Chapter 6
Agriculture, Forestry, and Waste Management

Overview of GHG Emissions

The agriculture, forestry, and waste management (AFW) sectors are directly responsible for moderate amounts of Minnesota's current greenhouse gas (GHG) emissions. The total AFW contribution to carbon dioxide equivalent (CO_2e) net emissions in 2005 was 30 million metric tons (MMt) or about 19% of the State's total. Agricultural emissions include methane (CH_4) and nitrous oxide (N_2O) emissions from enteric fermentation, manure management, agriculture soils, and agriculture residue burning. These emissions were estimated to be about 22 $MMtCO_2e$ in 2005. As shown in Figure 6-1, emissions from soil carbon losses from agricultural soils, manure management, fertilizer application, and crop residues all make significant contributions to the sector totals. Emissions include CO_2 emissions from oxidized soil carbon, application of urea, and application of lime. Sector emissions also include N_2O emissions resulting from activities that increase nitrogen in the soil, including fertilizer (synthetic, organic, and livestock) application and production of nitrogen-fixing crops (legumes). There is no significant agricultural burning activity in Minnesota, and so the emissions were estimated to be zero.

Note that, in keeping with EPA methods and international reporting conventions, the inventory and forecast covers anthropogenic sources of GHGs. There could be some natural sources of GHGs that are not represented in the inventory and forecast; however these are not addressed in the CAPAG process. In the forestry sector, all emissions are treated as anthropogenic; since all of the State's forests are managed in some way (GHG reporting conventions are to treat all managed forests as anthropogenic sources). Sources such as carbon dioxide from forest fires and decomposing biomass are captured within the inventory and forecast (as part of the carbon stock modeling performed by the U.S. Forest Service [USFS]). However, methane emissions from anaerobic decomposition of biomass in forests are not currently captured due to a lack of data.

The contributions from agricultural soils and manure management have grown significantly since 1990, and they are projected to contribute 90% of agricultural emissions by 2020. Emissions from enteric fermentation have stayed the same since 1990 and are projected to stay relatively constant until 2020.

Forestland emissions refer to the net carbon dioxide (CO_2) flux[1] from forested lands in Minnesota, which account for about 32% of the state's land area. As shown in Table 6-1, USFS data suggest that Minnesota forests emitted an average of 3.3 $MMtCO_2e$ per year from 1990 to 2003 (based on recommendations from the USFS). Hence, during this period, forest carbon losses due to forest conversion, wildfire, and disease was estimated to be larger than the CO_2 sequestered in forest carbon pools such as live trees, debris on the forest floor, and forest soils, as well as in harvested wood products (e.g., furniture and lumber) and the landfilling of forest products. It is important to note that on a per acre basis, forests are a net sink for carbon, not a source. A significant fraction of the carbon losses attributed to forests are likely the result of conversion of forest land to non-forest land between 1990 and 2003. The data show an

[1] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.

accumulation of carbon in harvested wood products, but losses in the each of the other forest carbon pools.[2] These rates of sequestration are assumed to remain constant through 2025.

Figure 6-1. Historical and projected net GHG emissions from the Agriculture Sector, Minnesota, 1990–2020

