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Agriculture, Forestry, and Waste Management (AFW) Technical Work Group

Summary List of Pending Priority Policy Options for Analysis

Policy No.	Policy Option		GHG Reductions ($MMtCO_2e$)			Net Present Value 2009–2025 (Million $)	Cost-Effectiveness ($/t$CO_2e$)	Status of Option
			2015	2025	Total 2009–2025			
AFW-1	Manure Management		TBD	TBD	TBD	TBD	TBD	Pending
AFW-2	Promotion of Farming Practices That Achieve GHG Benefits	Soil Carbon	0.62	1.50	13.6	TBD	TBD	Pending
		Nutrient Efficiency	0.11	0.27	2.39	TBD	TBD	
AFW-3	Improved Water Management and Use		0.02	0.06	0.53	TBD	TBD	Pending
AFW-4	Expanded Use of Agriculture and Forestry Biomass Feedstocks for Electricity, Heat, or Steam Production	Energy From Biomass	0.61	1.22	11.88	TBD	TBD	Pending
		Energy from Livestock Manure and Poultry Litter	0.01	0.02	0.19	0.8	4	
		Capture of Waste Heat	TBD	TBD	TBD	TBD	TBD	
AFW-5	Expanded Use of Liquid Biofuels		0.4	1.1	9.1	91	10	Pending
AFW-6	Expanded Use of Locally Produced Farm and Forest Products		TBD	TBD	TBD	TBD	TBD	Pending
AFW-7	Forest Management and Establishment for Carbon Sequestration		TBD	TBD	TBD	TBD	TBD	Pending
AFW-8	Advanced Recovery and Recycling		TBD	TBD	TBD	TBD	TBD	Pending
AFW-9	End-of-Use Waste Management Practices		TBD	TBD	TBD	TBD	TBD	Pending

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; TBD = to be determined.

The numbering used to denote the above pending priority policy options is for reference purposes only; it does not reflect prioritization among these important draft policy options.

Table 1. Biomass Supply Assessment

Biomass Resource	Annual Biomass Supply (10^3 dry short tons)	Heat Content (MMBtu/dry short ton)	Approximate Energy Available (MMBtu)	Notes
Forest residue	5,265	9.961	52,448,370	Biomass availability from Annual Biomass Supply Study.[1] Heat Content from Biomass Heat Content Study.[2]
Mill residue	3,239	9.961	32,263,679	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Urban wood waste	1,534	9.961	15,281,947	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Agricultural residue	3,198	8.248	26,378,630	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Municipal paper waste	293	13.03	3,813,568	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Municipal solid waste fiber	TBD	9.945	TBD	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Used cooking oil	4	TBD	TBD	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Yard and landscape waste debris	87	9.961	865,495	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study. Moisture contents from Wyoming study.[3]
Biosolids	41	TBD	TBD	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Energy crops	TBD	TBD	TBD	Annual Biomass Supply Study. Heat Content from Biomass Heat Content Study.
Total Annual Biomass Supply	**13,661**	**N/A**	**131,051,689**	**Excludes energy crops.**

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[1] Arkansas Economic Development Commission. *Arkansas Biomass Resource Assessment.* Annual Biomass Supply. Available at: http://arkansasedc.com/business_development/energy/?page=bioenergy.

[2] U.S. Department of Energy, Energy Information Administration. "Average Heat Content of Selected Biomass Fuels." April 2008. Available at: http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html.

[3] Moisture contents for paper waste (5%) and yard waste (40%) from: Wyoming Business Council. *Municipal Solid Waste*. Available at: http://www.wyomingbusiness.org/pdf/energy/Biomass_MunicipalWaste.pdf.

Table 1. Biomass Supply Assessment (continued)

Policy Requiring Biomass	2025 Annual Biomass Demand (10^3 dry short tons)	Heat Content (MMBtu/dry short ton)	Approximate Energy Available (MMBtu)	Notes
AFW-4	TBD	N/A	N/A	10% of available agriculture residue biomass by 2025. 10% of available in-state forest residue by 2025. 10% of marginal agriculture land by 2025. 10% of available methane from livestock manure and poultry litter.
AFW-5	TBD	N/A	N/A	10% of biomass supply to produce biofuels.

MMBtu = million British thermal units; N/A = not applicable; TBD = to be determined.

AFW-1. Manure Management

Policy Description

Potential manure management practices that reduce greenhouse gas (GHG) emissions associated with manure handling and storage include manure composting to reduce methane (CH_4) emissions, movement of manure from nutrient-rich to nutrient-deficient areas, and improved methods for application to fields (for reduced nitrous oxide [N_2O] emissions). Application improvements include incorporating manure into soil instead of surface spraying or spreading. Also, implementing digester and energy recovery projects at confined animal operations reduces methane emissions and uses the energy to displace fossil fuels. To date, most of these projects have been implemented at dairies and swine operations.

Policy Design

Goals: Reduce CH_4 and N_2O emissions from dairy, hog, and poultry operations by 40% by 2025, through improved manure handling and storage practices, compared to business as usual (BAU).

Timing: As described above.

Parties Involved: To be determined (TBD) – [as approved by the Technical Work Group (TWG)]

Other: Previous studies have determined that deep stacking litter produces significant N_2O emissions (deep stacking litter is very similar to composting). While composting may lower CH_4 emissions, it will probably raise N_2O emissions. This process also generates and wastes ammonia emissions.

Velthof et al. (2003)[4] found that more N_2O was emitted when manure was incorporated into soil compared to applied to the surface. They looked at applying manure at different depths, but found surface application was the best. It is suspected that incorporating manure into soil increases the potential for denitrification. Nevertheless, incorporating manure into soil may still be considered good practice, as it reduces nutrient runoff and ammonia emissions and improves nitrogen uptake.

Implementation Mechanisms

TBD – [as approved by the Technical Work Group (TWG)]

Related Policies/Programs in Place

Poultry Litter

Act 1061 (HB 1654)—The act declares various areas of Arkansas to be nutrient surplus areas for phosphorus and nitrogen, authorizes the Arkansas Natural Resources Commission to make rules

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[4] Velthof, Kuikman, and Oenema (2003), *Nitrous Oxide Emission From Animal Manures Applied To Soil Under Controlled Conditions*, Biol Fertil Soils (2003) 37:221–230

concerning management of nutrients in nutrient surplus areas, and creates penalties for violations of the act.

Poultry Feeding—Management Plans

Act 2294 (SB 1160)—This act requires that, after January 1, 2007, poultry litter be applied to soils or associated crops within a nutrient surplus area in accordance with a nutrient management plan or poultry litter management plan.

Type(s) of GHG Reductions

- **CH_4:** Captures and utilizes methane or prevents the creation of methane.
- **N_2O:** Reductions occur when nitrogen runoff and leaching are reduced. (Runoff and leaching lead to the formation and emission of N_2O.)

Estimated GHG Reductions and Costs or Cost Savings

Data Sources:

X. Hao, C. Chang, F.J. Larney, and G.R. Travis. "Greenhouse Gas Emissions During Cattle Feedlot Manure Composting." *Journal of Environmental Quality* 2001;30:376-386. Available at: http://jeq.scijournals.org/cgi/content/abstract/30/2/376.

Quantification Methods:

TBD

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until Governor's Commission on Global Warming (GCGW) meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

AFW-2. Promotion of Farming Practices That Achieve GHG Benefits

Policy Description

The state could provide incentives to farmers for using production processes that achieve net GHG benefits. For example, some organic farming practices could reduce GHG emissions compared to conventional farming, depending on the specific practices implemented (e.g., use of no-till cultivation and fewer chemicals).

Policy Design

Goals:

- By 2025, implement cultivation practices to enhance soil carbon levels on 40% of the acreage that is not already using these practices.
- By 2025, implement cultivation practices to increase nutrient efficiency by 20%, compared to BAU.

Timing: As described above.

Parties Involved: TBD – [as approved by the TWG]

Other: TBD – [as needed and approved by the TWG]

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

TBD – [as needed and approved by the TWG]

Type(s) of GHG Reductions

Carbon Dioxide (CO_2): Improved efficiency can reduce electricity and fuel consumption and the associated GHGs.

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources: Annual CO_2e emissions from synthetic fertilizer and manure applications were taken from the Arkansas Inventory & Forecast. Cost information for synthetic fertilizers was taken from the U.S. Department of Agriculture's (USDA's) Economic Research Service.[5]

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[5] U.S. Department of Agriculture, Economic Research Service. NASS Table 7. "Average U.S. Farm Prices of Selected Fertilizers." Available at: http://www.ers.usda.gov/Data/FertilizerUse/Tables/Table7.xls.

Quantification Methods:

Soil Carbon

Total cropland in Arkansas was estimated at about 14 million acres[6] in 2007. For the purposes of this analysis, it is assumed that conservation practices include conservation till (no-till and strip-till), and other conservation farming practices that provide enhanced ground cover, or other crop management practices that achieve similar soil carbon benefits. Conservation tillage is defined as any system that leaves 50% or more of the soil covered with residue.[7]

Based on the policy design parameters, the schedule for acres to be put into conservation tillage/no-till cultivation is displayed in Table 2. This table represents the percentage of cropland required by the policy. Because an estimate for the rate of no-till practices being used in Arkansas could not be found, the national rate of no-till was used, and then applied to the farm acreage in the state. The national data came from the Conservation Technology Information Center's National Crop Residue Management Surveys.[8]

For the policy period, it is assumed that the sequestration rate provided by the Chicago Climate Exchange for the carbon credit program (0.4 metric tons of carbon dioxide per acre [tCO_2/acre] per year, as Arkansas is considered to be 50% in "Zone A" (0.6 tCO_2/acre/year) and 50% in "Zone D" (0.2 tCO_2/acre/year)) is indicative of the sequestration that would occur as a result of improved tillage practices.[9] As such, 0.4 tCO_2/acre/year was used to estimate the amount of carbon to be sequestered.

