compliance with the state’s aggressive renewable electricity requirements; and
> e. Provide state investment in pilot scale projects at existing forest products facilities to test next generation bioenergy technologies (NextGen Board).

By 2015, establish criteria/standards for sustainable harvest and utilization of agricultural and forest residues. Build on FSC guidelines and other FRC, RIM-CE, Department of Agriculture guidelines for residue removal to ensure soil health and soil carbon storage.

Strong efficiency incentives will need to be put in place on both the heat and/or electricity side in order to reduce the land use pressures for the biomass development in meeting the % energy goals.

Need to get energy crops in the ground so the feedstock is available. Pilot projects maybe needed in the near term so research and economics can be assessed for intention of broader scale commercialization in the long term (i.e., via RIM-CE).

Dollars for sustainability standards development may need to be allotted. This would be to complete the research gaps identified by the Forest Resource Council on their woody biomass residue harvest guidelines, and establishment of agricultural sector energy crops (i.e., via BWSR programs).

MMBtu energy incentives for biomass conversion facilities may need to be established. This incentive may be needed for facilities to install biomass feedstock acceptance (conveyers, etc) on their facilities, storage needs. An MMBtu incentive is preferable as it focuses on incentivizing input of high MMBtu feedstocks and efficient conversion of the biomass into energy (for a high MMBtu output). This would be technology neutral (i.e., could be used for gasifiers, or whatever technology is developed in this rapidly changing market). It is performance based.

Need some type of template contract for between facilities and farmers/intermediary/coop – in order to minimize risk for both parties (i.e. what if farmer can’t meet long-term contractual need?).

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[46] The full text of the Task Force's 17-page Report to the Governor can be accessed at www.ironrangeresources.org. Click on Natural Resources, then on Forest Products, then on More Forestry Information.

Related Policies/Programs in Place

The Renewable Electricity Standard became Minnesota law in February of 2007. It requires that 30% of the electricity sold by Xcel Energy to Minnesota consumers be renewable by 2020 and, for all other utilities that 25% be renewable by 2025. Under the new RES and efficiency legislation passed, Minnesota will likely add between 5,000 to 6,000 MW of new renewable electricity to its system.

Biomass Mandate—Xcel Energy has a mandate to purchase 110 MW of biomass electricity. Currently that mandate has been filled with the St. Paul District Energy facility, the FibroMinn turkey litter project, and the Virginia/Hibbing biomass project. There is not expected to be space available within this mandate for further projects.

RIM-Clean Energy—a reinvest in Minnesota program within the Board of Soil and Water Resources. RIM-CE is a working lands program that allows for growing and harvesting of bioenergy crops with added payments for increased conservation, water quality benefits. The program still needs funds for granting easements for bioenergy crops.

There are currently multiple grants opportunities for biomass facility feasibility and project development. This includes granting authority from the Department of Commerce, the Renewable Development Fund, and the Department of Agriculture (via the NextGen Energy Board).

There are multiple existing and planned bioenergy heat and power projects in Minnesota, including

- A gasification plant that is planned for the University of Minnesota at Morris will use crop waste (corn stover) to produce heat, electricity, syngas and/or hydrogen. The University of Minnesota Duluth's Coleraine Lab has obtained a grant to develop a gasification project that will convert wood waste to hydrogen. (8)
- The Center for BioRefining at the University of Minnesota has developed a biomass/hydrolysis process that converts waste biomass, such as corn stover, into bio-oil which can be used to make polymers for products and hydrogen-rich gas. (8)
- St. Paul District Energy – provides over 80% of power for downtown from woody biomass. Also, Minnesota Power in Duluth has a large biomass to energy plant.
- Numerous other projects for reference such as: Koda Energy, CMEC, CVEC, municipal energy projects.
- For Certification, The Laurentian Energy Authority (Virginia/Hibbing) Biomass Energy Project has provided $150,000 to the Minnesota Forest Resources Council (MFRC) to establish guidelines for sustainable removal of woody biomass from forests for energy, and to the Minnesota DNR to develop similar guidelines for brushlands and open lands. The MFRC identified existing research gaps and may need increased allotment of funds to further refine the standards being developed. The guidelines have been developed and approved and will be published January 2008. The 2007 Minnesota legislature provided $300,000 to the MFRC to fund research on ecological impacts of woody biomass removal for energy.

Type(s) of GHG Reductions

CO_2, N_2O, CH_4: Displaces emissions from fossil fuel combustion.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2015, 2025 (MMtCO$_2$e): 1.3, 3.8

Net Cost per MtCO$_2$e: 9

Data Sources:

1. "Identifying Effective Biomass Strategies: Quantifying Minnesota's Resources and Evaluating Future Opportunities," Center for Energy and Environment, 2007. Funded by Xcel Energy's Renewable Development Fund. Layering maps for project siting, the report, and project feasibility spreadsheet are available at: http://www.mncee.org/public_policy/renewable_energy/biomass/index.php
2. "Plant Power: Biomass-to-Energy for Minnesota Communities," Shalini Gupta, 2004, prepared for Fresh Energy (Minnesotans for an Energy-Efficient Economy at the time) and the Department of Commerce.
3. Biomass Mandate: An assessment, David Morris, 2005, Institute for Local Self-Reliance.
4. *Processing Cost Analysis For Biomass Feedstocks*, Phillip C. Badger, General Bioenergy, Inc., Florence, Alabama, October 2002. Prepared for US DOE, Office of Energy Efficiency and Renewable Energy, Biomass Program, Budget Activity Number EB 24 04 00 0. Prepared by Oak Ridge National Laboratory (ORNL), Oak Ridge, TN. Managed by UT-Battelle, LLC, for the US DOE under contract DE-AC05-00OR22725, ORNL/TM-2002/199.
5. *A Geographic Perspective on the Current Biomass Resource Availability in the United States*, A. Milbrandt, Technical Report NREL/TP-560-39181, December 2005. Prepared under Task No. HY55.2200.
6. *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply,* Robert D. Perlack, Lynn L. Wright, Anthony F. Turhollow, Robin L. Graham. Environmental Sciences Division, ORNL; Bryce J. Stokes, Forest Service, USDA; Donald C. Erbach, Agricultural Research Service, USDA; A Joint Study Sponsored by US DOE and USDA. Prepared by ORNL. Managed by UT-Battelle, LLC, for the US DOE under contract DE-AC05-00OR22725, DOE/GO-102005-2135, ORNL/TM-2005/66.
7. ORNL 1999 database: http://bioenergy.ornl.gov/resourcedata/
8. NREL GIS database, updated with new sources of data: mill residue data are from the 2002 Timber Products Output Database by the USDA Forest Service; agricultural residue data are from the National Agricultural Statistics Service at USDA. http://www.nass.usda.gov:81/ipedb/
9. ILSR 1997 database: http://www.carbohydrateeconomy.org/library/admin/uploadedfiles/Survey_of_Minnesotas_Agricultural_Residues_and.html
10. *Minnesota Biomass-Hydrogen and Electricity Generation Potential*, a study by the National Renewable Energy Laboratory, Golden, CO. Provided with financial assistance from the US DOE for the Minnesota Department of Commerce and the Minnesota Office of Environmental Assistance, February 2005.
11. A Report to the Minnesota Legislature, Minnesota Department of Commerce, State Energy Office, January 2006.

12. Center for Energy & Environment Report on Biopower (theoretical, technical, economically available biomass for power production), 2007.
13. http://bioenergy.ornl.gov
14. http://www.eere.energy.gov/biomass/biomass_feedstocks.html
15. Recommendations excerpted from Report to the Governor, *Governor's Task Force on the Competitiveness of Minnesota's Primary Forest Products Industry*, July 2007.

Quantification Methods:

Biomass Utilization GHG Benefits

This policy calls for 16,000 billion btu of biomass energy per year by 2015 and 46,000 billion btu per year by 2025 to be used to offset fossil fuel combustion in the energy supply and the RCI sectors. The benefit of the utilization of this additional biomass assumes that the biomass is used to offset the consumption of fossil fuels. It is assumed that half of the available biomass will be utilized in the electricity sector and the other half in the RCI sectors. Based on the existing fuel mix, it is assumed that in the electricity sector biomass will offset coal while in the RCI sector, biomass is assumed to offset 50% coal and 50% gas[47]. The amount of biomass available is outlined in table 7-13 using the BioPET tool[48] and indicates that there is sufficient biomass available to meet the prescribed goals.

Table 7-13. Biomass Available (from BioPET)

Feedstock	**Dry Tons/yr**	**Btu/lb**	**MMBTU**	**Percent of total**
Hay/Straw non-CRP	2,321,987	7600	35,294,204	7.7%
Switch grass/other	1,007,905	7481	15,080,276	3.3%
Corn Stalk	21,680,081	8191	355,163,090	77.1%
sunflower stalk	45,846	8191	751,056	0.2%
Hay/straw from CRP lands	1,955,457	7375	28,842,991	6.3%
Unprocessed Logging residues	1,016,359	8669	17,621,632	3.8%
Mill Residues	595,099	6757	8,042,173	1.7%
Total	28,622,735		460,795,422	100.0%

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[47] Different benefits would occur if an alternative fuel mix was used or other fuels like oil were offset

[48] The Center for Energy and Environment's BioPET Software was used. This software is an Excel spreadsheet that contains information on the biomass available at the county level.

The GHG benefits were calculated by the difference in emissions associated with each of the input fuels (0.0959 tCO2e/mmbtu for sub-bituminous coal, 0.0539 tCO2e/mmbtu for natural gas and 0.0019 tCO2e/mmbtu for biomass, including non CH4 and N2O emissions)[49].

This policy directly overlaps with policy options considered under the ES and RCI TWGs. The biomass energy requirements under these options are greater than the requirement under this policy. To avoid double counting emission reductions, the GHG benefits from this option are assumed to be captured under the ES and RCI policies.

Biomass Utilization Costs

The cost analysis for this option is based on the difference in costs between supply of woody biomass fuel and the assumed fossil fuel that it is replacing (i.e. the relevant proportion of coal and gas outlined above). The cost was assumed to be $5/MMBtu for natural gas and $1.74/MMBtu for coal[50]. The cost of supplying biomass was $68/ton[51]. This value compares to an estimate of $140/ton associated with an 80-mile radius between supply and use and a cost of $108/ton for a 25-mile radius in a recent study on western biomass supply and use.[52] This equates to approximately $3.90/MMBtu for biomass. A summary of avoided emissions and cost for each year is presented in table 7-14.

