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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 $)	Cost-Effectiveness ($/tCO_2e$)	Status of Option
			2015	2025	Total 2009–2025			
AFW-1	Manure Management		Not quantified					Pending
AFW-2	Promotion of Farming Practices That Achieve GHG Benefits	Soil Carbon	0.62	1.50	13.6	–$49	–$3.6	Pending
		Nutrient Efficiency	0.11	0.27	2.39	–$56	–$23	
AFW-3	Improved Water Management and Use	Increased Surface Water	0.07	0.17	1.49	$1,241	$835	Pending
		Improved Purification	0.001	0.001	0.012	–$0.4	–$39	
AFW-4	Expanded Use of Agriculture and Forestry Biomass Feedstocks for Electricity, Heat, or Steam Production	Energy From Biomass	6.2	12.4	121.2	$3208	$26	Pending
		Energy From Livestock Manure and Poultry Litter	0.01	0.02	0.19	$0.8	$4	
		Capture of Waste Heat	0.02	0.06	0.50	–$70	–$140	
AFW-5	Expanded Use of Advanced Biofuels		1.35	2.15	19.7	114	$5.8	Pending
AFW-6	Expanded Use of Locally Produced Farm and Forest Products		0.03	0.06	0.61	$1	$2	Pending
AFW-7	Forest Management and Establishment for Carbon Sequestration	Urban Forestry	0.02	0.11	0.41	$17	$41	Pending
		Sustainable Forest Management	8.4	21.0	186	TBD	TBD	
		Afforestation	0.74	1.80	16.16	$201	$12	
AFW-8	Advanced Recovery and Recycling		1.52	4.35	35.8	–$259	–$7	Pending
AFW-9	End-of-Use Waste Management Practices		0.02	0.02	0.4	–$1	–$3	Pending
	Sector Total After Adjusting for Overlaps		**TBD**	**TBD**	**TBD**	**TBD**	**TBD**	
	Reductions From Recent Actions		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	
	Sector Total Plus Recent Actions		**TBD**	**TBD**	**TBD**	**TBD**	**TBD**	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_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/Demand Assessment

Biomass Resource	2015 Annual Biomass Supply (10^3 dry short tons)	2025 Annual Biomass Supply (10^3 dry short tons)	Notes
Forest residue	5,265	5,265	Biomass availability from Annual Biomass Supply Study.[1]
Mill residue	3,239	3,239	Annual Biomass Supply Study.
Urban wood waste	1,534	1,534	Annual Biomass Supply Study.
Agricultural residue	3,198	3,198	Annual Biomass Supply Study.
Municipal paper waste	342	523	Taken from AFW-8 analysis
Municipal solid waste organics	117	175	Taken from AFW-8 analysis
Energy crops	4,072	8,144	Energy crop biomass supply taken from the goals identified under AFW-4 identified through marginal agricultural land conversion.
Total Annual Biomass Supply	**17,767**	**22,078**	
Policy Requiring Biomass	**2015 Annual Biomass Demand (10^3 dry short tons)**	**2025 Annual Biomass Demand (10^3 dry short tons)**	**Notes**
AFW-4	See below	See below	See below
Methane from livestock manure and poultry litter	N/A	N/A	10% of available methane from livestock manure and poultry litter. Methane derived from Inventory and Forecast.
Total forest feedstocks	502	1,004	10% of available in-state forest residue by 2025.
Total agriculture residue	159	320	10% of available agriculture residue biomass by 2025.
Energy crop (e.g., switchgrass)	814	1,629	10% of marginal agriculture land by 2025.
AFW-5 (Biofuel)	1,500	2,208	10% of biomass supply to produce advanced biofuels.
Total Demand	**2,975**	**5,161**	

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

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

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)[2] found that more N_2O was emitted when manure was incorporated into soil compared to when 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

A variety of management practices could lead to reductions in GHG emissions including dry management systems, wet management systems (e.g. anaerobic lagoons, pit storage and liquid/slurry), daily spread, composting, covering and modifying animal feed. The key uncertainties section includes a discussion on each of these.

[2] Gerard Velthof, Peter Kuikman, and Oene Oenema, "Nitrous Oxide Emission From Animal Manures Applied to Soil Under Controlled Conditions," *Biol Fertil Soils* April 2003;37(4):221–230. Available at: http://www.springerlink.com/content/l9gx2jtlrq2fp3y9/.

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 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:

Not applicable.

Key Assumptions:

Not applicable.

Key Uncertainties

A variety of sources have been considered in attempting to quantify the best manure management practices to reduce GHG emissions. While it is very likely that reduced emissions through manure management are possible, it is not certain the level to which emissions reductions can be achieved. It is unclear if the goal of reducing emissions by 40% is overly ambitious.

In general, difficulties in quantifying this come from the tradeoff between N_2O emissions and CH_4 emissions. Dry management systems typically keep methane emissions low, but can lead to higher N_2O emissions. Wet management systems, such as anaerobic lagoons, pit storage and liquid/slurry, help reduce N_2O emissions, but often increase methane emissions. For areas with temperatures similar to those of Arkansas, the Intergovernmental Panel on Climate Change (IPCC) recommends daily spread as the best practice for reducing methane emissions, although N_2O emissions from this approach are not quantified by the IPCC, and instead are considered as part of soil emissions.[3] Composting manures can suppress methane emissions, but this can also increase formation of N_2O.[4] Covering manure can reduce N_2O emissions, but has an uncertain impact on methane formation.[5] Manure management can be achieved by modifying animal feed or by composting manure, but further study of the impact of these practices is necessary to determine their true efficacy.[6]

In addition, the Arkansas Natural Resources Commission recommended that Dr. Philip Moore at the University of Arkansas could provide assistance in quantifying this option. Dr. Moore did not have any specific recommendations for how to reduce emissions, but he did outline several methods that increase N_2O emissions, such as deep stacking manure, directly injecting manure into the soil, and composting poultry litter.[7] Other studies have found that composting manure increases GHG emissions,[8] and N_2O emissions increase by applying manure just below the surface.[9]

A recent article pertaining to GHG emissions from swine found that "on-farm wastewater treatment system consisting of liquid–solid separation, treatment of the separated liquid using aerobic biological N [nitrogen] removal, chemical disinfection and soluble P [phosphorus] removal using lime" could reduce GHG emissions by 97%.[10] Swine emissions in Arkansas are 9% of total manure management emissions. Because this particular practice is not applicable to poultry litter or cow manure, it is not likely there would be significant benefits in Arkansas from this new treatment. However, this does show a significant decrease possible through a new manure management approach.

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[3] Paul Jun, Michael Gibbs, and Kathryn Gaffney. "CH4 and N2O Emissions From Livestock Manure." In Intergovernmental Panel on Climate Change. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.* 2000. Available at: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_2_CH4_and_N2O_Livestock_Manure.pdf.

[4] Bert Metz, Ogunlade Davidson, Peter Bosch, Rutu Dave, and Leo Meyer, eds. *Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. New York, NY: Cambridge University Press, 2007. Available at: http://www.ipcc.ch/ipccreports/ar4-wg3.htm.

[5] Ibid.

[6] Ibid.

[7] Personal communication, Dr. Phillip Moore, June 23, 2008.

[8] 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.

[9] Velthof, Gerard, Peter Kuikman, and Oene Oenema, "Nitrous Oxide Emission From Animal Manures Applied to Soil Under Controlled Conditions," *Biol Fertil Soils* April 2003;37(4):221–230. Available at: http://www.springerlink.com/content/l9gx2jtlrq2fp3y9/.

[10] **M.B. Vanotti, A.A. Szogi, and C.A. Vives.** "Greenhouse Gas Emission Reduction and Environmental Quality Improvement From Implementation of Aerobic Waste Treatment Systems in Swine Farms." *Waste Management* 2008;28(4):759-766. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VFR-4R8KT18-3&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=db75fa272fe41653220c60dc09cb4733.

Additional research is required on the best management practices in order to reduce greenhouse gas emissions. Because swine emissions are responsible for the majority of manure emissions in the country, the majority of research has focused on the best management practices for swine farms. Poultry litter is by far the largest contributor to greenhouse gas emissions from manure sources in Arkansas, and therefore state research should focus on controlling emissions from poultry.

Additional Benefits and Costs

Improved manure management can have benefits in terms of reduced local air pollutants and improved odor.

Feasibility Issues

See Key Uncertainties.

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.11

11 U.S. Department of Agriculture, Economic Research Service. National Agricultural Statistics Service 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 acres12 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.13

Based on the policy design parameters, the schedule for acres to be put into conservation tillage/no-till cultivation is displayed in Table 2-1. 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.[14]

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.[15] 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.[16] The life-cycle fossil diesel GHG emission factor of 12.31 metric tons of carbon dioxide equivalent

12 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.

13 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.

[14] 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.

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

[16] Reduction associated with conservation tillage compared to conventional tillage. See: Purdue University, 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.

($MMtCO_2e$)/1,000 gal was used.[17] Results are shown in Table 2-1, along with a total estimated benefit from both carbon sequestration and fossil fuel reductions.

Table 2-1. 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.

The estimated cost savings ($2.75/acre) related to the adoption of no-till farming was derived from the low end of the range provided in "Economic Comparison of Three Cotton Tillage Systems in Three NC Regions," by S. Walton and G. Bullen.[18] The reduction in fossil diesel fuel

[17] 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. Available at: http://www.pnas.org/cgi/content/full/103/30/11099.

[18] S. Walton, and G. Bullen. "Economic Comparison of Three Cotton Tillage Systems in Three NC Regions." North Carolina Cooperative Extension. Available at: www.ces.ncsu.edu/depts/agecon/Cotton_Econ/production/Economic_Comparison.ppt, accessed February 2000.

use from the adoption of conservation tillage methods is 3.5 gal/acre.[19] The life-cycle fossil diesel GHG emission factor of 12.31 MtCO_2e/1,000 gal was used.[20]

Costs savings were estimated by multiplying the estimated savings per acre cited above ($2.75) by the number of acres in the program each year. This savings estimate takes into account budget changes for the cost of fuel, labor, chemicals, and equipment.

The costs of adopting soil management practices (e.g., conservation tillage/no-till practices) are based on cost estimates from the Minnesota Agriculture Best Management Practices (AgBMP) program.[21] This program provides farmers a low-interest loan as an incentive to initiate or improve their current tillage practices. The equipment funded is generally specialized tillage or planting implements that leave crop residues covering at least 15%–30% of the ground after planting. The average total cost for this equipment is $23,000, though the average loan for tillage equipment is $16,000. The average-size farm using an AgBMP loan to purchase conservation tillage equipment is 984 acres. The average loan size was determined based on the average size of a farm in Arkansas (308 acres)[22] and the amount of a loan per acre as estimated in the Minnesota AgBMP program ($16.26/acre).[23] This put the average loan size at $5,008 to finance no-till/conservation tillage practices. This loan payment was applied to each new acre entering the program to determine an approximate cost of encouraging the use of soil management practices. It was further assumed that carbon credits would be available through future programs similar to the National Farmers Union Carbon Credit Program[24] or the Iowa Farm Bureau's AgraGate Climate Credits Corporation. The resulting cost-effectiveness of soil carbon management is a cost savings of about $3.6/t$CO_2$e. See Table 2-2 for more details.

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[19] Reduction associated with conservation tillage compared to conventional tillage. See Purdue University, 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, accessed August 2006.

[20] Life-cycle emissions factor for fossil diesel from J. Hill et. al., *Proceedings of the National Academy of Sciences,* 103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life cycle impacts. Available at: http://www.pnas.org/cgi/content/full/103/30/11099.

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

[22] 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.

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

[24] Price of $2.10 per metric ton of CO_2e sourced from CCX Web site on November 13, 2007.

Table 2-2. Costs of a conservation tillage program

Year	Cost of Loan	Cost Savings of Program	Total Costs of Program	Discounted Costs of Program
2008	$0	$0	$0	$0
2009	$2,072,526	–$675,258	$1,397,268	$1,149,536
2010	$4,595,601	–$2,172,570	$2,423,031	$1,898,508
2011	$3,243,954	–$3,229,497	$14,457	$10,788
2012	$3,243,954	–$4,286,423	–$1,042,469	–$740,863
2013	$3,243,954	–$5,343,349	–$2,099,395	–$1,420,953
2014	$3,243,954	–$6,400,275	–$3,156,321	–$2,034,593
2015	$3,243,954	–$7,457,201	–$4,213,248	–$2,586,568
2016	$3,243,954	–$8,514,127	–$5,270,174	–$3,081,361
2017	$3,243,954	–$9,571,054	–$6,327,100	–$3,523,166
2018	$3,243,954	–$10,627,980	–$7,384,026	–$3,915,907
2019	$3,243,954	–$11,684,906	–$8,440,952	–$4,263,254
2020	$3,243,954	–$12,741,832	–$9,497,878	–$4,568,642
2021	$3,243,954	–$13,798,758	–$10,554,804	–$4,835,278
2022	$3,243,954	–$14,855,684	–$11,611,731	–$5,066,160
2023	$3,243,954	–$15,912,611	–$12,668,657	–$5,264,089
2024	$3,243,954	–$16,969,537	–$13,725,583	–$5,431,679
2025	$3,063,734	–$17,967,745	–$14,904,011	–$5,617,165
Total Costs				**–$49,290,846**

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 (AR I&F). This is then combined with a figure for the life-cycle emissions of nitrogen fertilizer (0.857 kg CO_2e/kg of N).[25] 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 AR I&F assumes 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

[25] The avoided life-cycle GHG emissions (i.e., emissions associated with the production, transport, and energy consumption during application) were taken from: Sam Wood and Annette Cowie. *A Review of Greenhouse Gas Emission Factors for Fertiliser Production.* Research and Development Division, State Forests of New South Wales, Cooperative Research Centre for Greenhouse Accounting. June 2004. Available at: http://www.ieabioenergy-task38.org/publications/GHG_Emission_Fertilizer%20Production_July2004.pdf.

The estimate provided for the United States in Wood and Cowie was taken from: T.O. West and G. Marland. "A Synthesis of Carbon Sequestration, Carbon Emissions and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States." Agriculture, Ecosystems and 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.

application is then multiplied by the nitrogen emissions factor to determine the GHG benefits of this policy. Table 2-3 presents the nitrogen reductions and the GHG benefits of the proposed nutrient efficiency policy.

Table 2-3. GHG reductions from the proposed nutrient efficiency policy

Year	Arkansas Fertilizer Used (baseline) (metric tons of nitrogen)	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.

The costs of the nutrient efficiency policy were estimated based on the implementation of a soil-testing policy to optimize fertilizer application. This policy assumes $20 cost to test a 75-acre field, with the field tested every 4 years, across all of Arkansas. There are also staffing costs for the testing and information program ($500,000/year) and costs of preparing a guidance document ($75,000). Subtracted from these costs are the savings from reduced fertilizer use, which results in a net savings over the policy period. See Table 2-4 for more details.

Key Assumptions: The conservation tillage policy assumes that 0.4 tCO_2/acre/year is a good estimate for the sequestration that comes from no-till. If this is not an accurate estimate of the benefits of conservation tillage on Arkansas soils, then this number will need to be changed. Soil carbon management includes all conservation farming practices that reduce GHG emissions and increase soil carbon sequestration. Conservation tillage has been used as an example for quantification purposes, and other options, such as cover crops, different rotations, and perennial crops, are of equal interest.

Table 2-4. Costs of a nutrient efficiency program

Year	Target Fertilizer Reduction (kg N)	Annual Cost of Fertilizer Programs ($MM)	Avoided Cost of Fertilizer ($MM)	Costs+Savings	Discounted Costs+Savings
2009	2,856	$3.11	–$1.10	$2.01	$1.65
2010	5,713	$2.86	–$2.20	$0.66	$0.52
2011	8,569	$3.11	–$3.30	–$0.19	–$0.14
2012	11,426	$2.86	–$4.39	–$1.53	–$1.09
2013	14,282	$2.86	–$5.49	–$2.63	–$1.78
2014	17,139	$2.86	–$6.59	–$3.73	–$2.41
2015	19,995	$2.86	–$7.69	–$4.83	–$2.97
2016	22,851	$2.86	–$8.79	–$5.93	–$3.47
2017	25,708	$2.86	–$9.89	–$7.03	–$3.91
2018	28,564	$2.86	–$10.99	–$8.13	–$4.31
2019	31,421	$2.86	–$12.08	–$9.22	–$4.66
2020	34,277	$ 2.86	–$13.18	–$10.32	–$4.97
2021	37,134	$2.86	–$14.28	–$11.42	–$5.23
2022	39,990	$2.86	–$15.38	–$12.52	–$5.46
2023	42,847	$2.86	–$16.48	–$13.62	–$5.66
2024	45,703	$2.86	–$17.58	–$14.72	–$5.82
2025	48,559	$2.86	–$18.68	–$15.82	–$5.96
Total		$29			–$57.84

kg N = kilograms of nitrogen; $MM = millions of dollars.

Several other key assumptions include: the carbon sequestration potential is representative of all the crop systems to which the policy is applied, a 20-year period is used for accumulating the soil carbon, any potential increase in N_2O emissions is not large enough to significantly affect the estimated CO_2 benefits, and cost savings used are representative of average savings to be achieved across all crop systems.