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 (gal)/acre.[10] The life-cycle fossil diesel GHG emission factor of 12.31 tCO_2e/1,000 gal was used.[11] Results are

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[6] U.S. Department of Agriculture, National Agricultural Statistics Service. Arkansas State Agriculture Overview–2007. Available at: http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_AR.pdf.

[7] The definitions of tillage practices from the 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 one-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.

[8] Iowa State University, Agronomy Department . "Residue Remaining After Planting, All Tillage Practices: Totals for United States—Annual Crops." Sourced from the Conservation Technology Information Center, National Crop Residue Management Surveys. Available at: http://extension.agron.iastate.edu/soils/pdfs/CTIC/cticus1.pdf.

[9] Chicago Climate Exchange. Agricultural Soil Carbon Offsets. Available at: http://www.chicagoclimatex.com/content.jsf?id=781.

[10] Reduction associated with conservation tillage compared with conventional tillage. See: Conservation Technology Information Center. "Reductions Associated With Conservation Tillage Compared With Conventional Tillage." Available at: http://www.ctic.purdue.edu/Core4/CT/CRM/Benefits.html.

[11] 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* July 25, 2006;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.

shown in Table 2, along with a total estimated benefit from both carbon sequestration and fossil fuel reductions.

Table 2. GHG reductions from conservation tillage practices

Year	Percentage of Available Cropland in Program	New Acres Under "No Till"	$MMtCO_2e$ Sequestered	Diesel Saved (1,000 gal)	$MMtCO_2e$ From Diesel Avoided	Total $MMtCO_2e$ Saved per Annum
2008	0%					
2009	2%	127,462	0.051	446	0.005	0.056
2010	5%	410,094	0.164	1,435	0.018	0.18
2011	7%	609,599	0.244	2,134	0.026	0.27
2012	10%	809,104	0.324	2,832	0.035	0.36
2013	12%	1,008,609	0.403	3,530	0.043	0.45
2014	14%	1,208,115	0.483	4,228	0.052	0.54
2015	17%	1,407,620	0.563	4,927	0.061	0.62
2016	19%	1,607,125	0.643	5,625	0.069	0.71
2017	21%	1,806,630	0.723	6,323	0.078	0.80
2018	24%	2,006,135	0.802	7,021	0.086	0.89
2019	26%	2,205,640	0.882	7,720	0.095	0.98
2020	28%	2,405,145	0.962	8,418	0.104	1.07
2021	31%	2,604,651	1.042	9,116	0.112	1.15
2022	33%	2,804,156	1.122	9,815	0.121	1.24
2023	35%	3,003,661	1.201	10,513	0.129	1.33
2024	38%	3,203,166	1.281	11,211	0.138	1.42
2025	40%	3,391,588	1.357	11,871	0.146	1.50
Total Reductions						**13.6**

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

Nutrient Efficiency

The GHG benefits of this option are quantified by calculating the CO_2e emissions per kilogram (kg) of nitrogen (N) applied in Arkansas. This uses a figure of the nitrogen emissions from fertilizer (4.70 kg CO_2e per kg of N applied), calculated from the Arkansas Inventory and Forecast. This is then combined with a figure for the life-cycle emissions of nitrogen fertilizer (0.857 kg CO_2e/kg of N).[12] Thus, the total CO_2e emissions in Arkansas are 5.55 kg CO_2e/kg of N applied. The BAU estimate of nitrogen fertilizer use in the Inventory and Forecast assumes

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[12] T.O. West and G. Marland. 2001. "A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States." *Agriculture, Ecosystems & Environment* September 2002:91(1-3):217-232. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T3Y-46MBDPX-10&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=4bf71c930423acddffbcef6d46d763c3.

constant rates of nitrogen application from 2005. To increase nutrient efficiency by 20%, nitrogen fertilizer use is then reduced from the BAU estimate. This reduction of nitrogen application is then multiplied by the nitrogen emissions factor to determine the GHG benefits of this policy. Table 3 presents the nitrogen reductions and the GHG benefits of the proposed nutrient efficiency policy.

Table 3. GHG reductions from the proposed nutrient efficiency policy

Year	AR Fertilizer Used (baseline) (metric tons N)	Efficiency Improvement	Nitrogen Fertilizer Used With Policies (metric tons),	Nitrogen Fertilizer Reduction	Emission Reductions ($MMtCO_2e$)
2008	242,797	0.0%	242,797	0	0.00
2009	242,797	1.2%	239,941	2,856	0.02
2010	242,797	2.4%	237,084	5,713	0.03
2011	242,797	3.5%	234,228	8,569	0.05
2012	242,797	4.7%	231,371	11,426	0.06
2013	242,797	5.9%	228,515	14,282	0.08
2014	242,797	7.1%	225,658	17,139	0.10
2015	242,797	8.2%	222,802	19,995	0.11
2016	242,797	9.4%	219,946	22,851	0.13
2017	242,797	10.6%	217,089	25,708	0.14
2018	242,797	11.8%	214,233	28,564	0.16
2019	242,797	12.9%	211,376	31,421	0.17
2020	242,797	14.1%	208,520	34,277	0.19
2021	242,797	15.3%	205,663	37,134	0.21
2022	242,797	16.5%	202,807	39,990	0.22
2023	242,797	17.6%	199,950	42,847	0.24
2024	242,797	18.8%	197,094	45,703	0.25
2025	242,797	20.0%	194,238	48,559	0.27
Total Reductions					**2.43**

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

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

AFW-3. Improved Water Management and Use

Policy Description

Using surface water versus groundwater and decreasing water consumption reduces pumping and energy consumption, in addition to other ancillary benefits. Implementing best management practices improves the efficiency of water use. Additionally, excess surface water can lead to runoff of nitrogen, with subsequent emission of N_2O to the atmosphere. Managing and improving water consumption and nutrients spread on crops will result in a minimal loss of carbon from the soil. Reusing water can create nutrient management problems, and must be considered when implemented. Water purification is an energy-intensive process that is an issue for farmers and land users in addition to other sectors, such as the residential, commercial and industrial (RCI) sector (this is related to options under the RCI Technical Work Group [TWG]). As such, water use in rural, suburban, and urban areas should be included under this policy option. The impact of catfish farms on GHG emissions could also be investigated under this option.

Policy Design

Goals:

- Increase the use of surface water for irrigation by 10% by 2025, compared to BAU, offsetting the need for energy-intensive groundwater (reducing energy consumption associated with groundwater pumping).
- Decrease energy use for water purification by 20% in 2025, compared to BAU (includes efficiency gains from reducing water and energy consumption).

Timing: As described above.

Parties Involved: TBD – [as approved by the TWG]

Other: TBD – [as needed and approved by the TWG]

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

Through Act 341 of 1995, Arkansas has invested significant funding and technical support (in addition to local and federal funding) toward using surface water as opposed to groundwater. Three projects currently under way are:

- Bayou Metro Water Management District,
- Boeuff Tensas Water Management District, and
- White River Irrigation District.

Each of the above projects is in various stages of development toward realizing its goals to use surface water instead of groundwater for irrigation.

Type(s) of GHG Reductions

- **CO_2:** Less energy used to pump water results in reduced CO_2 emissions.
- **N_2O:** Reductions occur when nitrogen runoff and leaching are reduced. (Runoff and leaching lead to the formation and emission of N_2O.)

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources:

Surface Water

Fuel price estimates:

- U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2007: With Projections to 2030.* IDOE/EIA-0383(2007). Washington, DC, February 2006. Available at: http://tonto.eia.doe.gov/ftproot/forecasting/0383(2007).pdf.
- U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2003: With Projections to 2025.* IDOE/EIA-0383(2003). Washington, DC, January 2003. Available at: http://tonto.eia.doe.gov/ftproot/forecasting/0383(2003).pdf.

Amount of energy used for irrigation in Arkansas:

- U.S. Department of Agriculture, National Agricultural Statistics Service. "2003 Farm and Ranch Irrigation Survey." South Carolina Table 20—Energy Expenses for On-Farm Pumping of Irrigation Water by Water Source and Type of Energy: 2003 and 1998. Available at: http://www.agcensus.usda.gov/Publications/2002/FRIS/tables/fris03_20.pdf

Growth rate for water use:

- U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2007: With Projections to 2030.* IDOE/EIA-0383(2007). Washington, DC, February 2006. Available at: http://tonto.eia.doe.gov/ftproot/forecasting/0383(2007).pdf.

Water Purification

Energy use:

- U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2007: With Projections to 2030.* IDOE/EIA-0383(2007). Washington, DC, February 2006. Available at: http://tonto.eia.doe.gov/ftproot/forecasting/0383(2007).pdf.

U.S. and Arkansas population figures:

- U.S. Census Bureau. "State & County QuickFacts, People QuickFacts." Available at: http://quickfacts.census.gov/qfd/states/19000.html; http://quickfacts.census.gov/qfd/states/05000.html

Emission factors for electricity and diesel fuel:

- Arkansas Inventory and Forecast.