Table 7-14. Cost and Avoided Emissions

Year	Biomass (MMBtu)	Cost/Savings	Discounted Savings	Avoided emissions (MMtCO2e)
2007	0			
2008	2,000,000	$2,670,527	$2,543,359	0.166996412
2009	4,000,000	$5,341,053	$4,844,493	0.333884859
2010	6,000,000	$8,011,580	$6,920,704	0.500827288
2011	8,000,000	$10,682,106	$8,788,195	0.667769717
2012	10,000,000	$13,352,633	$10,462,137	0.834712147
2013	12,000,000	$16,023,160	$11,956,728	1.001654576
2014	14,000,000	$18,693,686	$13,285,254	1.168597006
2015	16,000,000	$21,364,213	$14,460,140	1.335539435
2016	19,000,000	$25,370,003	$16,353,730	1.585953079
2017	22,000,000	$29,375,793	$18,034,188	1.836366723
2018	25,000,000	$33,381,582	$19,517,520	2.086780367
2019	28,000,000	$37,387,372	$20,818,688	2.337194011
2020	31,000,000	$41,393,162	$21,951,678	2.587607655

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[49] Emission factors obtained from CCS Minnesota Energy Supply GHG forecasts

[50] Source: EIA DOE (AEO2007) using the National Energy Modeling System. Data from EIA was averaged over the policy period.

[51] Average cost per ton for wet and dry Herbaceous Biomass Feedstock Collection, Preprocessing and Delivery to conversion Reactor Inlet, Sourced from DOE Office of Energy Efficiency and Renewable Energy's (EERE's) Biomass Program Biomass Multi-Year Plan, US Department of Energy, Office of Biomass Program, Energy Efficiency and Renewable Energy, October 2007.

[52] From McNeil Technologies Report: *Western Regional Biomass Energy Program*, Final Report, Evaluating Biomass Utilization Options for Colorado: Summit and Eagle Counties, 2003.

2021	34,000,000	$45,398,952	$22,929,556	2.838021299
2022	37,000,000	$49,404,742	$23,764,526	3.088434943
2023	40,000,000	$53,410,532	$24,467,980	3.338848587
2024	43,000,000	$57,416,322	$25,050,551	3.589262232
2025	46,000,000	$61,422,112	$25,522,156	3.839675876
			291,671,583	**31.469**

The cost estimates do not include capital costs for new equipment purchases or retrofits. It is assumed that changes in equipment use occur after the useful life of existing fossil fuel-fired equipment. The up-front cost of a biomass combustion system can be greater than a traditional system; however the fuel is far less expensive, such that, over time, fuel savings can more than offset upfront costs. Net cost savings are more likely in certain circumstances, in particular: 1) when the price of fossil fuel equipment options are relatively expensive and 2) in larger, heat-using facilities whose unit savings on heating fuel costs result in a better payback on the up-front investment.

Key Assumptions:

The benefit of the utilization of this additional biomass assumes that the biomass is used to offset a combination of gas and coal (different benefits would occur if an alternative fuel mix or other fuels like oil were offset). The emission factor developed for Minnesota biomass delivery does not include emissions for equipment used for on-site collection/processing of biomass due to a lack of information; All biomass under this option is utilized by the RCI or ES options.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

1. Expanded biomass resources can be developed from agricultural industry process residuals and agro forestry products as new industrial facilities are built and through conversion of existing facilities. Analyses project that there is theoretically enough residual biomass and energy crops in Minnesota that, if collected and fed to the most efficient conversion technologies available, they could produce a percentage of the energy currently used in Minnesota. Actual results are highly dependent on economically attractive methods for collection of materials, hauling, energy conversion and energy distribution systems, as well as sustainable ecological harvest methods. Current research and increasing numbers of demonstration projects occurring nationally are available to determine which system components are most functional and cost-effective for given locations.
2. Any action to expand use of biomass for energy conversion must consider ecological sustainability and standards for harvesting. In addition, actions must consider land use limitations and resource needs for relatively scaled heat/power facilities. Removal of

biomass, residue or perennial, removes plant nutrients essential for long run productivity. Balancing this removal is critical for biomass harvesting.

3. Feedstock has certain inherent physical and chemical characteristics. The fuel preparation steps must change the characteristics inherent in the feedstock into the characteristics needed for the conversion device, thus the feedstock requirements for the conversion device must be known. (1)
4. Various wood sources can have different physical and chemical characteristics, which can greatly influence its conversion to energy. Feeding of these materials with differing characteristics as slugs into the conversion device can cause rapid changes in operating conditions, and make control difficult. Even wood sources differing only in moisture content can cause significant variations in operating conditions and cause control problems. (1)
5. Environmental factors associated with processing wood include noise, solid waste disposal, air emissions, water pollution, and facility aesthetics. (1)
6. Actions must consider land use limitations and resource needs for relatively scaled heat/power facilities. The ability to cost-effectively collect, store, and transport biomass feedstock presents many challenges. A biobased industry will require a safe and sustainable supply system. Research and Development in this area is designed to overcome the engineering systems barriers of collection, delivery, and storage of agricultural residues. (US DOE, Energy Efficiency and Renewable Energy). Collecting and transporting bulk biomass is costly. Intermediate processing to compress bulk may be necessary. Alternatively, small-scale power generation near supply sources may be desirable.
7. Among the plant growth factors that pose barriers to yield increase, soil moisture is the most limiting factor. Thus, continued selection for stress tolerance, including tolerance to moisture deficits, will be critically important to achieving a crop's potential yield. (3)
8. Additional analyses would be required to discern the potential impact that larger-scale forest residue and crop residue collection and production of perennial crops could have on traditional markets for agricultural and forest products

Status of Group Approval

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

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]

AFW-5. Forestry Management Programs to Enhance GHG Benefits

Policy Description

Forests—public, private, urban, managed, and wild—provide many GHG benefits. The following actions are recommended:

1. Protect and enhance the carbon stored in tree biomass by maintaining and improving the health, longevity, and number of trees in urban and residential areas. Emissions reductions from reduced heating and cooling as a result of planting shade trees are a significant co-benefit.
2. Promote forest cover and associated carbon stocks by establishing forests on former forestland. Additional benefits include public recreation, water quality, wildlife habitat, and enhanced biodiversity. Implement practices such as soil preparation, erosion control, and stand stocking to ensure conditions that support forest growth.
3. Encourage activities that promote forest productivity and increase the amount of carbon sequestered in forest biomass and soils and in long-lived wood products. Practices may include adjusting rotation ages to increase carbon sequestration, increased stocking of poorly stocked lands, thinning and density management, increasing the acreage of short rotation woody crops (for fiber and energy) on agricultural lands previously converted from forest cover, fire management and risk reduction, and management of detrimental insects and disease.
4. Reduce the severity of wildfires to reduce GHG emissions by lowering the forest carbon lost during a fire and by maintaining carbon sequestration potential. Similarly, reducing damage from insects, disease, and invasive plants reduces GHG emissions by maintaining the carbon sequestration potential of healthy forests.

Policy Design

Goals:

Reforestation—Increase permanent forestland in the state by 1 million acres by planting trees on converted forestland.

Urban Forestry—Increase the canopy cover of urban forest in Minnesota communities by 25%.

Wildfire Fuel Reduction—Conduct fuel reduction on all forest areas requiring these treatments. Direct the biomass to most beneficial use. Primary benefits are displacement of fossil fuel and reduced combustion of live forest stands.

Forest Health and Carbon Sequestration—Develop scientific information for incorporating carbon sequestration into forest management plans. Evaluate impacts of increased forest harvest on GHG emissions and sequestration. Increase proportion of harvested wood going into durable wood products. Establish a monitoring program to document long-term impacts of climate change on Minnesota forests. **This is a non-quantified goal.**

Increase Stocking of Under-Stocked Lands—Identify under-stocked forestlands administered by the state and counties in Minnesota and optimally stock identified lands where appropriate.

Timing:

Forest Restoration—Identify lands appropriate for re-establishing forest by 2008. Restore/ establish 250,000 acres by 2015. Achieve full goal by 2025.

Urban Forestry—Increase the canopy cover of urban forest in Minnesota communities by 25% by 2025.

Wildfire Reduction—Identify and prioritize areas where wildfire fuel reduction, would substantially reduce the risk of stand-replacing fires. Conduct fuel reduction on 50% of identified areas by 2015 and 100% by 2025. Direct biomass to most beneficial uses, including biomass fuel production where appropriate.

Forest Health and Carbon Sequestration—Examine the carbon sequestration effects of shifting to desired future forest conditions using carbon friendly management methods. *Develop scientific information on forest management options and harvest methods to increase the amount of carbon sequestered in forests.* Incorporate this information into forest management plans for all publicly administered forests by 2015. Identify and increase incentives for durable wood product industry by 2010. Establish monitoring program to document long-term impacts of climate change to Minnesota forests by 2010.

Increase Stocking of Under-Stocked Lands—Identify under-stocked stands on state and county lands by 2010. Where appropriate, optimally stock 25% of identified stands by 2015 and all such stands by 2025.

Parties Involved: TBD.

Other: TBD.

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

TWG Note: Many funding sources can help implement these multi-faceted options.

Develop scientific foundation of carbon sequestration practices in Minnesota forests, including stocking, rotations (lengthened and shortened rotation), harvest methods, and tree species. Evaluate CO_2 impacts of fire management and fire-fighting activities. Evaluate the impacts of increasing annual timber harvest on GHGs and production of wood fiber products and other forest values. Analyze GHG impacts of different end uses of Minnesota timber harvest (e.g., engineered products, pulp and paper, energy, solid wood products).

Evaluate and provide incentives, such as tax benefits or government purchasing programs, to support investments into wood products that store carbon for long periods of times.

Increase the number of communities implementing inventory-based forest management plans from 50 to 150 by 2025.

Related Policies/Programs in Place

The Board of Soil and Water Resources (BSWR) has been directed by the 2007 Minnesota legislature to administer $500k in grants to conduct site level ecological research and assessments, a clean energy program, and technical teams for native seed harvesting and working lands initiatives.

State has spent many millions of dollars since 1990 on a nationally recognized program called Minnesota ReLeaf, a cost-share program designed to plant trees in urban and rural areas to sequester carbon, promote energy conservation, and provide an array of other co-benefits. The Minnesota DNR Division of Forestry may have cost per ton figures available.

Type(s) of GHG Reductions

CO_2: Promotion of forestry management programs serves to increase the sequestration of carbon in forested lands, as well as preventing carbon currently stored in Minnesota's forests from being released.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2015, 2025 ($MMtCO_2e$): TBD, TBD

Net Cost per $MtCO_2e$: TBD

Data Sources: [TBD by CCS on TWG approval]

Quantification Methods:

Suggested quantification approach divides option into three or four discrete components:

1. Reforestation goal—Note if the land had not been in a forest condition prior to development this might more accurately be called "afforestation." If "reforestation" is meant then this option might be logically quantified under (4), restocking under-stocked land. (What is meant by "planting trees on converted forestland" under "options"?)
2. Urban forestry
3. Wildfire reduction (has there been previous work on this in Minnesota?)
4. Increase stocking of under-stocked land owned by state and county (harvest, then replant?) Is there an existing estimate of the extent of under-stocked land in these ownerships?

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

Key Uncertainties

TBD – [as needed and approved by the TWGs]

TWG Note: Tree mortality has doubled since 1977, from 123 to 250 million cubic feet. Mortality rate could continue to increase, increasing susceptibility to wildfires and large releases of CO_2

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

TWG Suggestion: Management for carbon sequestration will also benefit production of high quality wood products for the construction industry keeping the carbon out of the cycle for a greatly increased time period.