The nutrient efficiency policy assumes that fertilizer use can be reduced without a decrease in yield. If yield decreases with reduced fertilizer application, determining both the costs and the GHG reductions of this policy will be more difficult. BAU fertilizer rates are assumed under historic fertilizer costs. The current explosion in energy and fertilizer costs may substantially alter BAU rates.

Key Uncertainties

The rate of no-till practices used is based on the national average, which may not reflect Arkansas conditions. The costs/acre for no-till management come from the Minnesota AgBMP program, which may not reflect Arkansas costs/acre.

There are key uncertainties surrounding the potential GHG benefits associated with no-till and conservation-till practices compared to conventional tillage practices. The soil sequestration rates associated with land management practices, including conservation tillage, remain extremely uncertain, and studies (including those by Manley et al.) highlight this uncertainty. Manley et al. suggest that determining the level of carbon being sequestered is difficult, and further research is required to clarify this issue.[26]

In relation to nitrogen fertilizer use efficiency, it should also be noted that there may be competing forces between the nitrogen efficiency goal and the tillage goal. For example, if there is a major shift to no-till, farmers may need to increase nitrogen rates because of reduced mineralization rates (less aeration and physical disturbance), cooler surface temperatures, and increased losses from volatilized unincorporated urea. Reduced-tillage systems will also make capturing nitrogen from manure more difficult.

Additional Benefits and Costs

Soil carbon management (e.g., no-tillage) systems provide a number of important ecological services, including erosion control and water quality benefits.

Feasibility Issues

- If changes in management result in decreased crop yields, the net carbon flux can be greater under the new system, assuming that crop demand remains the same and additional lands are brought into production. Conversely, if increasing crop yields lead to less land under cultivation, the overall carbon savings from changes in management will be greater than when soil carbon sequestration alone is considered.
- Options to increase carbon can be implemented in the short term, but the amount of carbon sequestered typically is low initially, then rising for a number of years before tapering off again as the total potential is achieved. There is also a significant risk that the carbon sequestered may be released again by natural phenomena or human activities.
- Practices for conserving carbon affect emissions of other GHGs. Of particular importance is the interaction of carbon sequestration with N_2O emissions because N_2O is such a potent GHG. In some environs, carbon-sequestration practices, such as reduced tillage, can stimulate N_2O emissions, thereby offsetting part of the benefit. Elsewhere, carbon-conserving practices may suppress N_2O emissions, amplifying the net benefit. Similarly, carbon-sequestration practices might affect CH_4 emissions if the practice, such as increased use of forages in rotations, leads to higher livestock numbers. Policies designed to suppress emission of one GHG need to also consider complex interactions to ensure that net emissions of total GHGs are reduced.
- International and domestic interactions of the marketplace have not been considered in the foregoing cost/benefit analysis. Current escalating energy costs may lead to sharp changes in

[26] James Manley, G. van Kooten, Klaus Moeltner, and Johnson Dale. "Creating Carbon Offsets in Agriculture Through No-Till Cultivation: A Meta-Analysis of Costs and Carbon Benefits." *Climatic Change* January 2005;68(1-2):41-65. Available at: http://ideas.repec.org/p/rep/wpaper/2003-05.html.

crop production practices, while international commodity prices may lead to more intense crop inputs.

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 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

Enhance current capabilities/capacities of storing surface water such that it is available at appropriate times and quantities.

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:

- AR I&F.

Quantification Methods:

Surface Water—This analysis used an Arkansas Natural Resources Commission estimate of the amount of groundwater (6.5 billion gal/day)[27] and surface water (19.9 billion gal/day)[28] used in Arkansas. An estimated 96% of all groundwater is used for irrigation,[29] and while no estimate exists for the amount of surfacewater going toward irrigation, it is assumed to be comparable. Thus, by 2025, surface water use will increase by (10%*96%*19.9 billion gal/day) in this policy. Groundwater and surface water use carry with them different electricity requirements (1.7 kilowatt-hours [kWh]/1,000 gal for groundwater and 1.3 kWh/1,000 gal for surface water). Thus, every thousand gallons of water that comes from surface water saves 0.4 kWh of electricity.[30,31] This electricity savings figure is then multiplied by the emissions factor for electricity (.592 tons CO_2e/megawatt-hour [MWh]) to get the tons of CO_2e saved. Costs were estimated based on Iowa average estimates of groundwater and surface water costs per 1,000 gal, which came from a publication by Iowa Association of Municipal Utilities.[32] The costs for the largest groundwater suppliers averaged $0.56/1,000 gal, while the costs for the largest surface water suppliers averaged $0.72/1,000 gal. This cost difference ($0.15/1,000 gal) in 2000 was then discounted forward to 2005 dollars, and multiplied by the number of gallons switched in a given year. See Table 3-1 for details.

Water Purification—The amount of energy going toward water purification in Arkansas could not be determined. National electricity consumption for water purification (1.1 million MWh)[33] was used as a proxy, and then applied to Arkansas based on the Arkansas percentage of the total U.S. population (.94%).[34] 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.[35] This was used to create a BAU

[27] Arkansas Natural Resources Commission. *Arkansas Groundwater Protection and Management Report for 2007.* January 2008.

[28] Arkansas Natural Resources Commission. *2005 Water Use Registration Surface Water Report.*

[29] Arkansas Natural Resources Commission. *Arkansas Groundwater Protection and Management Report for 2007.* January 2008.

[30] Scott Olson and Alan Larson. *Opportunities and Barriers in Madison, Wisconsin: Understanding Process Energy Use in a Large Municipal Water Utility.* Madison Gas and Electric Company and Madison Water Utility. Available at: http://www.cee1.org/ind/mot-sys/ww/mge2.pdf.

[31] Todd Elliot et al. *Energy Use at Wisconsin's Drinking Water Facilities*. Report Number 222-1. Energy Center of Wisconsin. July 2003. Available at: http://www.ecw.org/prod/222-1.pdf.

[32] Iowa Association of Municipal Utilities. *Energy Costs to Treat Water and Wastewater in Iowa.* November 2002. Available at: http://www.iamu.org/main/studies_reports/reports.htm.

[33] 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://www.eia.doe.gov/oiaf/archive/aeo07/pdf/0383(2007).pdf.

[34] U.S. Census Bureau. "State Interim Population Projections by Age and Sex: 2004–2030." Table 6: Total Population for Regions, Divisions, and States: 2000 to 2030. Available at: http://www.census.gov/population/www/projections/projectionsagesex.html.

[35] 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://www.eia.doe.gov/oiaf/archive/aeo07/pdf/0383(2007).pdf.

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 3-2 for details of the analysis.

Table 3-1. GHG benefits and costs of surface water policies

Year	Implementation Path	Gallons Switched (Groundwater to Surface Water) (million gallons)	Electricity Saved (MWh)	$MMtCO_2e$ Reduced	Additional Costs of Surface Water Use
2008	0	0	0	0.00	$0
2009	0.59%	41,017	16,407	0.01	$8,114,214
2010	1.18%	82,035	32,814	0.02	$16,228,428
2011	1.76%	123,052	49,221	0.03	$24,342,641
2012	2.35%	164,070	65,628	0.04	$32,456,855
2013	2.94%	205,087	82,035	0.05	$40,571,069
2014	3.53%	246,104	98,442	0.06	$48,685,283
2015	4.12%	287,122	114,849	0.07	$56,799,497
2016	4.71%	328,139	131,256	0.08	$64,913,710
2017	5.29%	369,157	147,663	0.09	$73,027,924
2018	5.88%	410,174	164,070	0.10	$81,142,138
2019	6.47%	451,192	180,477	0.11	$89,256,352
2020	7.06%	492,209	196,884	0.12	$97,370,565
2021	7.65%	533,226	213,291	0.13	$105,484,779
2022	8.24%	574,244	229,698	0.14	$113,598,993
2023	8.82%	615,261	246,104	0.15	$121,713,207
2024	9.41%	656,279	262,511	0.16	$129,827,421
2025	10.00%	697,296	278,918	0.17	$137,941,634
Total				**1.49**	**$1,241,474,710**

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

The costs of improved efficiency in water purification were estimated based on the costs of improved efficiency in Texas water purification. That particular analysis found that variable-frequency drives for water purification cost $85,000 and could save 206 MWh annually.[36] Assuming that this type of cost-savings ratio is typical of water purification efficiency investments, the costs of the efficiency improvements in Arkansas can be estimated. The cost

[36] B.A. Philips, C.H. Burnett, and J. James. "Energy Conservation Measures for a Large Metropolitan Groundwater Utility." *Proceedings from the 2001 American Water Works Association Annual Conference*. June 1, 2001. Cited in Todd Elliot et al. *Energy Use at Wisconsin's Drinking Water Facilities*. Report Number 222-1. Energy Center of Wisconsin. July 2003. Available at: http://www.ecw.org/prod/222-1.pdf.

savings of reduced electricity consumption were also considered, using the commercial cost of electricity in 2008 multiplied by the MWh of energy saved.[37]

Table 3-2. GHG benefits and costs of water purification policies

Year	Energy Use Water Purification (million kWh)	Reduction Goal	Energy Savings (million kWh)	tCO_2e Avoided	Costs of Modifications	Electricity Savings	Total Costs
2008	10.59	0%	0.00	0		$0	$0
2009	10.67	1.2%	0.13	74	$51,666	–$8,914	$42,752
2010	10.76	2.4%	0.25	150	$52,492	–$18,224	$34,268
2011	10.84	3.5%	0.38	227	$53,329	–$27,555	$25,774
2012	10.93	4.7%	0.51	305	$54,176	–$36,520	$17,656
2013	11.02	5.9%	0.65	384	$55,032	–$44,718	$10,314
2014	11.11	7.1%	0.78	464	$55,899	–$53,307	$2,592
2015	11.19	8.2%	0.92	546	$56,777	–$62,690	–$5,913
2016	11.28	9.4%	1.06	629	$57,664	–$72,218	–$14,554
2017	11.37	10.6%	1.20	713	$58,563	–$81,896	–$23,333
2018	11.47	11.8%	1.35	799	$59,472	–$93,072	–$33,600
2019	11.56	12.9%	1.50	885	$60,392	–$103,198	–$42,807
2020	11.65	14.1%	1.64	974	$61,322	–$113,480	–$52,158
2021	11.74	15.3%	1.80	1,063	$62,264	–$123,921	–$61,657
2022	11.84	16.5%	1.95	1,154	$63,217	–$134,521	–$71,304
2023	11.93	17.6%	2.11	1,246	$64,181	–$145,282	–$81,101
2024	12.03	18.8%	2.26	1,340	$65,157	–$156,208	–$91,051
2025	12.12	20.0%	2.42	1,435	$66,144	–$167,298	–$101,154
Total Reductions				**12,387**	**Total Costs**		**–$445,275**

kWh = kilowatt hours; tCO_2e = metric tons of carbon dioxide equivalent.

Key Assumptions: The energy consumption that comes with groundwater and surface water use comes from a report for the state of Wisconsin.[38,39] The difference in energy consumption (0.4 kWh/1,000 gal) found in this study is assumed to reflect Arkansas conditions. Costs from increased use of surface water come from an Iowa source. It is assumed that these costs are comparable to those in Arkansas.

[37] U.S. Department of Energy, Energy Information Administration. "Short Term Energy Outlook." Table 2: U.S. Energy Nominal Prices." July 2008. Available at: http://www.eia.doe.gov/emeu/steo/pub/2tab.pdf.

[38] Scott Olson and Alan Larson. *Opportunities and Barriers in Madison, Wisconsin: Understanding Process Energy Use in a Large Municipal Water Utility.* Madison Gas and Electric Company and Madison Water Utility. Available at: http://www.cee1.org/ind/mot-sys/ww/mge2.pdf.

[39] Todd Elliot et al. *Energy Use at Wisconsin's Drinking Water Facilities*. Report Number 222-1. Energy Center of Wisconsin. July 2003. Available at: http://www.ecw.org/prod/222-1.pdf.

The water purification option assumes that water purification energy use in Arkansas occurs at the same rate as the national average. If this is not the case, the costs and benefits will need to be adjusted. Likewise the 0.8% increase in water purification energy use from the EIA may not reflect Arkansas conditions. The costs of efficiency improvements in water purification come from a case study in Texas,[40] and these costs are assumed to reflect Arkansas efficiency improvements.

Key Uncertainties

It may not be possible or practical to increase the amount of surfacewater being used in Arkansas to the extent that is recommended by the goal.

Additional Benefits and Costs

Decreasing the rate of groundwater pumping will have benefits in terms of maintaining underground water reservoirs. Because these reservoirs replenish themselves over a very long time period, decreasing the consumption of this water could have significant benefits in the future.

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]

[40] B.A. Philips, C.H. Burnett, and J. James. "Energy Conservation Measures for a Large Metropolitan Groundwater Utility." *Proceedings from the 2001 American Water Works Association Annual Conference*. June 1, 2001. Cited in Todd Elliot et al. *Energy Use at Wisconsin's Drinking Water Facilities*. Report Number 222-1. Energy Center of Wisconsin. July 2003. Available at: http://www.ecw.org/prod/222-1.pdf.

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 to displace heating costs and fossil fuel use. Arkansas could increase the amount of biomass available for generating electricity and displace 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 USDA Natural Resources Conservation Service [NRCS]).[41] 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

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

their limitations for field 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 the 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[42] 3, 4, and 5, and the total land area is 16, 287, 592 acres, respectively.[43]

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.[44]

Type(s) of GHG Reductions

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

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[42] 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.

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

[44] 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

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.

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).[45]

The GHG benefits were calculated by the difference in emissions associated with each of the input fuels (0.0959 tCO_2e/million British thermal units [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).[46]

The amount of biomass utilized by each of the three components (agriculture, forestry, and energy crops) is illustrated in Tables 4-1, 4-2, and 4-3. The biomass available for energy crop utilization was determined using the available marginal agricultural land from NRCS (the total respective land area is assumed to be 16, 287, and 592 acres). Energy crop production is assumed to be 5 tons/acre/year based on Graham (1994).[47]

45 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.

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

47 R.L. Graham. "An Analysis of the Potential Land Base for Energy Crops in the Conterminous United States." *Biomass and Bioenergy* 1994;6(3):175-189, Oak Ridge National Laboratory. Lands that could not produce this minimum biomass yield were considered unsuitable.

Table 4-1. GHG benefits from agriculture crop residue

Year	Percentage of Utilization	Agriculture Residue Biomass (tons)	Agriculture Residue Biomass (MMBtu)	Avoided Emissions Agriculture Residue ($MMtCO_2e$)
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
Cumulative				**2.37**

MMBtu = million British thermal units; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table 4-2. GHG benefits from forestry biomass

Year	Percentage of Utilization	Forest Feedstocks* (dry tons)	Forest Feedstocks* (MMBtu)	Avoided Emissions All Forest Feedstocks ($MMtCO_2e$)
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	5.0%	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
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	10.0%	1,003,800	9,998,852	0.940
Cumulative				**9.17**

MMBtu = million British thermal units; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

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

Table 4-3. GHG benefits from dedicated energy crops

Year	Percentage of Marginal Land Utilization	Land Available for Energy Crops (acres)	Total Energy Crops (dry tons)	Total Energy Crops (MMBtu)	Avoided Emissions, Energy Crops ($MMtCO_2e$)
2009	0.7%	116,340	581,700	8,550,986	0.804
2010	1.4%	232,680	1,163,399	17,101,972	1.61
2011	2.1%	349,020	1,745,099	25,652,957	2.41
2012	2.9%	465,360	2,326,799	34,203,943	3.21
2013	3.6%	581,700	2,908,499	42,754,929	4.02
2014	4.3%	698,040	3,490,198	51,305,915	4.82
2015	5.0%	814,380	4,071,898	59,856,901	5.63
2016	5.5%	895,818	4,479,088	65,842,591	6.19
2017	6.0%	977,256	4,886,278	71,828,281	6.75
2018	6.5%	1,058,693	5,293,467	77,813,971	7.31
2019	7.0%	1,140,131	5,700,657	83,799,661	7.88
2020	7.5%	1,221,569	6,107,847	89,785,351	8.44
2021	8.0%	1,303,007	6,515,037	95,771,041	9.00
2022	8.5%	1,384,445	6,922,227	101,756,731	9.56
2023	9.0%	1,465,883	7,329,416	107,742,421	10.1
2024	9.5%	1,547,321	7,736,606	113,728,111	10.7
2025	10.0%	1,628,759	8,143,796	119,713,801	11.3
Cumulative					**109.7**

MMBtu = million British thermal units; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

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). Assumed costs used in the analysis are identified in Table 4-4.

Table 4-4. Assumed costs of biomass feedstocks

Fuel Type	Cost $/Ton Delivered	Heat Content (MMBtu/ton)	Cost $/MMBtu Delivered
Agricultural residues[48]	$42.50	8.3	$5.12
Energy crop (switchgrass)[49]	$60.00	14.7	$4.09
Forest feedstocks[50]	$35.00	10.0	$3.51

MMBtu/ton = million British thermal units per ton; $/MMBtu = dollars per million British thermal units.