Quantification Methods:

Surface Water: The money spent on pumping comes from the "2003 Farm and Ranch Irrigation Survey." This includes both distillate- and electricity-powered pumps, which account for the majority of pumping for irrigation in Arkansas. Cost estimates for distillate fuel and electricity are then used to determine the amount of electricity and the diesel gallons consumed for water pumping in Arkansas. This energy consumption was reduced in a linear fashion until consumption was reduced by 10% in 2025. These figures were then multiplied by the emission factors for electricity (.592 tons CO_2e/magawatt-hour [MWh]) or diesel fuel (.010 tons CO_2e/gal). These two numbers were then added together and divided by 1,000,000 to get the $MMtCO_2e$ saved. See Table 4 for details.

Table 4. GHG benefits of surface water policies

Year	Reduction Path	Gallons Used	Gallons Saved	Electricity Used (MWh)	Electricity Saved	$MMtCO_2e$ Saved (total)
2008	0	30,300,899	0	376,790	0	0.000
2009	0.59%	30,543,307	179,667	379,804	2,234	0.003
2010	1.18%	30,787,653	362,208	382,843	4,504	0.006
2011	1.76%	31,033,954	547,658	385,906	6,810	0.010
2012	2.35%	31,282,226	736,052	388,993	9,153	0.013
2013	2.94%	31,532,484	927,426	392,105	11,532	0.016
2014	3.53%	31,784,744	1,121,814	395,242	13,950	0.020
2015	4.12%	32,039,022	1,319,254	398,404	16,405	0.023
2016	4.71%	32,295,334	1,519,780	401,591	18,898	0.026
2017	5.29%	32,553,696	1,723,431	404,803	21,431	0.030
2018	5.88%	32,814,126	1,930,243	408,042	24,002	0.034
2019	6.47%	33,076,639	2,140,253	411,306	26,614	0.037
2020	7.06%	33,341,252	2,353,500	414,597	29,266	0.041
2021	7.65%	33,607,982	2,570,022	417,913	31,958	0.045
2022	8.24%	33,876,846	2,789,858	421,257	34,692	0.049
2023	8.82%	34,147,861	3,013,047	424,627	37,467	0.052
2024	9.41%	34,421,044	3,239,628	428,024	40,285	0.056
2025	10%	34,696,412	3,469,641	431,448	43,145	0.060

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MWh = megawatt-hours.

Water Purification: National electricity consumption for water purification (1.1 million MWh) was used, and then applied to Arkansas based on the Arkansas percentage of the total U.S. population (.94%). The electricity consumption for water purification was assumed to increase at 0.8% annually, based on U.S. Department of Energy (DOE) Energy Information Administration (EIA) *Annual Energy Outlook* (AEO) estimates. This was used to create a BAU estimate for Arkansas energy consumption. As per the goal, electricity consumption was then reduced by 20% in 2025. This electricity saved was then multiplied by the state emissions factor for electricity to determine the CO_2e reduced. See Table 5 for details of analysis.

Table 5. GHG benefits of water purification policies

Year	Energy Use Water Purification (million kWh)	Reduction Goal	Energy Savings (million kWh)	Metric Tons CO_2e Avoided	$MMtCO_2e$ Reduced
2008	10.59	0	0.00	0	0.0000
2009	10.67	1.2%	0.13	74	0.0001
2010	10.76	2.4%	0.25	150	0.0001
2011	10.84	3.5%	0.38	227	0.0002
2012	10.93	4.7%	0.51	305	0.0003
2013	11.02	5.9%	0.65	384	0.0004
2014	11.11	7.1%	0.78	464	0.0005
2015	11.19	8.2%	0.92	546	0.0005
2016	11.28	9.4%	1.06	629	0.0006
2017	11.37	10.6%	1.20	713	0.0007
2018	11.47	11.8%	1.35	799	0.0008
2019	11.56	12.9%	1.50	885	0.0009
2020	11.65	14.1%	1.64	974	0.0010
2021	11.74	15.3%	1.80	1,063	0.0011
2022	11.84	16.5%	1.95	1,154	0.0012
2023	11.93	17.6%	2.11	1,246	0.0012
2024	12.03	18.8%	2.26	1,340	0.0013
2025	12.12	20.0%	2.42	1,435	0.0014

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; kWh = kilowatt-hours.

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

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

Policy Description

Increasing the amount of biomass available from forests or agriculture for generating electricity can displace the use of fossil energy sources. This strategy also encourages the capture of waste heat at facilities using biomass (or fossil fuels), wherever possible. The waste heat could be used for cogeneration of electricity or other purposes that displace fossil fuel use. Arkansas could increase the amount of biomass available for generating electricity and displacing the use of fossil energy sources. Local electricity or steam production yields the greatest net energy payoff.

Policy Design

Goals:

- *Agricultural Residues:* Increase the use of agricultural residues for electricity, steam, and heat generation to utilize 5% of available in-state agricultural residue biomass by 2015 and 10% of available biomass by 2025.
- *Forest Residues:* Increase the use of forest residues for electricity, steam, and heat generation to utilize 5% of available biomass by 2015, and 10% of available in-state forest residue by 2025.
- *Energy Crops:* Increase the production of energy crops to produce biomass feedstock for electricity, steam, and heat generation by increasing acreage devoted to energy crops to 10% of marginal agricultural land by 2025.
- *Energy From Livestock Manure and Poultry Litter:* By 2025, utilize 10% of available energy from livestock manure and poultry litter for renewable electricity, heat, and steam generation. *[Note potential overlap with AFW-1.]*
- *Capture of Waste Heat:* By 2025, ensure that facilities using biomass for electricity, heat, and steam production are capturing and utilizing 10% of waste heat.

Timing: As described above.

Parties Involved: TBD – [as approved by the TWG]

Other:

The area of marginal agricultural land was determined using the State Soil Geographic Databases (STASGO) through reviewing the distribution of land by capability class for non-irrigated land (as defined by the Natural Resource Conservation Service)[13]. The land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. Crops that require special management are excluded. The soils are grouped according to their limitations for field

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[13] STASGO information was provided by the Arkansas State Conservation office of the USDA Natural Resources Conservation Service.

crops, the risk of damage if they are used for crops, and the way they respond to management. The criteria used in grouping the soils do not include major and generally expensive land forming that would change slope, depth, or other characteristics of the soils, nor do they include possible but unlikely major reclamation projects. Capability classification is not a substitute for interpretations that show suitability and limitations of groups of soils for rangeland, for woodland, and for engineering purposes.

In the capability system, soils are generally grouped at three levels—capability class, subclass, and unit. Only class and subclass are included in this data set.

Capability classes, the broadest groups, are designated by the numbers 1 through 8. The numbers indicate progressively greater limitations and narrower choices for practical use. Marginal agricultural land is considered to include capability classes[14] 3, 4, and 5, and the total land area is 16, 287, 592 acres, respectively.[15]

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

Electric Public Utility Renewable Energy Resources

Act 755 (HB 2812)— The Arkansas Public Service Commission (APSC) is authorized to consider, propose, develop, solicit, approve, implement, and monitor measures by electric public utilities subject to its jurisdiction that cause the companies to incur costs of service and investments that utilize, generate, or involve clean energy resources or renewable energy resources, or both. The APSC may encourage or require electric public utilities subject to its jurisdiction to consider clean energy or renewable energy resources, or both, as part of any resource plan. After proper notice and hearings, the APSC may approve any clean energy resource or renewable energy resource that it determines to be in the public interest. If the APSC determines that the cost of a clean energy resource or renewable energy resource is in the public interest, the APSC may allow the affected electric public utility to implement a temporary surcharge to recover a portion of the costs of such a resource until the implementation of new rate schedules in connection with the utility's next general rate filing, wherein such costs can be included in the utility's base rate schedules.[16]

Type(s) of GHG Reductions

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

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[14] Class 3 soils have severe limitations that reduce the choice of plants or that require special conservation practices, or both. Class 4 soils have very severe limitations that reduce the choice of plants or that require very careful management, or both. Class 5 soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.

[15] Note that this acreage assessment may overestimate marginal agricultural land because it was developed using soil data without considering land use.

[16] From the ARKLEG web site. See: http://www.arkleg.state.ar.us/NXT/gateway.dll?f=templates&fn=default.htm&vid=blr:ar.

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources:

- Princeton Energy Resources International, LLC and Exeter Associates Inc. *The Potential for Biomass Cofiring in Maryland*. DNR 12-2242006-107, PPES-06-02. Prepared for the Maryland Department of Natural Resources, Power Plant Research Program. March 2006. Available at: http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.
- U.S. Department of Energy, Energy Information Administration. "Average Heat Content of Selected Biomass Fuels." Table 10 Annual Electric Generator. Available at: http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html
- Oak Ridge National Laboratory. Table A.2: Approximate Heat Content of Selected Fuels for Electric Power Generation. Available at: http://cta.ornl.gov/bedb/appendix_a/Approximate_Heat_Content_of_Selected_Fuels_for_Electric_Power_Generation.xls (6,000–8,000 Btu per pound for solid wood products).
- Arkansas Economic Development Commission. *Arkansas Biomass Resource Assessment.* Annual Biomass Supply Available at: http://arkansasedc.com/business_development/energy/?page=bioenergy
- U.S. Department of Energy, Energy Information Administration. "Average Heat Content of Selected Biomass Fuels." April 2008. Available at: http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html.

Quantification Methods:

Energy from Biomass GHG Benefits

This analysis focuses on the incremental GHG benefits associated with the utilization of additional biomass to offset the consumption of fossil fuels. It assumes that biomass will be used to replace coal in the RCI and electricity sectors (where coal represents about 49% of electricity generated in Arkansas).[17]

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).[18]

The amount of biomass utilized by each of the three components (Agriculture, Forest and Energy Crops) is illustrated in Tables 6, 7, and 8.