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

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

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]

AFW-6. Forest Protection— Reduced Clearing and Conversion to Non-Forest Cover

Policy Description

In the mid- to late 1800s, forests covered 31 million acres in Minnesota. Over the subsequent 100+ years, l5 million acres of this forestland was converted to other uses, mainly to farmland but also to developed areas. Between 1990 and 2003, Minnesota forestland acreage was reduced by nearly one-half million acres, from 16.7 million acres to 16.2 million acres (Appendix H: Forestry, p. H3, Table H1, USFS Carbon Pool Data for Minnesota). Because forestland captures and stores carbon dioxide in trees, soil and other forest biomass at a much higher rate than developed areas and other areas without forest cover, priority should be placed on reducing conversion of forested lands to land uses with lower carbon sequestration potential.

Policy Design

Goals: Achieve “no net loss” or an increase in forest carbon stocks through local land use planning, conservation easements, technical and financial assistance to family forest landowners, education, revised tax policy, and other appropriate mechanisms.

Timing: Stabilize current statewide forest cover acres and achieve no net loss in carbon stocks by 2015. Decrease conversion of forestland to non-forest uses/cover. Increase carbon stocks by 2025 through reforestation and fully-stocking forestlands (see AFW-5).

Parties Involved: TBD

Other:

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

Related Policies/Programs in Place

Some counties have comprehensive land use plans in place that encourage retention of forestland (e.g., Aitkin County), but many counties either do not have such plans or their plans do not address forestland retention. The same statement applies to municipalities. It is unlikely that any of these plans encourage no net loss of carbon stocks.

The Minnesota Forest Legacy Partnership is a group of public and private business and non-profit interests engaged in promoting large-scale forest conservation easements in northern and central Minnesota. A 51,000+ acre forest easement in Koochiching and Itasca County was recently completed, and two additional easements comprising a total of 76,000 acres have been proposed in Koochiching County (located on the Ontario border in north central Minnesota). The funding for purchasing the 51,000 easement was obtained from private foundation, other private, and state sources, and funding for the additional easements is being sought from these plus federal sources. Additional forestland easements from 1,600 to over 5,000 acres have recently been completed in Itasca, Crow Wing, and Lake counties, in part with federal Forest Legacy funds. Smaller forestland easements have been completed in other counties (e.g., Rice County).

Although a number of federal and state technical and financial assistance and educational programs for family forestland owners have been in place for many years, these programs are not specifically directed at forestland or carbon stock retention. Federal funding for these programs has declined in recent years, and is highly likely to decline further in coming years.

The Sustainable Forest Incentive Act provides for reduced property taxes for private landowners who make a long-term commitment to sustainable management of their forestland. Neither this program nor other forestland tax policy, however, is specifically designed to retain forestland or carbon stocks.

The Minnesota Forest Resources Council has funded research by the University of Minnesota on rates of parcelization and subsequent development of forestland in Itasca County. Funds are being sought from private and public sources to extend this research across northern Minnesota, to evaluate current use and potential applicability in Minnesota of the policy tools listed above plus other tools (e.g., land exchange, fee title ownership, regulatory programs), and to make recommendations to the legislature.

Type(s) of GHG Reductions

CO_2: Avoided emissions from forest clearing and maintenance of annual carbon sequestration from forest growth.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2015, 2025 ($MMtCO_2e$): 5.4, 5.7

Net Cost per $MtCO_2e$: TBD

Data Sources: US Forest Service Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the US, General Technical Report NE-343 (also published as part of the Department of Energy 1605(b) Voluntary GHG Reporting Program); Strong, Terry F. 1997. Harvesting intensity influences the carbon distribution in a northern hardwood ecosystem. North Central Research Station Research Paper NC-329; Austin, Kemen. 2007. The intersection of land use history and exurban development: Implications for carbon storage in the northeast. Bachelor's thesis, Brown University. Data provided by the USFS for the Minnesota Forestry Inventory and Forecast.

Quantification Methods:

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 Minnesota, provided by the USFS as part of the Forest Inventory and Forecast for Minnesota (Appendix H).

Loss of forests to development results in a large one-time surge of carbon emissions. In this case, it was assumed that 53% of the vegetation carbon stocks (Strong 1997) and 35% of the soil carbon stocks (Austin 2007) would be lost in the event of forest conversion to developed uses, with no appreciable carbon sequestration in soils or biomass following development. Using the statewide average C densities from the Minnesota FIA results, roughly 92.5 tons C are avoided for every hectare of forest preserved in Minnesota (37.5 tons C avoided per acre preserved).

Between 1989 and 2003, roughly 14,952 hectares of forest were lost in Minnesota annually (FIA statistics). To reach the no-net-forest-loss target by 2015, this option therefore assumes that 14,952 hectares must be preserved each year beginning in 2015. The number of hectares targeted for policy implementation between 2008 and 2015 was calculated by dividing 14,952 by eight and implementing the option gradually and linearly over the 8 years between 2008 and 2015.

Each year, the number of hectares estimated to remain in forest as a result of the program was converted to units of million metric tons CO_2 equivalent ($MMtCO_2e$) to estimate avoided emissions. Table 7-11 shows the annual and total hectares targeted by the program and associated avoided emissions that would be generated between 2008 and 2020.

Table 7-11. Hectares protected from conversion and associated avoided emissions

Year	Hectares protected from development	Avoided emissions from development (tC/year)
2008	2,990	276,648
2009	5,980	553,295
2010	8,970	829,943
2011	11,960	1,106,591
2012	14,950	1,383,238
2013	14,950	1,383,238
2014	14,950	1,383,238
2015	14,950	1,383,238
2016	14,950	1,383,238
2017	14,950	1,383,238
2018	14,950	1,383,238
2019	14,950	1,383,238
2020	14,950	1,383,238
Cumulative totals	**164,450**	**15,215,621**

2. Annual Sequestration Potential in Protected Forests

The calculations in this section of the analysis used default carbon sequestration values for aspen-birch and spruce-fir forest types in the Northern Lake States (USFS GTR-343, Tables A7 and A11). Average annual carbon sequestration for these forest types was calculated over 125 years by subtracting non-soil carbon stocks in 125-year-old stands from non-soil carbon stocks in new stands and dividing by 125 (Table 7-12). Soil carbon density was assumed constant and is not included in the calculation.

Table 7-12. Forest carbon sequestration rates

	MtC/ha (0 year)	MtC/ha (125 year)	MtC/ha/year (average)
Aspen-birch	25.6	143.0	0.9
Spruce-fir	51.9	174.9	1.0

Since 41% of Minnesota forests statewide are aspen-birch and 27% are spruce-fir (FIA statewide data, Appendix H), this option assumes that forests saved from development are roughly proportional to existing forests. Protected forests were assumed to be 66% aspen-birch and 38% spruce-fir.

The results for annual sequestration potential under policy implementation are given in Table 7-13. 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 7-13. Annual and cumulative C sequestration in forests protected from conversion between 2008 and 2020

	Hectares Protected From Development		**Cumulative C Sequestration (tC/year)**
Year	**This Year**	**In Prior Years**	**For Land Protected in all Years**
2008	2990	0	2971.4
2009	5980	2990	8914.3
2010	8970	8970	17828.6
2011	11960	17940	29714.4
2012	14950	29900	44571.6
2013	14950	44850	59428.8
2014	14950	59800	74286.0
2015	14950	74750	89143.1
2016	14950	89700	104000.3
2017	14950	104650	118857.5
2018	14950	119600	133714.7
2019	14950	134550	148571.9
2020	14950	149500	163429.1
Cumulative totals		**164450**	**995431.8**

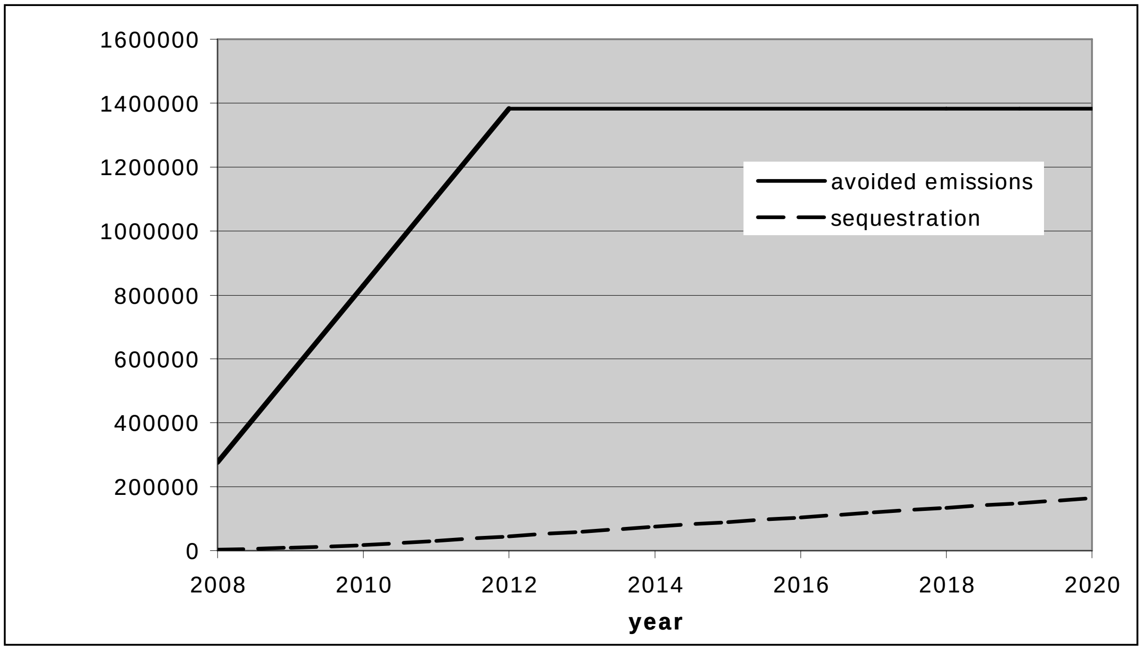
3. Overall GHG Benefit of Avoided Land Conversion

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 $MMtCO_2e$ (Table 7-14). Figure 7-1 shows the relative impact of avoided emissions and sequestration in protected acreage.

Table 7-14. Combined GHG impact of avoided forest land conversion under policy implementation

Year	tC/year	MMtCO$_2$e/year
2008	279619.1	1.0
2009	562209.6	2.1
2010	847771.6	3.1
2011	1136305.0	4.2
2012	1427809.9	5.2
2013	1442667.0	5.3
2014	1457524.2	5.3
2015	1472381.4	5.4
2016	1487238.6	5.5
2017	1502095.8	5.5
2018	1516953.0	5.6
2019	1531810.2	5.6
2020	1546667.4	5.7
Cumulative total		**59.4**

Figure 7-1. Relative impact of avoided emissions from protecting forest and annual sequestration on protected acreage for AFW-6



Economic Analysis

Need data from TWG on implementation mechanisms: easements, acquisition? $$ Costs of each?