Table 4-5. Assumed costs of coal feedstocks

Year	Coal (in 2005$/MMBtu)
2009	$2.04
2010	$2.10
2011	$2.11
2012	$2.07
2013	$2.02
2014	$1.99
2015	$1.96
2016	$1.94
2017	$1.92
2018	$1.92
2019	$1.88
2020	$1.87
2021	$1.86
2022	$1.85
2023	$1.85
2024	$1.85
2025	$1.85

MMBtu = million British thermal units.

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48 The price of agriculture residues and energy crops comes from the mid-point of the range provided in S.C. Brechbill and W.E. Tyner. "The Economics of Biomass Collection, Transportation, and Supply to Indiana Cellulosic and Electric Utility Facilities." Working Paper 08-03. Purdue University, College of Agriculture, Department of Agricultural Economics (April 2008). Available at: http://ideas.repec.org/p/pae/wpaper/08-03.html. Cost components including seed, fertilizer, and herbicide application, mowing/shredding, raking, baling, storage, handling, and transportation in the 30-mile range. The cost estimates also include nutrient replacement for corn stover. The heat content of selected fuels comes from 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.

49 Ibid.

50 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.

The cost is calculated by assuming the replacement of coal with biomass. The difference in costs ($/MMBtu), is multiplied by the amount of coal energy (MMBtu) being replaced by biomass (see Table 4-5). The assumed incremental capital costs and operational/maintenance 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 38 of the EIA AEO 2007.[51] The assumed costs for biomass included in the AEO are based on the cost and performance characteristics of new generating technologies, which in the case of biomass is assumed to be Integrated Gasification Combined Cycle. While use of biomass may be pursued through a variety of technology types (e.g., gasification, cofiring or direct firing) or end uses (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 4-6).[52]

51 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.

52 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.

Table 4-6. Estimated costs of biomass to energy

Year	Total Biomass Utilization (MMBtu)	Approxi-mate Cumulative Capacity (MW)	Annualized Capital Costs	Estimated Additional Variable Operational and Maintenance Costs	Estimated Additional Fixed Operational and Maintenance Costs	Total Additional Biomass Fuel Costs	Total Costs (Million 2005$)
2009	9,296,591	119	$3,929,452	–$1,186,422	$2,882,332	$18,650,017	$24.3
2010	18,781,590	240	$7,938,539	–$2,396,889	$2,940,746	$36,753,526	$45.2
2011	28,266,588	362	$11,947,627	–$3,607,355	$2,940,746	$55,132,164	$66.4
2012	37,751,587	483	$15,956,715	–$4,817,822	$2,940,746	$75,208,682	$89.3
2013	47,236,586	604	$19,965,802	–$6,028,288	$2,940,746	$96,516,365	$113.4
2014	56,721,584	725	$23,974,890	–$7,238,755	$2,940,746	$117,638,117	$137.3
2015	66,175,182	846	$27,970,705	–$8,445,214	$2,931,011	$139,229,725	$161.7
2016	72,792,700	931	$30,767,775	–$9,289,735	$2,051,707	$154,608,551	$178.1
2017	79,410,218	1,016	$33,564,845	–$10,134,256	$2,051,707	$170,252,078	$195.7
2018	86,027,736	1,100	$36,361,916	–$10,978,778	$2,051,707	$184,439,752	$211.9
2019	92,645,254	1,185	$39,158,986	–$11,823,299	$2,051,707	$202,333,235	$231.7
2020	99,262,773	1,270	$41,956,057	–$12,667,820	$2,051,707	$217,778,237	$249.1
2021	105,880,291	1,354	$44,753,127	–$13,512,342	$2,051,707	$233,355,589	$266.6
2022	112,497,809	1,439	$47,550,198	–$14,356,863	$2,051,707	$249,065,291	$284.3
2023	119,115,327	1,524	$50,347,268	–$15,201,385	$2,051,707	$263,716,190	$300.9
2024	125,732,845	1,608	$53,144,339	–$16,045,906	$2,051,707	$278,367,090	$317.5
2025	132,350,363	1,693	$55,941,409	–$16,890,427	$2,051,707	$293,017,989	$334.1
Cumulative							**$3,208**

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/year over the life of the project).

Energy From Livestock Manure and Poultry Litter GHG Benefits

Methane emissions (in $MMtCO_2e$) data from the AR I&F 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 manure and poultry litter. An assumed collection efficiency of 75%[53] 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.

[53] 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).

The second portion of the GHG benefit is obtained 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/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 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, by dividing total electricity consumption emissions in 2005 by electricity sales in 2005. This provided an electricity emissions factor of 0.592 tCO_2e/MWh.

The total GHG benefit was estimated as the sum of both portions of the benefits described above and indicated in Table 4-7.

Table 4-7. 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)	MMtCH_4	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
Total							**0.186**

MMtCO_2e = million metric tons of carbon dioxide equivalent; MMtCH_4 = million metric tons of methane; MMBtu = million British thermal units;

Energy From Livestock Manure and Poultry Litter Costs

The costs for the dairy and swine components were estimated using the NRCS analysis *An Analysis of Energy Production Costs From Anaerobic Digestion Systems on U.S. Livestock*

Production Facilities.[54] The production costs were assumed to be $0.11/kWh for swine anaerobic digesters and $0.05/kWh for dairy anaerobic digesters.[55] 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 (O&M) costs.[56] 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).[57] 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 2008.[58] 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 4-8.

[54] 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.

[55] 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.

[56] 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.

[57] 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.

[58] U.S. Department of Energy, Energy Information Administration. *Supplemental Tables to the Annual Energy Outlook 2008*. June 2008. Available at: http://www.eia.doe.gov/oiaf/aeo/supplement/index.html.

Table 4-8. 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
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

The amount of biomass being used for electricity production was determined using eGRID (257 MW).[59] This was then converted into MWh and then into MMBtu, based on the amount of biomass feedstock necessary to produce 1 MWh of energy.[60] The amount of usable (waste) heat available from a biomass plant is estimated to be 60% of biomass inputs, so this total MMBtu figure is multiplied by 60% to get the amount of energy that is lost as waste heat.[61] This heat is then captured at an increasing rate across the program, with 10% captured in 2025, as per the policy goal. This heat is assumed to go toward commercial heating, with 92% efficiency in transportation.[62] Assuming that natural gas boilers are 85% efficient,[63] we can determine the total

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[59] U.S. Environmental Protection Agency. "eGRID 2006 Year 2004 Summary Tables." April 2007.

[60] U.S. Department of Energy, Energy Information Administration, Office of Energy Statistics. "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.

[61] "Bioenergy Knowledge Center. "Options for Electricity Production from Biomass." Available at: http://www.bkc.co.nz/Portals/0/docs/options_for_electricity_generation_from_biomass.pdf.

[62] Hannes Schwaiger and Gerfried Jungmeier. "Overview of CHP plants in Europe and Life Cycle Assessment (LCA) of GHG Emissions for Biomass and Fossil Fuel CHP Systems." Institute of Energy Research. September 2007. Available at: http://www.atee.fr/cp/37/6-%2018-09%20SCHWAIGER%20JOANNEUM%20R.pdf.

[63] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Technology Fact Sheet: "Combined Heat and Power." Available at: http://www.ezec.gov/rbs/farmbill/Combined Heat and Power.doc.

energy being replaced by the Btus provided to commercial consumers in the form of heat. This figure is then multiplied by the emissions factor for natural gas (0.0531 tCO2e/MMBtu), which the heat is replacing.[64] This results in the GHG benefits of cogeneration for each year. See Table 4-9 for more details.

Table 4-9. GHG benefits of cogeneration

Year	Implementation Path	MMBtu Captured in the Program	MMBtu Available for Heating	MMBtu Natural Gas Avoided	$MMtCO_2e$ Avoided
2009	0%	0	0	0	0.00
2010	0.63%	64,021	58,899	69,293	0.00
2011	1.25%	128,041	117,798	138,586	0.01
2012	1.88%	192,062	176,697	207,879	0.01
2013	2.50%	256,083	235,596	277,172	0.01
2014	3.13%	320,104	294,495	346,465	0.02
2015	3.75%	384,124	353,394	415,758	0.02
2016	4.38%	448,145	412,293	485,051	0.03
2017	5.00%	512,166	471,192	554,344	0.03
2018	5.63%	576,186	530,092	623,637	0.03
2019	6.25%	640,207	588,991	692,930	0.04
2020	6.88%	704,228	647,890	762,223	0.04
2021	7.50%	768,249	706,789	831,516	0.04
2022	8.13%	832,269	765,688	900,809	0.05
2023	8.75%	896,290	824,587	970,102	0.05
2024	9.38%	960,311	883,486	1,039,395	0.06
2025	10.00%	1,024,331	942,385	1,108,688	0.06
Cumulative					0.50

MMBtu = million British thermal units; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Capture of Waste Heat Costs

To determine the costs of installing cogeneration in Arkansas, we first determine the amount of capacity that will need to be modified with combined heat and power (CHP). This is then multiplied by the capital costs of installing these modifications ($1,148/kW).[65] O&M costs of 1.10$/MWh are then multiplied by the total CHP production for the given year, which is then

[64] Arkansas Inventory and Forecast. Available at http://www.arclimatechange.us/ewebeditpro/items/O94F17378.pdf.

[65] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Technology Fact Sheet: "Combined Heat and Power." Available at: http://www.ezec.gov/rbs/farmbill/Combined Heat and Power.doc.

combined with capital costs to get total costs.[66] Cost savings come from the revenue of steam sold to the plant making an investment in CHP. Due to the difficulty of determining a market price for steam heat, this is assumed to be equal to the cost of the natural gas it is replacing.[67] This was determined by multiplying the amount of natural gas avoided by the cost of 1 MMBtu of natural gas. See Table 4-10 for more details.

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.

Table 4-10. Costs and cost savings of CHP

Year	Necessary CHP To Be installed (MW)	CHP To Be installed That Year (MW)	Cost of CHP Installation	CHP O&M Costs	Revenue From Steam Sales (Assumed To Be Equal to Natural Gas Costs)	Total Cost/Savings
2009	0	0	0	$0	$0	$0
2010	2.68	2.68	$3,076,879	$25,826	$902,483	$2,200,223
2011	5.36	2.68	$3,076,879	$51,653	$1,804,966	$1,323,566
2012	8.04	2.68	$3,076,879	$77,479	$2,707,449	$446,910
2013	10.7	2.68	$3,076,879	$103,306	$3,609,932	–$429,746
2014	13.4	2.68	$3,076,879	$129,132	$4,512,414	–$1,306,403
2015	16.1	2.68	$3,076,879	$154,959	$5,414,897	–$2,183,059
2016	18.8	2.68	$3,076,879	$180,785	$6,317,380	–$3,059,716
2017	21.4	2.68	$3,076,879	$206,612	$7,219,863	–$3,936,372
2018	24.1	2.68	$3,076,879	$232,438	$8,122,346	–$4,813,028
2019	26.8	2.68	$3,076,879	$258,265	$9,024,829	–$5,689,685
2020	29.5	2.68	$3,076,879	$284,091	$9,927,312	–$6,566,341
2021	32.2	2.68	$3,076,879	$309,918	$10,829,795	–$7,442,998
2022	34.8	2.68	$3,076,879	$335,744	$11,732,277	–$8,319,654
2023	37.5	2.68	$3,076,879	$361,571	$12,634,760	–$9,196,310
2024	40.2	2.68	$3,076,879	$387,397	$13,537,243	–$10,072,967
2025	42.9	2.68	$3,076,879	$413,224	$14,439,726	–$10,949,623
Cumulative Costs						**–$69,995,203**

[66] Kim Crossman. "Woody Biomass to CHP—Characteristics, Costs, and Performance of Commercially Available Technologies." U.S. Environmental Protection Agency, Combined Heat and Power Partnership. October 26, 2007. Available at: http://www.fpl.fs.fed.us/tmu/2007safconvention/ 2007safconvention--crossman.ppt.

[67] U.S. Department of Energy, Energy Information Administration. "Short-Term Energy Outlook." Table 2: U.S. Energy Nominal Prices." July 2008. Available at: http://www.eia.doe.gov/emeu/steo/pub/2tab.pdf.

CHP = combined heat and power; MW = megawatts; O&M = operation and maintenance.

In “Poultry Litter to Energy: Technical and Economic Feasibility,”[68] 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 [sic] 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.

It is assumed that the biomass plants installing CHP have a market for steam readily available. If steam must be transported long distances, that will reduce both the cost-effectiveness and the environmental benefits of CHP. In addition, many of the costs of CHP installation are from sites dedicated to CHP, rather than sites where generation is already in place and capture of waste heat is being installed.

The costs of CHP mostly come from installing CHP in new biomass power plants, rather than retrofitting currently existing biomass plants to include a CHP component. This could make a significant difference in the cost-effectiveness of CHP.

Key Uncertainties

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. Similar issues also surround the production of energy from livestock manure and poultry litter.

The fuel mix being replaced by biomass is assumed to be 100% coal. Biomass is assumed to have a reduction of 0.0940 tCO_2e/MMBtu when replacing coal combustion. Methane utilization is assumed to replace electricity.

The future price of electricity will affect the analysis.

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.

[68] 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.

Feasibility Issues

Many existing power plants, including biomass plants, are located some distance from population centers so as to avoid concerns of local air pollution. This makes establishing combined heat and power more difficult, because the heat will need to be transported a greater distance.

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

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 Advanced Biofuels

Policy Description

This strategy increases production of advanced 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: Increase the production of liquid advanced biofuel in Arkansas, such that by 2025 the state utilizes approximately 10% of available biomass supply per year to produce advanced 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: The intent of this option is to focus on non-food biomass resources.

According to the U.S. Energy Independence and Security Act of 2007, advanced biofuel "means renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions, as determined by the Administrator, after notice and opportunity for comment, that are at least 50 percent less than baseline lifecycle greenhouse gas emissions."[69] The bill stipulates that "the types of fuels eligible for consideration as `advanced biofuel' may include any of the following:

"(I) Ethanol derived from cellulose, hemicellulose, or lignin.

"(II) Ethanol derived from sugar or starch (other than corn starch).

"(III) Ethanol derived from waste material, including crop residue, other vegetative waste material, animal waste, and food waste and yard waste.

"(IV) Biomass-based diesel.

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[69] See Section 201—Definitions. The text of the bill is available at http://thomas.loc.gov/home/c110query.html by searching for "Energy Independence and Security Act of 2007."

"(V) Biogas (including landfill gas and sewage waste treatment gas) produced through the conversion of organic matter from renewable biomass.

"(VI) Butanol or other alcohols produced through the conversion of organic matter from renewable biomass.

"[70](VII) Other fuel derived from cellulosic biomass."

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 fuel producers and distributors, and feedstock processors. 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: 19.7 $MMtCO_2e$ cumulative by 2025.
- Estimated cost: $114 (2005 MM$) cumulative by 2025.

Data Sources: "Arkansas Biomass Resource Assessment" from the Arkansas Economic Development Commission[71] as summarized in "Table 1—Biomass Supply Assessment" at the front of this document; other sources as cited in the text.

Quantification Methods:

Biofuel GHG Reductions

For this option several different technologies can be used to meet the policy goal, including cellulosic ethanol, pyrolysis, Fischer-Tropsch esterification, and others. The GHG reduction as well as the cost will depend on the feedstock and conversion technology used. For the purpose of

[70] Ibid.

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

initial quantification, it is assumed that cellulosic ethanol production via fermentation will be used to meet the policy goal. This quantification may be updated, however, as other technologies are considered.

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

The incremental benefit of cellulosic production targeted by this policy over gasoline is 9.79 tCO_2e reduced/1,000 gal. The emission factor value is based on the difference between the life-cycle CO_2e emission factor of gasoline (10.30 t/1,000 gal)[72] and the life-cycle CO_2e emission factor of cellulosic ethanol (1.38 t/1,000 gal).[73] Emission factors for gasoline and cellulosic ethanol are based on the ANL GREET model.[74] The cellulosic benefit value will be used along with the production in each year to estimate GHG reductions.

Table 5-1 shows the number of cellulosic plants that will need to go on line in Arkansas to achieve the goal of using 10% of biomass of available in Arkansas (2.19 million short tons) annually by 2025, according to the *Arkansas Biomass Resource Assessment*.[75] Annual cellulose production is multiplied by the estimated ethanol yield per ton of biomass, based on the projection that ethanol yield will increase from 70 gal/ton biomass to 90 gal/ton biomass by 2012 and to 100 gal/ton biomass by 2020, as shown in Table 5-1.[76] This analysis is primarily based on a report from the National Renewable Energy Laboratory (NREL) regarding the capital costs of building a 69.3-million gal/year cellulosic ethanol plant that uses corn stover as the feedstock.[77] The emission reductions from this plan are calculated by multiplying the number of gallons produced in a given year by the emission reductions per gallon (9.79 tCO_2e/1,000 gal).

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[72] Argonne National Laboratory. GREET model 1.8b emission factor for 50% conventional gasoline, 50% reformulated gasoline blend in g/mi x GREET model average fuel economy (100 mi/4.7 gal). Available at: http://www.transportation.anl.gov/software/GREET/.

