Agriculture, Forestry, and Waste Management (AFW) Subcommittee

Summary List of Draft Priority Policy Options for Analysis

Policy No.	Policy Option	GHG Reductions (MMtCO$_2$e)			Net Present Value 2009–2020 (Million $)	Cost-Effective-ness ($/tCO$_2$e)	Status of Option
		2012	2020	Total 2009–2020			
AFW-1	Nutrient Management	0.13	0.64	3.58	$306	$86	Pending
AFW-2	Wetlands and Drainage	N/Q	N/Q	N/Q	N/Q	N/Q	Pending
AFW-3	Expanded Use of Agriculture and Forestry Biomass Feedstocks for Electricity, Heat or Steam Production	3.14	15.36	86.5	$4061	$47	Pending
AFW-4	Encourage Large-Scale Manure/Methane Management Capture Utilization						Pending
	Methane Management Capture Utilization	0.96	2.64	18.00	$135	$8	
	Manure Management	TBD	TBD	TBD	TBD	TBD	
AFW-5	Land Management to Promote Sequestration Benefits						Pending
	Conservation Tillage	2.87	8.60	55.92	–$188	–$3	
	Agriculture Land Conversion	0.13	0.40	2.53	$202	$80	
	Conservation Grazing	0.09	0.28	1.74	-$120	-$69	
	Afforestation	0.21	0.62	4.05	$211	$52	
	Urban Forestry	0.23	0.70	4.55	-$99	-$22	
AFW-6	Cellulosic Fuel Incentives	1.1	3.5	20.7	$1,020	$49	Pending
AFW-7	Improved On-Farm (or First Point of Purchase) Energy Use and Efficiency						Pending
	Renewable Energy	0.02	0.08	0.45	$13	$29	
	Energy Efficiency	0.24	0.94	5.86	–$533	–$91	
AFW-8	Waste Management Strategies	1.5	4.1	26.5	-$220	–$8	Pending
AFW-9	Landfill Methane Energy Programs	0.26	0.87	5.4	$2	$0.3	Pending

GHG = greenhouse gas; MMtCO$_2$e = million metric tons of carbon dioxide equivalent; $/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent N/Q = not quantified; TBD = to be determined.

ICCAC Policies: Biomass Supply and Demand Assessment

Biomass Resource	Annual Biomass Supply (dry tons)	Notes
Forest residue[1]	396,000	2005 NREL Report.[2] Estimated using USDA Forest Service's Timber Product Output database for 2002, includes logging residues and other removals.
Primary mill residue (unused)	2,000	2005 NREL Report. Derived from the USDA Forest Service's Timber Product Output database for 2002, includes mill residues burned as waste or landfilled.
Secondary mill residue	32,000	2005 NREL Report. Includes wood scraps and sawdust from woodworking shops— furniture factories, wood container and pallet mills, and wholesale lumberyards. Estimated using number of businesses from the U.S. Census Bureau, 2002 County Business Patterns and assumptions on the wood waste generated.
Urban wood waste	353,000	2005 NREL Report. Includes MSW wood—wood chips, pallets, and yard waste; utility tree trimming and/or private tree companies; and construction/demolition wood. Data on the collected urban wood waste are not available; thus numerous assumptions were applied for estimation.
Agricultural residue	26,003,000	2005 NREL Report. Estimated using 2002 total grain production, crop to residue ratio, moisture content, and taking into consideration the amount of residue left on the field for soil protection, grazing, and other agricultural activities. The NREL report assumes that about 35% of the total residue could be collected as biomass a biomass feedstock. The NREL report assumes that 30% residue cover is reasonable for soil protection, 20%–25% of the stover in grazing, and about 10%–15% of the crop residue is used for other purposes: bedding, silage, etc.
Energy crop		2005 NREL Report estimates a potential 11,297,000 tons of switchgrass could be grown on CRP lands.
Willow or hybrid poplar		2005 NREL Report estimates a potential 9,413,000 tons of willow or hybrid poplar could be grown on CRP lands.
Poultry litter		
Municipal solid waste (MSW) fiber		
Wood pulp		
Yard and landscape waste debris		
Total annual biomass supply	30,116,000	
Policy Requiring Biomass	**2020 Annual Biomass Demand (dry tons)**	**Notes**

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[1] Forest residue data for the NREL report was derived from the USDA Forest Service's Timber Product Output database for 2002. In this category NREL included logging residues and other removals. NREL defined logging residues as "the unused portions of trees cut, or killed by logging, and left in the woods. Other removals are considered trees cut or otherwise killed by cultural operations (e.g. pre-commercial thinning, weeding, etc.) or land clearings and forest uses that are not directly associated with round wood product harvests.

[2] *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.

Biomass Resource	Annual Biomass Supply (dry tons)	Notes
AFW-3	16,000,000	From goals: Annually harvest at least 5 million dry tons of dedicated energy crop production, 10 million tons of annual crop residue, and 1 million tons of forest products or wood residues.
AFW-6	10,000,000	From goals: Increase in-state cellulosic feedstock production by 10 million dry tons by 2020.

AFW-1. Nutrient Management

Policy Description

Demonstrate and encourage the implementation of GHG-beneficial management practices including: nutrient and soil management techniques to lower N_2O emissions and increase soil carbon retention;[3] limit or restrict nitrogen fertilizer application on seasonally flooded field areas; and increase use of cover crops.[4]

Improve the efficiency of fertilizer use and other nitrogen-based soil amendment use through implementation of improved management practices; development and use of crops and crop hybrids/varieties capable of improved nutrient uptake efficiency; and full accounting of nutrient applications through manure and other organic based nutrient sources.

Support research critical for identifying GHG emissions associated with different nutrient management practices and research identifying those practices leading to reduced net GHG emissions.

Policy Design

Goals:

- *Efficiency*—Increase fertilizer use efficiency (in terms of N applied per crop yield) by 10% by 2020.
- *Seasonally Flooded Areas*—Reduction of N application by 50% on 50% of seasonally flooded areas by 2020.
- *Improved Nutrient Distribution*—Provide more of the state's cropland nitrogen requirements through improved distribution of natural and organic nitrogen sources (manures). Replace 10 percent of manufactured nitrogen sources through better manure distribution by 2020.

Timing: Most of these are currently being considered and implemented for economic reasons, i.e., nutrient credit for manure (however all operators do not yet credit suitably). Restricting application from seasonally flooded areas will require additional technology capable of site specific applications based on land form in addition to that from soil test maps.

Parties Involved: Industry, scientists, and producers.

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[3] The dilemma relative to nutrient management, nitrogen in particular, involves balances. The Subcommittee is confident, for example, that mandating nitrogen application reductions would reduce N_2O emissions and GHG emissions associated with nitrogen manufacture. However, reduced rates would very likely result in lower yields, lower plant biomass production, and net loss of soil organic matter and CO_2 emissions. We have the science to understand direction of change, but do not have the scientific capability to quantify these input/output values on a highly variable landscape in a variable climate and thus determine whether or not a given recommendations would make us consistently winners or losers.

[4] Cover crops have been studied for decades with marginal advances and at this time seem somewhat risky as a required target mandate for this group. Research investment is needed to develop cropping systems in which cover crops are complimentary to rather than competitive with the primary crop.

Other:

Implementation Mechanisms

Possible methods to increase the efficiency (yield/N input) include:

- Incentives to encourage rapid adoption of new seed technologies that result in higher N utilization
- Incentives for more soil testing
- Support for educational efforts on N utilization and fertilization practices
- Incentives for more precision placement of N fertilizers

Related Policies/Programs in Place

None identified.

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

Data Sources:

Efficiency—Annual N_2O emissions from synthetic fertilizer and manure applications (Table H-5) were taken from the Iowa Inventory & Forecast. The average reduction in fertilizer usage resulting from implementation of nutrient management practices (15%) was taken from an EPA guidance document.[5] Cost information for synthetic fertilizers was taken from the USDA ERS.[6] The average cost of synthetic nitrogen fertilizers in the United States in 2007 was $370/ton. Information on US and Iowa corn crops were used to estimate corn yields for 2005–2020.[7]

Seasonally Flooded Areas—Iowa State University figures were used to determine the amount of wetlands in the state of Iowa.[8] CRP data was used to determine the amount of wetlands which are currently under cultivation in the state.[9]

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[5] "Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters," http://www.epa.gov/owow/nps/MMGI/Chapter2/ch2-2c.html#Practices, Table 2-14.

[6] USDA Fertilizer Costs, 2007. http://www.ers.usda.gov/Data/FertilizerUse/Tables/Table7.xls.

[7] Food and Agriculture Policy Research Institute. National Corn Production. http://www.fapri.iastate.edu/tools/outlook.aspx

[8] Iowa State University. National Wetlands Inventory. http://www.ag.iastate.edu/centers/iawetlands/NWIhome.html

[9] Conservation Reserve Program. Monthly Summary, March 2008. http://www.fsa.usda.gov/Internet/FSA_File/mar2008.pdf

Improved Nutrient Distribution—

Quantification Methods:

Nitrogen Efficiency GHG Benefits

The GHG benefits of this option are quantified by calculating the CO_2e emissions per kg of N applied in Iowa. This uses a figure of the N emissions from fertilizer (4.76 kg CO_2e per kg of N applied), calculated from the Iowa Inventory and Forecast. This is then combined with a figure for the life cycle emissions of nitrogen fertilizer (West and Marland, 2001).[10] A business as usual projection is created for both fertilizer use (1.4% annually, from a linear projection of historical fertilizer use) and corn production (from FAPRI database) through the year 2020. In order to increase efficiency (corn production/fertilizer use) by 10%, fertilizer use is then reduced from the BAU estimate. Costs were calculated based on an estimate of the staffing, laboratory and travel costs to create an information program to encourage better nutrient management (500k/year + startup costs) and soil testing costs (20$/75 acre field, tested every 4 years). There were also cost savings in terms of reduced costs of nitrogen fertilizer (385$/ton N).

Table 1-1 Costs and GHG Reductions from Nutrient Management

Year	Fertilizer Used (With Policies)	Target Fertilizer Reduction (kg N)	Annual Cost of Fertilizer Programs ($MM)	Avoided Cost of Fertilizer ($MM)	Net Cost	Discounted Cost ($MM)	$MMtCO_2e$ Emissions Reductions
2009	0	0	$0	$0	$0	$0	0.00
2010	0	0	$0	$0	$0	$0	0.00
2011	1,026,896	10,269	$2.85	$(3.95)	$(1.09)	$(0.82)	0.06
2012	1,016,828	20,337	$2.60	$(7.82)	(5.22)	$(3.71)	0.11
2013	1,006,956	30,209	$2.60	$(11.62)	$(9.01)	$(6.10)	0.17
2014	997,274	39,891	$2.60	$(15.34)	$(12.74)	$(8.21)	0.22
2015	987,776	49,389	$2.60	$(18.99)	$ (16.39)	$(10.06)	0.28
2016	978,458	58,707	$2.60	$(22.58)	$(19.97)	$(11.68)	0.33
2017	969,313	67,852	$2.60	$(26.10)	$(23.49)	$(13.08)	0.38
2018	960,338	76,827	$2.60	$(29.55)	$ (26.94)	$(14.29)	0.43
2019	951,528	85,637	$2.60	$(32.94)	$ (30.33)	$(15.32)	0.48
2020	942,877	94,288	$2.60	$(36.26)	$(33.66)	$(16.19)	0.53

Seasonally Flooded Areas—

The amount of farmable wetlands in Iowa was estimated based on the acres of farmable wetlands covered by the conservation reserve program divided by the number of acres of total wetlands under the CRP.[11] This percentage (51%) was then multiplied by the total amount of wetlands in

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[10] West, T. O. and Marland, G. 2001. A Synthesis of Carbon Sequestration, Carbon Emissions and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States. Agriculture, Ecosystems and Environment 1812.

[11] http://www.fsa.usda.gov/Internet/FSA_File/mar2008.pdf

Iowa, as estimated by Iowa State University. These farmable acres (218,821) were then assumed to have similar fertilizer use to the state as a whole. These acres were divided by the total acres under cultivation in Iowa to determine what percentage of Iowa farmland is located in wetlands (0.7%). This was then multiplied by the BAU estimates of fertilizer use created from the Nitrogen Efficiency quantification to determine the BAU fertilizer used on wetlands. This fertilizer use is then projected to decrease by 50% on 50% of land in the state, or a 25% reduction overall by 2020. The GHG benefits of this are estimated based on the reduced N fertilizer use multiplied by the CO_2e emissions/kg N applied, as described in the Nitrogen Efficiency quantification above. Costs of this program were estimated to be 30–50$/acre mostly in extra labor, fuel and capital costs for machinery upgrades to do the differential applications.[12] There were also cost savings in terms of reduced costs of nitrogen fertilizer (385$/ton N).

Table 1-2: Costs and GHG Reductions from Seasonally Flooded Areas

Year	Reduction Pathway	Acres Under Policy	Cost	Nitrogen Avoided (metric tons)	Cost Savings	Discounted Cost (2005$)	Emissions Reductions ($MMtCO_2e$)
2008	1.00	0	$0	0	$0	$0	0.000
2009	1.00	0	$0	0	$0	$0	0.000
2010	1.00	0	$0	0	$0	$0	0.000
2011	1.02	8,753	$350,114	141	$54,333	$220,716	0.001
2012	1.04	17,506	$700,228	277	$106,577	$421,897	0.002
2013	1.06	26,259	$1,050,341	408	$156,849	$604,751	0.002
2014	1.08	35,011	$1,400,455	534	$205,259	$770,434	0.003
2015	1.10	43,764	$1,750,569	655	$251,909	$920,047	0.004
2016	1.13	56,893	$2,275,740	829	$318,787	$1,144,190	0.005
2017	1.16	70,023	$2,800,910	994	$382,206	$1,346,825	0.006
2018	1.19	83,152	$3,326,081	1,150	$442,428	$1,529,263	0.006
2019	1.22	96,281	$3,851,252	1,299	$499,688	$1,692,768	0.007
2020	1.25	109,411	$4,376,423	1,441	$554,199	$1,838,555	0.008

Improved Nutrient Distribution—

Since this item involves reducing the amount of N fertilizers applied while keeping actual N application constant through the use of local manure applications, the GHG benefits of this item take into account only the life cycle costs of N fertilizer. The GHG emissions from the application of nitrogen are assumed to remain constant under this policy. A BAU estimate of fertilizer use is created for the state, as described in the Nutrient Efficiency quantification. BAU fertilizer use is then reduced by 10% by 2020. This amount of fertilizer saved is then multiplied by the life cycle emissions of N fertilizer to determine the GHG benefits of this item. There are two types of manure costs that are factored into this analysis. The first is the physical cost of the manure, estimated at $.30 a pound.[13] The second cost is transportation, which is estimated at

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[12] Based on Personal Communication with Dave Miller, 5/27/08.

[13] Agriculture Marketing Resource Center. “Valuing Manure Nutrients”. http://www.agmrc.org/agmrc/business/operatingbusiness/valuingmanurenutrients.htm

$0.001/gallon/mile.[14] It is assumed that manure will be travelling an average of 15 miles to be distributed.[15] The manure in Iowa is assumed to be pig manure, since that is producing the most manure in the state.[16] Pig manure has 38 lbs of N / 1000 gallons of manure,[17] so over 58,000 gallons are required to provide on ton of Nitrogen. These transportation and physical costs are added together to get the gross cost of the Nutrient Distribution program, and the avoided fertilizer costs are subtracted from this to get the net costs.

Table 1-3 Nutrient distribution costs and GHG benefits

Year	Baseline Fertilizer Use (metric tons N)	N fertilizer reduction	$MMtCO_2e$ saved	Purchase Cost of Manure	Transportation Cost of Manure	Fertilizer Costs Avoided	Total Cost of program	Discounted Cost of program
2010	1,110,627	0	0	$0	$0	$0	$0	$0
2011	1,125,933	11,148	0.01	$7,372,964	$9,701,269	$4,287,463	$12,786,770	$9,541,685
2012	1,141,449	22,381	0.02	$14,802,580	$19,477,079	$8,607,869	$25,671,791	$18,244,462
2013	1,157,179	33,704	0.03	$22,291,317	$29,330,680	$12,962,655	$38,659,343	$26,166,165
2014	1,173,126	45,120	0.04	$29,841,624	$39,265,294	$17,353,244	$51,753,674	$33,360,880
2015	1,189,293	56,633	0.05	$37,455,932	$49,284,121	$21,781,051	$64,959,001	$39,879,192
2016	1,205,682	68,246	0.06	$45,136,656	$59,390,337	$26,247,479	$78,279,514	$45,768,410
2017	1,222,298	79,963	0.07	$52,886,199	$69,587,104	$30,753,927	$91,719,377	$51,072,781
2018	1,239,142	91,788	0.08	$60,706,952	$79,877,568	$35,301,784	$105,282,736	$55,833,683
2019	1,256,219	103,724	0.09	$68,601,293	$90,264,860	$39,892,433	$118,973,720	$60,089,813
2020	1,273,530	115,775	0.10	$76,571,597	$100,752,102	$44,527,256	$132,796,443	$63,877,360
							Total Costs	**$403,834,431**

Key Assumptions: [TBD, as needed on subcommittee approval.]

Key Uncertainties

TBD – [as needed and approved by the subcommittees]

Additional Benefits and Costs

TBD – [as needed and approved by the subcommittees]

Feasibility Issues

TBD – [as needed and approved by the subcommittees]

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[14] Iowa State Extension Service. “Value of Manure Nutrients”. http://www.extension.iastate.edu/pages/communications/epc/Winter06/valuemanurenutrients.html

[15] Based on Personal Communication with Dave Miller, 5/27/08.

[16] Iowa Inventory and Forecast Report

[17] US EPA. “Using Manure as a Fertilizer For Crop Production” http://www.epa.gov/msbasin/taskforce/2006symposia/8ManureLory.pdf

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

AFW-2. Wetlands and Drainage

Policy Description

Research: Research is needed to identify and quantify the greenhouse gas (GHG) implications, both from N_2O and CO_2, of:

- Sub-surface drainage in agricultural croplands,
- Strategically located and designed nitrogen removal wetlands
- Denitrification in receiving streams and rivers.

Subsurface drainage: Improve subsurface drainage in poorly drained cropped lands to reduce denitrification and N_2O emissions.

Wetlands: Utilize strategically located and designed nitrogen-removal wetlands to reduce N_2O emissions from nitrogen transported to receiving streams through subsurface drainage.

Integrated Drainage—Wetland Systems Initiative: Support policy development and public costs of this voluntary, market–driven private–public partnership which combines nitrogen-removal wetlands with improved subsurface drainage for enhanced crop production.

Policy Design

Goals:

By 2015—Support research needed to identify and quantify GHG implications of subsurface drainage, strategically located and designed nitrate removal wetlands, and denitrification in receiving streams and rivers.