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

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

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

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]

AFW-7. Integrated Waste Management

Policy Description

Integrated waste management promotes the reduction of the sheer volume of waste produced as well as a reduction in consumption through incentives, awareness and increased efficiency. Three major areas of focus in Minnesota are source reduction, organic waste management and advanced recycling. Source reduction and recycling provide GHG benefits not only from avoided landfill emissions, but also product life cycle emission reductions (associated with the manufacture and transport of new packaging/products). Redirecting organic wastes (such as food, yard, and paper) from landfills into composting programs or energy recovery is very effective at reducing methane emissions, since the organic fraction of the waste stream is responsible for methane generation.

Policy Design

Goals:

Source Reduction Goal—Achieve a 3% per capita decrease in waste generation by 2025.

Recycling and Composting: Minnesota will achieve a combined recycling and composting (diversion) rate of 75% by the year 2025.

Timing:

Source Reduction—Achieve a 0% per capita increase by 2020 and a reduction of waste generation per capita of 3% by 2025.

Recycling and Composting—Recycling rate of 50% by 2011 and 60% by 2025. Composting rate of 10% by 2012 and 15% by 2020 (for a total diversion rate of 75% by 2025).

Parties Involved: Food Residuals Diversion Team (currently staffed from Minnesota Office of Environmental Assistance); MPCA; others,

Other: Current per capita increase in waste generation is 1.9%/year. In 2005, the state of Minnesota had a recycling rate of 41%, a composting rate of 5% (although mostly yard waste, 0.02% was source separated compostables which represented a doubling from the prior year) and an estimated source reduction rate of 3% (citation – 2005 SCORE report?). According to the 2005 SCORE report covering waste management in MN, the rates of recycling have leveled off since the 1989 enactment of the SCORE legislation (see Table 7-x below).[53]

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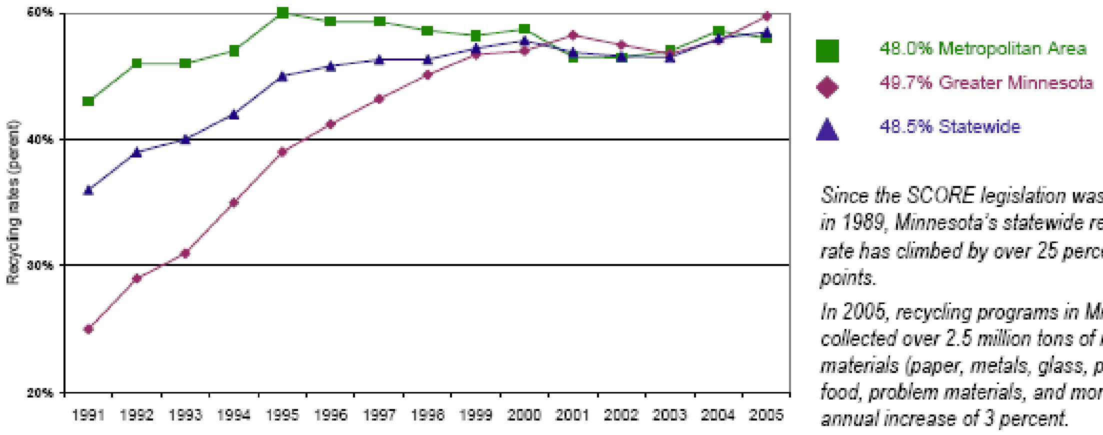
[53] Report on 2005 SCORE Programs, A Summary of Waste Management in Minnesota, MPCA, 2006.

Table 7-x. Current Minnesota Recycling Rates



Since the SCORE legislation was enacted in 1989, Minnesota's statewide recycling rate has climbed by over 25 percentage points.

In 2005, recycling programs in Minnesota collected over 2.5 million tons of recyclable materials (paper, metals, glass, plastic, food, problem materials, and more), an annual increase of 3 percent.

Implementation Mechanisms

Source Reduction: Reduce the volume of wastes from residential, commercial, and government sectors through programs that reduce overall disposal. Reduction of waste generation at the source – of production (including packaging) and of consumption – reduces both landfill and waste-to-energy (WTE) combustion emissions as well as upstream production emissions. To achieve the source reduction goals of this policy, Minnesota should:

1. Identify consumer products and packaging that are neither recyclable nor compostable;

2. Voluntary initiatives, including increasing consumer education about waste and working with manufacturers and retailers to change packaging type and reduce overall packaging would be developed, prioritized and targeted at products and packaging based on the quantities in the waste stream and the energy intensiveness of their production and the emissions resulting from their ultimate disposal. Depending on the success of these initiatives, other options could include product stewardship and regulations to reduce use of non recyclable and non-compostable materials;

3.

Organic Waste Recovery: Reduce methane emissions associated with landfilling by reducing the biodegradable fraction of waste emplaced and also remove the wet and dense fraction that reduces the Btu potential of the combustible components of the waste stream (for use in waste-to-energy or WTE applications, see AFW-8). To achieve the organic waste recovery goals of this policy, Minnesota should

- Increase recycling of organic wastes (e.g., lawn and garden, food waste, wood, paper) through the use of various methods including food to people (food recovery) and food to animals,
- Expand composting programs, and
- Digestion?

Recycling: Increase reuse and recycling in order to limit GHG emissions associated with landfill methane generation, waste combustion, waste-to-energy combustion processes, and the extraction of raw materials and energy consumption during the manufacturing process. To achieve the recycling goals of this policy, Minnesota should

- Expand existing reuse and recycling programs;
- Create new recycling programs;
- Provide incentives for the reuse/recycling of construction materials;
- Develop markets for recycled materials;
- Increase average participation/recovery rates for all existing recycling programs.

Related Policies/Programs in Place

Recycle More Minnesota Campaign. The Minnesota Pollution Control Agency (MPCA) is undertaking a campaign to "reinvigorate recycling." The state has one of the nation's highest recycling rates, but the MPCA intends to increase that rate. This effort is an important means to attaining the Agency's strategic goal to achieve a statewide 43% recycling rate by January 1, 2007, and a 50% recycling rate by January 1, 2011. Of garbage sent to the landfill, 75% is recyclable. In fact, the PCA is aware of over 500,000 tons of material (paper, plastic, metals, and glass) from residential waste that could be recycled. That material is worth over $82 million. Even a slight increase in the rate has a significant impact on reducing GHG emissions. http://www.pca.state.mn.us/publications/reports/lrw-sw-1sy06.pdf

Minnesota State Resource Recovery Program. The State Resource Recovery Program is intended to promote waste reduction and recycling in Minnesota government. It has targeted programs to reduce office paper waste, reduce the costs and materials associated with publication design and printing; promote reuse of materials and commodities; and recycle paper, cans, glass and plastic. Currently there is a recycling challenge involving state buildings. http://www.rro.state.mn.us/

Increase Organics Recovery. MPCA promotes increased composting of yard waste and other source separated organics. By applying it to soils, compost sequesters carbon by utilizing the short term carbon cycle. In 2005, about 19,000 tons of compost was created and used as soil amendment. That is only capturing about 1% of the organic materials in the solid waste stream. A more aggressive effort could capture 5% to 10% of the organics in the solid waste stream. The agency is also promoting the collection of restaurant and grocery store waste to be used as food for hogs and other recovery options. This does not include any industrial waste such as vegetable processing wastes, bio-solids, manure composting or digestion. There is a large potential here that is as yet untapped. MPCA is working to increase the amount of organic material recovered. http://www.reduce.org/compost/index.html

MPCA Waste-to-Energy Program. Waste-to-energy produces clean, reliable, renewable power, and is a vital part of the energy infrastructure in those Minnesota communities where such facilities are located. Currently, nine waste-to-energy facilities in Minnesota process 3,800 tons of MSW per day for industrial heat and electrical generation. The total energy reclaimed since 1982, when these facilities first began to come on-line, is the equivalent of 12 million tons of coal. Currently, these facilities produce approximately 100,000 megawatts of electrical energy, or enough energy to power 110,000 homes. The MPCA has a strategic objective to increase the state's waste-to-energy capacity by 60% by 2011. In 2005, Minnesota waste-to-energy reduced carbon dioxide and methane gases by an amount equivalent to taking 90,000 cars off the road. http://www.pca.state.mn.us/publications/reports/lrw-sw-1sy06.pdf

Type(s) of GHG Reductions

CO_2: Upstream Energy Use Reductions—The energy and GHG intensity of manufacturing a product/packaging is generally less using recycled feedstocks than from using virgin feedstocks. Source reduction also reduces upstream energy use, since fewer products/packaging are needed.

CH_4: Diverting biodegradable wastes from landfills will result in a decrease in methane gas releases from landfills.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2015, 2025 ($MMtCO_2e$): 0.96, 3.7

A. Source Reduction: 0, 1.3
B. Recycling: 0.83, 1.8
C. Composting: 0.15, 0.55

Net Cost per $MtCO_2e$: TBD

A. Source Reduction:
B. Recycling:
C. Composting:

Data Sources: Data on current waste generation and recycling rates taken from the 2005 SCORE Programs report.[54] As stated in the goals section above, in 2005, the state of Minnesota had a recycling rate of 41%, a composting rate of 5% (although mostly yard waste, 0.02% was source separated compostables which represented a doubling from the prior year) and an estimated source reduction rate of 3%.GHG emission reductions modeled using EPA's Waste Reduction Model (WARM).[55]

Quantification Methods: Table 7-15 provides the latest Minnesota municipal solid waste (MSW) generation data from the 2005 SCORE report.

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[54] Report on 2005 SCORE Programs, A Summary of Waste Management in Minnesota, MPCA, 2006.

[55] Version 8, May 2006. From http://www.epa.gov/climatechange//wycd/waste/calculators/Warm_home.html. EPA created the Waste Reduction Model (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, $MtCO_2e$, and energy units (million Btu) across a wide range of material types commonly found in MSW. For explanation of methodology, see the EPA report: Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks (EPA530-R-02-006), at http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html.

Table 7-15. Current Minnesota MSW generation

	1991	1998	1999	2000	2001	2002	2003	2004	2005	Changes 2004–2005
Greater Minnesota	1.54	2.07	2.14	2.21	2.32	2.37	2.41	2.53	2.56	1.3%
Metropolitan area	2.37	3.22	3.30	3.42	3.42	3.49	3.51	3.45	3.52	2.1%
Minnesota	3.90	5.29	5.44	5.63	5.74	5.86	5.92	5.98	6.09	1.8%

Projections for waste management in Minnesota were developed based on the 41% current level of recycling and information provided in the 2005 SCORE report. The business-as-usual (BAU) waste management projection for Minnesota is provided in Table 7-16.

Table 7-16. BAU waste management projection for Minnesota

Item	Tons				
	2005	2010	2015	2020	2025
MSW generation (1.9%/year growth 1998–2005)	6,090,000	6,690,957	7,351,215	8,076,627	8,873,623
MSW generation per capita (tons/person)	1.17	1.28	1.40	1.53	1.67
MSW recycled (41%)	2,496,900	2,743,292	3,013,998	3,311,417	3,638,185
MSW disposed in landfills	2,252,874	2,475,186	2,719,435	2,987,787	3,282,619
Waste-to-energy (35% of waste not recycled)	1,243,213	1,365,892	1,500,677	1,648,763	1,811,461
On-site disposal (2%)	71,862	78,953	86,744	95,304	104,709
MSW and source-separated compost (0.7%)	25,152	27,634	30,361	33,356	36,648

To estimate the GHG reductions associated with the changes in MSW management between Tables 7-16 and 7-17, two different WARM runs were conducted to represent BAU and Policy Scenario waste management in 2015 and 2020. WARM provided estimates of GHG reductions due to changes in landfilling practices (including subsequent landfill methane emissions), source reduction, and increased recycling. For source reduction and recycling, WARM estimates life cycle GHG reductions associated with lower energy use from fewer products/packaging being manufactured and fewer raw (virgin) materials being used.