[73] Argonne National Laboratory. GREET model 1.8b emission factor for mixed feedstock cellulosic E100 for flex-fuel vehicle in g/mi x GREET model average fuel economy (100 mi/4.7 gal). Available at: http://www.transportation.anl.gov/software/GREET/.

[74] Downloadable from http://www.transportation.anl.gov/software/GREET.

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

[76] Personal communication between J. Ashworth (National Renewable Energy Laboratory) and Steve. Roe (Center for Climate Strategies) April 2007.

[77] A. Aden et al. *Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover*. NREL/TP-510-32438. Golden, CO: National Renewable Energy Laboratory, June 2002. Accessed June 2008 at: http://www. nrel.gov/docs/fy02osti/32438.pdf.

Table 5-1. Annual biomass utilization and cellulosic ethanol production

Year	Biomass Feedstock Production (million short dry tons)	Ethanol Yield From Cellulosic Feedstock (gal/ton biomass)	Cellulosic Ethanol Production (million gal)	Avoided Emissions Compared to Gasoline ($MMtCO_2e$ reduction)
2009	0.0	70	—	—
2010	1.0	70	69	0.68
2011	1.0	70	69	0.68
2012	0.8	90	69	0.68
2013	0.8	90	69	0.68
2014	0.8	90	69	0.68
2015	1.5	90	139	1.35
2016	1.5	90	139	1.35
2017	1.5	90	139	1.35
2018	1.5	90	139	1.35
2019	1.5	90	139	1.35
2020	1.4	100	139	1.35
2021	1.4	100	139	1.35
2022	1.4	100	139	1.35
2023	1.4	100	139	1.35
2024	2.1	100	208	2.03
2025	2.2	100	221	2.15

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

Biofuel Costs

The costs of this option are estimated based on the capital and operating costs of cellulosic ethanol production plants. An NREL study estimated total capital costs for a 70-million gal/year cellulosic ethanol plant would be $200 million.[78] An EIA study cited a major biofuels manufacturer who estimated the costs of a first of its kind 50-million gal/year cellulosic ethanol plant to be $375 million.[79] An average of these costs was used in our estimate of capital costs. A new plant will need to be built for every 70 million gallons of annual ethanol production needed. It was assumed that the capital costs will be paid according to a cost recovery factor over the 20-year lifetime of the plant. O&M costs were also taken from the NREL study. The cost of biomass feedstocks made up a significant portion (~60%) of variable costs. Therefore, we replaced the NREL estimate of feedstock costs ($30/ton) with a more current estimate of the cost of delivered biomass ($74/ton).[80] The plant proposed by the NREL study produces some excess electricity

[78] Ibid.

[79] 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.

[80] Iowa policy option description. "Estimating a Value for Corn Stover." Ag Decision maker File A1-70. December 2007. Additional transportation costs of $14.75 were assumed, taken from Michael Duffy. "Estimated Costs for Production, Storage and Transportation of Switchgrass." Iowa State University, University Extension. December 2007. Available at:

that is sold back to the grid by the plant. Another revenue source for the ethanol plant is the value of the ethanol produced. The wholesale price of ethanol was taken from AEO 2008, and is multiplied by the number of gallons produced annually.[81] Table 5-2 outlines the estimated cost and revenue streams for the policy. The analysis shows a profit being made in the production of ethanol for several years in the policy period. This is primarily due to the increasing price of ethanol predicted. The total cost of the policy for 2008–2025 is estimated to be $114 million.

Table 5-2. Capital costs of constructing cellulosic ethanol plants

Year	Million Gallons of Ethanol Produced	Sale Price per Gallon of Ethanol (2005$)	Annual Operating Costs (Million $)	Annualized Capital Costs (Million $)	Annual Revenue (Million $)	Net Costs/Revenue (Discounted million 2005$)
2009	—	$1.91	—	—	—	—
2010	69	$1.72	$102	$31.0	$126	$5.49
2011	69	$1.95	$102	$31.0	$141	–$6.61
2012	69	$1.96	$102	$31.0	$142	–$6.56
2013	69	$1.59	$102	$31.0	$117	$10.82
2014	69	$1.68	$102	$31.0	$122	$ 6.57
2015	139	$1.63	$ 203	$61.9	$239	$16.25
2016	139	$1.62	$203	$61.9	$237	$16.45
2017	139	$1.60	$203	$61.9	$235	$16.93
2018	139	$1.61	$203	$61.9	$236	$15.51
2019	139	$1.83	$203	$61.9	$267	–$0.85
2020	139	$1.91	$203	$61.9	$278	–$5.90
2021	139	$1.81	$203	$61.9	$264	$ 0.55
2022	139	$1.83	$203	$61.9	$266	–$0.48
2023	139	$1.74	$203	$61.9	$254	$4.80
2024	208	$1.59	$305	$92.9	$349	$19.46
2025	219	$1.57	$324	$98.6	$366	$21.27

Key Assumptions: Advanced biofuel production is assumed to ramp up linearly from zero production in 2008, to full implementation of the policy goal by 2025.

For the purpose of initial quantification, it is assumed that cellulosic ethanol production via fermentation will be used to meet the policy goal. This quantification may be updated, however, as other technologies are considered.

Key Uncertainties

The cost competitiveness of biofuels will depend on cost of oil.

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https://www.extension.iastate.edu/store/ItemDetail.aspx?ProductID=12708&SeriesCode=&CategoryID=23&Keyword=.

[81] U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2008: With Projections to 2030.* IDOE/EIA-0383(2008). Reference Case Table 12—Petroleum Product Prices. Washington, DC, June 2008. http://www.eia.doe.gov/oiaf/aeo/pdf/tables.pdf.

Carbon Emissions From Land-Use Change: Recent publications, such as Searchinger et al. 2008,[82] 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."83

In June 2006, the U.S. Senate was told that the current cost of producing cellulosic ethanol is U.S. $2.25/U.S. gal (U.S. $0.59/litre). [This is the only place you include this conversion. Perhaps you should delete it for consistency purposes.] 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 gal), 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/U.S. gal (U.S. $0.28/litre) by 2012.

Additional Benefits and Costs

There is potential for the cultivation of biomass resources to compete with the production of food. For example, land that could be cultivated for food crops might be converted to energy crop production. Additionally, some feedstocks, such as oilseeds, could be diverted from food to fuel production. The intent of this policy is to focus on nonfood feedstocks. Analysis provided by DOE Secretary Bodman and USDA Secretary Schafer suggests that the impact of biofuels on food prices and demand is minimal.[84] They state that:

> "In 2007, the expansion in ethanol and biodiesel consumption is estimated to have increased the Consumer Price Index (CPI) for all food by 0.10–0.15 percentage point. In other words, ethanol and biodiesel consumption accounted for approximately 3–4 percent of the overall rise in retail food prices.
>
> "Increased demand for biofuel feedstocks has benefited com and soybean producers. Higher prices have encouraged production increases and some switching of acreage from soybeans to com. More dried distiller grains are available for feed, but higher grain prices are also prompting adjustments by

[82] 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* February 2008;319(5867):1238-1240. Available at: http://www.sciencemag.org/cgi/content/abstract/1151861.

83 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.

[84] Letter from Secretaries Bodman and Schafer to Senator Jeff Bingaman, dated June 11, 2008.

> livestock producers. In future years, production adjustments by livestock and dairy producers in response to higher feed costs resulting from the expansion in ethanol and biodiesel consumption could add a total of 0.6–0.7 percentage point to the CPI for all food.
>
> "Commodities prices, both agricultural and nonagricultural, have risen sharply in recent years for a number of reasons unrelated to biofuels development. For agricultural commodities, higher incomes, population growth, and depreciation of the dollar are increasing the demand for food; drought and dry weather have lowered production and reduced stocks; and some countries have imposed export restrictions. All these factors contribute to higher commodity prices. In addition, record prices for gasoline and diesel fuel are increasing the costs of producing, transporting, and processing food products."85

Other Benefits and Costs: Cellulosic ethanol could have less impact than corn ethanol on water quality and could actually reduce nutrient loads in some circumstances; could provide permanent new sources of income for farmers and foresters; could use current waste streams to replace U.S. fuel consumption; could result in environmental benefits or costs; could provide recycling money in local economies; could stimulate potential markets for other biomass feedstocks (forest treatment biomass, municipal solid waste fiber); could increase transportation energy security with shorter transport distances and on-farm use of fuel produced; and could reduce reliance on imported petroleum.

Feasibility Issues

Implementation of this option requires additional research and development in cellulosic ethanol production methods, development of feedstock collection and delivery infrastructure, and 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]

[85] Ibid.

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:

- *Local Produce*—By 2025, of the food Arkansans consume, 30% will consist of locally[86] grown produce and fish/meats/poultry.
- *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:

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

Implementation Mechanisms

To achieve the local produce goal, a number of actions could and should be taken within Arkansas, including the continued promotion of farmers' markets in the state, an enhanced information and research program and a re-evaluation of the most appropriate land use within Arkansas. Each of these is outlined below:

- *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 products.

[86] There is currently no universally accepted definition of "locally grown." For the purposes of the local produce goal, a distance of less than 100–150 miles is considered to be local.

- *Information*—By 2010, the state, in coordination with the University of Arkansas System, Extension, USDA and others, collect and analyze data on the number of acres in Arkansas converted to local food production systems, and, to the extent practical, 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.

In additional there is the potential for the extension of programs, such as farmers' markets, farm to school, community-supported agriculture 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.

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.

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

Data Sources:

Estimates of harvested acres were taken from National Agricultural Statistics Service Agricultural Census publication for Arkansas.[87] Crop yields were provided by Craig R. Andersen

[87] U.S. Department of Agriculture, National Agricultural Statistics Service. "Arkansas State and County Data." Volume 1, Geographic Area Series, Part 4. AC-02-A-4. 1997. *2002 Census of Agriculture*. June 2004. Available at: http://www.nass.usda.gov/census/census02/volume1/ar/ARVolume104.pdf.

Extension Horticulture Specialist-Vegetables Department of Horticulture University of Arkansas. U.S. per capita consumption rates were obtained from the USDA Economic Research Service Food Consumption (Per Capita) Data System.[88] Arkansas population data were obtained from the Center for Climate Strategies AR I&F.

Quantification Methods:

Local Produce

The amount of each crop produced in Arkansas was estimated using harvested acres and estimates of crop yields per acre. The amount of each crop consumed in Arkansas was estimated using U.S. per capita consumption rates and the Arkansas population.

The amount consumed for each crop was then subtracted from the amount produced to determine how much of the crop was imported. For each imported crop, a likely state of origin was assumed. The estimated amount of imports for each crop and the estimated round-trip mileage were used to estimate ton-miles transported and CO_2 emissions.

Transportation emissions were estimated by assuming 23 tons of payload per truck, 6 truck-miles per gallon of diesel fuel, and 22.4 pounds (lb) of CO_2 per gallon of diesel fuel. To estimate miles traveled, food from California was assumed to travel from Fresno, California, to Little Rock (~1,700 miles). These mileage estimates were then doubled, since it was assumed that each truck would return to its point of origin empty. The amount of food produced and exported is assumed to remain constant, while consumption is assumed to grow with population. The GHG benefits were estimated by reducing the imported food and increasing consumption of locally produced food by the proportion described by the policy goal, ramping up to achieve 30% local consumption by 2025.

Costs were based on the estimated need for one additional full-time-equivalent (FTE) employee employed by the state (e.g., Arkansas Agriculture Department) to implement the elements of this policy. Some of the elements of this policy could be incorporated into existing programs. The total cost for this additional FTE is $75,000/year in 2005 dollars.

The policy results are summarized in Table 6-1.

Key Assumptions:

- The amount of each crop consumed in Arkansas was estimated using U.S. per capita consumption rates and the Arkansas population.
- Transportation emissions were estimated by assuming 23 tons of payload per truck, 6 truck-miles per gallon of diesel fuel, and 22.4 lb of CO_2 per gallon of diesel fuel.

[88] U.S. Department of Agriculture, Economic Research Service. Data Sets. Food Availability: Spreadsheets. Food Consumption (Per Capita) Data System. Available at: http://www.ers.usda.gov/Data/FoodConsumption/FoodAvailSpreadsheets.htm.

Table 6-1. Benefits of locally produced food

Year	Policy Goal (%)	Emission savings ($MMtCO_2e$)	Discounted Costs
2009	2%	0.003	$64,171
2010	4%	0.007	$63,560
2011	5%	0.010	$62,954
2012	7%	0.014	$62,355
2013	9%	0.017	$61,761
2014	11%	0.020	$61,173
2015	12%	0.024	$60,590
2016	14%	0.027	$60,013
2017	16%	0.031	$59,441
2018	18%	0.034	$58,875
2019	19%	0.037	$58,315
2020	21%	0.041	$57,759
2021	23%	0.044	$57,209
2022	25%	0.048	$56,664
2023	26%	0.051	$56,125
2024	28%	0.054	$55,590
2025	30%	0.058	$55,061
Cumulative Total		**0.520**	**$1,076,404**

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

Key Uncertainties

One uncertainty is the amount of food products leaving the state. State export/import data were not available. As such the above analysis does not include state-to-state exports.

Also, this analysis does not take into account the portion of some crops that may be shipped out of Arkansas when they are in season, and imported into the state when they are not in season. The benefits were quantified at the state level. As such, they do not capture additional GHG benefits where local (e.g., community-level) production and consumption take place (resulting in addition ton-mile reductions). The quantified benefits could also be conservatively low, since the assumptions for out-of-state-produce were based on California as the likely producer state. Many commodities come from farther away (including foreign countries) and can travel by more energy-intensive methods (e.g., air transport). Further, the assumed transport routes are a single trip from the city of origin to Little Rock. Many commodities will make several trips prior to reaching their final point of consumption (for packaging, storage, processing, etc.).

This analysis only incorporates emission reductions due to reduced transportation. Other environmental and economic benefits associated with localizing packaging, refrigeration, storage, and processing are not included. The overall impact of all of the assumptions is that the benefits are likely to be underestimated.

It is assumed that the fuel savings accrued through reduced ton-miles offset the likely increase in production costs associated with more localized food production. While the exact interaction of these competing economic factors is uncertain, locally produced and consumed food products will become more cost-effective as fuel costs increase.

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

Arkansas is blessed with abundant and expanding forests—approximately 18.52 million acres, mostly in private ownership, covering 54% of the state. Arkansas' forests and forest management have a significant role to play in the state's strategies to reduce or offset GHGs and adapt to future climate effects. Nationally, managed forests and forest products store enough carbon each year to offset approximately 10% of U.S. CO_2 emissions.

Arkansas' forests naturally sequester GHGs (producing 1.07 metric tons of oxygen for every 1.47 metric tons of CO_2 absorbed through the power of photosynthesis) and produce biomass for alternative fuels, wood-building products, and paper containing sequestered carbon. Beyond atmospheric and economic benefits, a healthy forest also provides wildlife habitat, enhanced water quality, recreation, and an aesthetically pleasing backdrop for the Natural State's tourism promotion. On the other hand, conversion of forests to other land uses, poor forest health, natural decay, and wildfires reduce the sequestration and carbon storage values of the forest, as well as the potential economic values of forest products and carbon sequestration in regulated CO_2 offset markets.

This policy option establishes or re-establishes forests on land not currently forested, such as fallow or marginal 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 planting open land, replanting harvested land, increased stocking of poorly stocked lands, extending the age of managed stands, thinning, fertilizing, recycling waste, expanding the short rotation of woody crops (for fiber and energy), expanding the use of genetically preferred species, modifying biomass removal practices, managing and reducing the risk of fire, pests and disease.

Policy Design

Goals:

- Implement urban tree-planting and -retention programs in Arkansas urban areas. Plant 100,000 additional trees each year between 2009 and 2025, resulting in 1.7 million new trees in urban areas statewide (or a 4% increase in the number of urban trees).
- 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 publicly owned resource lands by 2025.

- Maintain existing forest cover by replanting harvested acres; restoring timbered acres lost to insects, fire, or natural causes; and establishing a net 500,000 new acres of forest by 2025.

Table 7-1. Current land area by land use type in Arkansas

Land Use Type	Data Year	Acres	Data source	Notes
Agricultural	2003	12,844,100	NRI	Cropland + pastureland
Forest	2008	18,520,000	FIA	All ownerships
Developed	2003	1,996,100	NRI	Developed + other rural

FIA = U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program; NRI = U.S. Department of Agriculture, Natural Resources Conservation Service, "2003 Annual National Resources Inventory: State Report."

Table 7-2. Forestland area by ownership class in Arkansas

Ownership Group	Acres	% of Total Forestland
Private ownership	14,842,619	80%
Public: federal	3,153,894	17%
Public: state/county/municipal	523,192	3%

Source: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program.