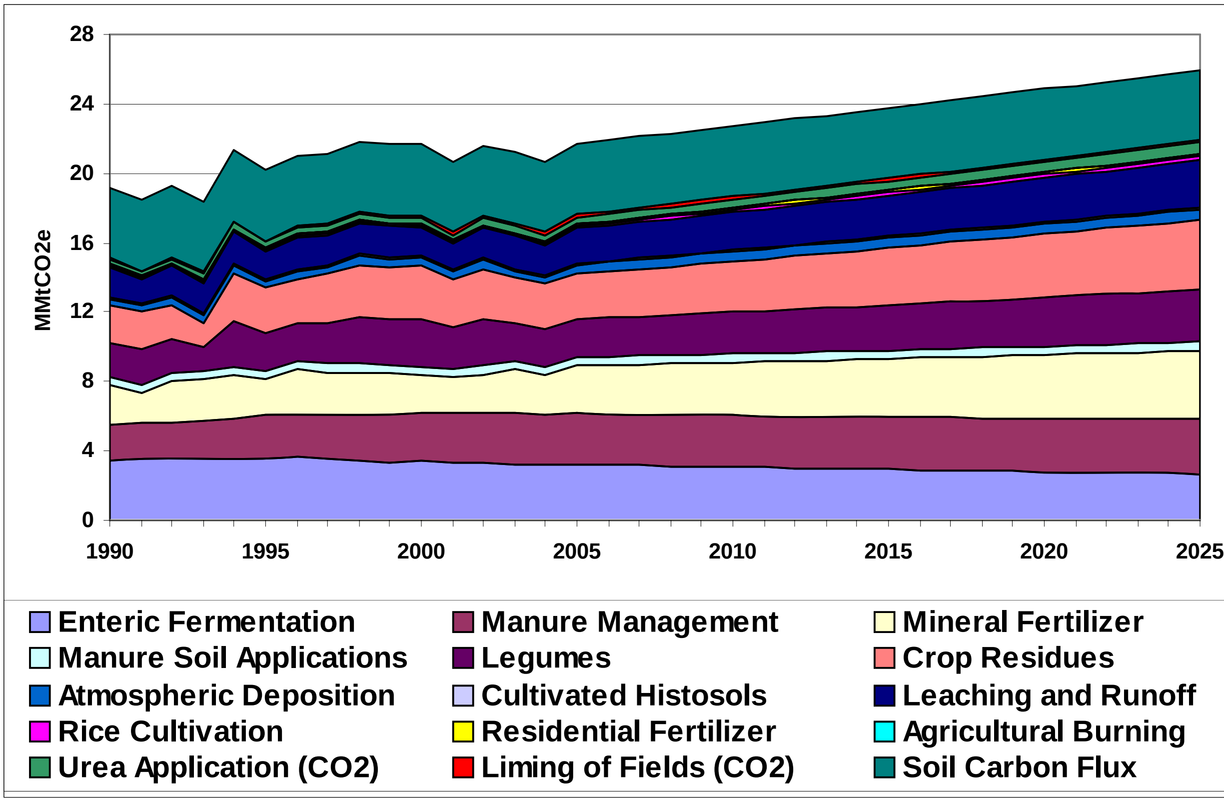


Table 6-1. GHG emissions (sinks) from the Forestry Sector

Forest Pool	1990–2003 Flux (MMtC/year)	1990–2003 Flux ($MMtCO_2$/year)
Forest carbon pools (non-soil)	1.5	5.5
Soil organic carbon	5.9	21.6
Harvested wood products	–0.6	–2.2
Totals	**6.8**	**24.9**
Totals (excluding soil carbon)	**0.9**	**3.3**

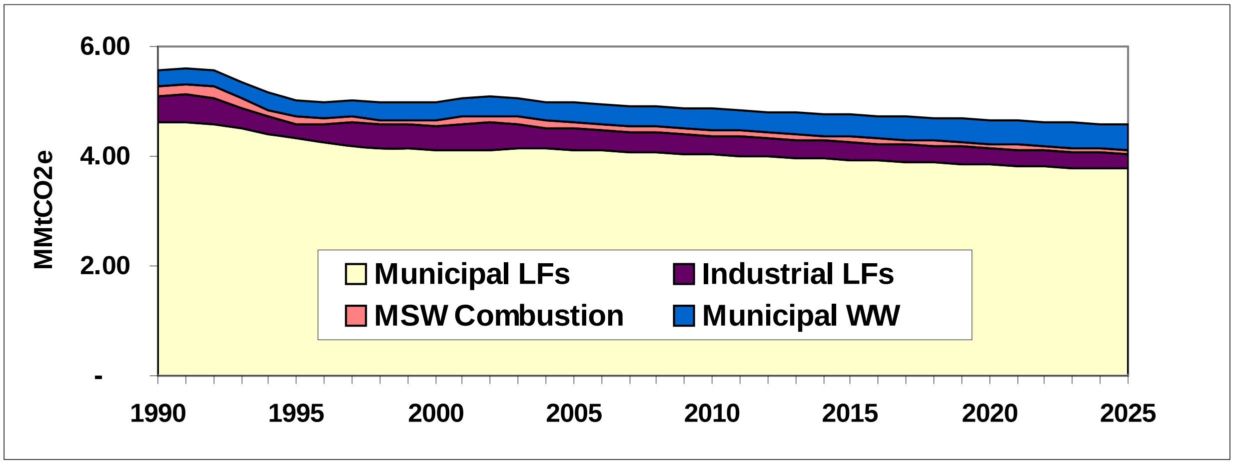
* Positive numbers indicate net emission. Based on USFS input, emissions from soil organic carbon are left out of the forestry sector summary due to a high level of uncertainty.