By 2050—Have fully supported the needed policy development and public sector costs for the voluntary Integrated Drainage–Wetland Systems Initiative and deployment of nitrogen-removal wetlands in Iowa's subsurface-drained row-cropped landscape.

Timing: As stated above.

Parties Involved: Involved parties include public conservation agencies, research institutions, existing Iowa drainage districts, and private landowners.

Other: While the research foundation is not adequate to quantify, improved subsurface drainage of row-cropped lands is felt to reduce N2O emissions by, reducing nitrogen losses through enhanced nitrogen uptake by plants as result of earlier crop planting, reducing in-field denitrification, and increasing feasibility of no-till cropping.

Permanent wetlands not being cropped are already protected under federal/state regulations and programs. Restoration of wetlands without significant nitrogen loadings have minimal GHG implications, with reductions primarily from surrounding grassed buffers that provide GHG reductions in linear relationship to land area converted from row-crop to grassed buffer.

Strategically located and designed wetlands for nitrogen removal technology developed and adapted to row-cropped landscapes in the corn belt by Iowa State University and currently being implemented through the Iowa Conservation Reserve Enhancement Program (CREP). Wetland pools of 0.5%–2.0% of the contributing watershed area receive predominantly subsurface drainage from watersheds of 500–4,000 acres and will remove 40%–90% of nitrate through denitrification, primarily as elemental N_2 rather than N_2O. Nitrate-removal wetlands will significantly reduce GHG emissions over that of denitrification in receiving watercourses and the Gulf of Mexico.

Combining nitrate-removal wetlands through this voluntary Iowa initiative will reduce nitrate transport to water resources, protect drinking water supplies, reduce hypoxia in the Gulf of Mexico, and reduce emissions of GHG.

Implementation Mechanisms

Additional funding for research.

Related Policies/Programs in Place

None Identified.

Type(s) of GHG Reductions

CO_2: Conservation of wetlands helps maintain the ability of the land to sequester carbon in soil and biomass.

CH_4: Improved drainage reduces anaerobic decomposition, thereby preventing methane creation.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD.

Data Sources: [TBD by CCS on subcommittee approval]

Quantification Methods:

Unquantified.

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

Key Uncertainties

TBD – [as needed and approved by the subcommittees]

Additional Benefits and Costs

TBD – [as needed and approved by the subcommittees]

Feasibility Issues

TBD – [as needed and approved by the subcommittees]

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

AFW-3. Expanded Use of Agriculture and Forestry Biomass Feedstocks for Electricity, Heat, or Steam Production

Policy Description

Increase the amount of biomass (including biomass from forest sources) available for co-generation of electricity or for use in combined heat and power applications to displace the use of fossil energy sources recognizing that local electricity or heat production yields greatest net energy and carbon displacement payoff. Increase both the acreage and the yield of energy crop production and utilization through the planning of energy purpose

Note that this option is focused on the supply-side aspects of promoting biomass fuel, with an emphasis on the development of feedstocks, collection, processing and transport technologies. The demand-side aspects of renewable fuels (including biomass use) are being addressed through options in the CRE Subcommittee (Generation Portfolio Standards; Technology-Focused Initiatives).

Policy Design

Goals:

Energy Crop—Annually harvest at least 5 million dry tons of dedicated energy crop production materials by 2020, which includes establishing 1 million acres of identified energy crop production by 2020, transitioning 50 percent of expiring CRP contracts to energy crop production.

Agriculture Crop Residue—Annually harvest at least 10 million tons of annual crop residue biomass for energy production by 2020.

Forest Biomass—Annually harvest at least 75% of available forest products or wood residues for biomass energy production by 2020.

Biomass Plant—Have at least one major industrial operation contracting with producers to use biomass as the primary energy source for plant operations by 2015 [unquantified].

Biofuels—Have at least one biofuels production plant contracting with producers to use biomass as the primary energy source by 2015 [unquantified].

Timing:

Parties Involved: Farmers and landowners.

Other:

Energy conversion facilities.

The ICCAC raised concerns on the sustainability of utilizing forest residue from harvesting operations. The forest residue data for the NREL report was derived from the USDA Forest Service's Timber Product Output database for 2002. In this category NREL included logging residues and other removals. NREL defined logging residues as "the unused portions of trees cut, or killed by logging, and left in the woods. Other removals are considered trees cut or otherwise killed by cultural operations (e.g. pre-commercial thinning, weeding, etc.) or land clearings and forest uses that are not directly associated with round wood product harvests.

Implementation Mechanisms

Voluntary Incentive programs:

- Section 476C tax incentives
- State and/or federal cost-share programs for energy crop establishment
- USDA value-added agriculture development grants
- Federal Renewable Fuel Standard
- Cellulosic fuel requirement standards and incentives
- Research funding
- State fuel standards and incentives

Related Policies/Programs in Place

Section 476C of the Iowa code provides for a renewable energy tax credit for biomass and other qualifying renewable energy sources that are used to generate electricity or heat for a commercial purpose.

A producer or purchaser of renewable energy may receive renewable energy tax credits under this chapter in an amount equal to $0.015 per kilowatt-hour of electricity, or $4.50/MMBtu of heat for a commercial purpose, or $4.50/MMBtu of methane gas or other biogas used to generate electricity, or $1.44/1,000 cu. ft. of hydrogen fuel generated by and purchased from an eligible renewable energy facility.

Alternative Energy Law (Iowa's Renewable Portfolio Standard): Iowa requires its two investor-owned utilities—MidAmerican Energy and Alliant Energy Interstate Power and Light—to contract for a combined total of 105 megawatts (MW) of their generation from renewable energy resources.

Fuel Mix Disclosure: Iowa's rate-regulated electric utilities must report annually to customers the percentage mix of fuel and energy used to produce electricity. The percentages for renewables must further be broken down into percentages of electricity generated by wind, solar, hydropower, biomass, and other resources. Each utility's annual report must also include an estimate of sulfur dioxide, nitrogen oxides, and carbon dioxide emissions for each fuel and resource.

Energy Research Grants: The Iowa Energy Center provides grants for energy research on topics that have strong relevance to Iowa.

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

Data Sources:

- *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.
- Maryland DNR "The Potential for Biomass Cofiring in Maryland," March 2006. Prepared by Princeton Energy Resources International, LLC and Exeter Associates INC for the DNR Maryland Power Plant Research Program.
- Average Heat Content of Selected Biomass Fuels Table 10 EIA (2008) Annual Electric Generator, http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html
- Heat Content of Selected fuels provided by Oak Ridge National Laboratory (ORNL) (6,000 to 8,000 Btu per pound for solid wood products), http://cta.ornl.gov/bedb/appendix_a/Approximate_Heat_Content_of_Selected_Fuels_for_Electric_Power_Generation.xls

Quantification Methods:

GHG Benefit

This analysis focuses on the incremental GHG benefits associated with the utilization of additional biomass to offset the consumption of fossil fuels. The analysis assumes that biomass will replace coal. This is based on the assumption that biomass will be used to replace coal in the RCI and electricity sector (where coal represents about 82% of electricity generated in Iowa).[18]

The GHG benefits were calculated by the difference in emissions associated with each of the input fuels (0.0959 tCO_2e/MMBtu for sub-bituminous coal, 0.0539 tCO_2e/MMBtu for natural gas, and 0.0019 tCO_2e/MMBtu for biomass, including non-CH_4 and non-N_2O emissions).19

The amount of biomass utilized by each of the three components (Agriculture, Forest and Energy Crops) is illustrated in the three tables below: 3.1, 3.2 and 3.3. The tables below also show the corresponding GHG benefits for each of the components.

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[18] Based on eGRID data: Coal 82%, Nuclear 11%, Oil 0.3%, Natural Gas 2%, Wind 2%, Biomass 0.3%.

[19] Emission factors obtained from CCS energy fuel emission factors.

Table 3.1. GHG benefits from agriculture crop residue

Year	Percent of Utilization	Agriculture Crop Residue Feedstock (dry tons)	Agriculture Crop Residue Feedstock (MMBtu)[20]	Avoided Emissions Agriculture Residue (MMtCO$_2$e)
2009	7%	714,286	5,928,571	0.557
2010	14%	1,428,571	11,857,143	1.115
2011	21%	2,142,857	17,785,714	1.672
2012	29%	2,857,143	23,714,286	2.229
2013	36%	3,571,429	29,642,857	2.787
2014	43%	4,285,714	35,571,429	3.344
2015	50%	5,000,000	41,500,000	3.902
2016	60%	6,000,000	49,800,000	4.682
2017	70%	7,000,000	58,100,000	5.462
2018	80%	8,000,000	66,400,000	6.242
2019	90%	9,000,000	74,700,000	7.023
2020	100%	10,000,000	83,000,000	7.803
Cumulative				**46.818**

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[20] Agriculture Residue heat content is assumed to be 8.3 MMBtu/ton which is taken from Average Heat Content of Selected Biomass Fuels Table 10 EIA (2008) Annual Electric Generator, http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html

Table 3.2 GHG benefits from forestry biomass

Year	Percent of Utilization	Forest Biomass Feedstock (Dry Tons)	Forest Biomass Feedstock (MMBtu)[21]	Avoided Emissions from Forest Biomass Feedstocks (MMtCO$_2$e)
2009	6%	48,938	587,250	0.055
2010	13%	97,875	1,174,500	0.110
2011	19%	146,813	1,761,750	0.166
2012	25%	195,750	2,349,000	0.221
2013	31%	244,688	2,936,250	0.276
2014	38%	293,625	3,523,500	0.331
2015	44%	342,563	4,110,750	0.386
2016	50%	391,500	4,698,000	0.442
2017	56%	440,438	5,285,250	0.497
2018	63%	489,375	5,872,500	0.552
2019	69%	538,313	6,459,750	0.607
2020	75%	587,250	7,047,000	0.662
Cumulative				**4.305**

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[21] Forest biomass heat content is assumed to be 12 MMBtu/ton which is the low end of the range (6000 BTU/lb) taken from Heat Content of Selected fuels provided by Oak Ridge National Laboratory (ORNL) (6,000 to 8,000 BTU per pound for solid wood products), http://cta.ornl.gov/bedb/appendix_a/Approximate_Heat_Content_of_Selected_Fuels_for_Electric_Power_Generation.xls

Table 3.3 GHG Benefits From Dedicated Energy Crops

Year	Percent of Utilization	Total Dedicated Energy Crop Available (Dry Tons)	Total Dedicated Energy Crop Available (MMBtu)[22]	Avoided Emissions, Energy Crops (MMtCO$_2$e)
2009	4%	200,000	2,936,400	0.276
2010	6%	300,000	4,404,600	0.414
2011	8%	400,000	5,872,800	0.552
2012	10%	500,000	7,341,000	0.690
2013	21%	1,062,500	15,599,625	1.466
2014	33%	1,625,000	23,858,250	2.242
2015	44%	2,187,500	32,116,875	3.018
2016	55%	2,750,000	40,375,500	3.794
2017	66%	3,312,500	48,634,125	4.570
2018	78%	3,875,000	56,892,750	5.347
2019	89%	4,437,500	65,151,375	6.123
2020	100%	5,000,000	73,410,000	6.899
Cumulative				**35.39**

Costs

There are two main components to the cost calculation, the fuel costs and capital costs. The fuel component is based on the difference in costs between supply of biomass fuel and the assumed fossil fuel that it is replacing (i.e., coal). Assumed costs of biomass are identified in Table 3-4 below. Delivered coal fuel cost ($/MMBTU) were taken the Energy Information Agency's Annual Energy Outlook (AEO) 2008 (http://www.eia.doe.gov/oiaf/aeo/prices.html).

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[22] Energy heat content is assumed to be 14.7 MMBtu/ton., taken from Heat Content of Selected fuels provided by Oak Ridge National Laboratory (ORNL) (7,341 BTU per pound for switchgrass), http://cta.ornl.gov/bedb/appendix_a/Approximate_Heat_Content_of_Selected_Fuels_for_Electric_Power_Generation.xls

Table 3-4. Assumed costs of feedstocks

Fuel Type	Cost $/Ton Delivered	Heat content (MBtu/Ton)	Cost $/MMBtu Delivered
Agricultural by-products[23]	$74.25	8.3	$8.95
Energy crop (switchgrass)[24]	$113.66	14.7	$7.47
Forest residue[25]	$35.00		$3.65

Table 3-5. Summary of Costs

Year	Total Biomass Utilization (Agriculture Residue, Forest Feedstocks, and Energy Crops) (MMBtu)	Approximate Cumulative Capacity (MW)	Annualized Capital Costs[26] ($2005)	Estimated Additional Variable Operational and Maintenance Costs[27] (2005$)	Estimated Additional Fixed Operational and Maintenance Costs[28] (2005$)	Fuel Costs (Agriculture Residue, Forest Feedstocks, and Energy Crops) ($2005)	Discounted Costs (Million $2005)
2009	9,452,221	142	$4,707,659	–$1,421,387	$3,453,163	$54,066,206	$60.8
2010	17,436,243	263	$8,684,084	–$2,621,991	$2,916,788	$95,698,290	$104.7
2011	25,420,264	383	$12,660,509	–$3,822,596	$2,916,788	$133,741,350	$145.5
2012	33,404,286	503	$16,636,935	–$5,023,201	$2,916,788	$168,284,704	$182.8
2013	48,178,732	726	$23,995,317	–$7,244,922	$5,397,521	$229,343,739	$251.5
2014	62,953,179	949	$31,353,699	–$9,466,643	$5,397,521	$284,586,979	$311.9
2015	77,727,625	1,171	$38,712,081	–$11,688,365	$5,397,521	$333,934,533	$366.4
2016	94,873,500	1,430	$47,251,548	–$14,266,692	$6,263,871	$388,904,949	$428.2
2017	112,019,375	1,688	$55,791,015	–$16,845,019	$6,263,871	$438,073,815	$483.3
2018	129,165,250	1,947	$64,330,482	–$19,423,346	$6,263,871	$481,859,917	$533.0
2019	146,311,125	2,205	$72,869,949	–$22,001,673	$6,263,871	$519,916,777	$577.0

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[23] Price of Agriculture residue comes from Iowa State University (University Extension) publication "Estimating a Value for Corn Stover" Ag Decision maker File A1-70, December 2007. Additional Transportation costs of $14.75 were assumed, taken from Iowa State University, University Extension, publication "Estimated Costs for Production, Storage and Transportation of Switchgrass" PM 2042, October 2007 . Average Heat Content of Selected Biomass Fuels Table 10 EIA (2008) Annual Electric Generator, http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html

[24] Cost of energy crop was taken from Iowa State University, University Extension, publication "Estimated Costs for Production, Storage and Transportation of Switchgrass" PM 2042, October 2007 Heat Content of Selected fuels ORNL (7,341 BTU per pound), http://cta.ornl.gov/bedb/appendix_a/Approximate_Heat_Content_of_Selected_Fuels_for_Electric_Power_Generation.xls

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

[26] Capital costs were taken from Table 39 of Energy Information Agency Annual Energy Outlook 2007. See http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/electricity.pdf

[27] Variable operational and maintenance costs were taken from Table 39 of Energy Information Agency Annual Energy Outlook 2007. see http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/electricity.pdf

[28] Fixed operational and maintenance costs were taken from Table 39 of Energy Information Agency Annual Energy Outlook 2007. See http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/electricity.pdf

Year	Total Biomass Utilization (Agriculture Residue, Forest Feedstocks, and Energy Crops) (MMBtu)	Approxi-mate Cumulative Capacity (MW)	Annualized Capital Costs[26] ($2005)	Estimated Additional Variable Operational and Maintenance Costs[27] (2005$)	Estimated Additional Fixed Operational and Maintenance Costs[28] (2005$)	Fuel Costs (Agriculture Residue, Forest Feedstocks, and Energy Crops) ($2005)	Dis-counted Costs (Million $2005)
2020	163,457,000	2,464	$81,409,417	–$24,580,000	$6,263,871	$553,256,520	$616.3
						Cumulative	**$4,061.4**

The cost of implementing the policy option is estimated by assuming the replacement of coal with biomass. The difference in cost of feedstock supply between biomass and coal is calculated using the costs outlined in Table 3-4. The difference in costs (dollars per million British thermal units [$/MMBtu]), is multiplied by the amount of coal energy (MMBtu) being replaced by biomass. The assumed incremental capital costs are based on the capital costs associated with establishing a biomass plant compared to a coal plant. Capital costs, operational and maintenance costs were taken from Table 39 of the Energy Information Agency Annual Energy Outlook 2007. While use of biomass may be pursued through other technology types (e.g., gasification) or end uses (e.g., heat or steam), this methodology was used to provide an estimate of possible capital costs required to enable the utilization of biomass.[29]

The capital infrastructure lifespan is assumed to be 30 years, and the interest rate of is assumed to be 5%, giving a Capital Recovery Factor of 0.065 (i.e., $1 million plant is assumed to cost approximately $65,000 per year over the life of the project).

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

Key Uncertainties

TBD – [as needed and approved by the subcommittees]

Additional Benefits and Costs

Biochar—Biochar is a byproduct produced from certain thermochemical energy production processes. The application of biochar to crop fields is believed increase soil productivity and increase soil carbon levels. The land application of biochar should be conducted although the level of GHG benefits is not fully understood and additional research is required.

Feasibility Issues

TBD – [as needed and approved by the subcommittees]

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

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

AFW-4. Encourage Large-Scale Manure/Methane Management Capture Utilization

Policy Description

Reduce methane emissions from livestock manure by installing large-scale anaerobic digester systems at locations that can service multiple concentrated animal feeding operations (CAFOs).

Reduce methane emissions from livestock manure by installing anaerobic digester systems at larger individual concentrated animal feeding operations.

Methane captured from the digesters is used to create heat or power, which offsets fossil fuel–based energy production and the associated GHG emissions. This option is focused on implementing these projects at the large-scale level (e.g., community-based systems or large CAFOs).

Reduce GHG emissions associated with manure handling and storage. Potential practices include but are not limited to manure composting (to reduce methane emissions) and improved methods for application of effluent to fields (for reduced nitrous oxide emissions). Application improvements include incorporation into soil instead of surface spray/spreading.

Policy Design

Goals:

Utilization—By 2020, utilize 50% of available methane from livestock manure (primarily dairy, swine and poultry) for renewable electricity, heat and steam generation or incorporation into natural gas distribution systems.

Management—By 2020, apply improved manure handling and storage practices on 50% of manure generated.

Timing:

Parties Involved:

Other:

Implementation Mechanisms

Reduce GHG emissions associated with manure handling and storage. Potential practices include but are not limited to manure composting (to reduce methane emissions) and improved methods for application of effluent to fields (for reduced nitrous oxide [N_2O] emissions). Application improvements include incorporation into soil instead of surface spray/spreading.

- Tax Incentives
- Grants

- Loan Guarantees

Related Policies/Programs in Place

Section 476C of the Iowa code provides for a renewable energy tax credit for biomass and other qualifying renewable energy sources that are used to generate electricity or heat for a commercial purpose.