Table 7-17. Waste management projection for Minnesota including policy goals

Item	Tons				
	2005	2010	2015	2020	2025
MSW generation (based on source reduction goals)	6,090,000	6,690,957	7,351,215	8,076,627	8,636,993
MSW generation per capita (tons/person)	1.17	1.28	1.40	1.50	1.46
MSW source reduced	–	–	–	–	236,630
Incremental MSW recycled (2011, 50% rate; 2025, 60% rate)	–	164,598	331,540	463,598	691,255

MSW disposed in landfills (after incremental recycling and composting)	2,252,874	2,171,480	2,078,946	2,081,980	1,848,225
Waste-to-energy (35% of waste not recycled)	1,243,213	1,308,941	1,385,964	1,488,358	1,490,413
On-site disposal (2%)	71,862	75,661	80,114	86,032	86,151
MSW and source-separated compost (2012, 10%; 2020, 15%)	25,152	226,984	460,653	645,242	646,133

To estimate the amount of waste by category in the waste stream, information on recycled/composted quantities was taken from the 2005 SCORE report. Also, the 2005 Solid Waste Policy Report provided some information on the waste characteristics of waste that is not recycled/composted from a 1999 waste sort (see Table 7-y below).[56]

Table 7-y. Profile for Non-Recycled Waste in MN

Component	**Weight %**
Paper	34%
Organics	26%
Mixed Plastic	11%
Mixed Metals	5%
Glass	3%
Other	21%

Additional details are needed for the first three components in the table above (paper, organics, mixed plastics) in order to assess the benefits of source reduction and recycling. Data from EPA's national assessment of solid waste disposal was used for this purpose.[57] The results are shown in Table 7-z below.

Table 7-z. Detailed Profiles for Non-Recycled Waste Components

Assumed Mixed Landfilled Waste Category Profiles	**Weight %**
% of Discarded Paper	
Corrugated Cardboard	31.4%
Magazines/Third Class Mail	12.6%
Newspaper	3.2%
Office Paper	5.9%
Phonebooks	1.3%
Textbooks	2.0%
Mixed Paper, Broad	43.6%
% of Discarded Organics	
Food Waste	70.0%
Yard Trimmings	30.0%

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[56] *2005 Solid Waste Policy Report*, MPCA, 2006, http://www.pca.state.mn.us/publications/reports/lrw-sw-1sy06.pdf, 34% of waste is paper, 11% is plastic, 26% organics (e.g. food, landscaping), 5% metals, and 3% glass.

[57] *Municipal Solid Waste in the United States, 2005 Facts and Figures*, U.S. EPA, Office of Solid Waste, EPA530-R-06-011, October 2006.

% of Discarded Plastics	
HDPE (high density polyethylene)	3.7%
LDPE (low density polyethylene)	10.8%
PET (polyethylene terephthalate)	37.1%
Other (assumed mixed plastics)	48.4%

For the modeling conducted for this policy analysis, the following WARM options were selected: methane generation from landfilled waste is collected; collected methane is used for energy recovery (based on the 2004 national average methane collection collection); and default distances of 20 miles were used between the generator and the landfill, recycling facility, composting facility, or waste to energy plant.

For the BAU modeling runs, in 2015, WARM predicted that current recycling and composting practices will achieve 8.4 MMtCO$_2$e in reductions compared to landfilling the waste. In 2025, current recycling and composting levels would achieve 10.2 MMtCO$_2$e in reductions, as compared to landfilling. For the policy waste management scenario, incremental GHG reductions above BAU were estimated to be 0.99 MtCO$_2$e in 2015 and 2.9 MMtCO$_2$e in 2025. Assuming that policies are being implemented by 2010, cumulative reductions through 2025 are estimated to be 26 MMtCO$_2$e.

Table 7-A below shows the 2025 WARM input data representing BAU waste management. Table 7-B provides the 2025 WARM input for waste management under the policy scenario (incorporating all components: source reduction, recycling, and composting).

Table 7-A. 2025 BAU waste management input data to WARM

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	39,904	39,904	-		NA
Steel Cans	30,980	30,980	-		NA
Copper Wire					NA
Glass	272,548	174,069	98,479		NA
HDPE	17,335	3,975	13,360		NA
LDPE	38,998		38,998		NA
PET	138,742	4,778	133,964		NA
Corrugated Cardboard	882,644	532,192	350,452		NA
Magazines/Third-class Mail	191,185	50,558	140,627		NA
Newspaper	323,797	288,082	35,715		NA
Office Paper	125,629	59,780	65,849		NA
Phonebooks	17,030	2,521	14,509		NA
Textbooks	22,322		22,322		NA
Dimensional Lumber	143,694	143,694	-		NA
Medium-density Fiberboard					NA
Food Scraps	846,811	NA	597,437		249,374
Yard Trimmings	292,692	NA	256,044		36,648
Grass		NA			
Leaves		NA			
Branches		NA			
Mixed Paper (general)	899,587	412,972	486,615		NA
Mixed Paper (primarily residential)		-			NA
Mixed Paper (primarily from offices)					NA
Mixed Metals	807,362	643,231	164,131		NA
Mixed Plastics	174,767	-	174,767		NA
Mixed Recyclables	1,587,633	898,283	689,350		NA
Mixed Organics	-	NA	-		
Mixed MSW	1,811,461	NA	-	1,811,461	NA
Carpet	243	243	-		NA
Personal Computers	10,240	10,240	-		NA
Clay Bricks		NA		NA	NA
Concrete[1]				NA	NA
Fly Ash[2]				NA	NA
Tires[3]	25,017	25,017	-		NA

Please enter data in short tons (1 short ton = 2,000 lbs.)

Please refer to the User's Guide if you need assistance completing this table.

[1] Recycled concrete used as aggregate in the production of new concrete

[2] Recycled fly ash is utilized to displace Portland cement in concrete production.

[3] Recycling tires is defined in this analysis as retreading and does not include other recycling activities (i.e. crumb rubber applications).

Table 7-B. 2025 policy scenario waste management input data to WARM

Material	Baseline Generation	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	39,904	-	39,904			NA
Steel Cans	30,980	-	30,980			NA
Copper Wire	-					NA
Glass	272,548	-	243,195	29,353	-	NA
HDPE	17,335	7,099	3,975	6,261	-	NA
LDPE	38,998	16,564		22,434	-	NA
PET	138,742	47,326	4,778	86,638	-	NA
Corrugated Cardboard	882,644	70,989	601,318	210,337		NA
Magazines/Third-class Mail	191,185	70,989	50,558	69,638		NA
Newspaper	323,797	-	288,082	35,715		NA
Office Paper	125,629	23,663	59,780	42,186		NA
Phonebooks	17,030	-	2,521	14,509		NA
Textbooks	22,322			22,322		NA
Dimensional Lumber	143,694	-	143,694			NA
Medium-density Fiberboard	-					NA
Food Scraps	846,811	NA	NA	145,144		701,667
Yard Trimmings	292,692	NA	NA	62,205		230,487
Grass	-	NA	NA			
Leaves	-	NA	NA			
Branches	-	NA	NA			
Mixed Paper, Broad	899,587	NA	412,972	486,615		NA
Mixed Paper, Resid.	-	NA				NA
Mixed Paper, Office	-	NA				NA
Mixed Metals	807,362	NA	712,357	95,005		NA
Mixed Plastics	174,767	NA	138,251	36,516		NA
Mixed Recyclables	1,587,633	NA	1,243,911	343,722		NA
Mixed Organics	-	NA	NA	-		
Mixed MSW	1,811,461	NA	NA	-	1,811,461	NA
Carpet	243		243			NA
Personal Computers	10,240		10,240			NA
Clay Bricks	-		NA		NA	NA
Concrete[1]	-	NA			NA	NA
Fly Ash[2]	-	NA			NA	NA
Tires[3]	25,017		25,017			NA

Please enter data in short tons (1 short ton = 2,000 lbs.)

Please refer to the User's Guide if you need assistance completing this table.

[1] Recycled concrete used as aggregate in the production of new concrete

[2] Recycled fly ash is utilized to displace Portland cement in concrete production.

[3] Recycling tires is defined in this analysis as retreading and does not include other recycling activities (i.e. crumb rubber applications).

Table 7-C below provides a summary of the overall 2025 GHG benefits achieved through source reduction, recycling, and composting (3.7 MMtCO$_2$e/yr). Of the total benefit achieved in 2025, source reduction provides over 1.3 MMtCO$_2$e (about 35%), recycling provides 1.8 MMtCO$_2$e (about 51%), and composting 0.55 MMtCO$_2$e (combined benefits of composting, plus lower landfilling emissions; about 14%).