Table 7-3. Forestland area by required by forestry goals

Goal	Approximate Acres by 2025	Additional or Existing Acreage	Potential Overlap	Notes
Increase urban canopy	N/A	N/A	No	N/A
Increase carbon benefits on privately owned land	7,377,082	Existing	No	No new forest - improve management on existing land.
Increase carbon benefits on publicly owned resource lands.	1,824,745	Existing	No	Includes federal, sate, county, and municipal. No change to forest coverage - improve management on existing land.
Restore/establish 500,000 acres of forest.	500,000	Additional	Yes	N/A
Sustain existing forests to ensure no net loss of existing forests.	18,403,654	Existing	Yes	Depends on the definition (e.g., no net loss across state or sustain existing forest).

N/A = not applicable.

Timing: As described above.

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

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

Implementation Mechanisms

Arkansas should redouble its efforts to promote reforestation, forest restoration, and new afforestation on lands in public as well as private ownership. It can do so by:

- Ensuring that forest landowners are eligible for CO_2 offset credits and incentives in any state, regional or national market-based initiatives.
- Providing financial and legislative incentives to landowners (in addition to offset market revenue) to increase carbon sequestration and storage.
- Supporting the development of market demand for forest biomass for energy (electricity and fuels) in lieu of fossil fuel energy.
- Taking a leadership role in regional and national policy development and efforts to encourage the participation of all forest landowners in ways that provide increased climate benefits.

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

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

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.G. McPherson and J.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.
- E.G. McPherson, J.R. Simpson, P.J. Peper, S.L. Gardner, K.E. Vargas, S.E. Maco, and Qingfu Xiao, *Piedmont Community Tree Guide: Benefits, Costs, and Strategic Planting*, USFS PSW-GTR-200, USDA/USFS Pacific Southwest Research Station, November 2006. Available at: http://www.fs.fed.us/psw/programs/cufr/products/2/cufr_647_gtr200_piedmont_tree_guide.pdf.

- U.S. Environmental Protection Agency (U.S. EPA). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006. USEPA #430-R-08-005. April 2008. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

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 currently grow in Arkansas, resulting in an average of 25% canopy cover in urban areas statewide.[89] Planting 100,000 additional trees each year between 2009 and 2025 would add 1.7 million trees in urban areas statewide, for a 3.9% increase in the number of trees, and boost the canopy cover in urban areas to about 26%.

The average annual per-tree gross carbon sequestration value for urban trees was found by dividing the total estimated annual carbon sequestration in Arkansas urban trees (258,000 metric tons of carbon/year, equating to 946,000 tCO_2e/year) by the total number of urban trees. Annual gross carbon sequestration per urban tree was thus calculated as 0.006 metric tons of carbon (0.022 tCO_2e) per tree per year. Gross sequestration as calculated above does not account for the emissions resulting from tree mortality, disposal, and decomposition. To account for these emissions, the estimated gross carbon sequestration per tree was multiplied by 0.72, which is the ratio of gross to net sequestration for urban trees reported by Nowak and Crane (2002)[90] and

[89] 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.

[90] D.J. Nowak and D.E. Crane. "Carbon Storage and Sequestration by Urban Trees in the USA." *Environmental Pollution* March 2002;116(3):381-389. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VB5-44JYXWH-5&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=3ce67e03c1680fd2dcf04ddad0469d79

used in EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.[91] Annual net carbon sequestration per urban tree in Arkansas is 0.004 metric tons of carbon (0.015 tCO_2e) per tree per year.

Since trees planted in one year continue to accumulate carbon in subsequent years, annual carbon sequestration in any given year was calculated as the sum of carbon stored in trees planted in that year, plus sequestration by trees that were planted in prior years. It was assumed that new trees planted in urban areas in Arkansas would sequester carbon at a rate consistent with sequestration by the average urban tree statewide.

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, though these benefits are not likely to be achieved the first year after planting. Normally, trees are quite small when they are planted, so some time is required before the full effect of the avoided emissions can be realized. To account for this, a sliding scale was employed, such that trees planted in 2009 would achieve the full avoided GHG emissions benefit in 2025, and a linear phase-in of avoided GHG benefits would occur each year. Avoided GHG benefits for trees planted in each year from 2009 to 2025 were thus calculated proportionally to their expected size in 2025, as shown in Table 7-4. Using this approach, it was assumed that the trees planted in 2009 would achieve their full shade and wind protection potential (shown in Tables 7-5a and 7-5b) in 2025. It was further assumed that any trees planted in 2010 or later would reach their full avoided GHG emissions potential sometime after the conclusion of the policy implementation period.

The total avoided GHG 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 potential GHG reduction factor of 0.075 tCO_2e/tree/year for trees in the Southeast region was calculated from data in McPherson and Simpson in GTR-PSW-171 (Appendix A, Table V.5).[92] 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 for the Southeast region provided by McPherson and Simpson of 28%, 54%, and 18%, respectively. This estimate further assumes a default distribution of trees planted around buildings, based on measured data from existing urban canopy in the region.

[91] U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006*. USEPA #430-R-08-005. April 2008. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[92] E.G. McPherson and J.R. Simpson. *Carbon Dioxide Reduction Through Urban Forestry*: *Guidelines for Professional and Volunteer Tree Planters*. Appendix A, Table V.5. 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.

Table 7-4. Sliding scale applied to calculate the avoided GHG emissions resulting from urban tree planting

Year	Proportion of Potential Benefit Achieved by Trees Planted in This Year																
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2009	0.06																
2010	0.12	0.06															
2011	0.18	0.12	0.06														
2012	0.24	0.18	0.12	0.06													
2013	0.29	0.24	0.18	0.12	0.06												
2014	0.35	0.29	0.24	0.18	0.12	0.06											
2015	0.41	0.35	0.29	0.24	0.18	0.12	0.06										
2016	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06									
2017	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06								
2018	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06							
2019	0.65	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06						
2020	0.71	0.65	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06					
2021	0.76	0.71	0.65	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06				
2022	0.82	0.76	0.71	0.65	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06			
2023	0.88	0.82	0.76	0.71	0.65	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06		
2024	0.94	0.88	0.82	0.76	0.71	0.65	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06	
2025	1.00	0.94	0.88	0.82	0.76	0.71	0.65	0.59	0.53	0.47	0.41	0.35	0.29	0.24	0.18	0.12	0.06

To calculate potential avoided GHG emissions due to increased shading, it was assumed that all of the new trees are planted where they can have shading effects. Because these data were used as potential maxima, large trees (half evergreen, half deciduous) planted and average tree distribution around buildings were also assumed. Note that 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 electricity fuel mix (coal, hydroelectric, nuclear, etc.) in the regions of interest, and may thus change if the mix changes. The average urban tree planted in Arkansas was assumed to result in avoided emissions of 0.0751 tCO_2e/year (Tables 7-5a and 7-5b).

Table 7-5a. Net GHG emission reductions from evergreen shade trees planted in the Southeast climate region

Housing Age	Proportion of Urban Trees in This Housing Age Category	Cooling (tCO_2 Saved per Tree)	Heating (tCO_2 Emitted per Tree)	Wind (tCO_2 Saved per Tree)	Net Effect (tCO_2e/tree)
Pre-1950	0.28	0.0378	–0.0237	0.0708	0.0849
1950–1980	0.54	0.0507	–0.0270	0.0784	0.1021
Post-1980	0.18	0.0641	–0.0319	0.0635	0.0957
Weighted Average (tCO_2e/tree/year)					0.09423

tCO_2 = metric tons of carbon dioxide.

Source: McPherson and Simpson, PSW-GTR-171, Appendix A, Table V.5.

Table 7-5b. Net GHG emission reductions from deciduous shade trees planted in the Southeast climate region

Housing Age	Proportion of Urban Trees in This Housing Age Category	Cooling (tCO_2 Saved per Tree)	Heating (tCO_2 Emitted per Tree)	Wind (tCO_2 Saved per Tree)	Net Effect (tCO_2e/tree)
Pre-1950	0.28	0.0586	–0.0197	0.0000	0.0389
1950–1980	0.54	0.0785	–0.0224	0.0000	0.0561
Post-1980	0.18	0.0993	–0.0264	0.0000	0.0729
Weighted Average (tCO_2e/tree/year)					0.05597

tCO_2 = metric tons of carbon dioxide; tCO_2e = metric tons of carbon dioxide equivalent.

Source: McPherson and Simpson, PSW-GTR-171, Appendix A, Table V.5.

The annual avoided GHG benefit of trees in each year of the policy implementation period was calculated proportionally to the expected size of the trees in each age cohort in each year (Table 7-6). For each year between 2009 and 2025, this was calculated by multiplying the number of trees planted in each preceding year by the maximum potential avoided GHG effect. This was then multiplied by the scaling factor (Table 7-4) that represents the proportion of the maximum benefit achieved in a given year by trees planted in a prior year. For each year of policy implementation, the shade- and wind-protection effects of trees planted in that year and each prior year were summed to find the total avoided GHG impact of urban tree planting in that year (Table 7-6).

Table 7-6. Avoided GHG emissions from urban tree planting over the policy implementation period.

Year	GHG Benefit of Trees Planted in this Year ($MMtCO_2e$/year)																	Total GHG Avoided in This Year
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
2009	0.000																	0.000
2010	0.001	0.000																0.001
2011	0.001	0.001	0.000															0.003
2012	0.002	0.001	0.001	0.000														0.004
2013	0.002	0.002	0.001	0.001	0.000													0.007
2014	0.003	0.002	0.002	0.001	0.001	0.000												0.009
2015	0.003	0.003	0.002	0.002	0.001	0.001	0.000											0.012
2016	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000										0.016
2017	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000									0.020
2018	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000								0.024
2019	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000							0.029
2020	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000						0.034
2021	0.006	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000					0.040
2022	0.006	0.006	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000				0.046
2023	0.007	0.006	0.006	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000			0.053
2024	0.007	0.007	0.006	0.006	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000		0.060
2025	0.008	0.007	0.007	0.006	0.006	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.000	0.068

$MMtCO_2e$/year = million metric tons of carbon dioxide equivalent per year.

The total GHG benefit was calculated as the sum of direct carbon sequestration plus fossil fuel offset from reduced cooling demand and wind reduction. The avoided emissions and carbon sequestration benefits are summed in Table 7-7 to show the total net benefits of urban tree planting.

Table 7-7. Carbon sequestered and avoided emissions from urban forestry in AFW-7

Year	Number of Trees Planted This Year	Number of Trees Planted in Prior Years	Carbon Sequestered in Cumulative Trees Planted ($MMtCO_2e$/year)	Carbon Savings From Shading Effects ($MMtCO_2e$/year)	Total Carbon Savings ($MMtCO_2e$/year)
2009	100,000	0	0.002	0.000	0.002
2010	100,000	100,000	0.003	0.001	0.004
2011	100,000	200,000	0.005	0.003	0.007
2012	100,000	300,000	0.006	0.004	0.011
2013	100,000	400,000	0.008	0.007	0.014
2014	100,000	500,000	0.009	0.009	0.019
2015	100,000	600,000	0.011	0.012	0.023
2016	100,000	700,000	0.013	0.016	0.028
2017	100,000	800,000	0.014	0.020	0.034
2018	100,000	900,000	0.016	0.024	0.040
2019	100,000	1,000,000	0.017	0.029	0.046
2020	100,000	1,100,000	0.019	0.034	0.053
2021	100,000	1,200,000	0.020	0.040	0.061
2022	100,000	1,300,000	0.022	0.046	0.068
2023	100,000	1,400,000	0.024	0.053	0.077
2024	100,000	1,500,000	0.025	0.060	0.085
2025	100,000	1,600,000	0.037	0.068	0.105
Total	1,700,000		0.250	0.161	0.411

$MMtCO_2e$/year - million metric tons of carbon dioxide equivalent per year.

Urban Forestry Costs

The costs and cost savings of urban tree planting are calculated separately for the one-time cost of tree purchase and planting; cost of annual maintenance (including pruning, removal and disposal, pest and disease treatment, infrastructure repair, cleanup, liability and legal coverage); and cost savings from avoided 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 are difficult to measure and are thus not explicitly quantified.

State-specific data for Arkansas were not available for cost estimates, so data from the Piedmont region, which includes states immediately to the south and east of Arkansas, were used. The *Piedmont Community Tree Guide* reports that on average it costs $100/tree to purchase and plant an urban tree.[93] The report also provides average annual maintenance costs and cost savings per tree for four tree types; an average across these tree types was calculated and used for this cost analysis (Table 7-8) (see Appendices A1-A4 in the guide for the original data).

Table 7-8. Average costs of and cost savings from urban tree planting

Costs and Cost Savings	A1 Red Maple	A2 Southern Magnolia	A3 Dogwood	A4 Loblolly Pine	Average
Cost savings ($saved/year/tree):					
Cooling savings	–$16.45	–$12.14	–$9.05	–$14.79	–$13.11
Heating savings	–$3.75	–$1.39	–$2.27	–$2.18	–$2.40
Total Average Cost Savings	**–$20.20**	**–$13.53**	**–$11.32**	**–$16.97**	**–$15.51**
Maintenance costs ($spent/year/tree)	$6.85	$5.49	$5.17	$3.54	$5.26

The number of trees planted each year was multiplied by a cost of $100/tree/year to estimate initial tree purchase and planting costs (Table 7-9). Then, the total number of additional trees planted to date (cumulative since the year planted) on existing urban areas was multiplied by $5.26/tree/year to estimate annual maintenance costs (Table 7-9). The cost savings of –$15.51/tree/year was multiplied by the number of trees planted for energy efficiency to date (cumulative since the year planted). This cost savings value was not adjusted for tree size. Cumulative values are used for the latter two estimates because the maintenance costs and cost savings occur in the year the tree is planted and each year thereafter.

Annual net costs are the sum of costs and cost savings. Annual net costs are discounted using a 5% discount rate. Net present value (NPV) is the sum of the annual net discounted costs and is estimated to be $17 million. Cost-effectiveness is calculated by dividing the NPV by cumulative GHG reductions for 2009–2025. Cost-effectiveness is estimated to be $41.49/t$CO_2$e reduced.

Sustainable Management in Public and Private Lands: GHG Benefits

The above Policy Design section articulates a goal of 50% of publicly owned and 50% of privately owned forests under sustainable management regimes by 2025. Assuming that federal forestland is not under state jurisdiction, this suggests that a total of 7.38 million acres of private forestland and 258,254 acres of state-owned resource lands would be managed in this way (Table 7-2). To achieve these cumulative levels, approximately 433,946 additional acres of privately owned land and 15,191 additional acres of publicly owned land would be managed in this way each year between 2009 and 2025.

[93] McPherson, E.G., J.R. Simpson, P.J. Peper, S.L. Gardner, K.E. Vargas, S.E. Maco, and Qingfu Xiao. *Piedmont Community Tree Guide: Benefits, Costs, and Strategic Planting*. USFS PSW-GTR-200. U.S. Department of Agriculture, Forest Service Pacific Southwest Research Station, November 2006. Available at: http://www.fs.fed.us/psw/programs/cufr/products/2/cufr_647_gtr200_piedmont_tree_guide.pdf.

Table 7-9. Summary of economic benefits of urban forest policy implementation

Year	Number of Trees Planted This Year	Number of Trees Planted in Prior Years	Planting Cost	Maintenance Cost	Cost Savings (Not Proportional to Tree Size)	Net Economic Cost	Discounted Cost
2009	100,000	0	$10,000,000	$0	–$1,550,500	$8,449,500	$8,449,500
2010	100,000	100,000	$10,000,000	$526,250	–$3,101,000	$7,425,250	$7,071,667
2011	100,000	200,000	$10,000,000	$1,052,500	–$4,651,500	$6,401,000	$5,805,896
2012	100,000	300,000	$10,000,000	$1,578,750	–$6,202,000	$5,376,750	$4,644,639
2013	100,000	400,000	$10,000,000	$2,105,000	–$7,752,500	$4,352,500	$3,580,813
2014	100,000	500,000	$10,000,000	$2,631,250	–$9,303,000	$3,328,250	$2,607,771
2015	100,000	600,000	$10,000,000	$3,157,500	–$10,853,500	$2,304,000	$1,719,280
2016	100,000	700,000	$10,000,000	$3,683,750	–$12,404,000	$1,279,750	$909,494
2017	100,000	800,000	$10,000,000	$4,210,000	–$13,954,500	$255,500	$172,932
2018	100,000	900,000	$10,000,000	$4,736,250	–$15,505,000	-$768,750	–$495,543
2019	100,000	1,000,000	$10,000,000	$5,262,500	–$17,055,500	–$1,793,000	–$1,100,746
2020	100,000	1,100,000	$10,000,000	$5,788,750	–$18,606,000	–$2,817,250	–$1,647,188
2021	100,000	1,200,000	$10,000,000	$6,315,000	–$20,156,500	–$3,841,500	–$2,139,091
2022	100,000	1,300,000	$10,000,000	$6,841,250	–$21,707,000	–$4,865,750	–$2,580,411
2023	100,000	1,400,000	$10,000,000	$7,367,500	–$23,257,500	–$5,890,000	–$2,974,850
2024	100,000	1,500,000	$10,000,000	$7,893,750	–$24,808,000	–$6,914,250	–$3,325,872
2025	100,000	1,600,000	$10,000,000	$8,420,000	–$26,358,500	–$7,938,500	–$3,636,718
Total	**1,700,000**		**$170,000,000**	**$71,570,000**	**–$237,226,500**	**$4,343,500**	**$17,061,571**

1. Impacts of Improved Management on Carbon Sequestration

Net changes in carbon stocks in forest biomass and soil are influenced by growth, mortality, and decay processes, and the amount of carbon removed during harvest, all of which are influenced by forest management to some degree. A range of forest management activities can promote productivity and increase the rate of carbon sequestration in Arkansas (see the Policy Description section, above, for details). Increasing productivity involves increasing the rate at which forests accumulate biomass—i.e., a high-productivity stand accumulates more carbon in biomass over the same amount of time as an otherwise equivalent low-productivity stand. This leads to a relatively higher growing-stock volume (i.e., the volume of living trees above the ground), some portion of which is harvested at periodic intervals (providing for potentially greater harvest volumes).