Figure 6-2 shows estimated historical and projected emissions from the management and treatment of solid waste and wastewater. Emissions from waste management consist largely of

[2] This is not to say that the dead carbon pools (e.g., standing dead, forest floor) are sequestering carbon directly from the atmosphere. These pools accumulate carbon from trees/biomass that transition from a live carbon pool to a dead carbon pool.

CH_4 emitted from landfills, while emissions from wastewater treatment include both CH_4 and N_2O. Emissions are also included for municipal solid waste (MSW) combustion. Overall, the waste management sector accounts for less than 4% of Minnesota's total gross emissions per year from 1990 through 2020.

Figure 6-2. Estimated historical and projected emissions from waste and wastewater management in Minnesota



$MMtCO_2e$ = million metric tons carbon dioxide equivalent; LFs = landfills; WW = wastewater.

The MCCAG acknowledges that there are higher levels of uncertainty in the GHG emissions and forecasts in the AFW sectors compared with those in other GHG sectors (e.g., those where emissions are tied directly to energy consumption). There is a need for continuing investment in research and measurement to refine the AFW I&F (details on key uncertainties are presented in the appendixes of the I&F report).

Opportunities for GHG mitigation in the AFW sector involve measures that can reduce emissions within the sector or reduce emissions in other sectors. Within the sector, changes in crop management practices can reduce GHG emissions by building soil carbon (indirectly sequestering carbon from the atmosphere) or through more efficient nutrient application (reducing N_2O emissions, embedded GHG emissions within the nutrients, and fossil fuel consumption). Reforestation projects can achieve GHG reductions by increasing the carbon sequestration capacity of the State's forests.

For GHG reductions outside of the AFW sector, actions taken within the sector such as production of liquid biofuels can offset emissions in the transportation sector, while biomass energy can reduce emissions in the energy supply (ES) or residential, commercial, and industrial (RCI) sectors. Similarly, actions that promote solid waste reduction or recycling can reduce emissions within the sector (future landfill CH_4), as well as emissions associated with the production of recycled products (recycled products often require less energy to produce than similar products from raw materials). Finally, urban forestry projects can reduce energy consumption within buildings through shading and wind protection.

The following are primary opportunities for GHG mitigation identified by the MCCAG.

- **Agricultural crop management:** Implement programs that incentivize growers to utilize cultivation practices that build soil carbon and reduce nutrient consumption. By building soil carbon, CO_2 is indirectly sequestered from the atmosphere. New technologies in the area of precision agriculture offer opportunities to reduce nutrient application and fossil fuel consumption.
- **Agricultural land use management approaches to protect/enrich soil carbon:** Incentive programs are needed to protect crop lands from conversion to developed use or the conversion of lands in conservation programs to conventional tillage. By protecting these areas from development, the carbon in above-ground biomass and below-ground soil organic carbon can be maintained and additional emissions of CO_2e to the atmosphere can be avoided. Indirectly, these measures also support the objectives of "smart" development by helping to direct more efficient development patterns (see TLU-1). Also, incentive programs could be used to convert lands with a recent history of annual crop production to perennial crops in order to build additional soil carbon. Peatlands and wetlands are recognized to have large stores of soil carbon. After additional study to gain a full understanding of overall carbon dynamics, peatland/wetland protection and enhancement programs should be initiated to protect this stored carbon and to sequester additional carbon in the future.
- **Production of liquid biofuels:** Production of renewable fuels, such as ethanol from crops, crop residue, forestry residue, or municipal solid waste, and biodiesel from crop seed oils can produce significant reductions when they are used to offset consumption of fossil fuels (e.g., gasoline and diesel in the TLU and RCI sectors). This is particularly true when these fuels are produced using processes and/or feedstocks that emit much lower GHG emissions than those from conventional sources. Significant GHG reductions could also be realized by converting existing in-state ethanol production processes to run on renewable fuels (thereby lowering the embedded GHG content and positioning the State's industry to supply states with low carbon fuels standards; including potentially Minnesota; see TLU-3).
- **Expanded use of forest and agricultural biomass:** Expanded use of biomass energy from residue removed from forested areas during treatments to reduce fire risk, crop residues, or purpose-grown crops can achieve GHG benefits by offsetting fossil fuel consumption (to produce either electricity or heat/steam). Programs to expand sustainably procured biomass fuel production will likely be needed to supply a portion of the fuel mix for the renewable energy goals of ES-5.
- **Enhancement/protection of forest carbon sinks:** Through a variety of programs, enhanced levels of CO_2 sequestration can be achieved and carbon stored in the State's forest biomass. These include reforestation programs, restocking of poorly stocked forests, urban tree programs, wildfire risk reduction, and other forest health programs. Programs aimed at reducing the conversion of forested lands to non-forest cover will also be important to turn what is currently a net forest CO_2 source into a net CO_2 sink.
- **Changes in municipal solid waste management practices:** By concentrating on enhancing the source reduction, recycling, and composting practices in the State, significant GHG emission reductions can be achieved. Also, for waste remaining after full implementation of these "front-end" practices, appropriate GHG-beneficial "end-of-life" practices should be