A producer or purchaser of renewable energy may receive renewable energy tax credits under this chapter in an amount equal to $0.015/kWh of electricity, or $4.50/MMMBtu of heat for a commercial purpose, or $4.50/MMMBtu of methane gas or other biogas used to generate electricity, or $1.44/1,000 cu. ft. of hydrogen fuel generated by and purchased from an eligible renewable energy facility.

Alternate Energy Revolving Loan Program (AERLP): The Iowa Energy Center provides zero-percent interest loans for up to half of the project cost, up to a maximum of $250,000. http://www.energy.iastate.edu/AERLP/index.htm

Energy Research Grants: The Iowa Energy Center provides grants for energy research on topics that have strong relevance to Iowa. http://www.energy.iastate.edu/Funding/gp-research.htm

Alternative Fuel Production Loans: The Value-Added Agricultural Products and Processes Financial Assistance Program offers a combination of forgivable and traditional low-interest loans for business projects involving the production of biomass or alternative fuels. http://www.iowalifechanging.com/business/vaapfap.html

Iowa DNR Anaerobic Digestion Outreach Program: Recognizing the enormous opportunity for the wide-scale implementation of farm-scale and community-based anaerobic digester systems in Iowa, the Iowa Department of Natural Resources Energy and Waste Management Bureau set about promoting the digester concept to Iowa Communities having large concentrations of livestock production, large volumes of organic wastes, and large energy users.

Type(s) of GHG Reductions

- **CO_2, N_2O, CH_4:** Displaces emissions from fossil fuel combustion.
- **CH_4:** Capture and utilization or preventing the creation of methane.
- **N_2O:** Reductions occur when nitrogen run-off and leaching are reduced, which leads to the formation and emission of N_2O.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources: [TBD by CCS on subcommittee approval]

Quantification Methods:

Utilization GHG Benefits

Methane emissions (in $MMtCO_2e$) data from the Iowa Inventory and Forecast was used as the starting point to estimate the GHG benefits of utilizing the volumes of methane targeted by the policy and to add in the additional benefit of electricity generation using this captured methane (through offsetting fossil-based generation). The first portion of GHG benefit is obtained through reduced methane emissions through the capture of emissions from manure and poultry litter. An assumed collection efficiency of 75%[30] is applied to methane emissions from manure and poultry litter which is then multiplied by the assumed policy target ramping up to achieve 50% utilization by 2020.

The second portion of the GHG benefit is through the offsetting of fossil-based electricity generation. This was estimated by converting the methane captured in each year to its heat content (in Btus) and then multiplying by a natural gas heat rate of 11,664 Btu/kWh to estimate the electricity produced.[31] The CO_2e associated with this amount of electricity in each year is estimated by converting the kWh to megawatt hours (MWh) and then multiplying this value by the Iowa-specific emission factor for electricity production from the inventory and forecast (0.69 tCO_2e/MWh).[32]

The total GHG benefit is estimated as the sum of both portions of the benefit described above.

Utilization Costs

The costs for the dairy and swine components are estimated using an analysis by Natural Resources Conservation Service (NRCS), *An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities.*[33] The production costs are assumed to be $0.11/kWh for swine anaerobic digesters and $0.05/kWh for dairy anaerobic digesters.[34] These costs were converted to 2005 dollars (from 2006 dollars) and assume a 30% thermal efficiency. The costs include annualized capital costs for the digester, generator, and Operation and Maintenance costs.[35] The assumed costs for the poultry component were taken from a Study in South Carolina *Availability of Poultry Manure as a Potential Bio-Fuel Feedstock for Energy Production* by J.R.V. Flora, and Cyrus Riahi-Nezhad ($0.103/kWh in 2005 dollars using anaerobic digestion).[36] The value of electricity produced is taken from the projected

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

[31] Energy Information Administration – Department of Energy (2007) Table A.6 Average Heat Rates by Prime Mover and Energy Source. http://www.eia.doe.gov/cneaf/electricity/epa/epata6.html

[32] Total electricity emissions were divided by total electricity sales to determine the electricity emissions factor for Iowa.

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

[34] It is assumed that the technology employed for both swine and dairy anaerobic digesters are covered anaerobic lagoon. Cost were obtained from table 1 of the NRCS paper sited above.

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

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

all sector average electricity price for the Mid-Continent Area Power Pool prices.[37] This price represents the value to the farmer for the electricity produced (to offset on-farm use) and is netted out from the production costs to estimate net costs.

Management GHG Benefits

TBD.

Management Costs

TBD.

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

Key Uncertainties

TBD – [as needed and approved by the subcommittees]

Additional Benefits and Costs

TBD – [as needed and approved by the subcommittees]

Feasibility Issues

TBD – [as needed and approved by the subcommittees]

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

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[37] DOE Energy Information Administration (EIA) Annual Energy Outlook http://www.eia.doe.gov/oiaf/aeo/supplement/index.html, accessed May 12 2008.

AFW-5. Land Management to Promote Sequestration Benefits

Policy Description

On cultivated lands, the amount of carbon stored in the soil can also be increased by the adoption of practices such as continuous conservation and no-till cultivation. By minimizing mechanical soil disturbance, these practices reduce the oxidation of soil carbon compounds and allow more stable aggregates to form. Other benefits include reduced wind and water erosion, reduced fuel consumption, and improved wildlife habitat.

Convert marginal agricultural land used for annual crops to permanent cover such as grassland/rangeland, orchard, or forest where the soil carbon and/or carbon in biomass is higher under the new land use. Adopt mechanisms to discourage theses acres from either returning to conventionally tilled production or to suburban/urban development.

Heavy grazing can cause significant soil disturbance and result in carbon losses from soils. Rotational grazing where animals are moved from field to field on a regular basis can reduce soil disturbance, improve plant vigor and enhance soil carbon levels.

Establish forests on land that has not historically been forested (e.g., afforestation of agricultural land) and promote forest cover and associated carbon stocks by regenerating or establishing forests in areas with little or no present forest cover (“reforestation”). Maintain and improve the health and longevity of trees in urban and residential areas to protect and enhance the carbon stored in tree biomass. Indirect emissions reductions may also occur by reducing heating and cooling needs as a result of planting shade trees.

Policy Design

Goals:

- *Conservation tillage*—By 2020, 75 percent of annual cropland will be managed with continuous no-till or low-till production practices.
- *Agriculture land conversion*—By 2020, convert 333,000 acres of marginal agricultural land to higher sequestration permanent cover (including grassland, rangeland, or orchard).
- *Conservation grazing*—By 2020, apply conservation grazing practices including rotational grazing to 50 percent of Iowa grazing lands.
- *Forestation*—By 2020, establish 250,000 acres of new forest lands and improve management practices on 500,000 acres of unmanaged grazed forested land.
- *Urban forestry*—By 2020, increase the canopy cover of urban forest in Iowa communities by 25%.

Timing:

Parties Involved:

Other:
Convert marginal agricultural land used for annual crops to permanent cover such as grassland/rangeland, or orchard where the soil carbon and/or carbon in biomass is higher under the new land use. Adopt mechanisms to discourage theses acres from either returning to conventionally tilled production or to suburban/urban development.

Heavy grazing can cause significant soil disturbance and result in carbon losses from soils. Rotational grazing where animals are moved from field to field on a regular basis can reduce soil disturbance, improve plant vigor and enhance soil carbon levels.

Implementation Mechanisms

TBD.

Related Policies/Programs in Place

None Identified.

Type(s) of GHG Reductions

CO_2: Increase the sequestration of carbon, as well as preventing carbon currently stored in Iowa’s forests and farm land from being released. Reductions also 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

Data Sources:

Reforestation and Afforestation:

- USDA Forest Service (USFS). “Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the US,” General Technical Report NE-343 (also published as part of the Department of Energy Voluntary GHG Reporting Program).
- USFS Forest Inventory Analysis data (Mapmaker 3.0), available at http://www.ncrs2.fs.fed.us/4801/fiadb/fim30/wcfim30.asp).
- Walker et al. 2007. Terrestrial carbon sequestration in the Northeast: Opportunities and Costs, Part 3A: Opportunities for Improving Carbon Storage through Afforestation of Agricultural Lands.

Urban Forestry:

- Nowak et al., USDA Forest Service, Northern Research Station, Urban Forest Effects on Environmental Quality State Summary data for Iowa, available at http://www.fs.fed.us/ne/syracuse/Data/State/data_IA.htm
- McPherson, E.G. and J.R. Simpson. 1999. “Carbon Dioxide Reduction Through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters.” General Technical Report USFS PSW-GTR-171, Washington, DC: U.S. Department of Agriculture, U.S. Forest Service, available at: http://www.treesearch.fs.fed.us/pubs/6779

Quantification Methods:

Conservation Tillage GHG Benefits

Total cropland in Iowa is estimated at about 23 million acres[38] in 1998. For the purposes of this analysis, conservation tillage is defined as any system that leaves 50% or more of the soil covered with residue.[39]

Based on the policy design parameters, the schedule for acres to be put into conservation tillage/no-till cultivation is displayed in Table 5-1. This table represents the percentage of cropland required by the policy, less the area currently implementing conservation tillage. In 1998, according to Conservation Technology Information Center (CTIC),[40] almost 4 million acres were using conservation tillage practices in Iowa. This represents approximately 17 percent of total cropland in Iowa.

For the policy period, it is assumed that the sequestration rate provided by the Chicago Climate Exchange (CCX) for the carbon credit program (0.6 metric tons of carbon dioxide per acre [tCO_2/acre] per year as Iowa is considered to be in "Zone A") is indicative of the sequestration that would occur as a result of improved tillage practices.[41] As such 0.6 tCO_2/acre/year was used to estimate the amount of carbon to be sequestered per acre. The issuance rates are viewed as a discounted average that could be expected to occur for the entire pool of enrolled acreage over the 5-year contract period.[42] It was assumed that carbon accumulation occurred for 20 years, which extends beyond the policy period. To estimate carbon stored each year, the annual accumulation rate was multiplied by the number of acres in still accumulating carbon each year. The CCX program currently runs until 2010 and while it is likely that the program will be extended, at this stage it is unknown.

Additional GHG savings from reduced fossil fuel consumption are estimated by multiplying the fossil diesel emission factor and diesel fuel reduction per acre estimate. The reduction in fossil diesel fuel use from the adoption of conservation tillage methods is 3.5 gallons/acre.[43] The life

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[38] 1998 Iowa total crop land from the Conservation Technology Information Center Iowa Crop Residue Management Survey (see http://www.conservationinformation.org/index.asp?site=1&action=crm_results)

[39] The definitions of tillage practices from Conservation Technology Information Center are used under this policy. However, only no-till/strip-till and ridge-till are 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 means that 4–6-inch-high ridges are formed at cultivation. Planters using specialized attachments scrape off the top 2 inches of the ridge before placing the seed in the ground.

[40] From 1998 Conservation Technology Information Center data, at: http://www.conservationinformation.org

[41] From Chicago Climate Exchange (CCX) Agricultural Soil Carbon Offsets, at: http://www.chicagoclimatex.com/content.jsf?id=781

[42] Chicago Climate Exchange Offsets for Carbon Capture and Storage in Agricultural Soils FAQs (see http://www.chicagoclimateexchange.com/docs/offsets/Soil_Carbon_Offsets_faq.pdf)

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

cycle fossil diesel GHG emission factor of 12.31 tCO_2e/1,000 gallons was used.[44] Results are shown in Table 5-1, along with a total estimated benefit from both carbon sequestration and fossil fuel reductions.

Table 5-1. GHG Reductions From Conservation Tillage Practices

Year	Percent of Total Cropland in Program	Acres In Program ("New" Acres)	$MMtCO_2e$ Sequestered	Diesel Saved (1,000 gal)	$MMtCO_2e$ From Diesel Avoided	Total $MMtCO_2e$ Saved per Annum
2009	22%	1,114,784	0.669	3,902	0.048	0.717
2010	27%	2,229,569	1.34	7,803	0.096	1.43
2011	31%	3,344,353	2.01	11,705	0.144	2.15
2012	36%	4,459,138	2.68	15,607	0.192	2.87
2013	41%	5,573,922	3.34	19,509	0.240	3.58
2014	46%	6,688,707	4.01	23,410	0.288	4.30
2015	51%	7,803,491	4.68	27,312	0.336	5.02
2016	56%	8,918,276	5.35	31,214	0.384	5.74
2017	60%	10,033,060	6.02	35,116	0.432	6.45
2018	65%	11,147,844	6.69	39,017	0.480	7.17
2019	70%	12,262,629	7.36	42,919	0.528	7.89
2020	75%	13,377,413	8.03	46,821	0.576	8.60
					Cumulative benefit	55.9

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Conservation Tillage Costs

The costs of adopting soil management practices (e.g., conservation tillage/no-till practices) are based on the financial incentives provided through the Minnesota] Agriculture Best Management Practices (AgBMP) program.[45] This program provides farmers a low-interest loan as an incentive to initiate or improve their current tillage practices. The equipment funded is generally specialized tillage or planting implements that leave crop residues covering at least 15%–30% of the ground after planting. The average total cost for this equipment is $23,000, though the average loan for tillage equipment is $16,000. The average-size farm using an AgBMP loan to purchase conservation tillage equipment is 984 acres. Based on the average loan size ($16,000) and the average size of the farm utilizing the loan (984 acres), it is assumed that a once-off loan of $16.26/acre is required to incentivize the adoption of conservation tillage practices. This loan payment is applied to each new acre entering the program to determine an approximate cost of

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[44] Life-cycle emissions factor for fossil diesel from J. Hill et al., "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," Proceedings of the National Academy of Sciences, 103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life-cycle impacts. See http://www.pnas.org/cgi/content/full/103/30/11099

[45] Minnesota Department of Agriculture (2006), Agricultural Best Management Practices Loan Program State Revolving Fund Status Report, February 28, 2006.

encouraging the use of soil management practices. Note that while there may be initial upfront incentives required to encourage the use of there may also be savings associated with reduced cost of fuel, labor, chemicals, and equipment.[46] The reduction in fossil diesel fuel use from the adoption of conservation tillage methods is 3.5 gallons/acre.[47] The life cycle fossil diesel GHG emission factor is assumed to be 12.31 tCO_2e/1,000 gallons.[48]

It was assumed that income from adopting no till could be obtained through a carbon credit program (for example the Chicago Climate Exchange). The price of carbon was assumed to be $7.25/$tCO_2e$.[49]

Table 5-2. GHG reductions from conservation tillage practices

Year	Total $MMtCO_2e$ Saved per Annum	Annual Cost of Funding Conservation Tillage Equipment	Costs Benefits From No-Till	Net Costs
2009	0.717	$18,126,576	–$5,197,533	$12,929,043
2010	1.43	$18,126,576	–$10,395,067	$7,731,510
2011	2.15	$18,126,576	–$15,592,600	$2,533,976
2012	2.87	$18,126,576	–$20,790,133	–$2,663,557
2013	3.58	$18,126,576	–$25,987,667	–$7,861,090
2014	4.30	$18,126,576	–$31,185,200	–$13,058,624
2015	5.02	$18,126,576	–$36,382,733	–$18,256,157
2016	5.74	$18,126,576	–$41,580,267	–$23,453,690
2017	6.45	$18,126,576	–$46,777,800	–$28,651,224
2018	7.17	$18,126,576	–$51,975,333	–$33,848,757
2019	7.89	$18,126,576	–$57,172,867	–$39,046,290
2020	8.60	$18,126,576	–$62,370,400	–$44,243,824
	55.9		–$405,407,600	–$187,888,686

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[46] 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 by Walton and Bullen. Sam Walton and Gary Bullen. “Economic Comparison of Three Cotton Tillage Systems in Three North Carolina Regions.” PowerPoint presentation. Raleigh, NC: North Carolina State University. See www.ces.ncsu.edu/depts/agecon/Cotton_Econ/production/Economic_Comparison.ppt, accessed January 2008.

[47] Reduction associated with less intensive land use (e.g., fewer passes). The estimate is based on conservation tillage compared with conventional tillage, at http://www.conservationinformation.org/Core4Brochures/CTBrochure.pdf, accessed May 2008.

[48] Life-cycle emissions factor for fossil diesel from J. Hill et al., “Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels,” *Proceedings of the National Academy of Sciences*, 103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life-cycle impacts. See http://www.pnas.org/cgi/content/full/103/30/11099.

[49] Price sourced from CCX website (http://www.chicagoclimateexchange.com) on May 22 2008.

Agriculture Land Conversion GHG Benefits

The GHG sequestration benefits of converting marginal agricultural land to higher sequestration permanent cover were quantified by assuming a constant rate of carbon accumulation of 1 tCO_2e/acre/year.[50] The sequestration rate was applied to acres in the program as indicated in Table 5-3. The benefits from reduced diesel use and reduced fertilizer use were calculated using a similar methodology to that used in AFW-1. It was assumed that nitrogen was not applied under the policy scenario but was applied in the reference case at a rate of 84 lb/acre,[51] and the average CO_2 emissions factor was 5.02×10^{-6} $MMtCO_2e$ per ton of nitrogen applied based on historical data and the life cycle emissions factor for nitrogen production (i.e., emissions associated with the production, transport, and energy consumption during application)[52]. Additional GHG savings from reduced fossil fuel consumption were estimated by multiplying the fossil diesel emission factor (12.31 tCO_2e/1,000 gallons)[53] by the diesel fuel reduction per acre (3.5 gallons/acre)[54].

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[50] Taken from CCX agricultural grass soil carbon sequestration offset project guidelines. Iowa is in zone A. See http://www.chicagoclimatex.com/docs/offsets/Grassland_Conversion_Protocol.pdf

[51] Based on average fertilizer use (lb/acre) in Iowa in 2005 (nitrogen applied in Iowa in 2005 was 1,037,165 Metric tons N and total cropland is 27.15 million acres).

[52] The avoided life cycle GHG emissions (i.e., emissions associated with the production, transport, and energy consumption during application) were taken from Wood and Cowie. The estimate provided for the U.S. (taken from West and Marland, 2001) was 857.5 grams (g) CO_2e per kilogram of nitrogen (kgN) or 0.778 $MtCO_2e$ per ton of nitrogen (tN). Sam Wood and Annette Cowie (2004) *A Review of Greenhouse Gas Emission Factors for Fertiliser Production* Research and Development Division, State Forests of New South Wales, Cooperative Research Centre for Greenhouse Accounting.

[53] J. Hill et al., “Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels,” *Proceedings of the National Academy of Sciences* 103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life-cycle impacts. See http://www.pnas.org/cgi/content/short/103/30/11206.

[54] Reduction associated with less intensive land use (e.g., fewer passes). The estimate is based on conservation tillage compared with conventional tillage, *What’s Conservation Tillage?* Available at http://www.conservationinformation.org/Core4Brochures/CTBrochure.pdf, accessed May 2008.