Data are available to estimate the carbon stock and growing-stock volume changes associated with increasing productivity of loblolly-shortleaf pine stands in Arkansas. Loblolly-shortleaf pine forests are the second most abundant type of forest in Arkansas, making up 29% of all classes of forest (oak-hickory is the most abundant forest type, making up 39% of forest area).[94]

[94] 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. USDA/USFS, Northern Research Station, 2006. Available at: http://www.treesearch.fs.fed.us/pubs/22954.

Because the loblolly-pine forests are the most heavily managed forest type in Arkansas, an analysis of this forest group alone is believed to be a good approximation of the overall potential GHG benefits of forest management in Arkansas. Thus, the analysis below is based on shifting productivity levels from average or below-average levels to high levels in privately owned loblolly-shortleaf stands.

The estimated changes are based on comparing carbon and growing-stock volume yield tables for average- and high-productivity loblolly-shortleaf pine stands in the South Central region published by U.S. Forest Service (USFS).[95] This type of comparison assumes that the newly treated stands will realize gains as if they were growing according to the yield table of a high-producing forest from their beginning. In reality, total gains will be influenced by the age of the stand when treatment is initiated.

The net impact of a shift from low- to high-productivity forests involves both forest carbon and harvested wood product (HWP) pools. From a carbon accounting perspective, harvested carbon represents a carbon stock loss to the forest and a carbon stock gain into the HWP pool, with only a portion of the carbon that is shifted into the HWP pool at harvest remaining stored for long periods of time. The changes in carbon stocks in both forest and HWP pools are quantified below.

2. Estimated Increases in Carbon Sequestration Rates and Growing-Stock Volumes

USFS publishes carbon stock tables for forest types by region for the entire country. In some regions, for some forest types, USFS provides tables for both average- and high-productivity stands. Such tables are available for loblolly-shortleaf pine in the South Central region. Carbon stock and growing-stock volume data in the USFS tables (see Tables 7-10 and 7-11) were used to calculate an annual carbon sequestration rate for average- and high-productivity loblolly-shortleaf pine forests in Arkansas (carbon stocks in 30-year-old stands were subtracted from carbon stocks in new stands and divided by 30). An average over 30 years is assumed to encompass the range of age classes for this forest type, though in reality, sequestration rates vary by stand age. Note that soil carbon stocks are constant over time and between productivity classes, so carbon stock gains occur only in biomass pools. Comparing Tables 7-10 and 7-11 shows that high-productivity stands sequester approximately 0.79 metric tons more carbon per acre per year. Therefore, regardless of the initial carbon stock levels, a forest stand that moves to higher productivity status will gain roughly 0.79 more metric tons of carbon per acre per year than it would if left as is.

[95] Ibid.

Table 7-10. Carbon stocks and mean growing-stock volumes by selected age class for loblolly-shortleaf pine in the southeastern United States

Age (years)	Mean Volume (cf/acre)	Biomass (tC/acre)	Soils (tC/acre)	Total (tC/acre)
0	0	10.4	17	27.4
30	1,554	32.9	17	49.9
Average Annual Sequestration (30-year average)				**0.75**

cf/acre = cubic feet per acre; tC/acre = metric tons of carbon per acre.

Source: Smith et al., GTR NE-343, Table A47.

Table 7-11. Carbon stocks and mean growing-stock volumes by selected age class for high-productivity sites (growth rates greater than 120 cubic feet/acre/year), with high-intensity management (replanting with genetically improved stocks)

Age (years)	Mean Volume (cf/acre)	Biomass (tC/acre)	Soils (tC/acre)	Total (tC/acre)
0	0	14.9	17	31.9
30	4,963	61.1	17	78.1
Average Annual Sequestration (30-year average)				1.54

cf/acre = cubic feet/acre; tC/acre = metric tons of carbon per acre.

Source: Smith et al., GTR NE-343, Table A48.

In addition, the growing-stock volume is greater in all age classes of high-productivity stands. Assuming that, on average, stands are harvested at 30 years, USFS HWP accounting methods were used to convert the 3,409-cubic-feet-per-acre (cf/acre) incremental increase in growing-stock volume into the equivalent carbon volume of 35.6 tC/acre. Note that this is the carbon stored in the incremental increase in growing stock, only a portion of which is removed during harvest (this analysis assumes 35% is removed, see below).

3. Calculation of Net Carbon Stock Change in Forests and HWP

The calculation of net forest carbon stock change takes into account that each year gains in biomass carbon stocks from higher accumulation rates are offset by the removal of larger volumes of carbon during harvest (Table 7-12). The incremental increase in biomass carbon stocks is calculated by multiplying the cumulative number of acres treated by 0.79 tC/acre/year (Table 7-12, Column A). Cumulative acres are used because once an area is treated, it continues to sequester carbon at a higher rate in subsequent years.

The incremental increase in carbon removed during harvest is calculated by multiplying the number of acres harvested each year by 35% of the carbon increase in growing-stock volume (i.e., 35% of 35.6 tC/acre = 12.5 tC/acre) (Table 48, Column B). This assumes that 35% of the growing-stock volume is removed during a harvest (based on a study of carbon removals at different harvest levels, 35% is roughly the proportion removed from moderate harvest levels).[96]

[96] T.F. Strong. "Harvesting Intensity Influences the Carbon Distribution in a Northern Hardwood Ecosystem." USFS Research Paper NC-329. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station, 1997. Available at: http://www.ncrs.fs.fed.us/pubs/812 - 20k.

The number of acres harvested is calculated by assuming 2.76% of the acres treated each year are harvested the following year.[97]

Carbon removed during harvest is subtracted from the carbon gains in biomass due to sequestration to yield a net change in forest carbon stocks each year (Table 48, Column C). If the calculation stopped here, this would imply that all carbon removed is essentially emitted to the atmosphere. Therefore, a subsequent step is taken to account for the portion of carbon that remains stored in HWP for a total carbon stock balance.

Standard USFS HWP accounting methods were used to estimate the incremental increase in harvested carbon that remains stored in HWP indefinitely. The amount of carbon stored in HWP carbon stocks is time-dependent relative to the year of harvest (carbon stocks are high initially and decrease over time as a result of disposal and decay), making carbon stock accounting for HWP complex. Therefore, an approach has been developed to standardize and simplify HWP carbon accounting, which applies the amount of carbon still stored in HWP 100 years after harvest as the estimated net increase in HWP carbon stocks; this gain is attributed to the year of harvest.

The USFS methods from Smith et al. were applied to coefficients for loblolly-shortleaf pine stands in the South Central region to estimate that approximately 22% of harvested carbon remains stored in HWP 100 years after harvest.[98] Therefore, the long-term storage of carbon in HWP increases by approximately 2.7 tC/acre when stands go from average- to high-productivity forests (i.e., an additional 12.45 tC/acre are harvested, of which 22% remains stored indefinitely). The net carbon stock increase in HWP attributable to increased productivity was calculated by multiplying the number of acres harvested by 2.7 tC/acre (Table 48, Column D). For standardization across all policy options, units are converted to $MMtCO_2e$ in Table 7-13.

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,[99] and Montana, where a value of $300 per acre was used.[100] 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.

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[97] The harvest rate of 2.76% was calculated from data published in J.F. Rosson, Jr. "Arkansas Forest Resources, 1995." Resource Bulletin SRS-78. Asheville, NC: USDA/USFS, Southern Research Station, 2002. Available at: http://srs.fs.usda.gov/pubs/4725.

[98] 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. USDA/USFS, Northern Research Station, 2006. Available at: http://www.treesearch.fs.fed.us/pubs/22954.

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

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

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.[101] To achieve the goal of 500,000 acres by 2025, a linear ramp to the goal level was assumed, such that 29,412 acres would be planted each year between 2009 and 2025.

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 activities can be assumed to occur at the same rate as carbon sequestration in average Arkansas forests. For this analysis, the forest type distribution used for the AR I&F was used: this analysis found that forest area in Arkansas is roughly 39% oak-hickory, 29% loblolly-shortleaf pine, 17% oak-pine, and 15% oak-gym-cypress.

[101] 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.

Table 7-12. Summary of calculated net changes in forest and HWP carbon stocks

Year	Privately Owned Acres/ Year	State-Owned Acres/ Year	Cumulative Private Acres	Cumulative Public Acres	Column A Increased Carbon Stocks in Forest Biomass (tC)	Column B Increased Carbon Stocks Removed at Harvest (tC)	Column C (A minus B) Net Change in Forest Carbon Stocks (tC)	Column D Net Increase in HWP Carbon Stocks (tC)	Column E (C plus D) Total Increase in Forest and HWP Carbon Stocks (tC)
2009	433,946	15,191	433,946	15,191	354,819		354,819	0	354,819
2010	433,946	15,191	867,892	30,383	697,636	154,390	543,246	33,995	577,242
2011	433,946	15,191	1,301,838	45,574	1,040,453	154,390	886,064	33,995	920,059
2012	433,946	15,191	1,735,784	60,766	1,383,271	154,390	1,228,881	33,995	1,262,876
2013	433,946	15,191	2,169,730	75,957	1,726,088	154,390	1,571,698	33,995	1,605,694
2014	433,946	15,191	2,603,676	91,148	2,068,905	154,390	1,914,516	33,995	1,948,511
2015	433,946	15,191	3,037,622	106,340	2,411,723	154,390	2,257,333	33,995	2,291,329
2016	433,946	15,191	3,471,568	121,531	2,754,540	154,390	2,600,150	33,995	2,634,146
2017	433,946	15,191	3,905,514	136,723	3,097,357	154,390	2,942,968	33,995	2,976,963
2018	433,946	15,191	4,339,460	151,914	3,440,175	154,390	3,285,785	33,995	3,319,781
2019	433,946	15,191	4,773,406	167,106	3,782,992	154,390	3,628,602	33,995	3,662,598
2020	433,946	15,191	5,207,352	182,297	4,125,809	154,390	3,971,420	33,995	4,005,415
2021	433,946	15,191	5,641,298	197,488	4,468,627	154,390	4,314,237	33,995	4,348,233
2022	433,946	15,191	6,075,244	212,680	4,811,444	154,390	4,657,054	33,995	4,691,050
2023	433,946	15,191	6,509,190	227,871	5,154,261	154,390	4,999,872	33,995	5,033,867
2024	433,946	15,191	6,943,136	243,063	5,497,079	154,390	5,342,689	33,995	5,376,685
2025	433,946	15,191	7,377,082	258,254	5,839,896	154,390	5,685,507	33,995	5,719,502
Total	**7,377,082**	**258,254**					**25,185,483**	**373,950**	**25,559,432**

tC = metric tons of carbon; HWP = harvested wood product.

Table 7-13. Summary results

Year	Net Change in Forest Carbon Stocks ($MMtCO_2e$)	Net Increase in HWP Carbon Stocks ($MMtCO_2e$)	Total Increase in Forest and HWP Carbon Stocks ($MMtCO_2e$)
2009	1.3	0.000	1.3
2010	2.0	0.125	2.1
2011	3.2	0.125	3.4
2012	4.5	0.125	4.6
2013	5.8	0.125	5.9
2014	7.0	0.125	7.1
2015	8.3	0.125	8.4
2016	9.5	0.125	9.7
2017	10.8	0.125	10.9
2018	12.0	0.125	12.2
2019	13.3	0.125	13.4
2020	14.6	0.125	14.7
2021	15.8	0.125	15.9
2022	17.1	0.125	17.2
2023	18.3	0.125	18.5
2024	19.6	0.125	19.7
2025	20.8	0.125	21.0
Total	**184**	**1.99**	**186**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; HWP = harvested wood product.

Average carbon storage was found using methods described by the USDA Forest Service in Smith et al., assuming that afforestation activity would occur on forests that were consistent with the existing forest type distribution in Arkansas.[102] 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 7-8). 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 average rate of carbon accumulation on afforested land in Arkansas is roughly 3.6 tCO_2e/acre/year (Table 7-8).

[102] 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, Tables A47, A48, B47, B49, B50, and B51. U.S. Department of Agriculture, Forest Service, Northern Research Station, December 21, 2005. Available at: http://www.treesearch.fs.fed.us/pubs/22954.

Table 7-8. Carbon sequestration rates in afforested stands in Arkansas

Forest Type	tCO_2e/acre (0 year)	tCO_2e/acre (35 year)	tCO_2e/acre/year (35-year average)	Proportion of Arkansas Forest
Oak-hickory (Table B50)	49.1	169.0	3.4	39%
Loblolly-shortleaf pine (Table B47)	52.8	183.0	3.7	29%
Oak-pine (Table B51)	52.8	183.3	3.7	17%
Oak-gum-cypress (Table B49)	61.2	187.7	3.6	15%
Weighted-Average Carbon Accumulation Rate for Afforestation				3.6%

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

Source: Smith et al., NE-GTR-343.

Forests planted in one year will continue to store carbon in subsequent years. Therefore, the GHG benefit of afforestation in one year is the cumulative impact of forests planted in prior years. The overall GHG benefit of afforestation activity in Arkansas is described in Table 7-9.

Table 7-9. Cumulative effect of afforestation in AFW-7

Year	Acres Planted This Year (acre/year)	Acres Planted in Prior Years	Carbon Sequestered in Cumulative Planted Acreage (tCO_2e/year)	Carbon Sequestered in Cumulative Planted Acreage ($MMtCO_2e$/year)
2009	29,412	0	105,609.2	0.106
2010	29,412	29,412	211,218.5	0.211
2011	29,412	58,824	316,827.7	0.317
2012	29,412	88,235	422,437.0	0.422
2013	29,412	117,647	528,046.2	0.528
2014	29,412	147,059	633,655.5	0.634
2015	29,412	176,471	739,264.7	0.739
2016	29,412	205,882	844,873.9	0.845
2017	29,412	235,294	950,483.2	0.950
2018	29,412	264,706	1,056,092.4	1.056
2019	29,412	294,118	1,161,701.7	1.162
2020	29,412	323,529	1,267,310.9	1.267
2021	29,412	352,941	1,372,920.2	1.373
2022	29,412	382,353	1,478,529.4	1.479
2023	29,412	411,765	1,584,138.7	1.584
2024	29,412	441,176	1,689,747.9	1.690
2025	29,412	470,588	1,795,357.1	1.795
Total	**500,000**			**16.158**

$MMtCO_2e$/year = million metric tons of carbon dioxide equivalent per year; tCO_2e/acre/year = metric tons of carbon dioxide equivalent per acre per year.

Restore/Establish Forest Cover: Economic Costs

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.[103] The opportunity cost for afforestation activity was assumed to be $51.82/acre/year, which was the annual average rental payment to farmers in Arkansas with land enrolled in the Conservation Reserve Program as of 2007.[104] One-time costs of vegetation establishment include site preparation and vegetation planting, and vary with planting method (hand planting or machine planting) and forest type (hardwood or softwood).[105] For afforestation in AR, the average cost of planting softwoods is $141 per acre and the average planting cost for hardwoods is $183 per acre (Table 7-10). Since planting will occur on both hardwood and softwood forest types, a weighted average for planting was computed for afforestation at $170.82/ acre. Maintenance and monitoring costs on afforested land were assumed to be negligible between 2009 and 2025.

Table 7-10. One-time costs of vegetation establishment for afforestation (pasture or open land forest establishment)

Forest Types	Hand Planting ($/acre)	Machine Planting ($/acre)	Average
Softwood forest types			
Site preparation: ripping*	$28	$0	
Site preparation: chemical band spraying**	$44	$44	
Planting: labor & seedlings	$82	$84	
Totals	**$154**	**$128**	**$141**
Hardwood forest types			
Site preparation: ripping	$28	$0	
Site preparation: chemical band spraying	$44	$44	
Planting: labor & seedlings	$125	$125	
Totals	**$197**	**$169**	**$183**

*Some properties that are machine planted will also do ripping, as the ripper may go deeper than the machine planter.

**Some properties do not have to have chemical band spraying if the vegetation is not requiring treatment.

Source: Arkansas Forestry Commission.

[103] S. Walker, S. Grimland, J. Winsten, and S. Brown. "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.

[104] U.S. Department of Agriculture, Farm Service Agency. *Conservation Reserve Program Summary and Enrollment Statistics: FY 2007.* Prepared by Alex Barbarika. April 2008. Available at: http://www.fsa.usda.gov/Internet/FSA_File/annual_consv_2007.pdf.