implemented including enhanced landfill gas collection & utilization and pre-processing of waste being sent to waste to energy recovery facilities.

Key Challenges and Opportunities

In the agricultural sector, the MCCAG found significant opportunity in promoting biofuels production using feedstocks and production methods with superior GHG benefits (superior to conventional starch-based ethanol and soybean oil–based biodiesel). It should be noted that the GHG benefits did not include any indirect impacts associated with emissions resulting from land use change.[3] Along with programs to promote the conversion of the existing Minnesota ethanol industry to the use of more renewable fuels, additional biofuels production programs were found to offer substantial GHG reduction potential with an estimated reduction of more than 11 $MMtCO_2e$ by 2025 (see AFW-3). A large fraction of these reductions is provided by the gasoline displacement element of AFW-3 (35% displaced using ethanol or other biofuels by 2025).[4]

MCCAG members were concerned that a 35% gasoline displacement goal (based on energy content) would stretch the state's agronomic and biomass resources and noted that additional and potentially significant impacts should be evaluated regarding availability of land, biomass, and water, consequences for food production, economic feasibility, and changes in overall fuel costs. The MCCAG recommends that the University of Minnesota and other experts, through the Initiative for Renewable Energy, study the biofuels goals and the low-carbon fuel standard (LCFS) contained in AFW-3 and TLU-3, respectively. The study should analyze the feasibility of the proposals for reducing CO_2 emissions, as well as their impacts on land and water use, food production, fuel costs and availability, and the economic impacts on consumers and businesses.

It should be noted that there is significant overlap in benefits with the TLU-3 LCFS recommendation. However, the MCCAG recognizes the need for programs to promote in-state biofuels production. Examples of biofuels that could be produced with much better GHG impacts are ethanol from cellulosic hydrolysis of biomass fiber. Feedstocks for the fiber needed for this recommendation could come from crop residue, energy crops, or forestry residue. A major challenge for the success of AFW-3 is the production of a viable commercial-scale cellulosic ethanol or other biofuels industry by 2015.

MCCAG recommendation AFW-4 promotes the expanded use of biomass as an energy source for producing electricity, heat or steam. Use of biomass to supplant fossil fuels was estimated to reduce about 4 $MMtCO_2e$ by 2025. The MCCAG conducted a limited assessment of the available biomass resources in the state which indicated that sufficient resources were available through 2025 to achieve the goals for both the liquid biofuels recommendation above and this biomass for energy option. However, the MCCAG also recognized the need for additional research into this issue and noted that there are potentially other biomass resources that were not

[3] Recent research (e.g., Searchinger, T., et al., "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change," *Sciencexpress*, February 2008) has indicated that incorporating land conversion impacts into GHG analysis may remove any GHG benefits.

[4] The state's current plan for gasoline displacement is to have 20% gasoline displacement by 2013. The goal for petroleum diesel fuel is 20% by 2015.

assessed (e.g., fiber in the municipal solid waste stream). Research on sustainable harvest standards is also needed with resulting yields potentially impacting available quantities. It was noted that although the initial assessments show sufficient resources to meet the MCCAG's biomass policies, there are a number of variables that are not taken into consideration, including the assumption that all land that is currently available for biomass will still be available in 2015 and 2025; that all available biomass is actually collected; the technology and process to harvest, and the transportation and storage logistics associated with corn stalk usage for biomass are still in the developmental stages; restrictions regarding haying and grazing on CRP; and weather conditions. It will also be necessary to analyze the impact of biomass harvest on plant nutrient removal.