Table 5-3: GHG benefits of agriculture land conversion

Year	Acres in Program	MMtCO$_2$e Sequestered	Diesel Fuel Saved (1000 gallons)	MMtCO$_2$e From Diesel Avoided	Amount of Nitrogen Avoided (short tons)	GHG Emissions Saved (MMtCO$_2$e)
2009	27,750	0.028	97	0.0000	1,169	0.034
2010	55,500	0.056	194	0.0000	2,337	0.067
2011	83,250	0.083	291	0.0000	3,506	0.101
2012	111,000	0.111	389	0.0000	4,674	0.135
2013	138,750	0.139	486	0.0000	5,843	0.169
2014	166,500	0.167	583	0.0000	7,011	0.202
2015	194,250	0.194	680	0.0001	8,180	0.236
2016	222,000	0.222	777	0.0001	9,348	0.270
2017	249,750	0.250	874	0.0001	10,517	0.303
2018	277,500	0.278	971	0.0001	11,685	0.337
2019	305,250	0.305	1,068	0.0001	12,854	0.371
2020	333,000	0.333	1,166	0.0001	14,022	0.405
					Cumulative	**2.53**

Agriculture Land Conversion Costs

The cost of the program was assumed to be constant over the period at $146 per acre per year in 2008 dollars.[55] The establishment costs were assumed to be $86/acre. The once of establishment fee is based on the average establishment costs provided by Iowa state study[56]. It is further assumed that the Federal government (through the USDA) will pay up to 50% of these establishment costs (e.g., cover crop or tree establishment costs. This results in a net establishment cost of $43/acre. It was assumed that carbon credits ($7.25/tCO$_2$) would be generated through the Chicago Climate Exchange or a similar future program.[57] Cost savings were also assumed to occur through reduced nutrient application and reduced fuel consumption, using a similar methodology to that applied above[58]. These costs are discounted to 2005 dollars

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[55] Total continuous CRP land annual payments for Iowa were $146.11 per acre as of March 2008. This payment includes annual incentive and maintenance allowance payments, but not one-time signing and practice incentive payments or payment reductions, such as for lands enrolled less than a full year and lands hayed or grazed (see http://www.fsa.usda.gov/Internet/FSA_File/mar2008.pdf).

[56] From: Estimated Costs of Pasture and Hay Production, Iowa State University University Extension, November 2000. See http://www.econ.iastate.edu/faculty/duffy/Pages/pastureandhay.pdf

[57] Assumes that carbon credits can be obtained through future programs. Price sourced from CCX Web site on May 22, 2008. See http://www.chicagoclimateexchange.com/

[58] Assuming an application rate of 84 lb/acre, and multiplying the total fertilizer reduction in each year by the average cost of fertilizer from "2007 Fertilizer Use and Cost," at: www.ers.usda.gov/Data/FertilizerUse/Tables/Fert%20Use%20Table%207.xls. For diesel, the assumed price is $4.69 per gallon taken from the national average from the EIA gasoline and diesel update (http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp), accessed on June 20, 2008

and assumed to be constant in real terms across the policy period. Costs for each year are indicated in Table 5-4.

Table 5-4. Costs of agriculture land conversion

Year	Avoided Cost of Fertilizer	Avoided Cost of Diesel	Total Costs (Including Conservation Costs, Establishment Costs, and Savings Avoided Use of Fertilizer)	Savings (Revenue Generated Through Carbon Credits)	Net Cost (2005$)
2009	-$449,418	-$455,711	$4,088,506	-$173,793	$3,914,713
2010	-$898,835	-$911,421	$6,230,142	-$347,587	$5,882,556
2011	-$1,348,253	-$1,367,132	$8,827,489	-$521,380	$8,306,109
2012	-$1,797,670	-$1,822,842	$11,424,836	-$695,173	$10,729,662
2013	-$2,247,088	-$2,278,553	$14,022,183	-$868,967	$13,153,216
2014	-$2,696,506	-$2,734,263	$16,619,529	-$1,042,760	$15,576,769
2015	-$3,145,923	-$3,189,974	$19,216,876	-$1,216,553	$18,000,323
2016	-$3,595,341	-$3,645,684	$21,814,223	-$1,390,347	$20,423,876
2017	-$4,044,759	-$4,101,395	$24,411,570	-$1,564,140	$22,847,430
2018	-$4,494,176	-$4,557,105	$27,008,916	-$1,737,933	$25,270,983
2019	-$4,943,594	-$5,012,816	$29,606,263	-$1,911,727	$27,694,537
2020	-$5,393,011	-$5,468,526	$32,203,610	-$2,085,520	$30,118,090
				Cumulative	**$201,918,263**

Conservation Grazing GHG Benefits

The GHG benefits of rotational grazing were estimated using the low end of the range provided by the Chicago Climate Exchange rangeland soil carbon management offset protocol.[59] Offsets are issued at standard rates depending on project type and location. Iowa has not been placed in a zone and rates vary from 0.12 to 0.52 tCO_2e/acre/year. As a conservative estimate, the midpoint of this range was assumed (0.32 tCO_2e/acre/year). The sequestration rate depends on the determination of whether the range is in a non-degraded or degraded condition. It was assumed that this rate of accumulation occurred for the duration of the policy period. The results are summarized in Table 5-5.

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[59] see http://www.chicagoclimateexchange.com/docs/offsets/CCX_Rangeland_Soil_Carbon.pdf

Table 5-5. GHG benefits and costs of conservation grazing

Year	Achieve Percent of Goal	Acres In Program	Total Carbon Sequestered (MMtCO$_2$e)	Costs (Includes Additional Upfront Establishment Costs)	Savings (Includes Revenue Generated Through Carbon Credits and Net Income From Adopting Rotational Grazing)	Net Cost (2005$)
2009	8%	72,500	0.023	$14,500,000	$3,770,297	$10,729,703
2010	17%	145,000	0.046	$14,500,000	$7,540,595	$6,959,405
2011	25%	217,500	0.070	$14,500,000	$11,310,892	$3,189,108
2012	33%	290,000	0.093	$14,500,000	$15,081,190	-$581,190
2013	42%	362,500	0.116	$14,500,000	$18,851,487	-$4,351,487
2014	50%	435,000	0.139	$14,500,000	$22,621,785	-$8,121,785
2015	58%	507,500	0.162	$14,500,000	$26,392,082	-$11,892,082
2016	67%	580,000	0.186	$14,500,000	$30,162,380	-$15,662,380
2017	75%	652,500	0.209	$14,500,000	$33,932,677	-$19,432,677
2018	83%	725,000	0.232	$14,500,000	$37,702,975	-$23,202,975
2019	92%	797,500	0.255	$14,500,000	$41,473,272	-$26,973,272
2020	100%	870,000	0.278	$14,500,000	$45,243,570	-$30,743,570
Cumulative			**1.74**			**-$120,083,204**

MMtCO$_2$e = million metric tons of carbon dioxide equivalent.

Conservation Grazing Costs

Unlike the land conversion programs, there is only a change of management practices and as such there are no land conversion costs. It was assumed that carbon credits ($7.25/tCO$_2$) would be generated through the Chicago Climate Exchange or a similar future program.[60]

In addition, there is likely to be annual income from the adoption of rotational grazing. The net annual income is assumed to be $50/acre/year. This is based on assumed additional income of $100/acre/year and assumed additional labor cost of adopting rotation grazing of $50/acre/year. To achieve this additional income, there are other up-front capital costs for fencing and watering systems (assumed to be $200/acre).[61] These costs are assumed to be in 2005 dollars and constant in real terms across the policy period. Costs for each year are indicated in Table 5-4.

Afforestation GHG Benefits

Forests grown or planted on land not currently in forest cover will likely accumulate carbon at a rate consistent with the accumulation rates of average forest in the region. Therefore, carbon sequestered by afforestation can be assumed to occur at the same rate as carbon sequestration in

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[60] Assumes that carbon credits can be obtained through future programs. Price sourced from CCX Web site on May 22, 2008. See http://www.chicagoclimateexchange.com/

[61] Personal Communications David Miller, Director, Research & Commodity Services, Iowa Farm Bureau Federation, via email dated 05/27/2008

average Iowa forests. For this analysis, it was assumed that afforested land would have otherwise been used for annual crop production.

Average carbon storage was found using methods described in USFS GTR-NE-343, assuming that afforestation activity would create forests that were consistent with the existing forest type distribution in Iowa. This distribution was based on USDA Forest Service Forest Inventory and Analysis data. Afforestation statewide was assumed to occur on 50% oak/hickory, 25% elm/ash/cottonwood, and 25% maple/beech/birch forests.

For afforestation calculations, annual carbon sequestration rates in each forest type group were calculated by subtracting carbon stocks in new stands (0 years) from carbon stocks in 35-year old stands and dividing by 35 years. A weighted statewide average carbon sequestration rate for afforestation activity was calculated, taking into account the variation in carbon sequestration across forest types (Table 5-6). The 35 year period was chosen to reflect the average length of an afforestation project period. In this afforestation calculation, soil carbon was taken into account. Soil carbon was assumed to accumulate at a rate consistent with soil carbon accumulation in afforested stands in GTR-NE-343.

Since afforested land would otherwise have been used for agricultural production, an additional GHG benefit of afforestation is the reduction of emissions from diesel fuel used to power farm equipment. This GHG benefit was considered to be parallel to expected reductions resulting from a switch to conservation tillage, as described above. GHG emission reductions associated with reduced management intensity were thus estimated by multiplying the fossil diesel emission factor (12.31 tCO_2e/1,000 gallons)[62] by the diesel fuel reduction per acre (3.5 gallons/acre)[63].

Table 5-6. Forest Carbon Sequestration Rates for Afforestation Activity (source: Smith et al. 2006, NE-GTR-343)

Afforestation	tCO_2e/acre (0 year)	tCO_2e/acre (35 year)	tCO_2e/acre/year (average)
Oak-hickory afforestation (NR-GTR-343 Table B15)	53.9	136.0	2.3
Elm-ash-cottonwood afforestation (NR-GTR-343 Table B13)	97.2	187.4	2.6
Maple-beech-birch afforestation (NR-GTR-343 Table B14)	75.5	164.3	2.5
Average carbon accumulation rate for afforestation			2.5

tCO_2e/acre = metric tons of carbon dioxide equivalent per acre.

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[62] J. Hill et al., "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," *Proceedings of the National Academy of Sciences* 103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life-cycle impacts. See http://www.pnas.org/cgi/content/short/103/30/11206.

[63] Reduction associated with less intensive land use (e.g., fewer passes). The estimate is based on conservation tillage compared with conventional tillage, *What's Conservation Tillage?* Available at http://www.conservationinformation.org/Core4Brochures/CTBrochure.pdf, accessed May 2008.

To achieve the goal of afforesting 250,000 acres by 2020, it was assumed that 20,833 acres would be planted each year from 2009 to 2020. Forests planted in one year continue to sequester carbon in subsequent years. Thus carbon storage in a given year was calculated as the sum of annual carbon sequestration on cumulative planted acreage. To determine total amount of carbon sequestered from 2009 to 2020, the number of acres planted in that year and all prior years was multiplied by the average annual carbon sequestration rate for each land use type (Table 5-7).

Table 5-7. Calculation of GHG benefits due to afforestation from 2009 to 2020.

Year	Acres planted this year (ac/yr)	Acres planted in prior years	Carbon sequestered in cumulative planted acreage (MMtCO2e/yr)	Diesel saved (1,000 gal)	MMtCO2e from Diesel avoided	Total MMtCO2e saved per year
2009	20,833	0	0.051	73	0.001	0.052
2010	20,833	20,833	0.102	146	0.002	0.104
2011	20,833	41,666	0.153	219	0.003	0.156
2012	20,833	62,499	0.204	292	0.004	0.208
2013	20,833	83,332	0.255	365	0.004	0.260
2014	20,833	104,165	0.306	437	0.005	0.312
2015	20,833	124,998	0.357	510	0.006	0.364
2016	20,833	145,831	0.409	583	0.007	0.416
2017	20,833	166,664	0.460	656	0.008	0.468
2018	20,833	187,497	0.511	729	0.009	0.520
2019	20,833	208,330	0.562	802	0.010	0.572
2020	20,837	229,163	0.613	875	0.011	0.624
Total	250,000		3.984	5687	0.070	4.054

MMtCO$_2$e = million metric tons of carbon dioxide equivalent.

Afforestation Costs and Benefits

Cost analyses of vegetation planting typically employ four categories: opportunity cost (of planting forest rather than another, potentially more lucrative land use), conversion cost, maintenance cost, and measuring/monitoring costs (Walker et al. 2007).

The opportunity cost for afforestation activity was assumed to be $106.15/ acre per year, which was the annual average rental payment to farmers in Iowa with land enrolled in the Conservation Reserve Program as of 2007.[64] One-time costs of vegetation establishment include site preparation and vegetation planting. For afforestation activity in IA, the Forest Land Enhancement Program (FLEP) indicates a willingness to cost-share 75% of the total project cost,

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[64] USDA Conservation Reserve Program: Summary and Enrollment Statistics, FY2007. Available at: http://www.fsa.usda.gov/Internet/FSA_File/annual_consv_2007.pdf.

to a maximum of $600/acre.[65] The full cost of afforestation activity, including site preparation and planting was thus estimated at 100% of a typical project cost, or $800/acre. Maintenance and monitoring costs on afforested land were assumed to be negligible between 2009 and 2020. It was further assumed that carbon credits due to afforestation activity would be available, such that the economic benefit of afforestation activity was calculated at the CCX market rate ($7.25/ tCO2e) for the C sequestration portion of the GHG benefit.[66]

Discounted costs to 2020 were calculated using a 5% discount rate. Results including annual costs are summarized in Table 5-8. The cost of implementing this option, expressed in 2005 dollars, was calculated to be $52.07 per ton of C stored or avoided.

Table 5-8. Net economic costs and benefits of afforestation activity in Iowa.

Year	Acres planted this year (ac/yr)	Acres planted in prior years	Opportunity cost	Establishment cost	Economic benefit (trading C credits)	Net economic cost
2009	20833	0	$2,211,423	$16,666,400	$370,262	$18,507,561
2010	20833	20833	$4,422,846	$16,666,400	$740,524	$20,348,722
2011	20833	41666	$6,634,269	$16,666,400	$1,110,786	$22,189,883
2012	20833	62499	$8,845,692	$16,666,400	$1,481,048	$24,031,044
2013	20833	83332	$11,057,115	$16,666,400	$1,851,310	$25,872,205
2014	20833	104165	$13,268,538	$16,666,400	$2,221,572	$27,713,366
2015	20833	124998	$15,479,961	$16,666,400	$2,591,834	$29,554,527
2016	20833	145831	$17,691,384	$16,666,400	$2,962,095	$31,395,688
2017	20833	166664	$19,902,807	$16,666,400	$3,332,357	$33,236,849
2018	20833	187497	$22,114,230	$16,666,400	$3,702,619	$35,078,010
2019	20833	208330	$24,325,652	$16,666,400	$4,072,881	$36,919,171
2020	20837	229163	$26,537,500	$16,669,600	$4,443,214	$38,763,886
Total	250000					

Improved management practices on unmanaged grazed forested land: GHG benefit

Improved management ractices on unmanaged grazed forested land: Economic costs

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[65] Iowa State Department of Natural Resources Bureau of Forestry, Forest Land Enhancement Program Components and Practices in Iowa. http://www.iowadnr.gov/forestry/pdf/FLEP%20Rates.pdf.

[66] Assume projects will be eligible for CCX enrollment. Price sourced from CCX Web site on May 22, 2008. See http://www.chicagoclimateexchange.com/.

Urban Forestry GHG Benefit

Carbon Sequestration in Urban Trees

Approximately 52,474,000 urban trees currently grow in Iowa.[67] A 25% increase in tree cover would require planting approximately 25% more, or a total of 13,118,500 trees. To achieve an increase in urban tree cover of this many trees by 2020, approximately 1,009,115 trees per year would be planted in Iowa communities beginning in 2009, assuming a constant planting rate to 2020. The average annual per-tree carbon sequestration value for urban trees was found by dividing the total estimated annual carbon sequestration in Iowa urban trees (313,000 metric tons of carbon/year, equating to 1.15 million tCO2e/year) by the total number of urban trees. Annual carbon sequestration per urban tree was thus calculated as 0.006 metric tons carbon (0.022 tCO2e) per tree per year. Since trees planted in one year continue to accumulate carbon in subsequent years, annual carbon sequestration in any given year was calculated as the sum of carbon stored in trees planted in that year, plus sequestration by trees that were planted in prior years. Because it takes the difference between total live carbon stocks at two points in time, this stock change approach accounts for normal tree mortality.

Avoided Fossil Fuel Emissions

GHG reductions from avoided fossil fuel use for heating and cooling can occur as a result of planting trees that provide additional shade and wind protection to buildings. The total benefits are a function of three different types of impacts: reduced cooling demand, reduced demand for heating due to wind reduction, and increased demand for heating due to wintertime shading. An average annual per tree GHG reduction factor of 0.03 tCO_2e/tree/year was calculated from data in McPherson et al. in GTR-PSW-171 (Table 5-9). The estimate assumed that the trees planted are split among residential settings with pre-1950, 1950–1980, and post-1980 homes using the default distribution provided by McPherson et al. of 42%, 48%, and 10%, respectively.

To calculate total avoided GHG emissions due to increased shading, it was assumed that all of the new urban trees are planted where they can have shading effects equivalent to the average shading effect of urban trees in the region. Medium-sized trees (half evergreen, half deciduous) and average tree distribution around buildings were also assumed. These fossil fuel reduction factors are average for existing buildings and do not necessarily assume that trees are optimally placed around buildings to maximize energy efficiency. These factors are further dependent on the fuel mix (e.g., coal, hydroelectric, nuclear) in the regions of interest, and may thus change if the electricity mix changes from its 1999 distribution.

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[67] USDA Forest Service Northern Research Station, USDA Forest Service, Northern Research Station, Urban Forest Effects on Environmental Quality State Summary data for Iowa http://www.fs.fed.us/ne/syracuse/Data/State/data_IA.htm

Table 5-9. Net GHG emission reductions from shade trees planted in the North Central climate region

Housing Age	Proportion of Urban Trees in This Housing Age Category	Cooling (tCO_2 Saved per Tree)	Heating (tCO_2 Emitted per Tree)	Wind (tCO_2 Saved per Tree)	Net Effect (tCO_2e/tree)
Pre-1950	0.42	0.0175	–0.0267	0.0435	0.0343
1950–1980	0.48	0.0127	–0.0239	0.0396	0.0283
Post-1980	0.1	0.0190	–0.0282	0.0431	0.0339
Weighted average (tCO_2e/tree/y)					**0.03138**

Source: PSW-GTR-171, Appendix A, Tables V.3. and 11.