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[17] Based on eGRID data: coal 49%, nuclear 30%, oil 1%, natural gas 10%, biomass 4%, hydro 4%, and wind 0%. U.S. Environmental Protection Agency. "Emissions & Generation Resource Integrated Database (eGRID). Data for Arkansas." Available at: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

[18] Emission factors obtained from the Center for Climate Strategies' (CCS's) energy fuel emission factors.

Table 6. GHG benefits from agriculture crop residue

Year	Percentage of Utilization	Ag. Residue Biomass (tons)	Ag. Residue Biomass (MMBtu)	Avoided Emissions Ag Residue (MMtCO$_2$e)
2009	0.1%	3,807	31,401	0.003
2010	1.0%	30,457	251,211	0.024
2011	1.8%	57,107	471,020	0.044
2012	2.6%	83,757	690,829	0.065
2013	3.5%	110,407	910,638	0.086
2014	4.3%	137,057	1,130,447	0.106
2015	5.0%	159,900	1,318,855	0.124
2016	5.5%	175,890	1,450,741	0.136
2017	6.0%	191,880	1,582,626	0.149
2018	6.5%	207,870	1,714,512	0.161
2019	7.0%	223,860	1,846,397	0.174
2020	7.5%	239,850	1,978,283	0.186
2021	8.0%	255,840	2,110,168	0.198
2022	8.5%	271,830	2,242,054	0.211
2023	9.0%	287,820	2,373,939	0.223
2024	9.5%	303,810	2,505,825	0.236
2025	10.0%	319,800	2,637,710	0.248
Total				**2.373**

MMtCO$_2$e = million metric tons of carbon dioxide equivalent; tCO$_2$e = metric tons of carbon dioxide equivalent; MMBtu = million British thermal units.

Table 7. GHG benefits from forestry biomass

Year	Percentage of Utilization	Forest Feedstocks* (dry tons)	Forest Feedstocks* (MMBtu)	Avoided Emissions All Forest Feedstocks (MMtCO$_2$e)
2009	0.7%	71,700	714,204	0.067
2010	1.4%	143,400	1,428,407	0.134
2011	2.1%	215,100	2,142,611	0.201
2012	2.9%	286,800	2,856,815	0.269
2013	3.6%	358,500	3,571,019	0.336
2014	4.3%	430,200	4,285,222	0.403
2015	5%	501,900	4,999,426	0.470
2016	5.5%	552,090	5,499,368	0.517
2017	6.0%	602,280	5,999,311	0.564
2018	6.5%	652,470	6,499,254	0.611
2019	7.0%	702,660	6,999,196	0.658
2020	7.5%	752,850	7,499,139	0.705
2021	8.0%	803,040	7,999,081	0.752

Year	Percentage of Utilization	Forest Feedstocks* (dry tons)	Forest Feedstocks* (MMBtu)	Avoided Emissions All Forest Feedstocks (MMtCO$_2$e)
2022	8.5%	853,230	8,499,024	0.799
2023	9.0%	903,420	8,998,967	0.846
2024	9.5%	953,610	9,498,909	0.893
2025	10%	1,003,800	9,998,852	0.940
Cumulative				**9.165**

MMtCO$_2$e = million metric tons of carbon dioxide equivalent; kWh = kilowatt-hours.

*includes forest residue, mill residue, and urban wood waste.

Table 8. GHG Benefits From Dedicated Energy Crops.

[Table under development.]

Energy From Biomass Costs

The cost calculation has two main components: 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). As an example, costs are identified in Table 9 and are taken from *The Potential for Biomass Cofiring in Maryland.*[19]

Table 9. Assumed costs of feedstocks

Fuel Type	Cost ($/Ton Delivered)	Cost ($/MMBtu Delivered)
Agricultural by-products	$40.00	$4.85
Switchgrass	$47.00	$3.20
Forest residue	$35.00	$3.65

MMtCO$_2$e = million metric tons of carbon dioxide equivalent; kWh = kilowatt-hours.

The cost is calculated by assuming the replacement of coal with biomass. 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 and operational and maintenance costs were taken from Table 39 of the EIA AEO 2007[20]. While use of biomass may be pursued through other technology types (e.g., gasification) or end uses

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[19] Princeton Energy Resources International, LLC, and Exeter Associates, Inc. *The Potential for Biomass Cofiring in Maryland*. DNR 12-2242006-107; PPES-06-02. Annapolis, MD: Maryland Department of Natural Resources, Maryland Power Plant Research Program, March 2006. Available at: http://esm.versar.com/PPRP/bibliography/PPES_06_02/PPES_06_02.pdf.

[20] U.S. Department of Energy, Energy Information Administration. "Electricity Market Module." In *Assumptions to the Annual Energy Outlook 2007*. DOE/EIA-0554(2007). April 2007. Available at: http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/electricity.pdf.

(e.g., heat or steam), this methodology was used to provide an estimate of possible additional capital and operational costs required to enable the utilization of biomass (Table 10).[21]

Table 10. Estimated costs of Biomass to Energy

Year	Total Biomass Utilization (Ag Residue, Forest Feedstocks) (MMBtu)	Approximate Cumulative Capacity (MW)	Annualized Capital Costs	Estimated Additional Variable Operational and Maintenance Costs (2005$)	Estimated Additional Fixed Operational and Maintenance Costs (2005$)	Fuel Costs (Ag Residue, Forest Feedstocks)	Total Costs
2009	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2010	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2011	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2012	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2013	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2014	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2015	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2016	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2017	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2018	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2019	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2020	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2021	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2022	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2023	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2024	TBD	TBD	TBD	TBD	TBD	TBD	TBD
2025	TBD	TBD	TBD	TBD	TBD	TBD	TBD

MMBtu = million British thermal units; MW = megawatt.

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., a $1 million plant is assumed to cost approximately $65,000 per year over the life of the project).

Energy From Livestock Manure and Poultry Litter GHG Benefits

Methane emissions (in MMtCO$_2$e) data from the Arkansas Inventory and Forecast were used as the starting point to estimate the GHG benefits of capturing and controlling the volumes of methane targeted by the policy and to add in the additional benefit of electricity generation using this captured methane (through offsetting fossil-based generation). The first portion of GHG benefit is obtained through reduced methane emissions through the capture of emissions from

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[21] 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 system, 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.

manure and poultry litter. An assumed collection efficiency of 75%[22] was applied to methane emissions from manure and poultry litter, which was then multiplied by the assumed policy target, ramping up to achieve 10% collection by 2025.

The second portion of the GHG benefit is through the offsetting of fossil-based electricity generation. This was estimated by converting the methane captured in each year to its heat content (in Btus), and then multiplying by an energy recovery factor of 17,100 Btu/kilowatt-hour (kWh) to estimate the electricity produced (assumes a 25% efficiency for conversion to electricity in an engine and generator set). The CO_2e associated with this amount of electricity in each year was estimated by converting the kWh to megawatt-hours (MWh) and then multiplying this value by the Arkansas-specific emissions. The emissions factor for grid electricity was derived from the Arkansas inventory and forecast, derived by dividing total electricity consumption emissions in 2005 by electricity sales in 2005. This provided an electricity emissions factor of 0.592 metric tons CO_2e per MWh.

The total GHG benefit was estimated as the sum of both portions of the benefits described above and indicated in Table 11.

Table 11. GHG benefits for energy utilization from livestock manure and poultry litter

Year	Methane Emissions From Dairy, Swine and Poultry ($MMtCO_2e$)	Policy Utilization Objective	Methane Captured and Utilized Under Policy ($MMtCO_2e$)	Million Metric Tons of Methane	Methane (MMBtu)	CO_2e Offset as Electricity (metric tons)	Total Emission Reductions ($MMtCO_2e$)
2009	0.247	1%	0.001	0.000	2,733	95	0.001
2010	0.247	1%	0.002	0.000	5,469	189	0.002
2011	0.248	2%	0.003	0.000	8,225	285	0.004
2012	0.248	2%	0.004	0.000	10,996	381	0.005
2013	0.249	3%	0.005	0.000	13,783	477	0.006
2014	0.250	4%	0.007	0.000	16,587	574	0.007
2015	0.251	4%	0.008	0.000	19,409	672	0.008
2016	0.251	5%	0.009	0.000	22,243	770	0.010
2017	0.252	5%	0.010	0.000	25,095	869	0.011
2018	0.253	6%	0.011	0.001	27,966	968	0.012
2019	0.253	6%	0.012	0.001	30,856	1,068	0.013
2020	0.254	7%	0.013	0.001	33,766	1,169	0.015
2021	0.255	8%	0.015	0.001	36,688	1,270	0.016
2022	0.256	8%	0.016	0.001	39,630	1,372	0.017
2023	0.257	9%	0.017	0.001	42,592	1,474	0.018
2024	0.257	9%	0.018	0.001	45,576	1,578	0.020
2025	0.258	10%	0.019	0.001	48,582	1,682	0.021

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; kWh = kilowatt-hours.

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[22] 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).

Energy From Livestock Manure and Poultry Litter Costs

The costs for the dairy and swine components were estimated using an analysis by the USDA Natural Resources Conservation Service (NRCS), *An Analysis of Energy Production Costs From Anaerobic Digestion Systems on U.S. Livestock Production Facilities.*[23] The production costs were assumed to be $0.11/kWh for swine anaerobic digesters and $0.05/kWh for dairy anaerobic digesters.[24] These costs are in 2006 dollars and assume a 30% thermal efficiency. They include annualized capital costs for the digester, generator, and operation and maintenance costs.[25] The assumed costs for the poultry component were taken from Flora and Riahi-Nezhad's *Availability of Poultry Manure as a Potential Bio-Fuel Feedstock for Energy Production* ($0.103/kWh in 2005 dollars using anaerobic digestion).[26] The value of electricity produced was taken from the all-sector average projected electricity price for the Southeastern Electric Reliability Council from EIA's AEO 2007 (see http://www.eia.doe.gov/oiaf/aeo/supplement/index.html). This price represents the value to the farmer for the electricity produced (to offset on-farm use) and is netted out from the production costs to estimate net costs. Total costs are indicated in Table 12.