Within the agriculture sector, the MCCAG also recommends programs to promote soil management programs the increase soil carbon levels, thereby indirectly sequestering carbon from the atmosphere. These programs, combined with additional measure to promote more efficient nutrient application, were estimated to achieve reduction of over 2.5 $MMtCO_2e$ per year by 2025. Programs that would assist farmers in reaching the goals of these recommendations include: the Agricultural Best Management Loan Program administered by the Minnesota Department of Agriculture; carbon credit trading programs coordinated by various farm organizations; and new and existing conservation such as the Reinvest in Minnesota Clean Energy Program (RIM-CE), which provide environmental benefits in addition to new opportunities for farmers in developing feedstock bioenergy production.

Land use management approaches to carbon management in the agriculture and forestry sectors are also recommended to protect existing above and below ground carbon stocks and potentially enhance terrestrial sequestration in the future. These include recommendations for additional study on the benefits of peatlands and wetlands conservation (areas that store substantial soil carbon). By preserving agricultural and forested lands (AFW-2a and 6), the MCCAG estimates GHG savings in 2025 of 3.1 $MMtCO_2e$. To achieve these reductions, the state will need to work closely with local planning agencies, land owners, and nongovernmental organizations to identify lands suitable for acquisition/conservation easements and funding mechanisms. Some of the support could come through the Forest Legacy Easements Program, which would minimize forest fragmentation and conversion as industrial land owners divest themselves of forest land holdings. Another benefit to these options, which was not quantified, is the reduction in vehicle-miles traveled due to more efficient development patterns (see TLU-1).

Within the forestry sector, forest management programs (AFW-5) have the potential to deliver over 13 $MMtCO_2e$/year of GHG reductions in 2025. These programs include forestation, urban forestry, wildfire reduction, restocking, and forest health approaches to minimizing terrestrial carbon losses, while enhancing carbon sequestration. The urban forestry component also has the potential to reduce fossil fuel consumption through shading and wind protection of homes and commercial buildings. The overall goal for the forestation option calls for reestablishing forest on one million acres by 2025. For the wildfire risk reduction element, the goals are to identify and prioritize areas where wildfire fuel reduction would substantially reduce the risk of stand-replacing fires and to conduct fuel reduction on 50% of the identified areas by 2015 and 100% by 2025. The MCCAG recommends directing the biomass to the most beneficial uses, including biomass fuel production, where appropriate. For the restocking element, the MCCAG recommends identifying understocked stands on state and county lands by 2010. Then, where appropriate, optimally stock 25% of identified stands by 2015, and all such stands by 2025.

For the forest health and carbon sequestration element of AFW-5, the MCCAG recommends examining the carbon sequestration effects of shifting to desired future forest conditions using carbon-friendly management methods. Further, the state should develop scientific information on forest management options and harvest methods to increase the amount of carbon sequestered in forests. This information should be incorporated into forest management plans for all publicly administered forests by 2015. Also, Minnesota should identify and increase incentives for the durable wood products industry by 2010. Finally, a monitoring program should be established to document the long-term impacts of climate change on Minnesota forests by 2010. While the GHG benefits and costs of this element have not been quantified, GHG benefits over the long-term could be significant.

For urban forestry, the goals are to increase canopy cover in Minnesota communities by 25% by 2025. The costs of tree planting programs can vary substantially depending on whether the labor is paid or unpaid. Hence, strong relationships between all of the related parties are needed (State Department of Forestry, utilities, communities, non-government organizations). Also, the ability to implement these programs in smaller and newer communities on previously cleared land may be limited by the administrative capacity of these communities.