The shading benefits occur in the year a tree is planted and every year thereafter. Thus, the GHG emissions reduction factor was multiplied by the cumulative number of trees planted each year to estimate annual avoided fossil fuel emissions. Total GHG benefit was calculated as the sum of direct carbon sequestration plus fossil fuel offset from reduced cooling demand and wind reduction. The avoided emissions and carbon sequestration benefits are summed in Table 5-10 to show the total net benefits of urban tree planting.

Table 5-10. Summary of GHG benefits from urban tree planting

Year	Number of Trees Planted This Year	Number of Trees Planted in Prior Years	Carbon Sequestered in Cumulative Trees Planted (tC/year)	Carbon Sequestered ($MMtCO_2e$/year)	Carbon Savings From Shading Effects ($MMtCO_2e$/year)	Total Carbon Savings ($MMtCO_2e$/year)
2009	1,093,208	0	6,559	0.024	0.034	0.058
2010	1,093,208	1,093,208	13,119	0.048	0.069	0.117
2011	1,093,208	2,186,417	19,678	0.072	0.103	0.175
2012	1,093,208	3,279,625	26,237	0.096	0.137	0.233
2013	1,093,208	4,372,833	32,796	0.120	0.172	0.292
2014	1,093,208	5,466,042	39,356	0.144	0.206	0.350
2015	1,093,208	6,559,250	45,915	0.168	0.240	0.408
2016	1,093,208	7,652,458	52,474	0.192	0.274	0.467
2017	1,093,208	8,745,667	59,033	0.216	0.309	0.525
2018	1,093,208	9,838,875	65,593	0.241	0.343	0.584
2019	1,093,208	10,932,083	72,152	0.265	0.377	0.642
2020	1,093,208	12,025,292	78,711	0.289	0.412	0.700
Total	**13,118,500**			**1.876**	**2.676**	**4.552**

tC = metric tons of carbon; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Urban Forestry Costs

Data are available on the costs and cost savings of urban tree planting in the Midwest (McPherson 2006). Economic costs of tree planting take into account the cost of tree planting and annual maintenance costs, including the costs of program administration and waste disposal.

Economic benefits of tree planting include the cost avoided from reduced energy use. Data are also available on the estimated economic benefits of services such as provision of clean air, hydrologic benefits such as stormwater control, and aesthetic enhancement; however, these co-benefits are not explicitly included in the analysis.

Costs and cost savings were estimated from published average annual costs and cost savings over 40 years, provided by public and private parties, for a range of tree sizes. The cost estimate used in this analysis, $26.38 per tree, was calculated as the average of small, medium, and large trees under public and private management. A cost savings of -$28.03 per tree per year was also calculated as the average of small, medium, and large trees under public and private management. The average cost and cost savings values yield a net cost savings of -$1.65 per tree (costs minus cost savings). Table 5-11 shows estimated economic costs and cost savings for all categories.

Table 5-11. DRAFT Cost data for public and private entities in the Midwest planting small, medium, and large trees (40-year annual averages)

Tree Size	Private ($/tree)	Public ($/tree)	Average of Public and Private ($/tree)
Small (crabapple)			
Cost savings (energy saved)	15.60	18.64	17.12
Costs*	17.02	26.87	21.95
Medium (red oak)			
Cost savings (energy saved)	20.31	25.62	22.97
Costs*	20.66	33.61	27.14
Large (hackberry)			
Cost savings (energy saved)	44.05	43.93	43.99
Costs*	23.10	36.99	30.05
Average across small, med, large trees ($ per tree)			
Cost savings (energy saved)			28.03
Costs*			26.38
Net costs			**(1.65)**

*Includes: tree and planting, pruning, removal and disposal, pest and disease, infrastructure repair, irrigation, cleanup, liability and legal, administration and other

The cost savings is estimated using 40-year averages, thus it represents lifetime costs applicable in the year planted and every year thereafter during the timeframe of this analysis (e.g., planting costs $80 per tree in the year the tree is planted; however the 40-year average cost is $10 per tree). To estimate total cost savings, –$1.65 per tree was multiplied by the cumulative number of trees planted each year (Table 5-12). This corresponds to a cumulative cost savings (or Net Present Value) of –$99 million from 2009 - 2020, with an estimated economic cost of –$21.84 per ton of CO_2e.

Table 5-12. Summary of cost savings from urban tree planting

Year	Cumulative number of trees in program	Total Carbon Savings (MMtCO$_2$e/year)	Net costs	Discounted costs
2009	1,093,208	0.058	-$1,803,794	-$1,803,794
2010	2,186,417	0.117	-$3,607,588	-$3,435,798
2011	3,279,625	0.175	-$5,411,381	-$4,908,282
2012	4,372,833	0.233	-$7,215,175	-$6,232,739
2013	5,466,042	0.292	-$9,018,969	-$7,419,928
2014	6,559,250	0.350	-$10,822,763	-$8,479,918
2015	7,652,458	0.408	-$12,626,556	-$9,422,131
2016	8,745,667	0.467	-$14,430,350	-$10,255,380
2017	9,838,875	0.525	-$16,234,144	-$10,987,907
2018	10,932,083	0.584	-$18,037,938	-$11,627,415
2019	12,025,292	0.642	-$19,841,731	-$12,181,102
2020	13,118,500	0.700	-$21,645,525	-$12,655,690
Total		**4.552**		**-$99,410,084**

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

Key Uncertainties

TBD – [as needed and approved by the subcommittees]

Additional Benefits and Costs

TBD – [as needed and approved by the subcommittees]

Feasibility Issues

TBD – [as needed and approved by the subcommittees]

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

AFW-6. Cellulosic Fuel Incentives

Policy Description

Promote research and production of sustainable in-state fuels derived from cellulose (biomass) to displace the use of conventional petroleum-based fuels. Promote the in-state development of cellulosic feedstocks (including perennials) that are able to be utilized for the production of cellulosic fuels. Promote research into conversion technologies, such as thermo-chemical Fischer-Tropsch processes and enzymatic conversion, to facilitate their development.

Promote cellulosic biofuel 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. This could help provide a strong economic market within the state and reduce GHG emissions through avoided fossil fuel consumption.

Note that this option is focused on the supply-side aspects of promoting biofuels, with an emphasis on the development of feedstocks and production technologies. The demand-side aspects of renewable fuels (including cellulosic biofuels) are being addressed through the Transportation and Land Use subcommittee through TLU-8.

Policy Design

Goals:
Increase in-state cellulosic feedstock production by 10 million dry tons by 2020.

Timing: Full implementation by 2020.

Parties Involved:
State of Iowa, farmers, biofuels producers, distributors, fuel retailers, fuel wholesalers, business owners, and relevant agriculture and trade associations.

Other:

Implementation Mechanisms

TBD

Related Policies/Programs in Place

None Identified.

Type(s) of GHG Reductions

CO_2: Lifecycle emissions are reduced to the extent that biofuels are produced with lower embedded fossil-based carbon than conventional (fossil) fuel. Feedstocks used for producing biofuels can be made from crops or other biomass, which contain carbon sequestered during photosynthesis (e.g., biogenic or short-term carbon).

Estimated GHG Reductions and Net Costs or Cost Savings

Estimated GHG reductions: 20.7 MMtCO_2e cumulative by 2020

Estimated cost: $1,020 (2007 MM$) cumulative by 2020

Data Sources:

Quantification Methods:

Biofuel GHG Reductions

For ethanol the benefits for this option are dependent on developing in-state production capacity that achieves benefits beyond petroleum fuels.

Based on the emission factors listed above, the incremental benefit of cellulosic production targeted by this policy over gasoline is 8.46 tCO_2 reduced/1,000 gallons minus the land use cost of converting land to cellulose production of 4.93 tCO_2/1,000 gallons.[68] The emission factor value is based on the difference between the lifecycle CO_2e emission factor of gasoline (11.74 metric tons/1,000 gallons) and the life cycle CO_2e emission factor of cellulosic ethanol (3.28 metric tons/1,000 gallons).[69] The cellulosic benefit value will be used along with the production in each year to estimate GHG reductions.

GHG reductions are estimated by assuming a linear increase in cellulose production to 10,000,000 tons in 2020. Annual cellulose production is multiplied by the estimated ethanol yield per ton biomass. The ethanol yield is then multiplied by 8.46 tCO_2e reduced/1,000 gallons ethanol to determine GHG reductions.

Biofuel Costs

For ethanol, costs for the incentives needed by this policy option are based on the estimated production costs of cellulosic ethanol. Estimates taken from an NREL-sponsored industry forum estimate a production cost differential of $0.69 per gallon for cellulose-based over corn-based ethanol (for more information on these costs, please see the Key Uncertainties section below).[70] This is used to estimate the incentive necessary to ramp up in-state cellulosic ethanol production. These estimates include capitals costs so additional incentives for capital and R&D are not included in this analysis. These incentives are considered necessary in the near term to help commercialize technologies that produce ethanol from cellulose. The incentives should also help to establish the infrastructure to deliver biomass to biorefineries, since producers will seek the local feedstocks or renewable fuels for their operations.

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[68] This one-half the value suggested by Searchinger, et al, 2008, of the land use cost of cellulosic ethanol over gasoline.

[69] DOE/EIA, http://www.eia.doe.gov/oiaf/analysispaper/biomass.html, accessed January 9, 2008. ANLGreet model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

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

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 could be discontinued beginning in 2015. Note that federal legislation has been proposed to offer cellulose an incentive of $0.765/gallon compared to the $0.51/gallon currently offered for ethanol production.[71] If enacted, this $0.255/gallon premium could cover the additional incentives that are assumed to be needed by the State of Iowa. The federal incentives do not assure, however, that production facilities would locate in Iowa, hence these federal incentives have not been factored into the cost estimates for this option.

To estimate the cost of cellulosic ethanol incentives, estimated ethanol yield from biomass is multiplied by $0.69 per gallon. Costs were discounted to 2007 dollars.

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

Key Uncertainties

Cost competitiveness of biofuels will depend on cost of oil.

Carbon emissions from land use change—Recent publications such as Searchinger, et al., 2008, have attempted to estimate the carbon emissions that result from land use being converted to cropland to grow crops for fuel. This is based on the argument that the conversion of current cropland from food/feed/fiber production in one part of the world will drop the food/feed/fiber supply on the market and drive grassland or forest conversion to cropland in other parts of the world. There is still significant uncertainty regarding the value of carbon emissions due to land use change. Additionally, conversion of cropland to fuel production may have impacts on food prices and supply.

Cost of cellulosic ethanol production—The Energy Information Administration (EIA) has stated "Capital costs for a first-of-a-kind cellulosic ethanol plant with a capacity of 50 million gallon per year are estimated by one leading producer to be $375 million (2005 dollars), as compared with $67 million for a corn-based plant of similar size, and investment risk is high for a large-scale cellulosic ethanol production facility. Other studies have provided lower cost estimates. A detailed study by the National Renewable Energy Laboratory in 2002 estimated total capital costs for a cellulosic ethanol plant with a capacity of 69.3 million gallons per year at $200 million."[72]

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

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

[72] http://www.eia.doe.gov/oiaf/analysispaper/biomass.html, accessed December 2007.

Additional Benefits and Costs

Biochar—Biochar is a byproduct produced from certain thermochemical energy production processes. The application of biochar to crop fields is believed increase soil productivity and increase soil carbon levels. The land application of biochar should be conducted although the level of GHG benefits is not fully understood and additional research is required.

Feasibility Issues

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

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

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

AFW-7. Improved On-Farm (or First Point of Purchase) Energy Use and Efficiency

Policy Description

Renewable energy can be produced and used on-site at agriculture operations. For example, installation of solar or wind power, use of hydro-powered generators for irrigation, and converting diesel farm equipment to more efficient or renewable energy technology will reduce carbon dioxide emissions. The use of energy efficient products should also be promoted. This could include improved grain dryers, heat exchangers (dairy), electric motors, and energy efficient building design.

Policy Design

Goals:

Renewable Energy—Increase renewable energy use at agriculture operations by 10% by 2020.

Energy Efficiency—Increase energy efficiency of on-farm operations by 30% by 2020.

Timing:

Parties Involved:

Other:

Implementation Mechanisms

Potential Technologies which could be used to improve on-farm efficiencies include efficient grain dryers and more efficient electric motors. Other technologies are considered in this analysis, but it is likely that they have similar costs.

Related Policies/Programs in Place

None Identified.

Type(s) of GHG Reductions

CO_2: Improved efficiency can reduce electricity and fuel consumption and the associated GHGs.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources:

Renewable Energy—Iowa Renewable Energy Guide[73] may be valuable in estimating costs of various renewable energy technologies on a small scale. If this policy is more intended to install on-farm renewable energy on a large scale, then different cost estimates will be used, such as the

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[73] http://www.iowadnr.gov/energy/renewable/files/renewableguide.pdf

Energy Information Agency Report titled "Assumptions for the Annual Energy Outlook 2006: with projections to 2025," 2006.

Energy Efficiency—Consumption of distillate fuel by the agriculture sector in Iowa was projected from historical data provided by the Energy Information Administration (EIA).74 The petro-diesel emissions factor used is consistent with the California Climate Action Registry (10.05 tCO_2e/1,000 gal).[75] The costs of efficient pump technology comes from the 2003 Farm and Ranch Irrigation Survey[76] and the US EPA.[77] Fuel savings estimates for tire inflation come from the AgTech Center.[78] The agricultural sector electricity consumption was derived from the National Agriculture Statistics Service (NASS)[79] and historical electricity prices from the EIA.[80]

Quantification Methods:

Renewable Energy GHG Benefits

Potential renewable energy options available for Iowa farmers include wind, solar photovoltaics, solar thermal heating and geothermal. Methane utilization is considered under AFW-4 and will not be covered here. A reasonable mix of these technologies will be based on Iowa's specific circumstances and will be informed by the state-wide energy portfolio. Table 7-1 shows the assumed generation mix used in this analysis. Table 7-2 shows the assumed capacity factors and levelised costs estimate used for each of these technologies. These numbers come from consultation with the Iowa Clean Renewable Energy Subcommittee.

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74 Energy Information Administration. "Colorado Total Distillate Sales/Deliveries to Farm Consumers." 1984–2006. Accessed on 4/25/08, at http://tonto.eia.doe.gov/dnav/pet/hist/kd0vfmsia1a.htm

[75] California Climate Action Registry. "General Reporting Protocol" March 2007.

[76] 2003 Farm and Ranch Irrigation Survey. Table 20. http://www.agcensus.usda.gov/Publications/2002/FRIS/index.asp

[77] US EPA. October 2006. "Diesel Pumping Efficiency Program" http://www.pumpefficiency.org/About/literature/Final%20Diesel%20Pumping%20Efficiency%20Report,%20USEPA.doc

[78] Agtech Center. "Farmers can save Big Money of Fuel". http://www1.agric.gov.ab.ca/$department/newslett.nsf/pdf/agin148/$file/Innovator%202.pdf?OpenElement

[79] National Agricultural Statistics Service. "Iowa Agriculture: A Profile." 2005 data. Accessed on April 25, 2008, at http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/

[80] Energy Information Administration. "Current and Historical Monthly Retail Sales, Revenues, and Average Retail Price by State and by Sector (Form EIA-826)." Table accessed on 4/25/08, at www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls.

Table 7–1. Assumed mix of generation

Year	Share of Wind	Share of Solar Thermal	Share of Solar PV	Share of Geothermal
2009	98%	1%	1%	0%
2010	98%	1%	1%	0%
2011	97%	1%	1%	0%
2012	96%	2%	2%	1%
2013	94%	2%	2%	1%
2014	93%	3%	3%	2%
2015	92%	3%	3%	2%
2016	92%	3%	3%	2%
2017	92%	3%	3%	2%
2018	91%	3%	3%	3%
2019	91%	3%	3%	3%
2020	91%	3%	3%	3%

Table 7-2. Assumed Capacity Factors

	Wind	Solar Thermal	Solar PV	Geothermal
Capacity Factor	35%	35%	30%	75%
Levelised Costs (2005$/mWh)	28	114	181	54

The GHG benefits were quantified based on the emission differences between the renewable portfolio and the grid electricity that it is replacing. The analysis assumes that renewable energy will be used to replace 10% of on-farm electricity. The business as usual projections of electricity use come from the Iowa Inventory and Forecast, using the electricity consumption estimates for 2005–2020. The share being consumed in on-farm use was calculated by taking the national agricultural electricity use and multiplying that by Iowa's share of total agricultural emissions.

Renewable Energy Costs

The costs/benefits of incentivizing each technology were considered. Costs were based on the portfolio of technologies considered, and the different costs of each, as seen in Table 7.2. The costs and GHG benefits of the Renewable Energy Option are shown below in Tables 7.3 and 7.4.

Table 7.3. GHG benefits of Renewable Energy Option

Year	BAU Iowa Agriculture Electricity Use (mWh)	Percentage of New Renewables	Additional Renewable Generation (mWh)	MMtCO2e Reduced from Renewable Generation
2009	931,905	0.7%	6,213	0.004
2010	945,697	1.3%	12,609	0.009

2011	959,693	2.0%	19,194	0.013
2012	973,897	2.7%	25,971	0.018
2013	988,311	3.3%	32,944	0.023
2014	1,002,938	4.7%	46,804	0.032
2015	1,017,781	6.0%	61,067	0.042
2016	1,032,844	6.7%	68,856	0.048
2017	1,048,130	7.7%	80,357	0.055
2018	1,063,643	8.7%	92,182	0.064
2019	1,079,385	9.3%	100,743	0.070
2020	1,095,359	10.0%	109,536	0.076
	Cumulative Savings (2009-2020)			0.453

Table 7.4. Costs of renewable energy option

Year	Cost of Wind Generation	Cost of Solar Thermal Generation	Cost of Solar PV Generation	Cost of Geothermal Generation	Total Costs
2009	$170,476	$7,082	$11,245	$0	$188,804
2010	$345,999	$14,375	$22,823	$0	$383,196
2011	$520,231	$30,633	$48,637	$4,146	$603,647
2012	$695,181	$53,292	$84,612	$11,219	$844,304
2013	$870,768	$82,623	$131,182	$21,348	$1,105,920
2014	$1,221,391	$138,726	$220,258	$40,438	$1,620,814
2015	$1,573,082	$208,849	$331,593	$65,952	$2,179,476
2016	$1,769,882	$235,488	$373,890	$81,801	$2,461,061
2017	$2,060,988	$274,820	$436,337	$104,142	$2,876,286
2018	$2,359,131	$315,264	$500,550	$129,424	$3,304,369
2019	$2,572,562	$344,540	$547,032	$152,323	$3,616,456
2020	$2,790,976	$374,613	$594,780	$177,448	$3,937,817
	Cumulative Costs				$23,122,151

PV = photovoltaics.