[105] Personal communication between J. Shannon, Arkansas Forestry Commission, and J. Jenkins, CCS, July 2008.

Discounted costs to 2025 were calculated using a 5% discount rate. Results, including annual costs, are summarized in Table 7-11. The NPV of this option, expressed in 2009 dollars, is roughly $201 million, and the overall cost of implementing this option was calculated to be $12.44/t$CO_2$e stored.

Table 7-11. Summary of net economic cost of afforestation activity in Arkansas

Year	Acres Planted This Year (acre/year)	Acres Planted in Prior Years	Opportunity Cost	Establishment Cost	Total Cost	Discounted Cost
2009	29,412	0	$1,524,118	$5,024,118	$6,548,235	$6,548,235
2010	29,412	29,412	$3,048,235	$5,024,118	$8,072,353	$7,687,955
2011	29,412	58,824	$4,572,353	$5,024,118	$9,596,471	$8,704,282
2012	29,412	88,235	$6,096,471	$5,024,118	$11,120,588	$9,606,382
2013	29,412	117,647	$7,620,588	$5,024,118	$12,644,706	$10,402,831
2014	29,412	147,059	$9,144,706	$5,024,118	$14,168,824	$11,101,644
2015	29,412	176,471	$10,668,824	$5,024,118	$15,692,941	$11,710,314
2016	29,412	205,882	$12,192,941	$5,024,118	$17,217,059	$12,235,842
2017	29,412	235,294	$13,717,059	$5,024,118	$18,741,176	$12,684,766
2018	29,412	264,706	$15,241,176	$5,024,118	$20,265,294	$13,063,189
2019	29,412	294,118	$16,765,294	$5,024,118	$21,789,412	$13,376,809
2020	29,412	323,529	$18,289,412	$5,024,118	$23,313,529	$13,630,938
2021	29,412	352,941	$19,813,529	$5,024,118	$24,837,647	$13,830,531
2022	29,412	382,353	$21,337,647	$5,024,118	$26,361,765	$13,980,207
2023	29,412	411,765	$22,861,765	$5,024,118	$27,885,882	$14,084,266
2024	29,412	441,176	$24,385,882	$5,024,118	$29,410,000	$14,146,713
2025	29,412	470,588	$25,910,000	$5,024,118	$30,934,118	$14,171,276
Total	**500,000**					**$200,966,180**

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 8-1 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 8-1. Municipal solid waste steams and tons recycled

Waste Streams	Tons/Year Recycled in 2006	Point of Generation[106]	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.
Waste Streams	**Tons/Year Recycled in 2006**	**Point of Generation[107]**	**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.

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

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

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:

- *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

Possibly strengthening existing recycling legislation or the provision of incentives/subsidies to the municipalities to have more aggressive recycling efforts (currently it is more expensive to recycle than to landfill).

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."

Opportunity to Recycle

Arkansas Code Annotated 8-6-720(a)(1): Beginning July 1, 1992, each regional solid waste management board shall ensure that its residents have an opportunity to recycle. "Opportunity to recycle" means availability of curbside pickup or collection centers for recyclable materials at sites that are convenient for people to use.

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

GHG Reduction Potential in 2015, 2025 ($MMtCO_2e$): 1.5, 4.4, respectively.

Net Cost per tCO_2e: –$8.

Data Sources:

Key data sources for the development of the quantification of AFW-8 are:

- Arkansas Department of Environmental Quality. *State of Recycling in Arkansas*. Reports available from 1999 through 2006. Accessed on June 12, 2008 from: http://www.adeq.state.ar.us/solwaste/branch_recycling/default.htm.
- U.S. Environmental Protection Agency. *2006 MSW Characterization Data Tables (PDF).* Accessed on July 7, 2008 from: http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/06data.pdf.
- 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.

Quantification Methods:

GHG Benefits

The GHG benefits resulting from increased waste diversion in Arkansas are quantified by:

- Establishing BAU projections for landfill disposal, incineration, recycling, and composting (as recycling and composting are fundamentally two different processes, they will be considered separately, with the sum of the two being equal to total waste "diversion);
- Using the goals set forth by the TWG to project the policy scenario for waste management;
- Using recycling data from the AR DEQ *State of Recycling in Arkansas r*eports and national-level generation and disposal data from the EPA *2006 Municipal Solid Waste Characterization Data Tables*, disaggregate the Arkansas recycling, composting, and disposal data; and
- Inserting the resulting waste characterization for the baseline and policy scenarios into WARM to determine the incremental GHG benefit resulting from the goals set forth in this policy.

The baseline recycling and composting rates for MSW in South Carolina are 40.3% and 1.8%, respectively. Based on the change in MSW generation over the last 5 years, it is assumed that the

BAU average annual increase in MSW generation is 4.7%. Population projections are consistent with those used in the development of the AR I&F.[108] These assumptions are used to develop the BAU waste management scenario presented in Table 8-2.

Table 8-2. Business-as-usual waste management projections for Arkansas

Item	2006	2010	2015	2020	2025
MSW generation (4.7%/year growth 2002–2006)	5,012,531	6,020,073	7,568,897	9,516,197	11,964,492
AR population (from AR I&F)	2,800,397	2,897,236	3,018,285	3,139,334	3,260,383
MSW generation per capita (tons/person)	1.79	2.08	2.51	3.03	3.67
MSW recycled (tons) (40.3% of generation, not including organics)	2,021,709	2,428,082	3,052,771	3,838,177	4,825,650
Organic composting (tons) (1.8% of generation)	90,133	108,250	136,100	171,116	215,140
MSW disposed in landfills (tons)	2,900,689	3,483,741	4,380,026	4,343,047	5,111,005

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

The policy goals set forth by the TWG are applied to the baseline recycling and composting tonnages to project future waste management under the policy scenario. The remainder of the waste generated is assumed to be disposed of in landfills. Table 8-3 shows the projected management of waste generated in Arkansas under the policy scenario. Table 8-4 shows the incremental waste diversion, or the difference between the policy and BAU scenarios.

Table 8-3. Waste management projection for Arkansas, including policy goals (short tons)

Item	2006	2010	2015	2020	2025
MSW generation	5,012,531	6,020,073	7,568,897	9,516,197	11,964,492
MSW recycled	2,021,709	2,593,412	3,405,553	4,463,923	5,841,464
Organic composting	90,133	115,621	151,828	199,013	260,428
MSW disposed in landfills	2,900,689	3,311,040	4,011,515	4,853,261	5,862,601

MSW = municipal solid waste.

Table 8-4. Incremental diversion under policy goals (short tons)

Item	2006	2010	2015	2020	2025
Recycling	—	165,330	352,783	625,746	1,015,813
Organic composting	—	7,371	15,728	27,897	45,288
Landfill disposal	—	–172,701	–368,511	–653,644	–1,061,101

108 Arkansas Greenhouse Gas Inventory and Reference Case Projections, 1990-2025. Available online at: http://www.arclimatechange.us/Inventory_Forecast_Report.cfm.

The national baseline composition of waste generated is used to develop the breakdown of waste generation for Arkansas by waste type.[109] The waste types used for this analysis correspond to the disaggregated recycling information provided in the 2002–2006 *State of Recycling in Arkansas* annual reports and the inputs available for the WARM. Table 8-5 shows the waste generation characteristics of broad waste categories, and Table 8-6 shows the mix of generation by specific waste type within some of these categories. Again, these tables present an estimated waste characterization for Arkansas, based on national generation and diversion rates that are assumed to adequately represent the Arkansas waste stream. Due to cases where a larger quantity of a given material was recycled than projected to be generated under the BAU scenario, adjustments to the raw national data were made to fit the Arkansas waste profile.

The mix of waste generation shown in Tables 8-5 and 8-6 is applied to the total waste generation in Arkansas. Next, the shares of waste recycled and composted (Table 8-7) within each of these categories are multiplied by the total amount of waste recycled (or composted for food waste, yard trimmings, and mixed organics), to yield the amount of waste recycled or composted by waste type.

Once the tonnages of waste generated, recycled, and composted are established, the recycled and composted wastes are subtracted from the amount generated leaving the amount of waste that has not been diverted. This amount is the assumed quantity of waste landfilled by waste type. The results of this process are entered into WARM. The WARM inputs for 2025 are displayed in Tables 8-8 and 8-9.

Table 8-5. Waste generation characteristics, by category

Category	Baseline Generation Composition (% of total generation)
Paper	12.6%
Organics	5.1%
Mixed plastic	9.7%
Metals	44.2%
Glass	0.2%
Other	28.0%

BAU = business as usual.

[109] U.S. Environmental Protection Agency. *2006 MSW Characterization Data Tables (PDF)*. Accessed on July 7, 2008 from: http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/06data.pdf.

Table 8-6. Waste generation characteristics, by waste type

Waste Type	Baseline Generation Composition (% of total generation)
Paper	
Corrugated cardboard	1.1%
Magazines/third-class mail	0.0%
Newspaper	0.5%
Office paper	0.0%
Phone books	0.3%
Textbooks	0.4%
Mixed paper, residential	3.3%
Mixed Paper, office	6.9%
Organics	
Food waste	1.1%
Yard trimmings	2.5%
Mixed Organics	1.5%
Plastics	
HDPE	7.2%
LDPE	1.5%
PET	0.1%
Other (assumed mixed plastics)	0.9%
Metals	
Aluminum cans	4.3%
Steel Cans	0.1%
Mixed metals	39.9%
Glass	
Glass	0.2%
Other	
Mixed Recyclables	25.9%
Personal Computers	1.2%
Tires	1.0%

BAU = business as usual; HDPE = high-density polyethylene; LDPE = low-density polyethylene; PET = polyethylene terephthalate.

Table 8-7. Recycled and composted waste characteristics, by waste type: 2006

Material	BAU Percentage Recycled	BAU Percentage Composted	Policy Percentage Recycled	Policy Percentage Composted
Aluminum Cans	3.8%	N/A	3.8%	
Steel Cans	0.1%	N/A	0.1%	
Glass	0.1%	N/A	0.1%	
HDPE	1.3%	N/A	1.3%	
LDPE	0.2%	N/A	0.2%	
PET	0.1%	N/A	0.1%	
Corrugated Cardboard	2.0%	N/A	2.0%	
Magazines/Third-class Mail	0.0%	N/A	0.0%	
Newspaper	1.1%	N/A	1.0%	
Office Paper	0.1%	N/A	0.1%	
Phonebooks	0.0%	N/A	0.2%	
Textbooks	0.0%	N/A	0.5%	
Food Scraps	N/A	0.0%		3.3%
Yard Trimmings	N/A	87.7%		87.7%
Mixed Paper (primarily residential)	0.6%	N/A	0.6%	
Mixed Paper (primarily from offices)	3.6%	N/A	3.6%	
Mixed Metals	36.0%	N/A	36.0%	
Mixed Plastics	0.1%	N/A	0.1%	
Mixed Recyclables	48.1%	N/A	47.5%	
Mixed Organics	N/A	12.3%		9.0%
PersoN/Al Computers	1.1%	N/A	1.1%	
Tires	1.7%	N/A	1.7%	
Totals	**100.0%**	**100.0%**	**100.0%**	**100.0%**

N/A = not applicable; HDPE = high-density polyethylene; LDPE = low-density polyethylene; PET = polyethylene terephthalate.

Table 8-8. 2025 baseline WARM inputs

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum cans	511,531	182,105	329,426		NA
Steel cans	7,172	4,540	2,632		NA
Copper wire					NA
Glass	29,213	6,316	22,897		NA
HDPE	861,933	64,841	797,092		NA
LDPE	183,592	7,836	175,756		NA
PET	16,187	3,280	12,907		NA

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Corrugated cardboard	132,704	95,548	37,155		NA
Magazines/third-class mail	645	253	392		NA
Newspaper	62,362	54,844	7,518		NA
Office paper	5,529	3,630	1,898		NA
Phone books	32,370	—	32,370		NA
Textbooks	53,791	—	53,791		NA
Dimensional lumber					NA
Medium-density fiberboard					NA
Food scraps	130,987	NA	130,987		—
Yard trimmings	304,219	NA	115,491		188,729
Grass		NA			
Leaves		NA			
Branches		NA			
Mixed paper (general)					NA
Mixed paper (primarily residential)	396,503	26,805	369,698		NA
Mixed paper (primarily from offices)	825,027	174,214	650,813		NA
Mixed metals	4,775,362	1,739,544	3,035,818		NA
Mixed plastics	103,881	4,903	98,978		NA
Mixed recyclables	3,098,342	2,319,221	779,121		NA
Mixed organics	176,565	NA	150,153		26,411
Mixed MSW		NA			NA
Carpet					NA
Personal computers	138,048	55,403	82,645		NA
Clay bricks		NA		NA	NA
Concrete				NA	NA
Fly ash				NA	NA
Tires	118,531	82,368	36,163		NA

WARM = [EPA's] WAste Reduction Model; N/A = not applicable; HDPE = high-density polyethylene; LDPE = low-density polyethylene; PET = polyethylene terephthalate; MSW = municipal solid waste.

Table 8-9. 2025 policy WARM inputs

Material	Baseline Generation	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum cans	511,531	220,439	291,092		
Steel cans	7,172	5,496	1,676		
Copper wire		—			
Glass	29,213	7,645	21,567		
HDPE	861,933	78,490	783,443		
LDPE	183,592	9,486	174,106		
PET	16,187	3,970	12,217		
Corrugated cardboard	132,704	115,661	17,042		
Magazines/third-class mail	645	306	338		
Newspaper	62,362	58,415	3,947		
Office paper	5,529	4,395	1,134		
Phone books	32,370	12,447	19,923		
Textbooks	53,791	27,766	26,025		
Dimensional lumber					
Medium-density fiberboard					
Food scraps	130,987		122,465		8,522
Yard trimmings	304,219		75,763		228,457
Grass					
Leaves					
Branches					
Mixed paper, broad					
Mixed paper, residential	396,503	32,448	364,055		
Mixed paper, office	825,027	210,886	614,141		
Mixed metals	4,775,362	2,105,723	2,669,639		
Mixed plastics	103,881	5,935	97,946		
Mixed recyclables	3,098,342	2,775,185	323,157		
Mixed organics	176,565		153,116		23,449
Mixed MSW					
Carpet					
Personal computers	138,048	67,065	70,983		
Clay bricks					
Concrete					
Fly ash					
Tires	118,531	99,706	18,825		

WARM = [EPA's] WAste Reduction Model; N/A = not applicable; HDPE = high-density polyethylene; LDPE = low-density polyethylene; PET = polyethylene terephthalate; MSW = municipal solid waste.

The WARM analysis predicts a GHG benefit of 1.5 $MMtCO_2e$ in 2015 and 4.4 $MMtCO_2e$ in 2025. Assuming the program implementation begins in 2010 and a linear increase in emission reductions between target years, the cumulative GHG benefit is estimated to be 36 $MMtCO_2e$ through 2025 (Table 8-10).

Table 8-10. Overall policy results—GHG benefits

Year	Avoided Emissions (MMtCO2e)	Incremental Waste Diversion (tons)	Incremental Recycling (tons)	Incremental Composting (tons)	Avoided Landfill Emplacement (tons)
2009	—	—	—	—	—
2010	0.25	172,701	165,330	7,371	–172,701
2011	0.51	223,533	213,993	9,540	–223,533
2012	0.76	268,797	257,325	11,472	–268,797
2013	1.02	308,232	295,077	13,155	–308,232
2014	1.27	341,565	326,987	14,578	–341,565
2015	1.52	368,511	352,783	15,728	–368,511
2016	1.80	440,210	421,422	18,788	–440,210
2017	2.08	504,909	483,359	21,549	–504,909
2018	2.35	562,279	538,281	23,998	–562,279
2019	2.63	611,977	585,858	26,119	–611,977
2020	2.91	653,644	625,746	27,897	–653,644
2021	3.18	753,583	721,420	32,163	–753,583
2022	3.46	844,720	808,668	36,052	–844,720
2023	3.73	926,643	887,094	39,549	–926,643
2024	4.01	998,921	956,287	42,634	–998,921
2025	4.35	1,061,101	1,015,813	45,288	–1,061,101
Total	**35.8**	**9,041,325**	**8,655,443**	**385,882**	**–9,041,325**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; WTE = waste-to-energy.

Cost-Effectiveness

Recycling—The net cost of increased recycling rates in Arkansas was estimated by adding the increased costs of collection for two-stream recycling, revenue obtained for the value of recycled materials, and avoided landfill tipping fees. The additional cost for separate curbside collection of recyclables is $2.50/household/month, or $30/household/year.[110] Dividing this number by the incremental recycling per capita in 2025,[111] and multiplying that number by the average household size of 2.49,[112] yields the maximum collection cost of $6.73/ton. The capital cost of

[110] T. Brownell, Eureka Recycling, personal communication with S. Roe, CCS, December 17, 2007. This value compares favorably with data provided to the AFW TWG (T. Troolin, St. Louis County) on recycling costs incurred by Minnesota counties.

[111] Population projection for 2025 from the AR I&F.