AFW-7 and AFW-8 provide an integrated set of recommendations for future management of municipal solid waste in Minnesota. AFW-7 focuses on “front-end” waste management technologies: source reduction, recycling, and composting, while AFW-8 focuses on “end-of-life” waste management approaches. The recommendations for AFW-7 represent a significant change from BAU waste management in the State: for source reduction, the goal is to achieve 0% increase in waste generation per capita by 2020 and a reduction of 3% in waste generation per capita by 2025;[5] for recycling, a 50% recycling rate should be achieved by 2011 and a 60% recycling rate by 2025;[6] and for composting, a rate of 10% by 2012 and 15% by 2020.[7] The recycling and composting elements achieve a total of 75% diversion of waste from landfilling or waste to energy (WTE) by 2025. The combined “front-end” waste management elements produce substantial GHG savings of 7.4 $MMtCO_2e$ in 2025. These include avoided landfill GHG emissions, as well as avoided product/packaging lifecycle GHG emissions from source reduction and recycling.

Although AFW-7 is estimated in net societal cost savings, successful implementation will require waste management infrastructure investment by communities in the form of material recovery facilities and composting operations. State and local agency costs will also be incurred to develop and implement source reduction programs. Cost savings result from avoided landfill fees and the addition of the value of recycled or composted materials.

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[5] Currently, waste generation per capita is increasing by a little less than 1% per year (as shown in the AFW-7 analysis of Appendix I).

[6] This recycling rate includes waste re-use (e.g. use of food waste in livestock feeding programs). The 2005 rate was 41%.

[7] While a full accounting of current composting levels in the State is not available, available data from MPCA suggest that it is no more than one or two percent of total generation (see Appendix I, AFW-7 analysis).

The recommendations provided in AFW-8 are expected to deliver another 0.6 $MMtCO_2e$ by 2025 (after accounting for the overlap with AFW-7). The important incremental “end-of-use” elements of AFW-8 are more stringent landfill gas collection and control requirements in the post-2020 time-frame and a requirement for all waste sent to WTE facilities to be pre-processed prior to combustion to remove non-combustible materials (e.g., metal and glass). This results in higher efficiencies for the WTE plant and lower GHG emissions.

In order to gain a sense of the importance of these two waste management options, the MCCAG also performed an assessment to compare the GHG benefits of current MPCA goals to the goals[8] of AFW-7&8. The following are the results of this comparison: the combined 2025 benefit of AFW-7&8 was 8.0 $MMtCO_2e$ compared with 0.57 $MMtCO_2e$ for the current MPCA waste management goals; the cumulative 2008–2025 benefit was 75 $MMtCO_2e$ for AFW-7&8 compared with 7.4 $MMtCO_2e$ for the current MPCA goals; and there was a cost-effectiveness of –\$4/tCO_2e for AFW-7&8 compared with \$117/tCO_2e for the current MPCA waste management goals.

Overview of Policy Recommendations and Estimated Impacts

As noted above, the 12 policy recommendation for the AFW sector address a diverse array of activities. Taken as a whole, they offer significant cost-effective emission reductions, as shown in Table 6-2.

Table 6-2. Summary list of policy recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008–2025 (Million $)	Cost-Effective-ness ($/$tCO_2e$)	Level of Support
		2015	2025	Total 2008 2025			
AFW-1	Agricultural Crop Management						Unanimous
	A. Soil Carbon Management	0.72	1.3	15	–$34	–$2	
	B. Nutrient Management	0.79	1.3	15	–$543	–$37	
AFW-2	Land Use Management Approaches for Protection and Enrichment of Soil Carbon						Unanimous
	A. Preserve Land	0.15	0.44	3.7	$120	$33	
	B. Reinvest in Minnesota–Clean Energy (RIM-CE)	0.09	0.19	1.8	$59	$34	
	C. Protection of Peatlands & Wetlands	*Not Quantified*					
AFW-3	In-State Liquid Biofuels Production						Supermajority (4 objections)
	A. Ethanol Carbon Content	1.8	2.2	27	–$242	–$9	
	B. Fossil Diesel Displacement	0.03	0.19	1.4	$74	$55	
	C. Gasoline 35% Displacement	2.8	9.1	73	$336	$5	
AFW-4	Expanded Use of Biomass Feedstocks for Electricity, Heat, or Steam Production	1.3	3.8	31	$102	$3	Unanimous

[8] As documented in Appendix I (AFW-8, Feasibility Issues), the assumptions of current MPCA waste management goals are: BAU waste generation, as shown in Table 35 of Appendix I, (i.e., no source reduction); recycling rates remain on a BAU track of 41% (38% conventional recycling and 3% organics reuse); and 30% of total waste generation is directed to WTE in 2011 (as shown in Table 35 of Appendix I, current BAU waste management is estimated to direct about 20% of waste generation to WTE in 2011).