Table 7-C. Combined 2025 policy scenario GHG benefits from WARM

Material	Source Reduction (Tons)	Incremental GHG Emissions from Source Reduction (MTCO$_2$E)	Incremental Recycling (Tons)	Incremental GHG Emissions from Recycling (MTCO$_2$E)	Incremental Landfilling (Tons)	Incremental GHG Emissions from Landfilling (MTCO$_2$E)	Incremental Combustion (Tons)	Incremental GHG Emissions from Combustion (MTCO$_2$E)	Incremental Composting (Tons)	Incremental GHG Emissions from Composting (MTCO$_2$E)	Total Incremental GHG Emissions (MTCO$_2$E)
Aluminum Cans	0	0	0	0	0	0	0	0	NA	NA	0
Steel Cans	0	0	0	0	0	0	0	0	NA	NA	0
Copper Wire	0	0	0	0	0	0	0	0	NA	NA	0
Glass	0	0	69,126	(19,207)	(69,126)	(2,627)	0	0	NA	NA	(21,834)
HDPE	7,099	(12,681)	0	0	(7,099)	(270)	0	0	NA	NA	(12,951)
LDPE	16,564	(37,553)	0	0	(16,564)	(629)	0	0	NA	NA	(38,182)
PET	47,326	(99,088)	0	0	(47,326)	(1,799)	0	0	NA	NA	(100,886)
Corrugated Cardboard	70,989	(396,824)	69,126	(215,070)	(140,115)	(56,090)	0	0	NA	NA	(667,983)
Magazines/third-class mail	70,989	(614,168)	0	0	(70,989)	21,373	0	0	NA	NA	(592,794)
Newspaper	0	0	0	0	0	0	0	0	NA	NA	0
Office Paper	23,663	(189,286)	0	0	(23,663)	(45,966)	0	0	NA	NA	(235,251)
Phonebooks	0	0	0	0	0	0	0	0	NA	NA	0
Textbooks	0	0	0	0	0	0	0	0	NA	NA	0
Dimensional Lumber	0	0	0	0	0	0	0	0	NA	NA	0
Medium Density Fiberboard	0	0	0	0	0	0	0	0	NA	NA	0
Food Scraps	NA	NA	NA	NA	(452,293)	(327,326)	0	0	452,293	(89,809)	(417,135)
Yard Trimmings	NA	NA	NA	NA	(193,839)	42,456	0	0	193,839	(38,489)	3,966
Grass	NA	NA	NA	NA	0	0	0	0	0	0	0
Leaves	NA	NA	NA	NA	0	0	0	0	0	0	0
Branches	NA	NA	NA	NA	0	0	0	0	0	0	0
Mixed Paper, Broad	NA	NA	0	0	0	0	0	0	NA	NA	0
Mixed Paper, Resid.	NA	NA	0	0	0	0	0	0	NA	NA	0
Mixed Paper, Office	NA	NA	0	0	0	0	0	0	NA	NA	0
Mixed Metals	NA	NA	69,126	(363,426)	(69,126)	(2,627)	0	0	NA	NA	(366,053)
Mixed Plastics	NA	NA	138,251	(206,568)	(138,251)	(5,254)	0	0	NA	NA	(211,822)
Mixed Recyclables	NA	NA	345,628	(1,007,121)	(345,628)	(48,203)	0	0	NA	NA	(1,055,324)
Mixed Organics	NA	NA	NA	NA	0	0	0	0	0	0	0
Mixed MSW	NA	NA	NA	NA	0	0	0	0	NA	NA	0
Carpet	0	0	0	0	0	0	0	0	NA	NA	0
Personal Computers	0	0	0	0	0	0	0	0	NA	NA	0
Clay Bricks	0	0	NA	NA	0	0	NA	NA	NA	NA	0
Concrete	NA	NA	0	0	0	0	NA	NA	NA	NA	0
Fly Ash	NA	NA	0	0	0	0	NA	NA	NA	NA	0
Tires	0	0	0	0	0	0	0	0	NA	NA	0
Total	236,630	(1,349,599)	691,257	(1,811,391)	(1,574,019)	(426,961)	0	0	646,132	(128,298)	(3,716,250)

Costs

Source Reduction. The net cost for source reduction is the cost associated with implementing the associated programs minus the landfill tipping fees. Program implementation costs include education and program staffing. Costs estimated for implementing source reduction via "Pay as You Throw" (PAYT) programs was estimated at $2.00/household) during the analysis of a similar option in Colorado.[58] Landfill tipping fees are currently $15/ton and are expected to double by 2020.

Recycling. The cost of increasing recycling rates in Minnesota is calculated by taking the difference of the sum of the capital cost and collection cost and the cost saved through avoided landfill tipping fees. The capital costs are determined on a per-household basis, with the figure of $129 per household derived from input given to a similar state climate change planning process in Vermont.[59] The annual cost of collection per household is assumed to be $60 per year ($5 per month per household).[60] The landfill tipping fee is currently $15 per ton, expected to double by 2020.[61]

Composting. 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.[62] These data are summarized in Table 7-18.

Table 7-18. 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

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 7-18. The composting volumes in 2015 and 2025 shown in Table 7-17 suggest the need for about 10 large composting operations by 2015 and another 4 large operations by 2025. To annualize the capital costs for these facilities, CCS assumed a 15-year operating life and a 5% interest rate.

Table 7-19 provides a summary of the annualized costs for each of the policy elements, as well as a total policy cost. The GHG reductions in each year are also included along with the overall cost-effectiveness for the policy.

Table 7-19. Summary of policy costs

To be added.

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[58] Personal communication from E. Lombardi, Eco-Cycle, to B. Strode, CCS, September 5, 2007.

[59] P. Calabrese, Cassella Waste Management, personal communication with S. Roe, CCS, April 26, 2007.

[60] Personal communication from E. Lombardi, Eco-Cycle, to B. Strode, CCS, September 5, 2007.

[61] Ibid.

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

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 MPCA recycling and composting campaigns has been incorporated into the BAU assumptions for this analysis).

Another important assumption is that under BAU, the waste directed to landfilling would include methane recovery (75% collection efficiency) and utilization. The need for this assumption is partly based on limitations of the WARM model (which doesn't allow for management of landfilled waste into both controlled and uncontrolled landfills), but also based on the overall direction of the policy recommendations of AFW-7&8. As shown in AFW-8, one of the policy elements is that all waste deposited in landfills by 2020 will be served by a methane collection system capable of achieving 90% collection and control of methane generated during the lifespan of the landfill.

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 MCCAG moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]

AFW-8. End of Use Waste Management Practices

Policy Description

Promote activities that reduce GHG production during end-of-life disposal activities. Encourage and promote the use of energy recovery technologies for waste materials for which more desirable front–end waste management alternatives are not available or feasible. These projects will help reduce GHG emissions from waste management while producing cleaner energy. These technologies make a two-fold contribution to climate protection: the discharge of methane and other GHGs into the atmosphere is reduced, and the burning of fossil fuels is replaced with recovered energy. For example, the energy created by bioreactor landfills (methane) can be used to make electric power, space heat, or liquefied natural gas.

Policy Design

Goals:

Landfilled Waste—For all waste entering landfills in 2020, 90% of the methane generated over the lifespan of the facility will be captured.

*Organics Recovery and Waste-To-Energy—B*y 2015, achieve a 35% reduction in the landfilling of organic waste through organics recovery (see AFW-7) or waste-to-energy.

Waste-To-Energy Facilities—by 2020, all waste entering waste-to-energy facilities will be pre-processed to remove recoverable materials and enhance energy recovery.

Timing: By 2015, identify which of the available end-of-use practices are best applied to the 1) most energy intensive materials to produce, 2) the largest GHG emitting materials, and 3) by type, the materials that are found in the greatest quantity in the end-of-use waste stream.

Parties Involved: TBD.

Other: After implementing the upper hierarchy Front-End Waste Management goals (Reduce, Reuse, Recycling, Composting in AFW-7), the best End-of-Use practices should be employed to minimize the release of GHG emissions. The Minnesota Pollution Control Agency shall conduct ongoing evaluation of the success of front end abatement activities and the environmental viability and GHG reduction feasibility of different waste management technologies to refine and update information on best practices.

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

Related Policies/Programs in Place

Currently, nine waste-to-energy facilities in Minnesota process 3,800 tons of MSW per day for industrial heat and electrical generation. The total energy reclaimed since 1982, when these facilities first began to come on-line, is the equivalent of 12 million tons of coal. Currently, these facilities produce approximately 100,000 megawatts of electrical energy, or enough energy to power 110,000 homes. The MPCA has a strategic objective to increase the state's waste-to energy capacity by 60% by 2011. In 2005, Minnesota waste-to-energy reduced carbon dioxide and methane gases by an amount equivalent to taking 90,000 cars off the road.

There are twenty-one open mixed municipal landfills in Minnesota. The majority of these facilities are owned and operated by county governments. Two of these facilities (Waste Management's Elk River Facility, and BFI's Pine Bend Facility) currently generate electricity derived from the collection and combustion of the methane gas generated as a result of waste decomposition. Methane is a potent GHG. A third facility, Three Rivers Landfill in Kanabec County, will be capturing methane for the production of energy in the near future. Lyon County is currently assessing the potential of a landfill gas-to-energy project at their county owned facility. The MPCA has been proactive with landfill owners and operators in promoting and encouraging the capture and utilization of this valuable resource.

Type(s) of GHG Reductions

CH_4: Reductions in landfill methane via composting or digestion of organics instead of landfilling. Landfill methane reductions via collection and control (via flaring, or preferentially via energy utilization).

CO_2: Reduction of fossil fuels and associated GHGs through the generation of electricity from landfill methane.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2015, 2025 ($MMtCO_2e$): *Breakout by policy element below.*

A. Landfilled Waste: 0.031, 0.34;

B. Organics Recovery & WTE: 0.11, 0.13;

C. WTE Preprocessing: 0.002, 0.005

Net Cost per $MtCO_2e$: *Breakout by policy element below.*

A. Landfilled Waste: $1;

B. Organics Recovery & WTE: TBD;

C. WTE Preprocessing: not quantified due to lack of data.

Data Sources: This analysis builds on the analysis conducted for AFW-7. Therefore, the same data sources are applicable to this option.

Quantification Methods: ***GHG Reductions.***

A. Methane recovery from landfilled waste. For the waste still entering landfills in 2020 and beyond, CCS used EPA's Landfill Gas Emissions Model (LandGEM) to determine the amount of methane to be generated in subsequent years.[63] Per the policy design, 90% of the methane is to be captured and controlled (either via flaring or for energy recovery). The GHGs reductions associated with this capture and control were then compared to a baseline of methane capture and use from information developed by MPCA to support the MN GHG inventory & forecast.[64]

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[63] The LandGEM User's Guide can be downloaded from: http://www.epa.gov/ttncatc1/dir1/landgem-v302-guide.pdf. The MS Excel-based spreadsheet model can be downloaded from: http://www.epa.gov/ttncatc1/products.html.

[64] P. Ciborowski, MPCA, personal communication and spreadsheet data, supplied to S. Roe, CCS, May 2007.

The benefit of the policy is the incremental GHGs reduced per the 90% collection/control requirement as compared to the baseline.

Based on the results of the WARM modeling to support the analysis of AFW-7, CCS estimated that 1,477,231 tons per year of MSW will be landfilled in 2020 (following all diversion associated with AFW-7&8 policy elements). This annual amount of waste was entered into LandGEM to estimate methane generation from 2020 through 2025. Following the LandGEM modeling, the waste was assumed to be placed into landfills in proportion to the 2004 modeled methane emissions from the I&F (meaning that methane emissions are also assumed to be in proportion to the 2004 data). Based on the 2004 modeled methane emissions, the emplacement fractions for sites with landfill gas to energy (LFGTE) plants, flares, and no controls are provided in Table 8-a below:

Table 8-a. Assumed 2020 waste emplacement

Landfill Type	Emplacement Fraction	2020 Waste Emplacement (tons)
LFGTE	0.49	723,843
Flared	0.10	147,723
Uncontrolled	0.41	605,665

For LFGTE and flared landfills, the BAU assumptions for methane collection and control are 75% (in accordance with standard EPA assumptions). The benefit for achieving 90% collection and control in waste emplaced after 2020 was estimated as the difference between BAU collection/control and the policy scenario. This is shown in Table 8-b below:

Table 8-b. Estimated benefit for increased methane recovery

2025 BAU Methane Emissions by Landfill Type			
LFGTE	87,316	MtC0$_2$e/yr	based on 75%
Flared	18,048	MtC0$_2$e/yr	based on 75%
Uncontrolled	287,820	MtC0$_2$e/yr	
Total	**393,184**	**MtC0$_2$e/yr**	
2025 Policy Scenario Methane Emissions by Landfill Type			
LFGTE	34,927	MtC0$_2$e/yr	based on 90%
Flared	7,219	MtC0$_2$e/yr	based on 90%
Uncontrolled	28,782	MtC0$_2$e/yr	based on 90%
Total	**70,928**	**MtC0$_2$e/yr**	
2025 Benefit	**322,256**	**MMtC0$_2$e/yr**	BAU emissions minus policy scenario emissions