Energy Efficiency GHG Benefits

This analysis also considered various technology possibilities available to reduce on-farm energy consumption, including: education programs to optimize tire inflation, improving efficiency of water pumps, more efficient lighting, and incentives for more efficient tractors. Other options, such as efficient grain dryers and more efficient electric motors are likely available to provide GHG benefits, and will be utilized when farms undertake the energy audit. The GHG benefits were calculated based on the emissions that have been avoided because of the new technologies. This could come in the form of fuel savings or reduced electricity consumption. The total GHG benefit was calculated based on the emissions factors of the various fuels (CO_2e/Btu or gallon) or electricity (CO_2e/kWh). The business as usual projections of electricity use come from the Iowa

Inventory and Forecast, using the electricity consumption estimates between 2005–2020. The share being consumed in on-farm use was calculated by taking the national agricultural electricity use and multiplying that by Iowa's share of total agricultural emissions. The business as usual fuel use was derived by dividing the amount sold in agricultural use in Iowa by the cost of a gallon of diesel fuel in 2006 (both figures from the USDA). No growth in diesel fuel consumption was assumed because of conflicting growth estimates. The savings for the energy efficiency technologies considered did not meet the goal of the policy, so an energy audit program was also included. This program will provide state funding for energy audits to improve the energy efficiency of farms across Iowa. It is assumed that these audit programs will find energy efficiency gains at a similar cost/benefit to that of the efficiency technologies considered in this analysis.

Efficiency Costs

This analysis will be done by examining the cost of installing or optimally using various technologies (for example more efficient pumps). In order to maximize pump efficiency, they must be tested and replaced periodically, which requires a capital investment.

Using estimates of the total number of pumps potentially available in Iowa, we can determine the total costs of this project. This total cost figure will be balanced against the fuel/ electricity savings which occur with such an efficiency investment. The diesel pump program includes costs of testing (200$/test, 1 test assumed every five years) and the cost of retrofitting older pumps to be more efficient ($24,913)[81]. Since this results in an average efficiency improvement of 41%, it will on average save over 23,000 gallons in the lifetime of the pump.

The cost of the energy audit program are assumed to be 500k annually for staffing/travel costs, and $2,000 for every energy audit performed. The number of energy audits performed depends on the amount of energy savings required to meet the energy efficiency goal for the year. Since all of the energy efficiency programs considered in this analysis (efficient pumps, tire inflation, and lighting) have negative net costs, the money spent on the energy audit program is recouped throughout the period. See Table 7.5 to see the Costs and savings for each year are discounted back to 2005 dollars.

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[81] US EPA. October 2006. "Diesel Pumping Efficiency Program" http://www.pumpefficiency.org/About/literature/Final%20Diesel%20Pumping%20Efficiency%20Report,%20USEPA.doc

Table 7.5 Costs and GHG benefits of Energy Efficiency Program

Year	$MMtCO_2e$ Saved	Goal, $MMtCO_2e$ Saved	Percent Attained With Example Programs	Cost of Energy Audit Program	Cost Savings, Energy Audit Program	Discounted Costs of Program
2010	0.07	0.121	0.58	$15,596,957	–$25,621,748	–$7,854,686
2011	0.08	0.183	0.43	$21,037,814	–$38,574,201	–$13,085,922
2012	0.09	0.244	0.35	$23,766,420	–$51,615,810	–$19,792,041
2013	0.09	0.306	0.31	$25,410,186	–$64,744,935	–$26,623,307
2014	0.10	0.430	0.24	$27,921,355	–$90,954,417	–$40,631,673
2015	0.11	0.555	0.20	$29,320,184	–$117,339,156	–$54,036,013
2016	0.12	0.619	0.19	$29,596,774	–$130,817,435	–$59,181,624
2017	0.12	0.714	0.17	$30,111,132	–$150,946,632	–$67,285,728
2018	0.13	0.810	0.16	$30,509,446	–$171,209,153	–$74,616,059
2019	0.14	0.875	0.16	$30,629,454	–$184,999,409	–$77,967,317
2020	0.15	0.941	0.16	$30,735,800	–$198,881,739	–$80,881,072

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

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

Key Uncertainties

TBD – [as needed and approved by the subcommittees]

Additional Benefits and Costs

TBD – [as needed and approved by the subcommittees]

Feasibility Issues

Implementing renewable projects at a small scale (e.g., on-farm operations) can often be difficult and/or expensive. This may be a limiting factor in the implementation of this option.

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

AFW-8. Waste Management Strategies

Policy Description

Reduce the volume of waste from residential, commercial, and government sectors through programs that reduce the generation of wastes. Reduction of generation at the source reduces both landfill emissions and upstream production emissions.

Increase recycling or reuse of waste in order to limit GHG emissions associated with landfill methane generation and with the production and transport of products/packaging from virgin materials (noting that different recycled materials will exhibit different costs and benefits on a life cycle basis). Increase recycling programs, create new recycling programs, provide incentives for recycling construction materials, develop markets for recycled materials, and increase average participation/recovery rates for all existing recycling programs.

Increase organics management programs, such as composting, in order to reduce GHG emissions associated with land-filled organic waste.

Policy Design

Three approaches are possible: recycling approach, waste prevention approach, market driven approach, i.e., producer responsibility (voluntary systems and mandatory systems).

Goals:

Waste Prevention—Achieve a 5% per capita decrease in waste production (as compared to 2005), from residential commercial, and government sectors by 2020.

Reuse and Recycling—Increase statewide recycling rate average to 50% by 2020 as compared to the amount of waste produced. (If waste is minimized, then there will be less materials to recycle.)

Extended Producer Responsibility—Reach an agreement with manufacturers, producers, and retailers to reduce by 10 percent the quantity of packaging on the market and pursue more environmentally friendly packaging.

Work with U.S. industry to achieve life cycle product stewardship, so that products are designed for reuse, repair (not planned obsolescence), and recycling. Alternatively, shift the responsibility for managing discarded products and packaging from local government to producers of products. (non-quantified goal)

Timing:

Parties Involved:

Other:

In 2005, Iowa diverted 29.3% of generated municipal solid waste from landfills (see Table 1 below). The recycling rate was 27.1% and the composting rate was 2.1%. Compostable organics comprised 9.8% of the total waste generated, setting the upper bound for the Subcommittee's composting goal. [82]

Table 1. 2005 Baseline Waste Generation and Diversion

Item	2005
Total generation (tons)	3,775,550
Iowa population	2,955,587
MSW generation per capita	1.28
Landfill disposal (tons)	2,679,700
Total diversion (tons)	1,108,531
Diversion %	29.3%
Recycling (tons)	1,028,077
Recycling %	27.1%
Composting (tons)	80,454
Composting %	2.1%

Data needed to estimate the future generation of MSW in Iowa are not available from the resources on the DNR Web site. Therefore, CCS assumed that the per capita MSW generation rate would follow the same trend as the national MSW generation. Table 2 below identifies the average annual increase in per capita generation as 0.14%.[83] This results in an increase in waste generation from 1.28 tons/person/year in Iowa in 2005 to 1.30 tons/person/year in 2020.

Table 2. National MSW generation rates

Year	Generation (tons)	Population	Generation (tons/per capita/year)	Generation (lb/per capita/day)	Annual % Change in Generation per Capita
1990	205,210,000	249,907,000	0.82	4.50	
2000	238,260,000	281,422,000	0.85	4.64	0.31%
2002	239,390,000	287,985,000	0.83	4.55	–0.91%
2004	249,180,000	293,660,000	0.85	4.65	1.04%
2005	248,150,000	296,410,000	0.84	4.59	–1.34%
2006	251,340,000	299,398,000	0.84	4.60	0.27%
Average Annual Change 1990–2006					**0.14%**

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[82] Iowa Department of Natural Resources. "Economic Impacts of Recycling in Iowa." December 2007. Accessed on March 7, 2008 from; http://www.iowadnr.com/waste/recycling/files/ecofullreport.pdf. The 2005 baseline data is estimated from Table 7.1 of the "Economic Impacts of Recycling in Iowa" report.

[83] US EPA. US Municipal Solid Waste Stream 1960-2006. Accessed on May 23 at http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/06data.pdf

Waste Prevention

The route to waste prevention requires a combination of initiatives by manufacturers and retailers, governmental intervention, as well as better informed consumers.

Waste prevention and recycling are at different ends of the spectrum. Recycling programs do not further the goals of waste prevention.

The incentive for manufacturers, producers, and consumers to minimize waste is greatly reduced when the emphasis is on municipal recycling programs.

There is insufficient awareness and understanding of the benefits and methodology of waste prevention. There is predominantly an emphasis in both the public and private sectors on "end-of-pipe" waste treatment rather than prevention.

With waste prevention, greenhouse gas emissions associated with waste disposal are not only avoided, but also all the emissions associated with extraction, manufacturing and transport. Waste prevention is genuinely sustainable resource management.

Manufacturing take back programs create an incentive for waste minimization.

Consumer education on waste-related purchase behavior results in little impact as consumers have a tendency to rank price, convenience and brand name as more critical than environmental considerations.

EPA estimates that for each person participating in a PAYT program, greenhouse gas emissions are reduced by an average of 0.088 metric tons of carbon equivalent. (EPA, 1999) A community of 100,000 people could potentially reduce GHG emissions by 8,800 metric tons of carbon equivalent.

Recycling

Goals of ever higher recycling targets will have higher costs. There is increasing demand for more materials to be added to recycling programs, which will further escalate costs and add to risks of being able to market the materials collected.

High recycling rates inadvertently justify high consumption rates. Statutory recycling targets do not prevent waste but force the focus on recycling.

Providing garbage collection more frequently than recycling collection encourages disposal rather than recycling.

The development of integrated waste management facilities such as commercial MRFs and biodegradable waste composting facilities are complex and expensive and siting such facilities is problematic if not impossible.

Flow control will become an issue if Iowa establishes waste rules and regulations that are more stringent, onerous, and more costly than surrounding states.

The overriding goal should be on climate change; we should evaluate the potential of source reduction or recycling to achieve the goal of reducing greenhouse gas emissions.

As the principal generator of waste, industry is a crucial stakeholder in the effective implementation of waste reduction and recycling.

Implementation Mechanisms

- Assist in the creation and expansion of sustainable markets to support diversion and recycling efforts.
- Introduce appropriate financial, legal and policy incentives and sanctions to induce waste generators to prevent waste and recycle.
- Focus local government efforts to require multi-family recycling.
- Focus local government efforts to require construction and demolition recycling.
- Make recycling more convenient and cost-effective when compared to waste disposal, e.g., implement curbside single stream recycling systems and food waste collection.
- Implement incentives for customers to reduce waste through meaningful Unit Based Pricing systems for waste disposal in all regions with large populations.
- Establish composting programs for yard waste and food waste in all regions with combined large populations.
- Pilot Commercial Material Recovery Facilities (COMM MRFs) through which all commercial waste will be processed before residuals are disposed of (not front-end).
- Require mandatory life cycle product stewardship (extended producer responsibility) which is designed, financed, and managed by manufacturers of consumer goods.
- Hold manufacturers responsible for the waste and environmental impact of their products and packaging (producer responsibility) rather than passing that responsibility to the consumer.
- Place a tax on plastic bags.
- Establish statewide landfill bans for select materials that can be reused, recycled, or otherwise recovered.
- Expand the materials collected through the Bottle Bill and increase financial incentives for collectors.
- Educate the community about the consequences of generating waste and responsible consumerism.
- Clearly define waste reduction and establish as a priority.
- Distribute information on how to reduce unwanted mail and catalogues.
- Encourage use of reusable shopping bags.
- Promote "simple living," local purchasing
- Promote an economic environment that favors the use of recycled materials.

Related Policies/Programs in Place

Waste Management Programs: The State of Iowa runs several programs to promote waste reduction, recycling, and composting. These programs include Iowa DNR's Solid Waste Alternatives Program, Pollution Prevention Services Program, and Iowa Waste Exchange, as well as Iowa Waste Reduction Center at the University of Northern Iowa.

Landfill Diversion Goals: The State of Iowa adopted the goal of diverting 50% of waste from landfills by the year 2000 from year 1988 levels.

Type(s) of GHG Reductions

CO_2: Upstream Energy Use Reductions—The energy and GHG intensity of manufacturing a product is generally less using recycled feedstocks than from using virgin feedstocks.

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 2012, 2020 (MMtCO_2e): 1.49, 4.06, respectively.

Net Cost per tCO_2e: –$8.

Data Sources: Data on current waste generation and recycling rates were taken from the IA DNR *Economic Impacts of Recycling, 2007.*[84] IA DNR reports the composting of yard trimmings and food wastes as a part of the recycling stream in this report. GHG emission reductions were modeled using EPA's WAste Reduction Model (WARM).[85]

Quantification Methods:

The waste management profile in Iowa presented in the "Policy Design" section was used as a baseline to project business as usual (BAU) and policy scenarios, which form the basis for this quantitative analysis. The average annual increase in per capita waste generation is assumed to be 0.14% (see Table 2). The share of waste management comprised of recycling and composting is assumed not to change throughout the policy period. Therefore, the assumed recycling rate

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[84] Iowa Department of Natural Resources. "Economic Impacts of Recycling in Iowa." December 2007. Accessed on March 7, 2008 from; http://www.iowadnr.com/waste/recycling/files/ecofullreport.pdf. The 2005 baseline data is estimated from Table 7.1 of the "Economic Impacts of Recycling in Iowa" report.

[85] "WAste Reduction Model (WARM)." Version 8, May 2006. Available at: http://www.epa.gov/climatechange//wycd/waste/calculators/WARM_home.html. EPA created WARM to help solid waste planners and organizations track and voluntarily report GHG emission 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 tCe, tCO_2e, and energy units (MMBtu) across a wide range of material types commonly found in MSW. For an explanation of the methodology, see the EPA report *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*, EPA530-R-02-006, available at http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html

was 27.1% and the assumed composting rate was 2.1%.[86] The population projection for Iowa through 2020 is consistent with the projection used by the Draft Iowa GHG Inventory and Forecast. Table 3 outlines the projected BAU waste management scenario for Iowa.

Table 3. BAU waste management, 2005–2020

Item	2005	2010	2012	2015	2020
MSW generation per capita (tons/person)	1.28	1.29	1.29	1.30	1.30
Iowa population (from I&F)	2,955,587	3,009,907	3,016,485	3,026,380	3,020,496
MSW generation (tons)	3,775,550	3,871,850	3,891,152	3,920,286	3,940,048
MSW recycled (tons, 27.2% of generation, not including organics)	1,024,636	1,050,770	1,056,008	1,063,915	1,069,278
Organic composting (tons, 2.1% of generation)	80,185	82,230	82,640	83,259	83,678
MSW disposed in landfills (tons)	2,670,730	2,738,850	2,752,504	2,773,113	2,787,092

MSW = municipal solid waste; I&F = Inventory and Forecast.

The policy scenario was determined by applying the Subcommittee targets to the BAU waste management projection in Table 3. Interim targets for 2012 were estimated, assuming that recycling and composting each comprise a constant proportion of the goal. The 2012 targets for recycling and composting are 35.5% and 3.5%, respectively. The 2020 targets for recycling and composting are 45.0% and 5.0%, respectively. The waste reduction goal (5% decrease in waste per capita by 2020) is applied by assuming a constant reduction in the difference between the BAU projected annual increase in generation per capita and the 2005 baseline generation per capita rate. Table 4 outlines the policy waste management scenario.

Table 4. Policy waste management, 2005–2020

Item	2005	2010	2012	2015	2020
MSW generation per capita (tons/person)	1.28	1.28	1.27	1.25	1.22
Iowa population (from I&F)	2,955,587	3,009,907	3,016,485	3,026,380	3,020,496
MSW generation (tons)	3,775,550	3,847,020	3,816,478	3,770,379	3,665,543
MSW recycled (tons)	1,024,636	1,214,823	1,380,346	1,527,600	1,773,022
Organic composting (tons)	80,185	107,197	132,280	156,551	197,002
MSW disposed in landfills (tons)	2,670,730	2,524,999	2,303,851	2,086,229	1,695,519

Table 5 displays the incremental changes in waste management, or the difference between the BAU and policy scenarios. These numbers represent the changes in waste management as a

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[86] As a result of modeling constraints, all organic material that is "recycled" is considered to be "composted." As recycling and composting have different implications on the analysis of the GHG benefit and cost effectiveness of this option, the two management methods will be treated separately, with the total diversion equal to the Subcommittee target of 35%. Please note that the term "diversion" refers to the combination of recycling and composting.

result of this option. They are the basis for the GHG benefit and cost effectiveness measurements.

Table 5. Incremental Changes in Waste Management, 2005–2020

Item	2005	2010	2012	2015	2020
MSW generation (tons, source reduction)	—	24,830	74,675	149,907	274,505
Recycling (tons)	—	164,053	324,338	463,685	703,743
Organic composting (tons)	—	24,967	49,640	73,292	113,324
Landfill disposal (tons)	—	-213,851	-448,653	-686,884	-1,091,573

GHG Benefits

GHG benefits were determined using the EPA's WAste Reduction Model (WARM).[87] WARM uses information for specific material inputs and disposal/diversion methods to estimate GHG emission reductions based on a business-as-usual (BAU) and policy scenario. Table 6 below describes the 2005 Data Inputs for the WARM model.[88] These numbers will represent the baseline scenario.

Table 6. Baseline WARM Model Inputs for Iowa, 2005.

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum cans	28,411	21,979	6,432		N/A
Steel cans	31,418	10,516	20,902		N/A
Copper wire					N/A
Glass	99,872	63,428	36,444		N/A
HDPE	26,438	5,000	21,438		N/A
LDPE	610	610			N/A
PET	25,139	11,740	13,399		N/A
Corrugated cardboard	330,237	149,625	180,612		N/A
Magazines/third-class mail	186,775		186,775		N/A
Newspaper	325,214	240,000	85,214		N/A

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[87] WAste Reduction Model (WARM)." Version 8, May 2006. Available at: http://www.epa.gov/climatechange//wycd/waste/calculators/WARM_home.html. EPA created WARM to help solid waste planners and organizations track and voluntarily report GHG emission 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 tCe, tCO_2e, and energy units (MMBtu) across a wide range of material types commonly found in MSW. For an explanation of the methodology, see the EPA report *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*, EPA530-R-02-006, available at http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html

[88] Iowa Department of Natural Resources. "Economic Impacts of Recycling in Iowa." December 2007. Accessed on March 7, 2008 from; http://www.iowadnr.com/waste/recycling/files/ecofullreport.pdf. The 2005 baseline data is estimated from Table 7.1 of the "Economic Impacts of Recycling in Iowa" report.