Table 12. Production costs for dairy, swine, and poultry technologies

Year	Cost of Dairy Technology (2005$)	Cost of Swine Technology (2005$)	Cost of Poultry Technology (2005$)	Total Costs (2005$)
2008	–$210	$2,480	$2,400	$4,671
2009	–$385	$4,895	$4,793	$9,303
2010	–$532	$7,595	$7,516	$14,579
2011	–$645	$10,544	$10,549	$20,448
2012	–$747	$13,525	$13,668	$26,446
2013	–$849	$16,419	$16,748	$32,318
2014	–$947	$19,273	$19,839	$38,165
2015	–$1,064	$21,828	$22,646	$43,410
2016	–$1,186	$24,219	$25,316	$48,349

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[23] J.C. Beddoes, K.S. Bracmort, R.T. Burns, and W.F. Lazarus. *An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities*. Technical Note No. 1. Washington, DC: U.S. Department of Agriculture, Natural Resources Conservation Service, October 2007. Available at: policy.nrcs.usda.gov/TN_BIME_1_a.pdf.

[24] It was assumed that the technology employed for both swine and dairy anaerobic digesters was covered anaerobic lagoon. Costs were obtained from Table 1 of the NRCS economic analysis cited above.

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

[26] Joseph R.V. Flora and Cyrus Riahi-Nezhad. *Availability Of Poultry Manure As A Potential Bio-Fuel Feedstock For Energy Production*. Columbia, SC: University of South Carolina,, Department of Civil and Environmental Engineering, August 31, 2006. Available at: http://www.scbiomass.org/Publications/Poultry Litter Final Report.pdf

Year	Cost of Dairy Technology (2005$)	Cost of Swine Technology (2005$)	Cost of Poultry Technology (2005$)	Total Costs (2005$)
2017	–$1,302	$26,581	$27,998	$53,278
2018	–$1,378	$29,323	$31,151	$59,095
2019	–$1,455	$31,974	$34,253	$64,771
2020	–$1,512	$34,814	$37,603	$70,906
2021	–$1,574	$37,496	$40,824	$76,746
2022	–$1,621	$40,329	$44,269	$82,978
2023	–$1,689	$42,762	$47,304	$88,377
2024	–$1,742	$45,333	$50,546	$94,137
Total				**$827,976**

Capture of Waste Heat GHG Benefits

TBD

Capture of Waste Heat Costs

TBD

Key Assumptions: [TBD, as approved by the TWG]

It is uncertain how willing and able farmers will be to develop on-site projects (i.e., the technical expertise of farmers in energy utilization or electricity production). It is anticipated that it would be difficult to convince poultry farmers to adopt energy generation on site. Off-site cooperative and regional energy-generating facilities may be more viable.

In "Poultry Litter to Energy: Technical and Economic Feasibility,"[27] Bock notes that poultry litter is a more challenging fuel than wood for several reasons, including “that the nitrogen content is about 10 times higher in poultry litter than wood. This increases the potential for fuel nitrogen oxide emissions and requires special measures to reduce these emissions. The sulfur content of poultry litter is more than 10 times higher than that of wood. High chloride levels, in conjunction to high alkali levels, increase the potential for particulate emissions, corrosion problems, and acid gas emissions, and require special measures. Ash levels are much higher in poultry litter than in wood, requiring higher-volume ash-handling equipment and more attention to particulate removal, slagging, and fouling.” These factors indicate that emission control measures may be more elaborate and more expensive on systems utilizing poultry litter compared to other feedstocks.

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[27] B.R. Bock. "Poultry Litter to Energy: Technical and Economic Feasibility." Muscle Shoals, AL: TVA Public Power Institute. TVA Public Power Institute. Available at: http://www.msenergy.ms/Bock-National Poultry Waste _8-15-00_.pdf.

The future price of electricity will affect the analysis.

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

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

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

AFW-5. Expanded Production and Use of Biofuels

Policy Description

This strategy increases production of biofuel from agriculture and/or forestry feedstocks (raw materials) to displace the use of conventional petroleum-based fuels. It promotes the development of emerging biofuel technologies (such as cellulosic ethanol technologies) and biofuel production systems that use renewable fuels to improve the embedded energy content of biofuel. Increased in-state production and consumption result in the highest benefits.

Policy Design

Goals: Maximize the production of liquid biofuels in Arkansas, such that by 2025 the state utilizes approximately 10% of available biomass supply per year to produce biofuels with significantly lower embedded GHG emissions compared to conventional fuel products (from a life-cycle perspective).

Timing: The above goal identifies a time frame to achieve the final utilization goal. However, the Governor's Commission on Global Warming (GCGW) has suggested that the Agriculture, Forestry, and Waste Management (AFW) TWG investigate the level of development of relevant biofuel technologies. Using this information, the AFW TWG should determine an appropriate commercialization pathway for Arkansas, including identifying when the technology will most likely become commercially available.

Parties Involved: TBD – [as approved by the TWG]

Other: TBD – [as needed and approved by the TWG]

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

Alternative Fuels Development Program

Act 873 (HB 1379)—The act creates the Arkansas Alternative Fuels Development Program, to be administered by the Arkansas Agriculture Department, with the purpose of providing grant incentives for alternative fuels producers, feedstock processors, and alternative fuels distributors. The act also creates the Arkansas Alternative Fuels Development Fund, and repeals obsolete sections of the Arkansas Code related to alternative fuels.

Type(s) of GHG Reductions

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

Estimated GHG Reductions and Costs or Cost Savings

- Estimated GHG reductions: 9.1 $MMtCO_2e$ cumulative by 2025.
- Estimated cost: $91 (2007 MM$) cumulative by 2025.

Data Sources: National Renewable Energy Laboratory (NREL) biomass study;[28] other sources as cited in the text.

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. The emission factor value is based on the difference between the life-cycle emission factor of gasoline (11.74 tCO_2e/1,000 gallons) and the life-cycle CO_2e emission factor of cellulosic ethanol (3.28 tCO_2e/1,000 gallons).[29] 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 1.26 tCO_2e in 2025 (10% of the biomass available in Arkansas, according to the NREL biomass study),[30] as summarized in Table 13. 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 gal 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/gal for cellulose-based over corn-based ethanol. *[Note: this number may change, pending review of new studies from DOE.]* (For more information on these costs, please see the Key Uncertainties section below).[31] 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 research and

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[28] A. Milbrandt. “A Geographic Perspective on the Current Biomass Resource Availability in the United States.” Technical Report NREL/TP-560-39181. Golden, CO: U.S. Department of Energy, National Renewable Energy Laboratory, December 2005. Available at: www.nrel.gov/docs/fy06osti/39181.pdf.

[29] U.S. Department of Energy, Energy Information Administration. "Biofuels in the U.S. Transportation Sector." February 2007. Available at: http://www.eia.doe.gov/oiaf/analysispaper/biomass.html. ANLGreet model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

[30] A. Milbrandt. “A Geographic Perspective on the Current Biomass Resource Availability in the United States.” Technical Report NREL/TP-560-39181. Golden, CO: U.S. Department of Energy, National Renewable Energy Laboratory, December 2005. Available at: www.nrel.gov/docs/fy06osti/39181.pdf.

[31] Braemar Energy Ventures. "The Path to the Commercialization of Cellulosic Ethanol." 19th NREL Industry Growth Forum, October 24–26, 2006. Golden, CO: National Renewable Energy Laboratory. Available at: http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/19_forum/braemar_cellulosic.pdf, slide 21.

development are not included in this analysis. These incentives are considered necessary in the near term to help commercialize technologies that produce ethanol from cellulose. The incentives should also help to establish the infrastructure to deliver biomass to biorefineries, since producers will seek the local feedstocks or renewable fuels for their operations.

By 2015, it is assumed that advances in cellulosic ethanol production (e.g., enzyme costs, production processes) will make cellulosic ethanol production cost competitive with starch-based production. Hence, the incentives could be discontinued after 2015. Note that federal legislation has been proposed to offer cellulose an incentive of $0.765/gal compared to the $0.51/gal currently offered for ethanol production.[32] If enacted, this $0.255/gal premium could cover the additional incentives that are assumed to be needed by the state. However, the federal incentives do not ensure that production facilities would locate in Arkansas; hence these 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/gal (Table 13). Costs were discounted to 2007 dollars.

Table 13. Annual biomass utilization for cellulosic ethanol production

Year	Biomass Feedstock Production (short tons)
2009	74,059
2010	148,118
2011	222,176
2012	296,235
2013	370,294
2014	444,353
2015	518,412
2016	592,471
2017	666,529
2018	740,588
2019	814,647
2020	888,706
2021	962,765
2022	1,036,824
2023	1,110,882
2024	1,184,941
2025	1,259,000

Key Assumptions: [TBD, as approved by the TWG]

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

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[33], 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: EIA has stated: "Capital costs for a first-of-a-kind cellulosic ethanol plant with a capacity of 50 million gallons 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."[34]

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

Additional Benefits and Costs

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

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[33] T. Searchinger, Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu T-H. *Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change*. Science Express Report 7 February 2008. Available at www.sciencexpress.org.