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2008–2025 (Million $)	Cost-Effective-ness ($/tCO_2e$)	Level of Support
		2015	2025	Total 2008 2025			
AFW-5	Forestry Management Programs to Enhance GHG Benefits						Unanimous
	A. Forestation	0.55	2.2	17	$218	$13	
	B. Urban Forestry	1.2	2.7	26	–$295	–$12	
	C. Wildfire Reduction	*Not quantified*					
	D. Restocking	2.1	8.4	65	$2,187	$33	
	E. Forest Health and Enhanced Sequestration	*Not quantified*					
AFW-6	Forest Protection—Reduced Clearing and Conversion to Non-Forest Cover	2.2	2.7	34	$101	$3	Unanimous
AFW-7	Front-End Waste Management Technologies						Unanimous
	A. Source Reduction	0	3.6	20	$59	$3	
	B. Recycling	3.1	3.4	45	–$207	–$5	
	C. Composting	0.29	0.41	4.9	$137	$28	
AFW-8	End-of-Life Waste Management Practices						Unanimous
	A. Landfilled Waste Methane	0.07	0.73	4.4	$5.7	$1	
	B. Residuals Management	0.52	0.63	8.1	$650	$80	
	C. WTE Preprocessing	0.37	0.84	7.9	$257	$32	
	Sector Total After Adjusting for Overlaps*	**13.2**	**29.5**	**279**	**$2,090**	**$7**	
	Reductions From Recent Actions	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	
	Sector Total Plus Recent Actions	**13.2**	**29.5**	**279**	**$2,090**	**$7**	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons carbon dioxide equivalent; $/$tCO_2e$ = dollars per ton of carbon dioxide equivalent; WTE = waste to energy.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings associated with the recommendations. Totals in some columns may not add to the totals shown due to rounding.

*Overlaps include an assumed 100% overlap of AFW-3b&3c with TLU-3 (reductions excluded from AFW totals); an assumed 100% overlap of AFW-4 with ES-5 (reductions and costs excluded from AFW totals); overlap of AFW-7&8 (incremental benefits and costs of AFW-8 included in the AFW totals).

Agriculture, Forestry, and Waste Management Sector Policy Descriptions

The Agriculture, Forestry, and Waste Management Sectors include emissions mitigation opportunities related to the use of biomass energy, protection and enhancement of forest and agricultural carbon sinks, control of agricultural N_2O emissions, production of renewable liquid fuels, production of additional biomass energy, forestation on non-forested lands, and an increase in municipal solid waste source reduction, recycling, composting, landfill gas collection, and waste to energy pre-processing.

AFW-1 Agricultural Crop Management

This policy recommendation 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 may regulate the net flux of carbon dioxide (CO_2) from soil. Each farm operation and each field management unit has unique traits that may allow management practices to influence nutrient, water, and carbon cycling and sequestration. Defining GHG outcomes based upon management indices may 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 and 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, which can result in plants not fully metabolizing the nitrogen, allowing the nitrogen to leach into groundwater and/or be emitted to the atmosphere as nitrous oxide (N_2O). Better nutrient utilization can lead to lower N_2O emissions from runoff. An example is tile drainage systems that use the latest technology and design models to reduce nitrates leaching into surface water and groundwater.

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

This policy converts 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. This includes opportunities to keep CRP, Conservation Reserve Enhancement Program (CREP), and Reinvest in Minnesota (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.

Wetlands have among the highest potential carbon-sequestration capacities for any type of land cover in Minnesota. Peatlands are likely Minnesota's largest single carbon sink, containing 37% of all carbon stored in the state, compared with 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 CO_2 and CH_4. 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 wetland conservation policies to reduce the risk of releases of stored GHGs from these systems.

AFW-3 In-State Liquid Biofuels Production

This policy promotes sustainable in-state production and consumption of transportation biofuels from agriculture and/or agroforestry feedstocks to displace the use of gasoline and diesel. It decreases 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 needed to be developed for low-carbon biofuels, so that producers are rewarded accordingly.

This policy also promotes the in-state development of feedstocks, such as cellulosic material and perennials that are able to be utilized. Recognizing that conversion technologies, such as thermo-chemical Fischer-Tropsch processes and enzymatic conversion, are developing fast in this sector, the policy recommends facilitating, but not requiring, their development.