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Office paper	55,004	2,750	52,254		N/A
Phonebooks					N/A
Textbooks					N/A
Dimensional lumber	344,525	167,665	176,860		N/A
Medium-density fiberboard					N/A
Food scraps	225,595	N/A	225,095		500
Yard trimmings	101,573	N/A	34,300		67,273
Grass		N/A			
Leaves		N/A			
Branches		N/A			
Mixed paper (general)	349,636	153,214	196,422		N/A
Mixed paper (primarily residential)					N/A
Mixed paper (primarily from offices)					N/A
Mixed metals	250,620	178,000	72,620		N/A
Mixed plastics	298,059	16,959	281,100		N/A
Mixed recyclables					N/A
Mixed organics	44,301	N/A	31,620		12,681
Mixed MSW	1,007,566	N/A	1,007,566		N/A
Carpet	575	575			N/A
Personal computers	51,281	634	50,647		N/A
Clay bricks		N/A		N/A	N/A
Concrete	5,382	5,382		N/A	N/A
Fly ash				N/A	N/A
Tires					N/A
Totals	3,788,231	1,028,077	2,679,700	–	67,773

The WARM model was run for the years 2012 and 2020, in order to produce GHG reduction estimates for the policy target years. GHG benefits are assumed to increase linearly between policy initiation (2010) and between modeled years. The proportional generation and recycling are assumed to stay the same throughout the policy period. The exceptions, however, are those categories for which source reduction is an acceptable input for the policy scenario. It is assumed that source reduction offsets landfilled waste, with the amount of waste recycled generally increasing for these categories. The breakdown of source reduction for each waste category is shown in Table 7.[89] Tables 8 and 9 display the BAU and policy WARM modeling for 2020.

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[89] This breakdown is similar to the one used for the Minnesota CCS process, adjusted to prevent more tons from being "source reduced" than would have been generated under BAU. Also, it is assumed that no more than 75% of any given material may be source reduced. These percentages may be adjusted according to the Subcommittee's input.

Table 7. Share of Source Reduction for WARM Input

Tons Source Reduced	2012	2020
HDPE	4.5%	9.0%
LDPE	0.5%	0.2%
PET	25.0%	7.1%
Corrugated Cardboard	30.0%	34.5%
Magazines/Third Class Mail	30.0%	34.5%
Office Paper	10.0%	14.5%

Table 8. 2020 BAU WARM Inputs

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	29,550	22,860	6,690		NA
Steel Cans	32,677	10,937	21,740		NA
Copper Wire					NA
Glass	103,874	65,970	37,905		NA
HDPE	27,498	5,200	22,297		NA
LDPE	634	634	-		NA
PET	26,146	12,210	13,936		NA
Corrugated Cardboard	343,472	155,621	187,850		NA
Magazines/Third-class Mail	194,260	-	194,260		NA
Newspaper	338,247	249,618	88,629		NA
Office Paper	57,208	2,860	54,348		NA
Phonebooks					NA
Textbooks					NA
Dimensional Lumber	358,332	174,384	183,948		NA
Medium-density Fiberboard					NA
Food Scraps	234,636	NA	234,116		520
Yard Trimmings	105,644	NA	35,675		69,969
Grass		NA			
Leaves		NA			
Branches		NA			
Mixed Paper (general)	363,648	159,354	204,294		NA
Mixed Paper (primarily residential)					NA
Mixed Paper (primarily from offices)					NA
Mixed Metals	260,664	185,134	75,530		NA
Mixed Plastics	310,004	17,639	292,365		NA
Mixed Recyclables					NA

Material	**Tons Generated**	**Tons Recycled**	**Tons Landfilled**	**Tons Combusted**	**Tons Composted**
Mixed Organics	46,076	NA	32,887		13,189
Mixed MSW	1,047,945	NA	1,047,945		NA
Carpet	598	598	-		NA
Personal Computers	53,336	659	52,677		NA
Clay Bricks		NA		NA	NA
Concrete[1]	5,598	5,598	-	NA	NA
Fly Ash[2]				NA	NA
Tires[3]					NA
Totals	**3,940,048**	**1,069,278**	**2,787,092**	**-**	**83,678**

Table 9. 2020 Policy WARM Inputs

Material	**Baseline Generation**	**Tons Source Reduced**	**Tons Recycled**	**Tons Landfilled**	**Tons Combusted**	**Tons Composted**
Aluminum cans	29,550		29,550	-		
Steel cans	32,677		23,889	8,788		
Copper wire						
Glass	103,874		103,874	-		
HDPE	27,498	24,831	2,667	-		
LDPE	634	476	159	-		
PET	26,146	19,610	6,537	-		
Corrugated cardboard	343,472	94,830	248,642	-		
Magazines/ third-class mail	194,260	94,830	-	99,430		
Newspaper	338,247		338,247	-		
Office paper	57,208	39,929	6,247	11,032		
Phonebooks						
Textbooks						
Dimensional lumber	358,332		358,332	-		
Medium-density fiberboard						
Food scraps	234,636			189,354		45,282
Yard trimmings	105,644			-		105,644
Grass						
Leaves						
Branches						
Mixed paper, broad	363,648		348,053	15,595		
Mixed paper, residential						
Mixed paper, office						
Mixed metals	260,664		260,664	-		

Material	Baseline Generation	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Mixed plastics	310,004		38,525	271,479		
Mixed recyclables						
Mixed organics	46,076			-		46,076
Mixed MSW	1,047,945			1,047,945		
Carpet	598		598	-		
Personal computers	53,336		1,440	51,896		
Clay bricks						
Concrete[1]	5,598		5,598	-		
Fly ash[2]						
Tires[3]						
Totals	**3,940,048**	**274,505**	**1,773,022**	**1,695,519**	**-**	**197,002**

The resulting output for the 2012 and 2020 WARM model runs predict the GHG reductions for these years to be 1.49 and 4.06 $MMtCO_2e$, respectively. The cumulative GHG reductions are calculated to be 26.5 $MMtCO_2e$.Table 10 displays a summary of the waste diversion, reduction, and GHG benefits of this option.

Table 10. Overall Policy Results—GHG Benefits

Year	Avoided Emissions ($MMtCO_2e$)	Incremental Waste Diversion (tons)	Source Reduction (tons)	Incremental Recycling (tons)	Incremental Composting (tons)	Avoided Landfill Emplacement (tons)
2009	-	-	-	-	-	-
2010	0.50	213,851	24,830	164,053	24,967	-213,851
2011	0.99	426,527	49,721	326,960	49,845	-426,527
2012	1.49	448,653	74,675	324,338	49,640	-448,653
2013	1.81	528,008	99,690	370,793	57,525	-528,008
2014	2.13	607,418	124,767	417,242	65,409	-607,418
2015	2.45	686,884	149,907	463,685	73,292	-686,884
2016	2.77	767,848	174,850	511,698	81,299	-767,848
2017	3.09	848,798	199,782	559,711	89,305	-848,798
2018	3.41	929,736	224,701	607,723	97,312	-929,736
2019	3.74	1,010,661	249,609	655,734	105,318	-1,010,661
2020	4.06	1,091,573	274,505	703,743	113,324	-1,091,573
Totals	**26.5**	**7,559,956**	**1,647,037**	**5,105,682**	**807,236**	**-7,559,956**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Cost Effectiveness

Source Reduction—The total amount of waste managed in Iowa under the policy scenario is reduced, due to the goal requiring a zero percent increase in the per capita waste generation rate by 2020. The cost effectiveness estimate for source reduction in Iowa is comprised of three elements; the cost of program implementation, the avoided cost of waste collection, and the avoided cost of waste disposal.

The cost of program implementation is assumed to be $1 per capita per year.[90] The cost figure uses the population projection consistent with that used for the Iowa Inventory and Forecast. These funds are assumed to cover any education and marketing programs necessary to implement the source reduction goal.

Source reduction is expected to save money by reducing the amount of waste that has to be collected and disposed of in landfills. The avoided collection cost is $80/ton[91] and the avoided landfill disposal fee is $40/ton.[92]

The analysis assumes that costs begin to be incurred in 2010. The estimated cost savings result in an NPV of –$112 million. Cumulative GHG reductions attributed to recycling are 10.3 MMtCO$_2$e, and the estimated cost-effectiveness is –$11/tCO$_2$e, as shown in Table 11.

Table 11. Cost Analysis for Source Reduction

Year	Tons Reduced	Avoided Landfill Tipping Fee (2006$MM)	Program Costs (2006$MM)	Net Source Reduction Costs (2006$MM)	Discounted Costs (2006$MM)	GHG Reductions (MMtCO$_2$e)	Cost-Effective-ness ($/tCO$_2$e)
2009	-	$0	$0	$0	$0	0.0	
2010	24,830	$3	$3	$0	$0	0.1	
2011	49,721	$6	$3	-$3	-$3	0.3	
2012	74,675	$9	$3	-$6	-$5	0.4	
2013	99,690	$12	$3	-$9	-$7	0.6	
2014	124,767	$15	$3	-$12	-$9	0.8	
2015	149,907	$18	$3	-$15	-$11	0.9	
2016	174,850	$21	$3	-$18	-$13	1.1	
2017	199,782	$24	$3	-$21	-$14	1.3	
2018	224,701	$27	$3	-$24	-$15	1.4	
2019	249,609	$30	$3	-$27	-$17	1.6	
2020	274,505	$33	$3	-$30	-$17	1.8	
				-$164	**-$112**	**10.3**	**-$11**

2006$MM = million 2006 dollars; MMtCO$_2$e = million metric tons of carbon dioxide equivalent; $/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent.

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[90] The source reduction program cost is a preliminary estimate that is consistent with costs assumed in similar options considered by CCS projects in WA and CO.

[91] IA DNR *Evaluation of Recycling Programs*. Average of case studies from Cedar Rapids, Marion, Iowa City, and Central City. Accessed on May 23, 2008 at http://www.iowadnr.com/waste/pubs/files/ecicogfinal.pdf.

[92] Average of tip fee of landfills in Iowa reporting a per-ton tip fee. Iowa Tip Fee Survey Results. Last Updated July, 2007. Accessed on May 23, 2008 from: http://www.iowadnr.com/waste/sw/files/tp_survey.pdf

Recycling—The net cost of increased recycling rates in Iowa was estimated by adding the increased costs of collection for two-stream recycling, revenue obtained for the value of recycled materials, and avoided landfill tipping fees. The additional cost for separate curbside collection of recyclables is $133/ton.[93] The capital cost of additional recycling facilities in Iowa is $148 million.[94] Annualized over the 10-year policy period at 5% interest, the capital cost is $9.6 million per year. The avoided cost for landfill tipping is $40/ton, plus a $10 tip fee paid to the hauler.[95] CCS also factored in the commodity value of recycled materials with a value of $156/ton.[96] Table 12 provides the results of the cost analysis. The analysis assumes that costs begin to be incurred in 2010. The estimated cost savings result in an NPV of –$188 million. Cumulative GHG reductions attributed to recycling are 16 MMtCO$_2$e, and the estimated cost-effectiveness is –$12/tCO$_2$e.

Table 12. Cost analysis results for recycling

Year	Tons Recycled	Annual Collection Cost (MM$)	Annual Capital Cost (MM$)	Annual Recycled Material Revenue (MM$)	Landfill Tip Fees Avoided (MM$)	Net Policy Cost (Recycling) (MM$)	Discounted Costs (MM$)	GHG Reductions (MMtCO$_2$e)	Cost-Effective-ness ($/tCO$_2$e)
2009	-	$0	$0	$0	$0	$0	$0	-	
2010	164,053	$22	$10	$26	$8	-$2	-$2	0.4	
2011	326,960	$43	$10	$51	$16	-$14	-$13	0.7	
2012	324,338	$43	$10	$51	$16	-$14	-$12	1.1	
2013	370,793	$49	$10	$58	$19	-$18	-$14	1.2	
2014	417,242	$55	$10	$65	$21	-$21	-$16	1.4	
2015	463,685	$62	$10	$72	$23	-$24	-$18	1.5	
2016	511,698	$68	$10	$80	$26	-$28	-$20	1.7	
2017	559,711	$74	$10	$87	$28	-$31	-$21	1.8	
2018	607,723	$81	$10	$95	$30	-$35	-$23	2.0	
2019	655,734	$87	$10	$102	$33	-$38	-$24	2.1	
2020	703,743	$93	$10	$110	$35	-$42	-$25	2.3	
Total						**-$269**	**-$188**	**16.0**	**-$12**

MM$ = million dollars; MMtCO$_2$e = million metric tons of carbon dioxide equivalent; $/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent.

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[93] IA DNR Evaluation of Recycling Programs. Average of case studies from Cedar Rapids, Marion, Iowa City, and Central City. Accessed on May 23, 2008 at http://www.iowadnr.com/waste/pubs/files/ecicogfinal.pdf.

[94] Based upon the ratio of capital cost per household used in the Vermont analysis. Vermont capital cost a result of personal communication between P. Calabrese (Cassella Waste Management) and S. Roe (CCS).

[95] Average of tip fee of landfills in Iowa reporting a per-ton tip fee. Iowa Tip Fee Survey Results. Last Updated July, 2007. Accessed on May 23, 2008 from: http://www.iowadnr.com/waste/sw/files/tp_survey.pdf. Tip fee to hauler based on personal communication from J. Ketchum, VT waste management and S. Roe, CCS, November 20. 2007.

[96] Iowa Department of Natural Resources. "Economic Impacts of Recycling in Iowa." December 2007. Accessed on March 7, 2008 from; http://www.iowadnr.com/waste/recycling/files/ecofullreport.pdf. The 2005 baseline data is estimated from Table 7.1 of the "Economic Impacts of Recycling in Iowa" report.

Composting—Composting is included in the total recycling volume in the *Economic Impacts of Recycling in Iowa Final Report*. However, as WARM considers the sole form of diversion for yard trimmings and food waste to be composting, the tons of these items that are "recycled" are assumed to be composted. The net costs for increased composting in Iowa were estimated by adding the additional costs for collection (same calculation as recycling) and the net cost for composting operations. The net cost for composting operations is the sum of the annualized capital and operating costs of composting, increased collection fees, revenue generated through the sale of compost, and the avoided tipping fees for landfilling. 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.[97] These data are summarized in Table 13.

Table 13. Capital and operating costs of composting facilities

Annual Volume (tons)	Capital Cost ($1,000)	Operating Cost ($/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 (a capital cost of $8 million, and O&M cost of $30/ton) shown in Table 13. The composting volumes in 2012 and 2020 shown in Table 14 suggest the need for three additional large composting operation by 2020. To annualize the capital costs of these facilities, CCS assumed a 15-year operating life and a 5% interest rate. Other cost assumptions include an assumed landfill tipping fee of $40/ton,[98] an additional source-separated organics collection fee of $113/ton (as used above in the recycling element), a compost facility tipping fee of $15/ton,[99] and a compost value of $11.75/ton.[100]

Table 14 presents the results of the cost analysis for composting. GHG reductions were assumed not to begin until 2010, and the cumulative reductions estimated were 0.16 $MMtCO_2e$. An NPV of $80 million was estimated, along with a cost-effectiveness of $489/$tCO_2e$.

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[97] P. Calabrese (Cassella Waste Management), personal communication with S. Roe (CCS) June 5, 2007. Because the cost was not originally specified in terms of 2007$, assume the cost to be valid for 2005.

[98] IA DNR *Evaluation of Recycling Programs*. Average of case studies from Cedar Rapids, Marion, Iowa City, and Central City. Accessed on May 23, 2008 at http://www.iowadnr.com/waste/pubs/files/ecicogfinal.pdf.

[99] Emerson, Dan. *Latest Trends in Yard Trimmings* Composting. 2005. Accessed on May 23, 2008 from: http://hs.environmental-expert.com/resultEachArticle.aspx?cid=6042&codi=5723&idproducttype=6

[100] The 2004 price of $10/yard was obtained from a case study of the City of Davenport, IA, available at: *http://www.cityofdavenportiowa.com/department/division.asp?fDD=28-375*. Assuming a dry solids content of 55% and a bulk density of 0.5 tons/yard, the value of composted material was calculated to be $11/ton of initial feedstock.

Table 14. Cost analysis results for composting

Year	Annual Cost O&M ($MM)	Annualized Capital Cost ($MM)	Annual Collection Cost ($MM)	Avoided Landfill Tipping Fees ($MM)	Value of Composted Material ($MM)	Tons of Waste Composted	Total Annual Composting Cost ($MM)	Discounted Costs ($MM)	GHG Reductions (MMtCO$_2$e)	Cost-Effectiveness ($/t)
2009	$0	$0	$0	$0	$0	-	$0	$0	-	
2010	$1	$0	$3	$1	$0	24,967	$3	$3	0.00	
2011	$1	$1	$7	$1	$1	49,845	$7	$6	0.00	
2012	$1	$1	$7	$1	$1	49,640	$7	$6	0.01	
2013	$2	$1	$8	$1	$1	57,525	$8	$7	0.01	
2014	$2	$1	$9	$2	$1	65,409	$9	$7	0.01	
2015	$2	$1	$10	$2	$1	73,292	$10	$8	0.01	
2016	$2	$1	$11	$2	$1	81,299	$11	$8	0.02	
2017	$3	$1	$12	$2	$1	89,305	$12	$8	0.02	
2018	$3	$2	$13	$2	$1	97,312	$14	$9	0.02	
2019	$3	$2	$14	$3	$1	105,318	$15	$9	0.03	
2020	$3	$2	$15	$3	$1	113,324	$16	$9	0.03	
Total								**$80**	**0.16**	**$489**

$MM = million dollars; MMtCO$_2$e = million metric tons of carbon dioxide equivalent; $/t = dollars per metric ton.

The overall cost analysis, as seen in Table 15, yields an NPV of –$220 million and a cost-effectiveness of –$8.3, based on the cumulative emission reductions of 26.5 MMtCO$_2$e.

Table 15. Overall policy results—cost-effectiveness

Year	Net Program Cost: Source Reduction ($MM)	Net Program Cost: Recycling ($MM)	Net Program Cost: Composting ($MM)	Total Net Program Cost ($MM)	Discounted Cost ($MM)	Cost-Effectiveness ($/tCO$_2$e)
2009	$0	$0	$0	$0	$0	
2010	$0	-$2	$3	$1	$1	
2011	-$3	-$14	$7	-$10	-$9	
2012	-$6	-$14	$7	-$13	-$11	
2013	-$9	-$18	$8	-$18	-$15	
2014	-$12	-$21	$9	-$24	-$19	
2015	-$15	-$24	$10	-$29	-$22	
2016	-$18	-$28	$11	-$35	-$25	
2017	-$21	-$31	$12	-$40	-$27	
2018	-$24	-$35	$14	-$45	-$29	
2019	-$27	-$38	$15	-$51	-$31	
2020	-$30	-$42	$16	-$56	-$33	
Total					**-$220**	**-$8.3**

$MM = million dollars; $/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent.

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 fully or partly achieve the goals of this policy, the GHG reductions estimated would be lower (no additional penetration from the current Iowa recycling and composting campaigns has been incorporated into the BAU assumptions for this analysis). Therefore, the most important assumption relates to the assumed BAU projection for solid waste management. This BAU forecast is based on current practices and does not factor in the effects of further gains in recycling or composting rates during the policy period. The BAU assumptions are needed to tie into the assumptions used to develop the GHG forecast for the waste management sector, which does not factor in these changes in waste management practices during the policy period (2008–2020). To the extent that these gains in recycling and composting would occur without this policy, the benefits and costs are overstated.