[34] U.S. Department of Energy, Energy Information Administration. "Biofuels in the U.S. Transportation Sector." February 2007. Available at: http://www.eia.doe.gov/oiaf/analysispaper/biomass.html.

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 – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

TBD – [blank until final vote by the GCGW]

AFW-6. Expanded Use of Locally Produced Farm and Forest Products

Policy Description

The production and consumption of locally produced agricultural goods displace the consumption of goods transported from other states or countries, and thus reduce transportation-related GHG emissions. Increasing the amount of renewable wood products used for residential and commercial buildings can increase carbon sequestration in wood products and displace GHG emissions associated with processing high-energy input materials, such as steel, plastic, and concrete. Also, using locally grown wood can lower transportation-associated GHG emissions.

Policy Design

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

Goals:

- *Farmers' Markets*: Increase the number of local farmers' markets in Arkansas from 54 to 65 (or 20% increase) by 2025, thereby increasing market *access to* locally/regionally grown fresh produce and fish/meats/and poultry.
- *Local Produce*: By 2025, of the food Arkansans consume, 30% will consist of locally grown produce and fish/meats/poultry.
- *Information:* By 2010, the state, in coordination with the University of Arkansas System, Extension, USDA and others will collect and analyze data on the number of acres in Arkansas converted to local food production systems, and to the extent practical, will evaluate the positive economic and environmental impact on Arkansas farmers, communities, and the state as a whole.
- *Land-use*: By 2025, convert 10% of existing Arkansas agricultural land to locally based food systems, and convert another 5% of rural and urban nonagricultural land to gardens, saving emissions from reduced petroleum-based transportation, packaging, refrigeration, marketing, and production costs.
- *Locally Grown and Processed Wood Products*: Displace the amount of imported wood products with locally grown and processed products by 15% by 2015 and 30% by 2025.

Timing: As described above.

Parties Involved:

University of Arkansas System, Extension, USDA.

Other:

Increasing the number of farmers' markets in the state, as well as encouraging existing ones to grow, are major goals for the Arkansas Agriculture Department. The Agriculture Department has an ongoing program financed by block grants from USDA. Participants in the program total 54 markets, some of which are relatively small. The Agriculture Department has organized an Arkansas Farmer's Markets Association, which has 32 members, mostly representing the larger markets. Encouraging multi-county regional markets in some locations, such as Hot Springs, provides a greater opportunity for a larger variety of home-grown products over a longer period of time.

A "wood product" includes composite lumber and products with recycled content.

Implementation Mechanisms

Extension of programs such as farmers' markets, farm to school, community-supported agriculture (CSA) share programs, 4-H Youth Development, community gardens, extension programs, and home gardening.

Related Policies/Programs in Place

Energy and Natural Resource Conservation Act—The act encourages the use of wood in green buildings and requires certain state buildings to meet specified environmental construction standards (AR Code 22-3-1801). The Leadership in Energy and Environmental Design Green Building Rating System™ (LEED) was reformed in Arkansas to explicitly encourage the use of wood products in green buildings. (Previously it was eligible, but not encouraged.) Initiated by the Arkansas legislature and subsequently adopted by a number of other states, this reform specifically includes the use of products that promote the sequestration of carbon.

Type(s) of GHG Reductions

CO_2: Extends carbon sequestration in durable wood products and wood construction. Maintains carbon sequestration in healthy forests. Avoids emissions through reduced transportation miles, refrigeration and use of high-energy-input construction materials.

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources: [TBD, as approved by the TWG]

Quantification Methods:

Farmers' Market GHG Benefits

The GHG benefits for the farmers' market option are based on a study from Iowa State University[35] that compared miles traveled, fossil fuel used, and CO_2 emitted in the transport sector of several food systems. The study estimated the fuel use and the CO_2 emissions for transporting (from farm to point of sale) 10% of 28 different fresh produce items using three different food systems: conventional, regional, and local (which includes farmers' markets).

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[35] Rich Ping, Timothy Van Pelt, Kimyar Enshayan, and Ellen Cook. Food, Fuel, and Freeways: An Iowa Perspective on How Far Food Travels, Fuel Usage, and Greenhouse Gas Emissions. Ames, IA: Leopold Center for Sustainable Agriculture, Iowa State University, June 2001. Available at: http://www.leopold.iastate.edu/pubs/staff/ppp/food_mil.pdf.

This study will be scaled to Arkansas using state population adjustments and the relevant percentage of produce to be sourced locally (as determined by the policy goals). This scaling is summarized in Table 14. The 2006 population estimates were based on U.S. Census Bureau data for Iowa and Arkansas[36]—2,982,085 for Iowa and 2,810,872 for Arkansas.

Table 15. Fuel consumption and emissions from the Iowa study and the assumed scaling for Arkansas

Food System and Type of Truck	Fuel Consumption (gal/year)	CO_2 Emissions (metric tons/year)
Iowa conventional semi-trailer	368,102	3,807
Iowa local—CSA farmers market small truck (gas)	49,359	439
Arkansas conventional semi-trailer		
Arkansas local—CSA farmers market small truck (gas)		
Estimated Benefit of Sourcing 10% Locally Grown Fresh Produce		

Table 16 presents the GHG savings from increasing the proportion of produce sold at farmer's markets.

Table 16. GHG savings from increasing the proportion of produce sold at farmer's markets

Year	Increase in Local Farmers' Market	Metric Tons CO_2e
2008		
2009		
2010		
2011		
2012		
2013		
2014		
2015		
2016		
2017		
2018		
2019		
2020		
2021		
2022		
2023		
2024		
2025		
Cumulative		

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[36] U.S. Census Bureau. "State & County QuickFacts, People QuickFacts." Available at: http://quickfacts.census.gov/qfd/states/19000.html and http://quickfacts.census.gov/qfd/states/05000.html.

Farmers' Market Costs

Costs to administer this program and the possible incentives required to increase the number of farmers' markets in Arkansas are difficult to determine. Further work in this area is required.

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

AFW-7. Forest Management and Establishment for Carbon Sequestration

Policy Description

This strategy establishes forests on land not currently forested, such as agricultural land (“afforestation”); promotes retaining forest cover and associated carbon stocks by regenerating forests (“reforestation” or “restoration”); helps maintain and improve the health and longevity of trees in urban and residential areas (urban forestry); and implements, in a carbon-sensitive manner, such practices as site preparation, erosion control, and stand stocking to ensure conditions that support forest growth. Forest management activities promote forest productivity and increase the rate of CO_2 sequestration in forest biomass and soils and in harvested wood products. Also, specific trees could be selected that sequester other non-GHG chemicals in addition to sequestering CO_2. Practices may include increased stocking of poorly stocked lands, age extension of managed stands, thinning, fertilization and waste recycling, expanded short rotation of woody crops (for fiber and energy), expanded use of genetically preferred species, modified biomass removal practices, fire management and risk reduction, and pest and disease management.

Policy Design

Education and outreach, especially for citizens and land managers, will be an important part of this goal, both to underscore the importance of forests and to teach forest management practices that promote carbon sequestration.

Goals:

- Implement urban tree-planting and -retention programs to increase urban canopy by 25% by 2025 (approximately 10.8 million new trees by 2025).
- Implement sustainable forest management practices to achieve carbon benefits on 50% of privately owned land by 2025.
- Implement sustainable forest management practices to achieve carbon benefits on 50% of state-owned resource lands by 2025.
- Restore/establish 500,000 acres of forest by 2025.
- Sustain existing forests to ensure no net loss of existing forests.

Timing: As described above.

Parties Involved: TBD – [as approved by the TWG]

Other: TBD – [as needed and approved by the TWG]

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

TBD – [as needed and approved by the TWG]

Type(s) of GHG Reductions

CO_2: Removes fuels that contribute to wildfire emissions. Maintains carbon sequestration through the production of durable wood products. Reduces emissions by reducing the use of fossil fuels replaced by energy from woody biomass, and by preventing the release of carbon from dead and dying trees. Reduces wildfire emissions by maintaining healthy forests.

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources:

Urban Forestry:

- D.J. Nowak et al. "Effects of Urban Forests and Their Management on Human Health and Environmental Quality. State Urban Forest Data: Arkansas." USDA Forest Service, Northern Research Station. Available at: http://www.fs.fed.us/ne/syracuse/Data/State/data_AR.htm.
- E. Gregory McPherson and James R. Simpson. *Carbon Dioxide Reduction Through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters*. Gen. Tech. Rep. PSW-GTR-171. Washington, DC: U.S. Department of Agriculture, U.S. Forest Service, 1999. Available at: http://www.treesearch. fs.fed.us/pubs/6779.

Restore/Establish Forest Cover:

- J.E. Smith, L.S. Heath, K.E. Skog, and R.A. Birdsey. *Methods for Calculating Forest Ecosystem and Harvested Carbon With Standards Estimates for Forest Types of the United States*. General Technical Report NE-343. U.S. Department of Agriculture, Forest Service, Northern Research Station, December 21, 2005. Available at: http://www.treesearch.fs.fed.us/pubs/22954. (Also published as part of the U.S. Department of Energy Voluntary GHG Reporting Program.)
- J.A. Stanturf, C.J. Schweitzer, and E.S. Gardiner. "Afforestation of Marginal Agricultural Land in the Lower Mississippi River Alluvial Valley, U.S.A. *Silva Fennica* 1998;32(3):281-297.
- S. Walker et al. "Opportunities for Improving Carbon Storage Through Afforestation of Agricultural Lands." Part 3A in *Terrestrial Carbon Sequestration in the Northeast: Quantities and Costs*, The Nature Conservancy, Winrock International, and The Sampson Group. October 2007. Available at: http://www.sampsongroup.com/Papers/carbon.htm.