An additional small reduction occurs when the additional methane collected is used for energy. Assuming that the methane recovered from LFGTE sites and uncontrolled sites is used for energy recovery, CCS estimates that an additional 11.9 million cubic meters would be available for energy recovery. Using a factor for landfill methane conversion to electricity with a standard engine/generator set (2.54 kW-hr/m^3)[65], CCS estimated that 30,158 MW-hrs could be produced

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[65] U.S. EPA Landfill Methane Outreach Program, Landfill Gas Energy Cost Model (LFGcost), Version 1.4 *Summary Report, Pechan for NC GHG Mitigation Plan - Scenario 4, LFGE Project Type: Standard Reciprocating Engine-Generator Set*, March 02, 2007.

with this methane. If this electricity is used to offset fossil-based power in MN, the resulting emission reductions would be 21,714 $MtCO_2e$ in 2025.[66]

It was assumed that progress towards implementation of this policy element begins in 2015, so emission reductions begin to accrue in 2015. The estimated cumulative reductions are shown in Table 8-c below:

Table 8-c. Estimated cumulative reductions for increased methane recovery

Year	Avoided Emissions (MMtCO2e)
2007	-
2008	0.000
2009	0.000
2010	0.000
2011	0.000
2012	0.000
2013	0.000
2014	0.000
2015	0.031
2016	0.063
2017	0.094
2018	0.125
2019	0.156
2020	0.188
2021	0.219
2022	0.250
2023	0.281
2024	0.313
2025	0.344
Total	**2.06**

B. Organics recovery and waste-to-energy. From the AFW-7 analysis, CCS developed estimates of the organic fraction of waste still being landfilled following the implementation of the source reduction/recycling. Organic wastes under this policy element include food/yard ("organics") waste, paper and plastic. The total organic waste was multiplied by 35% to determine the amount of organic waste targeted under this policy element. The amount of organic waste being utilized under the AFW-7 composting element was subtracted from this amount to estimate the amount of organic waste remaining for waste to energy (WTE) recovery. The quantification of organic waste available for energy recovery is summarized in Table 8-d below:

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[66] Based on an electricity generation emission factor of 0.72 $MtCO_2e/MW\text{-}hr$ derived from the MN I&F.

Table 8-d. Estimated organic waste for WTE recovery

Waste Management Data	2005	2015	2025
MSW Generation (tons; 1.9%/yr growth 1998-2005)	6,090,000	7,351,215	8,873,623
MSW Generation per capita (tons/person)	1.17	1.40	1.67
BAU MSW Recycled (tons; 41%)	2,496,900	3,013,998	3,638,185
BAU MSW Disposed in landfills (tons)	2,252,874	2,719,435	3,282,619
BAU On-site Disposal (tons; 2%)	71,862	86,744	104,709
BAU MSW & Source-Separated Compost (tons; 0.7%)	25,152	30,361	36,648
Total Organics Landfilled (tons)	1,599,540	1,930,799	2,330,660
35% of Organics Landfilled (tons)	559,839	675,780	815,731
Incremental Organics Composted under AFW-7 (tons)	-	460,653	646,133
Incremental Organics for AFW-8 WTE (tons)	-	184,766	132,950
Total Additional Waste for WTE (tons/day)	-	506	364
“Organics” fraction (e.g. food/yard waste; tons)	-	67,611	48,686
Paper fraction (tons)	-	88,480	63,666
Plastics (tons)	-	28,626	20,598

The benefits of the incremental waste managed by WTE plants were estimated using EPA’s WARM model (see AFW-7 for citations). To do this, further characterization of the waste was needed. Using the same assumptions for landfilled waste characterization as were used in the AFW-7 analysis, the data shown in Table 8-e were developed for input into WARM:

Table 8-e. Estimated 2organic waste tonnages for WTE in WARM

“Organics”	**2015 tons**	**% of total**	**Tons directed to WTE**
Food Waste	494,397	70.0%	53,586
Yard Waste	212,116	30.0%	14,075
Total	706,513		67,661
Landfilled Paper for WTE	**2015 tons**	**% of total**	**Tons directed to WTE**
Corrugated Cardboard	290,327	55.67%	49,260
Magazines/Third-class Mail	116,501	22.34%	19,767
Newspaper	29,587	5.67%	5,020
Office Paper	54,552	10.46%	9,256
Phonebooks	12,020	2.30%	2,039
Textbooks	18,492	3.55%	3,138
Total	521,479		88,480
Landfilled Plastics for WTE	**2015 tons**	**% of total**	**Tons directed to WTE**
HDPE	11,068	4.75%	1,361
LDPE	32,307	13.88%	3,972
PET	110,980	47.67%	13,645
Mixed Plastics	78,475	33.70%	9,648
Total			28,626
“Organics”	**2025 tons**	**% of total**	**Tons directed to WTE**
Food Waste	597,437	70.0%	34,080
Yard Waste	256,044	30.0%	14,606
Total	853,481		48,686

Landfilled Paper for WTE	**2025 tons**	**% of total**	**Tons directed to WTE**
Corrugated Cardboard	350,452	55.67%	35,445
Magazines/Third-class Mail	140,627	22.34%	14,223
Newspaper	35,715	5.67%	3,612
Office Paper	65,849	10.46%	6,660
Phonebooks	14,509	2.30%	1,467
Textbooks	22,322	3.55%	2,258
Total	629,474		63,666
Landfilled Plastics for WTE	**2025 tons**	**% of total**	**Tons directed to WTE**
HDPE	13,360	3.70%	762
LDPE	38,998	10.80%	2,225
PET	133,964	37.10%	7,642
Mixed Plastics	174,767	48.40%	9,969
Total	361,089		20,598

The 2025 input data to WARM are shown in Table 8-f below.

Table 8-f. 2025 waste management input data to WARM

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	39,904	39,904	-		NA
Steel Cans	30,980	30,980	-		NA
Copper Wire					NA
Glass	272,548	243,195	29,353		NA
HDPE	10,236	3,975	6,261		NA
LDPE	22,434		22,434		NA
PET	91,416	4,778	86,638		NA
Corrugated Cardboard	811,655	601,318	210,337		NA
Magazines/Third-class Mail	120,196	50,558	69,638		NA
Newspaper	323,797	288,082	35,715		NA
Office Paper	101,966	59,780	42,186		NA
Phonebooks	17,030	2,521	14,509		NA
Textbooks	22,322		22,322		NA
Dimensional Lumber	143,694	143,694	-		NA
Medium-density Fiberboard					NA
Food Scraps	846,811	NA	145,144		701,667
Yard Trimmings	292,692	NA	62,205		230,487
Grass		NA			
Leaves		NA			
Branches		NA			
Mixed Paper (general)	899,587	412,972	486,615		NA
Mixed Paper (primarily residential)		-			NA
Mixed Paper (primarily from offices)					NA
Mixed Metals	807,362	712,357	95,005		NA
Mixed Plastics	174,767	138,251	36,516		NA
Mixed Recyclables	1,587,633	1,243,911	343,722		NA
Mixed Organics	-	NA	-		
Mixed MSW	1,811,461	NA	-	1,811,461	NA
Carpet	243	243	-		NA
Personal Computers	10,240	10,240	-		NA
Clay Bricks		NA		NA	NA
Concrete[1]				NA	NA
Fly Ash[2]				NA	NA
Tires[3]	25,017	25,017	-		NA

Please enter data in short tons (1 short ton = 2,000 lbs.)

Please refer to the User's Guide if you need assistance completing this table.

[1] Recycled concrete used as aggregate in the production of new concrete

[2] Recycled fly ash is utilized to displace Portland cement in concrete production.

[3] Recycling tires is defined in this analysis as retreading and does not include other recycling activities (i.e. crumb rubber applications).

The results of this WARM modeling provided the incremental benefits for WTE above and beyond that achieved using the waste management approaches recommended in AFW-7. GHG benefits are the sum of reduced landfill methane emissions and GHG emissions offset from fossil fuel combustion using the additional energy in the organic waste directed to WTE plants. In 2015, WARM estimated additional reductions of 0.11 MMtCO$_2$e/yr. In 2025, the estimated incremental GHG reductions are 0.07 MMtCO$_2$e/yr. The reason for the lower reductions in 2025 is that less waste is being directed towards WTE (due to ramp up of the composting element of AFW-7). For the purposes of estimating cumulative benefits, it was assumed that implementation begins in 2008, but that full implementation is not achieved until 2025. The summation of cumulative reductions (1.4 MMtCO$_2$e) is shown in Table 8-g below:

Table 8-g. Estimated cumulative reduction for organic waste to WTE policy element

Year	Avoided Emissions ($MMtCO_2e$)
2007	0.000
2008	0.014
2009	0.028
2010	0.041
2011	0.055
2012	0.069
2013	0.083
2014	0.096
2015	0.110
2016	0.106
2017	0.102
2018	0.098
2019	0.094
2020	0.090
2021	0.086
2022	0.082
2023	0.078
2024	0.074
2025	0.070
Total	**1.38**

C. Preprocessing of MSW at WTE plants. Information developed under AFW-7 on waste generation, characterization and management were used as the starting point for this analysis. In addition, data on current WTE plant combustion of MSW was gathered from the 2005 MPCA waste policy report.[67] Also, information from MPCA on the current (2004) levels of MSW burned in refuse-derived fuel (RDF) versus mass burn facilities in the state was provided by MPCA.[68] This policy element addresses both the existing (BAU) and incremental WTE combusted under the previous AFW-8 policy element. The WTE data are summarized in Table 8-h below. Note that these estimates factor in the additional waste removed from the waste stream via the source reduction, recycling, and composting under AFW-7.

Table 8-h. Estimated future levels of MSW WTE combustion

Current (2005) WTE Combustion (tons)	1,400,000	From 2005 MPCA Solid Waste Report
RDF Fraction	0.25	Derived from MPCA-supplied data
Mass Burn Fraction	0.75	Derived from MPCA-supplied data
2025 WTE Combustion (tons)	1,490,413	Includes the effects of AFW-7 waste management elements.
2025 Incremental WTE Combustion (tons)	647,736	From previous AFW-8 policy element.

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[67] *2005 Solid Waste Policy Report*, MPCA, 2006, http://www.pca.state.mn.us/publications/reports/lrw-sw-1sy06.pdf.

[68] P. Ciborowski, MPCA, personal communication and data files, provided to S. Roe, CCS, May 2007.