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

Another important assumption is that under BAU, the waste directed to landfilling would include methane recovery (75% collection efficiency) and utilization. The need for this assumption is partly based on limitations of WARM (which doesn't allow for management of landfilled waste into both controlled and uncontrolled landfills), but is also based on the overall direction of the policy recommendations of AFW-8.

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

The cost estimates do not include cost savings that would be achieved through avoiding the need for additional waste-to-energy (WTE) plants.

Key Uncertainties

A large portion of the benefits yielded by the goals set forth in this option are derived from the indirect, life-cycle emission reductions that result from recycling and source reduction. The change in direct landfill emissions as a result of full implementation of the goals in this option would be an *increase* of 39,097 tCO_2e in 2012 and a reduction of 69,451 tCO_2e in 2020. The GHG benefits from reduced transportation resulting from a decrease in generation would be 211 tCO_2e in 2012 and 711 tCO_2e in 2020.[101]

Additional Benefits and Costs

TBD – [as needed and approved by the subcommittees]

Feasibility Issues

- Sufficient political commitment

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[101] Assumes default distances from EPA WARM model of 20 miles from the source of the waste to each management facility.

- Budget constraints
- Sufficient regulatory/financial incentives
- Inconsistent enforcement
- Insufficient data
- Low landfill disposal costs result in less interest in waste prevention/recycling
- Resistance to change
- Must have sufficient local capacity for collected recyclables

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]

AFW-9. Landfill Methane Energy Programs

Policy Description

Use the renewable energy within landfills gas (methane) to make electric power, space heat, or liquefied natural gas. Methane gas generation by landfills is a GHG reduction strategy that may benefit from a cap and trade system, encouraging landfills to install flares at a minimum and possibly achieve electric generation if the economic incentives are sufficient.

Policy Design

Goals:

Control—Increase the number of landfills from recovering methane as an energy source wherever it is economically feasible to do so. By 2020, ensure that all large are fully controlling the release of methane, such that 50% of the landfill gas being generated is controlled by 2020. This can be done through development of additional landfill gas to energy (LFGTE) projects. For sites where LFGTE is not feasible, implement flaring controls to achieve the goal.

Technology Research and Evaluation—Since conversion technologies hold promise for environmentally managing waste and producing energy, annually examine the experience and costs of emerging technologies for waste management with a goal to determine feasibility of the technology for Iowa (non-quantified goal).

Education—Begin to educate the public about the impact and costs of various waste-to-energy technologies (non-quantified goal).

Timing: Not specified by TWG. Fully implement policies to achieve above goals by 2020.

Parties Involved: Municipal and county governments, private solid waste management companies, local economic development agencies, IA DNR, NGOs, and public interest groups.

Other:

Iowa currently has four landfill operations which are recovering methane (2 generate electricity). EPA Land-fill Methane Outreach Program (LMOP) identifies 17 facilities that may have the opportunity to recover methane. These landfills have the potential to capture an additional 35% of methane beyond the baseline methane capture of 40%.

Methane Energy Programs

The capture of one ton of methane from landfill gas (LFG) is equivalent to reducing approximately 20 tCO_2e. (Benefits of LFG Energy, Landfill Methane Outreach Program, USEPA, www.epa.gov/lmop/benefits.htm)

According to the EPA Landfill Methane Outreach Program (WMW Review Issue 2006) landfills generate about 26% of the U.S. methane emissions. Methane is the second most important greenhouse gas (GHG).

If landfilling of organic materials is to be continued, future landfills must be fully controlled bioreactors where most of the methane generated is captured and used to produce energy. (Capture and Utilization of Landfill Gas, Nickolas Themelis and Priscilla Ulloa, Earth Engineering Center and Department of Earth and Environmental Engineering, Columbia University, New York, NY 10027, USA).

Actual emissions of CH4 from landfills are sensitive to dozens of site-specific factors and can vary over a wide range, but we do not have either the direct measurement data or the detailed site data that would be required to conduct more than an approximate estimate of CH4 emissions from Iowa landfills. (from a North Carolina study)

Waste-to-energy (WTE) Mass Burn

Incineration, the combustion of organic material such as waste, with energy recovery is the most common WTE implementation.

Other than removing oversized items and HHW, little preprocessing is necessary.

Depending on the location, size and other factors, the capital costs range from $110,000 to $140,000 per daily ton of capacity. Therefore, a plant that processes 1,000 tons of municipal solid wastes per day may cost between $110 and $140 million. In addition to the capital costs, a 1000-ton-per-day plant would engage personnel of about 60. Other costs are services, materials, and supplies and the cost of disposal of ash. (The ABC of Integrated Waste Management, Waste-to-Energy Research and Technology Council, www.seas.columbia.edu/earth/wtert/faq.html)

Tipping fees at WTE plants, based on 15 respondents, ranged from $40/ton in North Carolina (1 facility) to $98/ton (3 facilities). (Biocycle, April 2006, The State of Garbage in America)

Experts and local community groups are concerned with modern incinerators because of fine particulate emissions, metal, trace dioxins and acid gas emissions, toxic fly ash, bottom ash management as well as waste resource ethics such as valuable resource destruction and low energy efficiency.

Incineration or combustion in any form is rejected in the zero waste movement as a viable, sustainable or ethical solution to waste management. Public acceptability, or rather lack of it, remains a barrier to emerging waste management technologies.

Emerging Technologies for MSW (Gasification, plasma arc, thermal depolymerization, ethanol production from waste, anaerobic digestion)

Currently long-term experience with alternative technologies is unavailable. Waste conversion technologies have very high costs, and the vast majority have not been proven on a commercial scale or as full scale plants using municipal solid waste. More than 90% of these technologies are still in the experimental, development, small-scale, or pilot project stage, i.e., they are not mature technologies. Experts agree that they are not currently a reliable, cost-effective alternative.

Only gasification and plasma arc can handle the entire MSW waste stream with limited residuals. Most other processes require preprocessing and/or pretreatment, either by separating out incompatible and recyclable materials, homogenizing and shredding. This means that materials must either be separated at the source or processed through an MRF.

Some processes produce an ash containing constituents of lead, cadmium and mercury which need to be managed in a manner that is environmentally responsible.

Proponents for conversion technologies report them to produce not only energy but usable products and by-products, e.g., slag. The slag bonds metals, halogen and sulfur atoms with silicate to make leaching of the materials difficult. The profitability of products and by-products is dependent on viable markets and the value of the products produced. There are risks with constructing such facilities with a goal of profiting from products and by-products.

Current Projects in Iowa

Gasification Project in Greve (1,200 TPD of RDF) ($1,996)

- $170 million capital costs
- $35.6 million O&M costs
- $16.3 million/year in revenues

Plasma Arc–Green Power Systems

- $182 million capital costs
- $18 million/year revenue

Implementation Mechanisms

TBD – [CCS drafts based on subcommittee 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 subcommittee approval]

Related Policies/Programs in Place

Methane Gas Conversion Property Tax Exemption: Under Iowa's Methane Gas Conversion Property Tax Exemption, property used for methane gas collection and conversion into energy and connected with, or in conjunction with, a publicly owned sanitary landfill, is exempt from property tax. If other fuels are burned as well, the exemption is equal to the ratio of methane in the overall fuel mix.

Type(s) of GHG Reductions

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

CH_4: Methane reductions via collection and control (via flaring, or preferentially via energy utilization).

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2012, 2020 ($MMtCO_2e$): 0.3, 0.9, respectively.

Net Cost per tCO_2e: $1.83.

Data Sources: Data on current landfill operations using methane recovery for energy generation (direct or electric) are taken from the EPA LMOP Web site.[102] Baseline landfill gas emissions are consistent with the IA I&F.[103] CCS used the results of LFGTE cost modeling performed with EPA's LFG cost model (LFGcost) to estimate the costs for this policy element.[104]

Quantification Methods:

GHG Benefits

As the goal stated in the above Policy Design section requires control of methane emissions specifically from uncontrolled landfills, CCS is able to use the emission estimates for uncontrolled landfills from the IA I&F as the baseline emission scenario. According to the IA I&F, 20.5% of methane emissions in Iowa were controlled through an LFGTE project in 2005. Therefore, the incremental methane emission recovery goal in Iowa will be 29.5% in 2020.

As emissions from uncontrolled landfills are controlled, three GHG benefits are realized: the conversion of landfill methane to CO_2, the displacement of grid-based electricity, and the displacement of fossil fuel combustion for direct heat.[105] The first benefit is calculated by multiplying the baseline CH_4 emissions from uncontrolled landfills from the IA I&F by the landfill gas control goal set by the TWG. The second benefit (offset electricity) is found by converting the methane captured from tCO_2e units to cubic meters of gas, then calculating the electricity generated and the emissions offset through avoided grid-based generation.[106] The third GHG benefit is calculated by multiplying the fraction of captured landfill gas combusted for direct use by the quantity of landfill gas captured under this policy option, assuming that an equal amount of natural gas is not combusted for direct heat use. The estimated GHG benefits in 2012 and 2020 are 0.3 and 0.9 $MMtCO_2e$, respectively. The cumulative GHG benefit through 2020 is estimated to be 5.4 $MMtCO_2e$. Table 1 depicts the results of these calculations.

Table 1. Overall policy results—GHG benefit

Year	Methane Control Goal	CH_4 Emissions From Uncontrolled Landfills (tCO_2e)	GHG Benefit: CH_4 Reduction From Methane Control ($MMtCO_2e$)	CH_4 Controlled (m^3CH_4)	Electricity Generated (MWh)	GHG Benefit: Avoided Electricity Production ($MMtCO_2e$)	Electricity Emissions Factor from SC I&F (tCO_2e/MWh)	GHG Benefit: Avoided Natural Gas Combustion for Direct Use ($MMtCO_2e$)	Total GHG Benefit ($MMtCO_2e$)
2008	0.0%	1,748,943	-	-	-	0.4	-	-	-

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[102] U.S. EPA, Landfill Methane Outreach Program. LMOP Database—Iowa. Available at: http://www.epa.gov/landfill/proj/xls/lmopdataia.xls

[103] IA I&F, available at: http://www.iaclimatechange.us

[104] U.S. EPA, Landfill Methane Outreach Program. Landfill Gas Energy Cost Model (LFGcost), Version 1.4. Model run performed by B. Strode on June 24, 2008. For more information on LFGCost, visit http://www.epa.gov/lmop/res/index.htm.

[105] Assumed to be natural gas.

[106] (Fraction of landfill gas used for electricity generation) × (CH_4 captured in $MtCO_2e$) × ($1\ MtCH_4 / 21\ MtCO_2e$) × ($1\ m^3CH_4 / 0.00125\ MtCH_4$) × ($0.00254\ MWh / m^3CH_4$) × ($4.15 \times 10^{-7}\ MMtCO_2e / MWh$).

Year	Methane Control Goal	CH_4 Emissions From Uncontrolled Landfills (tCO_2e)	GHG Benefit: CH_4 Reduction From Methane Control ($MMtCO_2e$)	CH_4 Controlled (m^3CH_4)	Electricity Generated (MWh)	GHG Benefit: Avoided Electricity Production ($MMtCO_2e$)	Electricity Emissions Factor from SC I&F (tCO_2e/ MWh)	GHG Benefit: Avoided Natural Gas Combustion for Direct Use ($MMtCO_2e$)	Total GHG Benefit ($MMtCO_2e$)
2009	2.5%	1,776,269	0.0	1,663,490	2,594	0.4	0.00	0.0	0.1
2010	4.9%	1,804,022	0.1	3,378,962	5,268	0.4	0.00	0.0	0.1
2011	7.4%	1,832,209	0.1	5,147,634	8,026	0.4	0.00	0.1	0.2
2012	9.8%	1,860,836	0.2	6,970,749	10,868	0.4	0.00	0.1	0.3
2013	12.3%	1,889,910	0.2	8,849,577	13,798	0.4	0.01	0.1	0.3
2014	14.8%	1,919,438	0.3	10,785,415	16,816	0.4	0.01	0.1	0.4
2015	17.2%	1,949,428	0.3	12,779,584	19,925	0.4	0.01	0.1	0.5
2016	19.7%	1,979,886	0.4	14,833,434	23,128	0.4	0.01	0.2	0.5
2017	22.1%	2,010,821	0.4	16,948,345	26,425	0.4	0.01	0.2	0.6
2018	24.6%	2,042,238	0.5	19,125,723	29,820	0.4	0.01	0.2	0.7
2019	27.0%	2,074,147	0.6	21,367,003	33,314	0.3	0.01	0.2	0.8
2020	29.5%	2,106,554	0.6	23,673,651	36,911	0.3	0.01	0.2	0.9
Totals		**24,994,701**	**3.8**	**145,523,567**	**226,893**		**0.1**	**1.5**	**5.4**

CH_4 = methane; tCO_2e = metric tons of carbon dioxide equivalent; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; m^3CH_4 = cubic feet of methane; MWh = megawatt-hours.

Cost-Effectiveness

Using the results from anLFGcost model run, the costs of this option are estimated based on whether the methane is converted to usable energy by a small engine, through direct use, or a large engine (800 kW and greater).[107] CCS assumes that the current share of each of the three energy conversion techniques remains constant as uncontrolled sites are converted to control sites to meet the policy goal (Table 2). As of the latest LMOP data output, however, Iowa employed the use of two direct thermal LFGTE converter and two large electricity-generating units.[108]

Table 2. LFGcost modeling results

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[107] U.S. EPA, Landfill Methane Outreach Program. Landfill Gas Energy Cost Model (LFGcost), Version 1.4. Model run performed by B. Strode on June 24, 2008. For more information on LFGCost, visit http://www.epa.gov/lmop/res/index.htm.

[108] U.S. EPA, Landfill Methane Outreach Program. "Landfill Gas Energy Projects and Candidate Landfills." Accessed on January 28, 2008, at: http://www.epa.gov/lmop/proj/index.htm

EPA LFGcost Modeling Data	**Scenario 1 Direct Use (0.5-mi. pipeline)**	**Scenario 2 Small Engine (< 800 kW)**	**Scenario 3 Standard Engine (> 800 kW)**
Total capital	$613,382	$1,186,832	$4,024,238
Average annual O&M	$105,925	$150,655	$591,522
Annualized costs	$197,337	$327,528	$1,191,252
Annual revenue	$95,445	$155,117	$788,670
Annual average reductions (MMtCO$_2$e)	0.03	0.03	0.10
Project reductions (MMtCO$_2$e)	0.45	0.45	1.47
Cost-effectiveness ($/tCO$_2$e)	–$1.2	$2.44	$1.57
Net present value (NPV)	–$524,612	$1,087,597	$200,660
Blended cost-effectiveness (Iowa)			
Baseline share of methane control in Iowa	39%	—	61%
Fractional cost-effectiveness ($/tCO$_2$e)	–$0.45	—	$0.96
Average Cost-Effectiveness ($/tCO$_2$e)	**$0.51**		

EPA = U.S. Environmental Protection Agency; LFG = landfill gas; kW = kilowatts; O&M = operations and maintenance; MMtCO$_2$e = million metric tons of carbon dioxide equivalent; $/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent. Assumes 8% interest rate over 10 years, 15 year project life, and cost of LFG collection and flaring included in total cost.

The modeling assumptions were based on the average opening and closing year of landfills in Iowa (1997 and 2029, respectively), average annual acceptance for large landfills (114,090 tons), average annual acceptance for small landfills (36,334 tons). It was assumed that large landfills will utilize large engines and small landiflls will utilize either small engines or direct heat technology. The average depth of the landfills was assumed to be 50 ft (LFGCost Default). The assumed number of wells for small landfills was 17, and the number of wells for large landfills was 62.[109] The default values for the revenue from energy sold were used ($0.045/kWh, $4.50/million Btu).

The average cost-effectiveness ($0.51/tCO$_2$e) is multiplied by the GHG benefit calculated in the GHG Benefit section for each year to determine the cost-effectiveness of this policy option (Table 3). The NPV of costs incurred through the implementation of this option is $1.8 million, and the discounted cost-effectiveness is $0.3/tCO$_2$e (assumes no escalation of costs during the policy period).

Table 3. Overall policy results—cost-effectiveness

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[109] Consistent with LFGCost model run completed by CCS for North Carolina CAPAG process.

Year	Avoided Emissions ($MMtCO_2e$)	Annual Costs (MM$)	Discounted Costs (MM$)	Cost-Effective-ness ($/$tCO_2e$)
2008	-	$0.0	$0.0	
2009	0.1	$0.0	$0.0	
2010	0.1	$0.1	$0.1	
2011	0.2	$0.1	$0.1	
2012	0.3	$0.1	$0.1	
2013	0.3	$0.2	$0.1	
2014	0.4	$0.2	$0.2	
2015	0.5	$0.2	$0.2	
2016	0.5	$0.3	$0.2	
2017	0.6	$0.3	$0.2	
2018	0.7	$0.4	$0.2	
2019	0.8	$0.4	$0.2	
2020	0.9	$0.4	$0.2	
Total	**5.4**	**$2.7**	**$1.8**	**$0.3**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MM = million; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

Key Assumptions: The analysis does not factor in the closure of specific landfills or the adoption of LFG controls at specific landfills. Modeling GHG emissions and reductions at individual sites is beyond the scope of this analysis; however, the approach used is consistent with the methods used to develop the GHG forecast for the waste management sector.

Each of the cost inputs above contains key assumptions; additional study of these inputs could reduce the associated uncertainty in the cost estimates.

Key Uncertainties

As stated above, the GHG reduction potential of this option is comprised of both direct and indirect benefits. The direct benefit of the goal is estimated to reduce 0.2 tCO_2e in 2012 and 0.6 tCO_2e in 2020, for a cumulative reduction of 3.8 tCO_2e. The indirect GHG benefits related to this option are the offset energy use from both electricity and natural gas (in the case of direct use LFGTE). These indirect benefits are estimated to total 0.1 tCO_2e in 2012 and 0.2 tCO_2e in 2020, for a cumulative indirect benefit of 1.6 tCO_2e.

A key source of uncertainty related to cost effectiveness is the price of energy that may produce a source of revenue for LFGTE projects. For the above analysis, the default assumptions of $0.045 per kWh of electricity and $4.50 per million Btu of natural gas were used. Note that these figures will not necessarily be the retail price of energy, but the actual price that the facility would be paid by the utility for the additional energy. Thus, this price is likely lower than the retail energy prices. The electricity purchase prices that would be needed for the electricity projects (projected to incur a net cost over time by the LFGCost model under the default energy prices) are $0.067 per kWh for large facilities (over 800 kW rated capacity) and $0.097 for small facilities.

Additional Benefits and Costs

TBD – [as needed and approved by the subcommittees]

Feasibility Issues

There is a danger of over committing on infrastructure to recover value.

Status of Group Approval

Pending –

Level of Group Support

TBD – [blank until ICCAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the ICCAC]