Quantification Methods:

Urban Forestry GHG Benefit

Carbon Sequestration in Urban Trees

Approximately 43,412,000 urban trees are currently growing in Arkansas, resulting in an average of 25% canopy cover in urban areas statewide.[37] A 25% increase in tree cover would require planting approximately 25% more, or a total of 10,853,000 trees. To achieve an increase in urban tree cover of this many trees by 2025, approximately XX trees per year would need to be planted in Arkansas communities beginning in 2009, assuming a constant planting rate to 2025. The average annual per-tree carbon sequestration value for urban trees was found by dividing the total estimated annual carbon sequestration in Arkansas urban trees (XXX tC/year) by the total number of urban trees. Annual carbon sequestration per urban tree was thus calculated as XXX tC/tree/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 GHG reduction factor of 0.03 tCO_2e/tree/year was calculated from data in McPherson et al. in GTR-PSW-171 (Table XXX). 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 X%, X%, and X%, 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. Medium-sized trees (half evergreen, half deciduous) planted and average tree distribution around buildings were also assumed (i.e., 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 also dependent on the fuel mix (coal, hydroelectric, nuclear, etc.) in the regions of interest, and may thus change if the electricity mix changes.

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

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[37] D.J. Nowak et al. "Effects of Urban Forests and Their Management on Human Health and Environmental Quality. State Urban Forest Data: Arkansas." U.S. Department of Agriculture, U.S. Forest Service, Northern Research Station. Available at: http://www.fs.fed.us/ne/syracuse/Data/State/data_AR.htm.

reduction. The avoided emissions and carbon sequestration benefits are summed in the table below to show the total net benefits of urban tree planting.

Urban Forestry Costs

The economic costs included in this analysis will be the costs of planting and annual maintenance, including the costs of program administration and waste disposal. The economic benefits of tree planting will include the cost avoided from reduced energy use. Data are available on the estimated economic benefits of such services as provision of clean air, hydrologic benefits (e.g., stormwater control), and aesthetic enhancement, but these indirect co-benefits will not be explicitly quantified.

Costs and cost savings will be estimated from average annual costs and cost savings over 40 years for a range of tree sizes. The cost estimate used in this analysis will be calculated as the average of small, medium, and large trees under public and private management. The cost savings will also be calculated as the average of small, medium, and large trees under public and private management. The cost savings will be estimated using 40-year averages; thus, it will represent lifetime costs applicable in the year planted and every year thereafter during the time frame of the analysis. To estimate total cost savings, the cost per tree will be multiplied by the cumulative number of trees planted each year.

Sustainable Management in Public and Private Lands: GHG Benefits

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

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

Sustainable Management in Public and Private Forests: Economic Costs

The economic cost of implementing enhanced forest management on forest acreage is a one-time cost (over and above the cost to implement standard management techniques) of improved forest management practices, and is estimated to be $151.50/acre. This value is an average of values from other states where similar policy options have been quantified: Vermont, where a value of

$3 per acre was used,[38] and Montana, where a value of $300 per acre was used.[39] Clearly, there is little consensus about what is required to implement an enhanced forest management program; as a result the estimates of how much it will cost to implement these policies vary widely. State-specific data would substantially improve the validity of the estimate of economic costs for this option in Arkansas.

Restore/Establish Forest Cover: GHG Benefits

Due to intense competition for land among various uses, it is likely that afforestation and reforestation will be most successful on lands where crop production is likely to fail. Land in the Lower Mississippi River Alluvial Valley that is subject to spring and early summer backwater flooding is ideal for forest establishment. It has been suggested that 200,000 hectares (roughly 500,000 acres) of this land could be available for planting.[40]

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

Average carbon storage was found using methods described in Smith et al., assuming that reforestation and afforestation activity would occur on forests that were consistent with the existing forest type distribution in Arkansas.

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 xx). The 35-year period was chosen to reflect the average length of an afforestation project period. In this afforestation calculation, soil carbon was assumed to accumulate at a rate consistent with soil carbon accumulation in afforested stands in Smith et al.

The methods described in Smith et al. for quantifying carbon storage following reforestation activity assume that forests established on land that was once forested are first clearcut, and are then replanted or allowed to regrow. This harvesting activity results in substantial decomposition for the first 5 years after harvest. For the current analysis, it was assumed that forests were replanted on land that had once been forested, but that at least 5 years had passed since the most recent harvest. Thus, annual carbon sequestration rates in reforested stands for each forest type group were calculated by subtracting carbon stocks in 5-year-old stands from carbon stocks in 35-year old stands and dividing by 30 years. A weighted statewide average carbon sequestration rate for afforestation activity was calculated, taking into account the variation in carbon

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[38] Vermont Climate Change Advisory Group. See: http://www.vtclimatechange.us.

[39] Montana Climate Change Advisory Group. See: http://www.mtclimatechange.us.

[40] J.A. Stanturf, C.J. Schweitzer, and E.S. Gardiner. "Afforestation of Marginal Agricultural Land in the Lower Mississippi River Alluvial Valley, U.S.A." *Silva Fennica* 1998;32(3):281-297. Available at: http://www.metla.fi/silvafennica/full/sf32/sf323281.pdf.

sequestration across forest types (Table xx). The 30-year period was chosen to reflect the average length of a project period. In this reforestation calculation, soil carbon remained constant because soil carbon does not change with time in reforestation activity in Smith et al.

Restore/Establish Forest Cover: Economic Costs

Cost analyses of vegetation planting costs 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). For this analysis, opportunity cost will be assumed to be zero, because the land considered for afforestation and reforestation is currently underutilized.

One-time costs of vegetation establishment include site preparation and vegetation planting. These costs are incurred in the year of planting, one time only. Ongoing costs of maintenance and monitoring are incurred annually on all acreage planted in all years of policy implementation. Costs will vary, depending on the specific goals of the tree-planting project, species planted, and site conditions. If natural growth rather than planting occurs on a site, many of these costs may not be incurred.

Discounted costs to 2025 will be calculated using a 5% discount rate. Net present value (NPV) is the sum of the discounted costs—in other words, the economic cost or benefit of implementing the option between 2009 and 2025, calculated in today's dollars. Levelized cost-effectiveness is the NPV of a scenario divided by the cumulative GHG benefit of that scenario. This will be expressed in $/tCO_2$e sequestered or avoided, and is intended to give a sense for the cost of each scenario standardized for its actual GHG benefit across numerous scenarios and options that vary in terms of overall cost and cumulative GHG benefit.

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

AFW-8. Advanced Recovery and Recycling

Policy Description

Increasing waste recovery and recycling and reducing waste generation limits GHG emissions associated with landfill methane generation and with the production of raw materials. Additional actions include increasing existing recycling programs, creating new recycling programs, providing incentives for recycling construction materials, developing markets for recycled materials, and increasing average participation/recovery rates for all existing recycling programs.

Policy Design

Goals:

Increase the recycling rate for "GHG significant solid waste streams" by 2% every 5 years where geographically cost-effective.

Timing:

Continuing on from the statutory recycling goal of 45% by 2010, the 2015 goal would be a 2% improvement on the 2010 actual recycling rate; the 2020 goal would be a 2% improvement on the 2015 actual recycling rate; and the 2025 goal would a 2% improvement on the 2020 actual recycling rate.

Parties Involved: TBD – [as approved by the TWG]

Other:

To measure the GHG impacts of municipal solid waste (MSW), the U.S. Environmental Protection Agency (EPA) first decided which wastes to analyze. The universe of materials and products found in MSW was surveyed, and those that are most likely to have the greatest impact on GHGs were identified. These determinations were based on (1) the quantity generated, (2) the differences in energy use for manufacturing a product from virgin versus recycled inputs, and (3) the potential contribution of materials to CH_4 generation in landfills. By this process, EPA limited the analysis to the following 21 single-material items:

- Three categories of metal: aluminum cans, steel cans, and copper wire;
- Glass;
- Three types of plastic: HDPE (high-density polyethylene); LDPE (low-density polyethylene); and PET (polyethylene terephthalate);
- Six categories of paper products: corrugated cardboard, magazines/third-class mail, newspaper, office paper, phonebooks, and textbooks;
- Two types of wood products: dimensional lumber and medium-density fiberboard;
- Food discards;
- Yard trimmings;

- Clay bricks;
- Concrete;
- Fly ash; and
- Tires.

EPA's researchers also included two products that are composites of several materials: carpet and personal computers.

The goals in this policy represent a linear extrapolation of Arkansas's state recycling goals set forth by Act 94 (HB 1055). Data for 2006 document an overall solid waste recycling rate of 42% (See Table 17 for waste steams and tons recycled.) It is not known how many tons of these waste streams were disposed in Arkansas landfills, as there is no reporting requirement for these data.

Table 17. Municipal solid waste steams and tons recycled

Waste Streams	Tons/Year Recycled in 2006	Point of Generation[41]	Comments	Potential to Increase Amount Recycled
Batteries (lead acid)	357	Residential and nonresidential	Return policy in place (Act 749 of 1991).	No.
Computers/electronic	23,211	Residential and nonresidential	Banned from landfilling in 2010 (Act 512 of 2007). Incentive funding will be available in 2009 for collection and recycling.	Will happen under existing laws.
Cooking oil	5,265	Nonresidential	Private companies purchase and collect for use as a biofuel.	Yes, for use as an energy source.
Glass	2,646	Non-residential	Need AR-based recycling and approved alternative uses.	Yes, need better markets.
Metals	806,978	Residential and nonresidential	Good programs in place for collection and recycling.	No.
Motor oil	60,292	Residential and nonresidential		Yes, for use as an energy source.
Pallets and other wood wastes	910,518	Nonresidential		Yes, for use as an energy source.