2025 Total WTE Combustion (tons)	**2,138,149**	
2025 Total Mass Burn Tons	**1,603,612**	75% of the total MSW combusted

Information from within the WARM model documentation was used to estimate the effects of pre-processing the MSW burned within Minnesota's mass burn plants (based on current practices, 75% is burned in mass burn plants). It was assumed that no additional preprocessing of waste was needed for RDF plants. Since no data were available on the characteristics of waste entering mass burn plants, CCS used information developed under AFW-7 on the assumed characteristics of landfilled waste as a surrogate profile for MSW entering mass burn plants. The estimates for waste entering mass burn WTE plants in 2025 are provided in Table 8-i below:

Table 8-i. Estimated 2025 profile of MSW combusted in mass burn WTE plants

MSW Component	Fraction	2025 Tons
Glass	0.037	59,329
HDPE	0.005	8,542
LDPE	0.016	24,935
PET	0.053	85,658
Corrugated Cardboard	0.083	133,456
Magazines/Third-class Mail	0.044	69,852
Newspaper	0.011	17,739
Office Paper	0.020	32,708
Phonebooks	0.004	7,207
Textbooks	0.007	11,087
Food Scraps	0.224	358,424
Yard Trimmings	0.070	111,607
Mixed Metals	0.079	125,960
Mixed Plastics	0.038	60,569
Mixed Recyclables	0.310	496,538
Total		**1,603,612**

Table 8-j summarizes the calculation of the incremental benefit associated with preprocessing the waste to remove non-combustibles (glass, metals). The heat contents, mass burn combustion efficiencies, and emission factor for avoided utility electricity were all taken from the WARM model documentation.[69] A relatively small benefit of 0.005 MMtCO$_2$e was estimated for 2025 (difference in emissions calculated with and without preprocessing). Implementation is assumed to begin in 2008 with ramp up to full preprocessing of waste by 2025. The 2015 reductions would be 0.002 MMtCO$_2$e and the cumulative reductions would be 0.04 MMtCO$_2$e.

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[69] *Solid Waste Management and Greenhouse Gases, A Life-Cycle Assessment of Emissions and Sinks*, 3rd Ed., September 2006, http://www.epa.gov/climatechange/wycd/waste/SWMGHGreport.html#sections.

Table 8-j. Estimated 2025 benefit for preprocessing waste for mass burn WTE plants

Mass Burn Waste Component	2025 tons	Energy Content (MMBtu/ton)	Mass Burn Combustion System Efficiency	EF for Utility-Generated Electricity ($MtCO_2$/MMBtu Electricity Delivered)	Avoided Utility CO_2/ton combusted	2025 Avoided CO_2 no preprocessing	2025 Avoided CO_2 with preprocessing
Glass	59,329	-0.5	17.8%	0.282	-0.0251	(1,489)	-
HDPE	8,542	37.4	17.8%	0.282	1.8773	16,037	16,037
LDPE	24,935	37.4	17.8%	0.282	1.8773	46,812	46,812
PET	85,658	19.4	17.8%	0.282	0.9738	83,413	83,413
Corrugated Cardboard	133,456	14.1	17.8%	0.282	0.7078	94,456	94,456
Magazines/Third-class Mail	69,852	10.5	17.8%	0.282	0.5271	36,816	36,816
Newspaper	17,739	15.9	17.8%	0.282	0.7981	14,158	14,158
Office Paper	32,708	13.6	17.8%	0.282	0.6827	22,329	22,329
Phonebooks	7,207	15.9	17.8%	0.282	0.7981	5,752	5,752
Textbooks	11,087	13.6	17.8%	0.282	0.6827	7,569	7,569
Food Scraps	358,424	4.7	17.8%	0.282	0.2359	84,560	84,560
Yard Trimmings	111,607	5.6	17.8%	0.282	0.2811	31,372	31,372
Mixed Metals	125,960	-0.5	17.8%	0.282	-0.0251	(3,161)	-
Mixed Plastics	60,569	31.3	17.8%	0.282	1.5711	95,162	95,162
Mixed Recyclables	496,538	10	17.8%	0.282	0.5020	249,242	249,242
Totals	**1,603,612**					**783,027**	**787,678**

Costs

Cost estimates are developed for each of the policy elements below.

A. Methane recovery from landfilled waste. CCS used the results of landfill gas to energy cost modeling performed for a similar policy analysis with EPA's LFGcost model to estimate the costs for this policy element.[70] Landfill methane can be used in a variety of ways for energy recovery. The three most common types of recovery projects are: direct use (gas piped to a nearby facility for use in generating heat or steam); small engine/generator sets (<800 kW); and large engine/generator sets. These three project types were assumed to be the types that would be used for energy recovery. A hypothetical LFGcost model run was performed for each of these three project types with the input data shown in Table 8-k below (NOTE: while the landfill open and closure years do not match up to the post-2020 time period for this policy, they are used to estimate methane generation rates for use within the model and don't affect the estimated costs in 2007 dollars).

Table 8-k. Three landfill methane utilization options modeled

Scenario	**1**	**2**	**3**
Current Controls	None	None	Collection & Flare
Year Landfill Opened	1988	1988	1983
Year Landfill Closed	2010	2010	2017
Annual Waste Acceptance Rate (tons)	38,000	38,000	88,000
Landfill Size (acres)	100	100	200
Technology Employed	Small Engine/ Generator Set	Direct Use (heat or steam)	Engine/ Generator Set
LFGcost Value of Energy Produced	$0.045/kWh	$4.50/MMBtu	$0.045/kWh
Modeled Costs ($/Mt/CO$_2$e)	$2.72	-$0.82	$0.15

The data in the table show that the direct use option results in a net savings (project revenues greater than costs), while the small and standard engine/generator set options result in net costs. Direct use is typically only cost effective when the landfill is within a short radius to the end user (usually a half mile or less). Hence, the opportunities for direct use are limited. Standard engine/generator set projects (800 kW and greater) are used at projects with moderate to large methane production (48 MM cubic feet/year collected on average). Small engine/generator set projects are applicable at smaller sites.

To develop an overall cost for this policy option, CCS used the following assumptions on the mix of projects that would be implemented to achieve the policy's goals: 17% of methane reduced via standard engine/generator set projects (17% of the EPA Landfill Methane Outreach

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[70] U.S. EPA Landfill Methane Outreach Program, Landfill Gas Energy Cost Model (LFGcost), Version 1.4 *Summary Report, Pechan for NC GHG Mitigation Plan - Scenario 4, LFGE Project Type: Standard Reciprocating Engine-Generator Set*, March 02, 2007; *Summary Report, Pechan for NC GHG Mitigation Plan - Scenario 2, No Section 45 Tax Credit LFGE Project Type: Small Engine-Generator Set*, March 02, 2007*; Summary Report, Pechan for NC GHG Mitigation Plan - Scenario 1, LFGE Project Type: Direct Use (0.5 mile pipeline)*, March 02, 2007.

Program database waste in place is at flared sites, which could be candidates for these projects); 20% of methane is controlled by direct use projects (number of projects assumed to be limited by location of end users); and the remaining 63% is assumed to be controlled by small engine/generator set projects. The cost data are summarized in Table 8-l.

Using this blend of LFG energy projects and the LFG cost output data, a blended cost effectiveness estimate of \$1.57/MtCO$_2$e was estimated. This value is fairly conservative (high) in that it assumes a large fraction of the new LFG projects will be small engine/generator set projects, which have higher costs than the other two project types. The blended cost effectiveness estimate was applied to the emission reductions to be achieved in each year by the policy to estimate costs in each year (see Table 8-l).

CCS did not include the effects of the Section 45 Tax Credit for production of renewable energy, since this credit may or may not be available to many of the projects that would be installed due to this policy. Inclusion of this tax credit would have a small effect at lowering the costs for the policy. For example, the cost effectiveness for the small engine/generator set option would decrease from the \$2.72/Mt estimate shown above to \$2.46/Mt.

CCS assumed that additional costs for landfill gas control would begin to be incurred in 2015 (i.e. some sites would need to begin installing controls to meet the 2020 goal of 90% methane collection). Table 8-m below presents the calculation of net present value (NPV) costs and the discounted/levelized cost effectiveness (reductions divided by discounted costs). The NPV of \$2.1 MM was derived using the CCS standard 5% discount rate for the CCAG process.

Table 8-l. Blended cost effectiveness (CE) estimate for three landfill methane utilization options

EPA LFGcost Modeling Data	Total Capital	Average Annual O&M	Annualized Costs	Annual Revenue	Annual Average Reductions (MMtCO2e)	Project Reductions (MMtCO2e)	CE ($/MtCO2e)
Scenario 1. Direct Use (0.5 mi. pipeline)	$621,573	$105,474	$198,088	$219,870	0.024	0.36	(0.82)
Scenario 2. Small Engine	$753,365	$102,141	$214,392	$70,020	0.023	0.34	2.72
Scenario 3. Standard Engine	$2,612,674	$335,475	$724,763	$631,620	0.088	1.32	0.15

Blended Cost Effectiveness	Assumed Methane Fraction Controlled	Fractional CE	Notes
Scenario 1. Direct Use (0.5 mi. pipeline)	0.20	$ (0.16)	For non-LFGTE sites, 83% of LMOP Waste in Place is at uncontrolled sites
Scenario 2. Small Engine	0.63	$ 1.71	Break-out for direct use versus small engine is assumed.
Scenario 3. Standard Engine	0.17	$ 0.03	For non-LFGTE sites, 17% of LMOP Waste In Place is at Flared Sites
		$ 1.57	**Blended CE Estimate**

Table 8-m. Calculation of costs for methane recovery policy element

Year	Avoided Emissions (MMtCO2e)	Annual Costs (2007$)	Discounted Costs	Cost Effectiveness
2007	-	0	0	
2008	0.000	0	0	
2009	0.000	0	0	
2010	0.000	0	0	
2011	0.000	0	0	
2012	0.000	0	0	
2013	0.000	0	0	
2014	0.000	0	0	
2015	0.031	$44,516	$44,516	
2016	0.063	$89,031	$84,792	
2017	0.094	$133,547	$121,131	
2018	0.125	$178,063	$153,817	
2019	0.156	$222,579	$183,116	
2020	0.188	$267,094	$209,275	
2021	0.219	$311,610	$232,528	
2022	0.250	$356,126	$253,092	
2023	0.281	$400,642	$271,170	
2024	0.313	$445,157	$286,952	
2025	0.344	$489,673	$300,617	
Totals	**2.06**	**$2,938,038**	**$2,141,007**	**$1.04**

Costs—Based on the mass of waste available, we'll need to determine if additional WTE plants are needed. If additional plants are needed, we'll need some estimates on capital and operating costs.

Costs. CCS requests feedback on the following assumptions: most of the waste entering Minnesota landfills by 2020 will be directed to larger modern landfill sites that have collection and control systems in place (due to federal NSPS/EG requirements). To achieve compliance with the policy goals, waste would need to be directed to these modern sites. Most industry contacts feel that their modern landfills already do capture 90% or more of the methane generated. Hence, incremental capital costs do not seem to apply to this policy element.

Since it was not included in the policy design, CCS requests input from the TWG on whether to include the incremental costs of methane utilization versus flaring (which could be considered o.k. with the current text).

Waste-To-Energy Facilities. *CCS requests information from the TWG on information regarding the costs and benefits of this policy element. e.g. previous assessments at Minnesota WTE facilities.*

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

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

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

Level of Group Support

TBD – [blank until MCCAG meeting #5 or #6]

Barriers to Consensus

TBD – [blank until final vote by the MCCAG]