AFW-3 also promotes multiple biofuel (ethanol, biodiesel, biobutanol) production systems that improve the embedded energy content, life cycle, and carbon profile of biofuels. It focuses on plant material feedstocks that favor energy production, that are carbon neutral or negative, and that 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.

To achieve true gains in reducing GHGs, promoting biofuel production must be coupled with strong policies to reduce overall transportation fuel consumption. 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 (resulting from out-of-state fuels produced using feedstocks/production methods with lower GHG benefits, and from transportation of biodiesel, ethanol, other fuels, or their feedstocks from distant sources).

Note: This recommendation is linked with the Transportation and Land Use recommendation TLU-3, a Low-Carbon Fuels Standard. It seeks to achieve incremental GHG benefits beyond the TLU recommendation by promoting in-state production of biofuels using feedstocks with greater GHG benefits than the likely BAU national production methods. Further, AFW-3 focuses on the supply elements of the implementation of a biofuels program while TLU-3 focuses on the demand side (e.g., vehicle technology requirements, E10, E85).

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

This policy dedicates a sustainable quantity of biomass from agricultural lands, land restoration activity, agricultural industry residues, wood industry process residues, those normally unused forestry residues, and agroforestry 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, impacts on water supply and quality, control of air emissions, solid waste management, cropping management, nutrient management, soil and non-soil carbon management, and impacts on biodiversity and wildlife habitat). The objective is to create concurrent reduction of CO_2 due to displacement of fossil fuel considering life cycle GHG emissions associated with viable collection, hauling, and energy conversion and distribution systems.

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

- Any organic material grown for the purpose of being converted to energy.
- Any organic by-product of agriculture that can be converted into energy.
- 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:
  - A forest-related organic resource, including mill residues, pre-commercial thinnings, slash, brush, or by-product from conversion of trees to merchantable material; or
  - 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 Minnesota theoretically has enough residual biomass and energy crops that, if collected and fed to the most efficient conversion technologies available, could produce up to 99% of the total electricity currently used in the state. Actual results are highly dependent on economically attractive methods for collection of materials, hauling, and energy conversion and 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.

AFW-5 Forestry Management Programs to Enhance GHG Benefits

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

- 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. Emission reductions from reduced heating and cooling as a result of planting shade trees are a significant co-benefit.
- 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 such practices as soil preparation, erosion control, and stand stocking to ensure conditions that support forest growth.
- 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, increasing the stocking of poorly stocked lands, managing thinning and density, and increasing the acreage of short-rotation woody crops (for fiber and energy) on agricultural lands previously converted from forestland.

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 decreases GHG emissions by maintaining the carbon sequestration potential of healthy forests.

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

In the mid- to late 1800s, forests covered 31 million acres in Minnesota. Over the subsequent 100-plus years, 15 million acres of this forestland were 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.[9] Because forestland captures and stores CO_2 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.

AFW-7 Front-End Waste Management Technologies

Front-end waste management technologies promote the reduction of the sheer volume of waste produced, as well as 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 disposal emissions, but also from product life cycle emission reductions (associated with the manufacture and transport of new packaging and products). Redirecting organic wastes (such as food, yard, and paper) from landfills into composting programs is very effective at reducing GHG emissions.

AFW-8 End-of-Life Waste Management Practices

This policy promotes activities that further reduce GHG production by encouraging the use of energy recovery technologies for materials not managed by AFW-7 (Front-End Waste Management Technologies). It also encourages the use of energy recovery technologies for waste materials for which more desirable front-end waste management alternatives are not available or feasible. These technologies will help reduce GHG emissions from waste management, while producing cleaner energy. They make a two-fold contribution to climate protection, by reducing the discharge of methane and other GHGs into the atmosphere, and replacing fossil fuel burning with recovered energy. For example, the energy created by landfills (methane) can be used to make electric power, space heat, or liquefied natural gas. WTE

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[9] Minnesota Pollution Control Agency and Center for Climate Strategies. Appendix H: Forestry, p. H-3, Table H1, "USFS Carbon Pool Data for Minnesota." June 7, 2007. See http://www.mnclimatechange.us/ewebeditpro/items/O3F12645.pdf

facilities already in existence in Minnesota generate 100 MW of electricity and 150,000 lb/hour of steam for heating and cooling and use by other industries.