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[41] For the purposes of this discussion, the point of generation will be categorized as either residentially or nonresidentially generated.

Waste Streams	Tons/Year Recycled in 2006	Point of Generation[42]	Comments	Potential to Increase Amount Recycled
Paper—cardboard	40,030	Nonresidential		Yes.
Paper—mixed	11,230	Nonresidential		Yes.
Paper–newsprint	22,977	Residential		Yes.
Paper–white ledger	72,987	Nonresidential		Yes.
Paper–magazines	106	Residential		Yes.
Paper–other	1,521	Nonresidential		Yes.
Plastic–HDPE, LDPE and Pet	1,648; 3,283; 1,374	Residential	Mostly going out of state for processing.	Yes, need better collection.
Plastics–poly pipe	25,517	Nonresidential	Mostly going out of state for processing.	Yes.
Plastics–other	2,054	Nonresidential	Mostly going out of state for processing.	Yes.
Sawdust	5,800	Nonresidential		Yes.
Textiles and leather	472	Residential and nonresidential		No, too small a waste stream.
Tires and rubber	34,508	Residential and nonresidential	Currently banned from disposal in a landfill (Act 749 of 1991). Mostly shipped out of state for recycling.	Yes, for more in-state uses.
Yard wastes	79,086	Residential and nonresidential	Currently banned from disposal in a landfill (Act 751 of 1991). Mostly being composted.	Yes, potential use as an energy source.

To increase the diversion of recycled materials from the solid waste disposal stream for those waste identified as having the biggest global warming impacts, several factors need to be considered:

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[42] For the purposes of this discussion, the point of generation will be categorized as either residentially or nonresidentially generated.

- *Economics*—Arkansas disposal rates at MSW landfills are some of the lowest in the nation. Communities, businesses, industries have no incentives to collect and divert recyclable materials from waste streams directed to landfills.
- *Curbside Programs Enhanced*—Currently 97 communities have curbside recycling programs. Some 190 communities offer recycling opportunities at drop-off centers. Programs need to be encouraged to expand the number of items collected and to offer residents incentives to reduce waste destined for the landfills. Pay-As-You-Throw rewards residents for reuse and recycling by charging lower solid waste disposal rates.
- *Pre-Consumer Recycling*—Arkansas industries should be offered more incentives to reduce waste destined to MSW landfills.
- *Commercial Recycling*—Less than 10% of Arkansas municipalities offer local businesses the opportunity to reduce the amount of waste deposited in landfills. Incentives need to be developed at the local level to encourage participation in recycling programs.
- *End User*—Encourage the development of state or regional end users. Long-haul transportation costs to end users affect profit margins, and profits are how recycling programs exist. Arkansas offers the 30% State Income Tax Credit for collection and use of recyclable materials in the manufacturing process.

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

Recycling Goals

Act 94 (HB 1055)—The act adds a new goal to the year 2000 recycling goals for Arkansas, which is to recycle 40% of the MSW by the end of 2005 and 45% of the MSW by the end of 2010. The act also defines MSW.

Solid Waste Management and Recycling Fund

Act 1325 (SB 575)—This act permits grants from the Solid Waste Management and Recycling Fund to be used for the cost of "recycling programs." Previous law permitted grants to be used for "recycling programs and market development."

Type(s) of GHG Reductions

- **CO_2:** *Reductions in Upstream Energy Use*—The energy and GHG intensity of manufacturing a product are generally less when using recycled, rather than virgin, feedstocks.
- **CH_4:** Diverting biodegradable wastes from landfills decreases methane gas releases from landfills.

Estimated GHG Reductions and Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources:

- U.S. Environmental Protection Agency. "WAste Reduction Model (WARM)." Version 8, May 2006. Available at: http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html.
- Simmons, P., N. Goldstein, S.M. Kaufman, N.J. Themelis, and J. Thompson, Jr. *The State of Garbage in America. 15th Nationwide Survey of Municipal Solid Waste Management in the United States*. A joint study by BioCycle and Columbia University Earth Engineering Center. April 2006. Available at: http://www.seas.columbia.edu/earth/wtert/sofos/Simmons_SOG06.pdf.

Quantification Methods:

Below is an outline of expected quantification methods that may be used by the Center for Climate Strategies (CCS) to estimate the GHG reduction potential of this option. While some text may be left in for the final version of the Policy Options Document, this outline will be removed once the draft quantification has been completed.

GHG Benefits

- GHG benefits are determined using EPA's WAste Reduction Model (WARM). WARM uses information for specific material inputs and disposal/diversion methods to estimate GHG emission reductions based on a BAU and policy scenario. The BAU scenario will extrapolate the baseline waste management data using an average annual change in generation. This rate has yet to be identified, and more information from the TWG is requested.
- The WARM will be run for the years 2015 and 2025, in order to produce GHG reduction estimates for the policy target years. A linear extension in all other years is expected.
- For the policy scenario, the baseline annual waste generation rate will be altered to incorporate the recycling goal set by the TWG.
- WARM considers composting of organic material differently from traditional recycling. Also, the cost of composting programs differs from that of recycling programs. Therefore, the total recycling goal set by the TWG will be referred to as "diversion," and the "recycling" and "composting" rates will add up to the total goal.

Cost-Effectiveness

- Arkansas-specific information will be preferable for all of the factors listed below. For recycling and composting, the net cost will be the sum of the program cost, the tipping fee received at the diversion facility, additional capital cost, and additional operation and maintenance (O&M) cost, less any avoided landfill tipping fee and the market value of the recycled or composted product. For source reduction, the net cost will generally be any program costs required for the implementation of the program, less the value of the averted landfill tipping fees.
  - Average landfill tipping fee
  - Average recycling facility tipping fee (paid to either the hauler or recycler)
  - Average compost facility tipping fee

  - Average value of compost
  - Capital and O&M cost for recycling facilities
  - Capital and O&M cost for composting facilities
  - Collection cost for source-separated compost and recycling programs
  - Education and/or enforcement program costs.

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until final vote by the GCGW]

AFW-9. End-of-Use Waste Management Practices

Policy Description

These programs use the renewable energy created at landfills by anaerobic digesters (methane) to make electric power, space heat, or liquefied natural gas. New processes for converting waste energy include biomass gasification and pyrolysis. A range of renewable products can be developed from these processes, including gaseous and liquid fuels, biochar, and chemical products. Existing processes include waste combustion and energy recovery (as electricity, steam, or both).

Policy Design

TBD

Goals: 25% of all landfills develop landfill gas-to-energy (LFGTE) and anaerobic digester projects by 2025.

Timing: TBD – [as approved by the TWG]

Parties Involved: TBD – [as approved by the TWG]

Other:

There are currently 24 municipal solid waste landfills operating in Arkansas. Of that number, 6 have an active gas collection system; 4 of the 6 are, or will be flaring landfill gases, and 2 are collecting and using these gases for energy.

Based on the baseline data from the Draft Inventory and Forecast, the 2005 GHG emissions averted through flaring or LFGTE projects is 12% of the total CH_4 emissions from MSW generation.

Implementation Mechanisms

TBD – [as approved by the TWG]

Related Policies/Programs in Place

TBD – [as needed and approved by the TWG]

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 Costs or Cost Savings

TBD – [as approved by the TWG]

Data Sources:

- U.S. Environmental Protection Agency, Landfill Methane Outreach Program. "Energy Projects and Candidate Landfills." Online database accessed on May 22, 2008, at: http://www.epa.gov/lmop/proj/index.htm.
- U.S. Environmental Protection Agency. Landfill Methane Outreach Program U.S. Environmental Protection Agency, Landfill Methane Outreach Program. Landfill Gas Energy Cost Model (LFGcost), Version 1.4. "Summary Report, Pechan for NC GHG Mitigation Plan." March 2, 2007.
- Arkansas Inventory and Forecast (I&F), Waste Appendix.

Quantification Methods:

[Below is an outline of expected quantification methods that may be used by CCS to estimate the GHG reduction potential of this option. While some text may be left in for the final version of the Policy Options Document, this outline will be removed once the draft quantification has been completed.]

GHG Benefits

- Since the goal is based on a percentage reduction in emissions, the total MSW landfill emissions from the Arkansas I&F will be multiplied by this percentage to determine the GHG reduction.

Cost-Effectiveness

- The cost-effectiveness of this option is determined using the LFGcost model. The current model inputs assume an 8% interest rate over 10 years for capital and energy prices of $4.50/MMBtu and $0.045/kWh.
- Based on the current utilization of LFGTE, assumptions will be made to determine the proportion of landfill gas captured by small engines (less than 800 kW capacity), large engines, and direct use. Then, the total emissions captured by each technology will be multiplied by the respective cost-effectiveness estimates from the LFGcost model to determine an overall cost-effectiveness for this option

Key Assumptions: [TBD, as approved by the TWG]

Key Uncertainties

TBD – [as needed and approved by the TWG]

Additional Benefits and Costs

TBD – [as needed and approved by the TWG]

Feasibility Issues

TBD – [as needed and approved by the TWG]

Status of Group Approval

Pending – [until GCGW moves to final agreement at meeting #8, #9, or #10]

Level of Group Support

TBD – [blank until GCGW meeting #8, #9, or #10]

Barriers to Consensus

TBD – [blank until GCGW meeting #8, #9, or #10]