[112] U.S. Census Bureau. "State & County QuickFacts—Arkansas." Accessed on July 10, 2008, at: http://quickfacts.census.gov/qfd/states/05000.html.

additional recycling facilities in Arkansas is $134 million.[113] Annualized over the 15-year policy period at 5% interest, the capital cost is $8.7 million/year. The avoided cost for landfill tipping is $28/ton.[114] CCS also factored in the commodity value of recycled materials with a value of $38/ton.[115] Table 8-11 provides the results of the cost analysis. The analysis assumes that costs begin to be incurred in 2010. The estimated cost savings result in an NPV of –$295 million. Cumulative reductions are 17.0 $MMtCO_2e$, and the estimated cost-effectiveness is –$17/$tCO_2e$.

Table 8-11. Cost analysis results for recycling

Year	Tons Recycled	Annual Collection Cost (MM$)	Annual Capital Cost (MM$)	Annual Recycled Material Revenue (MM$)	Landfill Tip Fees Avoided (MM$)	Net Policy Cost (Recycling) (MM$)	Discounted Costs (MM$)	GHG Reductions ($MMtCO_2e$)	Cost-Effective-ness ($/$tCO_2e$)
2009	—	$0.0	$0	$0	$0	$0	$0	—	
2010	165,330	$1.1	$6	$6	$6	–$5	–$5	0.3	
2011	213,993	$1.4	$6	$8	$8	–$8	–$8	0.5	
2012	257,325	$1.7	$6	$10	$10	–$11	–$10	0.8	
2013	295,077	$2.0	$6	$11	$11	–$14	–$12	1.0	
2014	326,987	$2.2	$6	$13	$12	–$16	–$13	1.3	
2015	352,783	$2.4	$6	$14	$13	–$18	–$14	1.5	
2016	421,422	$2.8	$6	$16	$16	–$23	–$16	1.8	
2017	483,359	$3.3	$6	$19	$18	–$27	–$18	2.1	
2018	538,281	$3.6	$6	$21	$20	–$31	–$20	2.3	
2019	585,858	$3.9	$6	$22	$22	–$34	–$21	2.6	
2020	625,746	$4.2	$6	$24	$24	–$37	–$22	2.9	
2021	721,420	$4.9	$6	$28	$27	–$44	-$24	3.2	
2022	808,668	$5.4	$6	$31	$31	–$50	–$26	3.4	
2023	887,094	$6.0	$6	$34	$34	–$55	–$28	3.7	
2024	956,287	$6.4	$6	$37	$36	–$60	–$29	4.0	
2025	1,015,813	$6.8	$6	$39	$39	–$64	–$29	4.3	
Total						**–$499**	**–$295**	**17.0**	**–$17**

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

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[113] Based upon the ratio of capital cost per household used in the Vermont analysis. Vermont capital cost a result of personal communication between P. Calabrese (Cassella Waste Management) and S. Roe (CCS) on June 5, 2007.

[114] Georgia Department of Community Affairs (DCA). *MSW and C&D Landfill Tipping Fees: 2005 Solid Waste Management Update.* Accessed on July 10, 2008 from: http://www.dca.state.ga.us/development/research/programs/downloads/SWAR_2005_Chap01.pdf. Note that this tip fee estimate is for Arkansas MSW landfills.

[115] RecycleNet Composite Index. "U.S. Municipal Recycling Index—Spot Market Prices: February 1, 2008." Accessed on February 1, 2008, at: http://www.scrapindex.com/municipal.html. Adjusted to 2005$ using the Consumer Price Index calculator found at Federal Reserve Bank of Minneapolis, "What Is a Dollar Worth?" Available at: http://minneapolisfed.org/Research/data/us/calc/.

Composting—Composting is included in the total recycling volume in the *State of Recycling in Arkansas* reports. However, as WARM considers the sole form of diversion for yard trimmings and food waste to be composting, the tons of these items that are "recycled" are assumed to be composted. The net costs for increased composting in Arkansas were estimated by adding the additional costs for collection (same calculation as recycling) and the net cost for composting operations. The net cost for composting operations is the sum of the annualized capital and operating costs of composting, increased collection fees, revenue generated through the sale of compost, and the avoided tipping fees for landfilling. Information on the capital and operating costs of composting facilities was received from Cassella Waste Management during the analysis of a similar policy in Vermont.[116] These data are summarized in Table 8-12.

Table 8-12. Capital and operating costs of composting facilities

Annual Volume (tons)	Capital Cost ($1,000)	Operating Cost ($/ton)
< 1,500	$75	$25
1,500–10,000	$200	$50
10,000–30,000	$2,000	$40
30,000–60,000+	$8,000	$30

CCS assumed that the composting facilities to be built within the policy period would tend to be from the largest category (achieving the most efficient operating costs) shown in Table 8-12. The composting volumes in 2015 and 2025 shown in Table 8-13 suggest the need for one additional large composting operation to meet the incremental increase in composting through 2025. To annualize the capital costs of these facilities, CCS assumed a 15-year operating life and a 5% interest rate. Other cost assumptions include an assumed landfill tipping fee of $28/ton,[117] an additional source-separated organics collection fee of $2.50/household (or $51/ton, as used above in the recycling element), a compost facility tipping fee of $15/ton,[118] and a compost value of $11/ton.[119]

Table 8-13 presents the results of the cost analysis for composting. GHG reductions were assumed not to begin until 2010, and the cumulative reductions estimated were 0.06 $MMtCO_2e$. An NPV of $11 million was estimated, along with a cost-effectiveness of $179/$tCO_2e$.

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

[117] Georgia Department of Community Affairs, Office of Environmental Management. "MSW and C&D Landfill Tipping Fees: 2005 Solid Waste Management Update." Accessed on July 10, 2008, from: http://www.dca.state.ga.us/development/research/programs/downloads/SWAR_2005_Chap01.pdf.

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

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

Table 8-13. Cost analysis results for composting

Year	Annual Cost O&M ($MM)	Capital Cost ($MM)	Annualized Capital Cost ($MM)	Annual Collection Cost ($MM)	Avoided Landfill Tipping Fees ($MM)	Value of Composted Material ($MM)	Tons of Waste Composted	Total Annual Composting Cost ($MM)	Dis-counted Costs ($MM)	GHG Reductions ($MMtCO_2e$)	Cost-Effective-ness ($/t)
2009	$0	$0	$0.0	$0	$0	$0	—	$0	$0	—	
2010	$0	$8	$0.8	$0	$0	$0	7,371	$1	$1	0.00	
2011	$0	$0	$0.8	$0	$0	$0	9,540	$1	$1	0.00	
2012	$0	$0	$0.8	$0	$0	$0	11,472	$1	$1	0.00	
2013	$0	$0	$0.8	$0	$0	$0	13,155	$1	$1	0.00	
2014	$0	$0	$0.8	$0	$0	$0	14,578	$1	$1	0.00	
2015	$0	$0	$0.8	$0	$0	$0	15,728	$1	$1	0.01	
2016	$1	$0	$0.8	$0	$0	$0	18,788	$1	$1	0.01	
2017	$1	$0	$0.8	$0	$0	$0	21,549	$1	$1	0.01	
2018	$1	$0	$0.8	$0	$0	$0	23,998	$1	$1	0.01	
2019	$1	$0	$0.8	$0	$0	$0	26,119	$1	$1	0.01	
2020	$1	$0	$0.8	$0	$0	$0	27,897	$1	$1	0.01	
2021	$1	$0	$0.8	$0	$0	$0	32,163	$1	$1	0.01	
2022	$1	$0	$0.8	$0	$0	$0	36,052	$1	$1	0.01	
2023	$1	$0	$0.8	$0	$1	$0	39,549	$1	$1	0.01	
2024	$1	$0	$0.8	$0	$1	$0	42,634	$1	$1	0.01	
2025	$1	$0	$0.8	$0	$1	$0	45,288	$1	$1	0.02	
Total									**$11**	**0.06**	**$179**

O&M = operation and maintenance; $MM = millions of dollars; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t = dollars per metric ton.

The overall cost analysis, as seen in Table 8-14, yields an NPV of –\$284 and a cost-effectiveness of –\$7.9/tCO_2e, based on the cumulative emission reductions of 35.8 MMtCO_2e.

Table 8-14. Overall policy results—cost-effectiveness

Year	Net Program Cost: Recycling (\$MM)	Net Program Cost: Composting (\$MM)	Total Net Program Cost (\$MM)	Discounted Cost (\$MM)	Cost-Effectiveness (\$/tCO_2e)
2009	\$0.0	\$0.0	\$0.0	\$0	
2010	–\$5.1	\$0.9	–\$4.2	–\$4	
2011	–\$8.4	\$0.9	–\$7.5	–\$7	
2012	–\$11.5	\$0.9	–\$10.5	–\$9	
2013	–\$14.1	\$0.9	–\$13.1	–\$11	
2014	–\$16.3	\$1.0	–\$15.4	–\$12	
2015	–\$18.1	\$1.0	–\$17.1	–\$13	
2016	–\$22.9	\$1.0	–\$21.9	–\$16	
2017	–\$27.2	\$1.0	–\$26.2	–\$18	
2018	–\$31.0	\$1.1	–\$30.0	–\$19	
2019	–\$34.3	\$1.1	–\$33.2	–\$20	
2020	–\$37.1	\$1.1	–\$36.0	–\$21	
2021	–\$43.8	\$1.2	–\$42.6	–\$24	
2022	–\$49.9	\$1.2	–\$48.6	–\$26	
2023	–\$55.3	\$1.3	–\$54.0	–\$27	
2024	–\$60.1	\$1.3	–\$58.8	–\$28	
2025	–\$64.3	\$1.3	–\$62.9	–\$29	
Total				**–\$284**	**–\$7.9**

\$MM = millions of dollars; \$/tCO_2e = dollars per metric ton of carbon dioxide equivalent.

Key Assumptions: For the MSW management input data to WARM, the key assumption is that none of the goals would be achieved via existing programs in place. To the extent that those programs will fully or partly achieve the goals of this policy, the GHG reductions estimated would be lower (no additional penetration from the current Arkansas recycling and composting campaigns has been incorporated into the BAU assumptions for this analysis). Therefore, the most important assumption relates to the assumed BAU projection for solid waste management. This BAU forecast is based on current practices, and does not factor in the effects of further gains in recycling or composting rates during the policy period. The BAU assumptions are needed to tie into the assumptions used to develop the GHG forecast for the waste management sector, which does not factor in these changes in waste management practices during the policy period (2010–2025). To the extent that these gains in recycling and composting would occur without this policy, the benefits and costs are overstated.

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

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

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

Key Uncertainties

One factor of uncertainty with the analysis, as performed above, is the interest rate used for capital expenditures. Table 8-15 displays the effect on the results of this policy option that an 8% and 10% interest rate would have on the results, which are based on a 5% interest rate.

Table 8-15. Sensitivity to interest rate on capital expenditure

Interest Rate	Annualized Capital Cost ($MM/year)	Net Present Value Policy Cost ($MM)	Cost-Effectiveness ($/t$CO_2$e)
5%	$7.2	–$283.5	–$7.9
8%	$8.8	–$266.8	–$7.4
10%	$9.9	–$254.9	–$7.1

Currently, the amount of clay bricks, concrete, fly ash, or carpet disposed in Arkansas is not tracked by DEQ. Bricks and concrete go to class four landfills in a mixture of materials. At this time, fly ash and carpet can be very costly to transport to disposal sites and the markets for these materials are not very strong. Although these materials are a discernable part of the waste stream in Arkansas, resources could be concentrated on them in the future in order to better understand both current and potential disposal strategies.

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

GHG Reduction Potential in 2015, 2025 (MMtCO_2e): 0.02, 0.02, respectively.

Net Cost per tCO_2e: –$3.

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 Department of Environmental Quality (AR DEQ). "2007 MSW Quarterly Report Yearly Totals." Received by B. Strode via e-mail communication with K. Bassett on July 9, 2008.
- AR DEQ. "LFGTE List." Excel spreadsheet of landfills in AR highlighting those with LFGTE capabilities, and those with currently installed gas collection systems. Received by B. Strode via e-mail communication with K. Bassett on July 9, 2008.
- Arkansas Greenhouse Gas Inventory and Reference Case Projections, 1990–2025: Waste Appendix. Available online at: http://www.arclimatechange.us/Inventory_Forecast_Report.cfm.

Quantification Methods:

GHG Benefits

The goal set forth by the AFW TWG requires 25% of all landfills in Arkansas to utilize LFGTE technology. According to the AR DEQ, there are currently 24 landfills in Arkansas, meaning that LFGTE technology will have to be installed at six landfills in order to meet the TWG goal. Currently, there are two landfills that already utilize LFGTE technology and four others that have installed active gas collection systems, flaring the collected gas.[120] It was assumed that these four landfills that already have an active gas collection system will be the most cost-efficient landfills to target for LFGTE.

The potential GHG benefit from the installation of LFGTE technologies at landfills comes from two sources: the conversion of the methane in landfill gas to carbon dioxide (a gas with a lower global warming potential) and the indirect benefit from the offset electricity or natural gas use. Since CCS assumed that the four additional landfills installing LFGTE needed to meet the goal will be those that already have active gas collection systems, only the indirect benefit of offset fossil energy use will be considered incremental to the business-as-usual (BAU) scenario.

[120] AR DEQ. "LFGTE List." Excel spreadsheet of landfills in AR highlighting those with LFGTE capabilities, and those with currently installed gas collection systems. Received by B. Strode via e-mail communication with K. Bassett on July 9, 2008.

CCS used the EPA LFGcost model to estimate the amount of electricity that could be generated in each year by the four additional landfills installing LFGTE.[121] Based on 2007 waste generation rates,[122] the LFGcost model predicted that 46,160 MWh could be generated at the landfills with new LFGTE equipment. Using the same emission factor for offset electricity as the Electricity Supply TWG used in its analysis of option ES-3a, it was estimated that the fulfillment of the goal for AFW-9 would produce a GHG benefit of 0.02 $MMtCO_2e$ in 2025, with a cumulative benefit of 0.4 $MMtCO_2e$ for the policy period 2010 through 2025.

Cost-Effectiveness

The cost-effectiveness of this option was determined using the LFGcost model.[123] The current model inputs assume an 8% interest rate over 15 years for capital and an electricity price of $0.045/kWh. The LFGcost model predicts the total capital expense and average annual O&M costs.[124] The sum of the annualized capital and O&M costs, less revenue generated from the sale of electricity, yields the net cost of this policy option. The NPV of this option was estimated to be –$1.1 million, with a cost-effectiveness of –$3/$tCO_2e$ (see Table 9-1).

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

[122] Arkansas Department of Environmental Quality (AR DEQ). "2007 MSW Quarterly Report Yearly Totals." Received by B. Strode via e-mail communication with K. Bassett on July 9, 2008.

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

[124] O&M costs are assumed to inflate by 2.5% per year, while the price of electricity is assumed to increase by 2% per year.

Table 9-1. Summary of results

Year	Avoided Emissions ($MMtCO_2e$)	Annual Capital Cost (MM$)	Annual O&M Cost (MM$)	Electricity Purchase Price ($/kWh)	Annual Revenue (MM$)	Net Annual Cost (MM$)	Discounted Costs (MM$)	Cost Effectiveness ($/tCO₂e)
2009	—	$0.0	$0.0	$0.045	$0.0	$0.0	$0.0	
2010	0.03	$1.0	$1.0	$0.045	$2.1	–$0.1	–$0.1	
2011	0.03	$1.0	$1.1	$0.046	$2.1	–$0.1	–$0.1	
2012	0.02	$1.0	$1.1	$0.047	$2.2	–$0.1	–$0.1	
2013	0.02	$1.0	$1.1	$0.048	$2.2	–$0.1	–$0.1	
2014	0.02	$1.0	$1.1	$0.049	$2.2	–$0.1	–$0.1	
2015	0.02	$1.0	$1.2	$0.050	$2.3	–$0.1	–$0.1	
2016	0.02	$1.0	$1.2	$0.051	$2.3	–$0.2	–$0.1	
2017	0.02	$1.0	$1.2	$0.052	$2.4	–$0.2	–$0.1	
2018	0.02	$1.0	$1.3	$0.053	$2.4	–$0.2	–$0.1	
2019	0.02	$1.0	$1.3	$0.054	$2.5	–$0.2	–$0.1	
2020	0.02	$1.0	$1.3	$0.055	$2.5	–$0.2	–$0.1	
2021	0.02	$1.0	$1.4	$0.056	$2.6	–$0.2	–$0.1	
2022	0.02	$1.0	$1.4	$0.057	$2.6	–$0.3	–$0.1	
2023	0.02	$1.0	$1.4	$0.058	$2.7	–$0.3	–$0.1	
2024	0.02	$1.0	$1.5	$0.059	$2.7	–$0.3	–$0.1	
2025	0.02	$1.0	$1.5	$0.061	$2.8	–$0.3	–$0.1	
Totals	**0.4**	**$15.6**	**$20.1**		**$38.7**	**–$3.0**	**–$1.1**	**–$3.0**

Key Assumptions:

The modeling that produced the above results was based on the assumption that the landfills that would implement LFGTE were those that already utilize active gas collection. However, as this analysis was not intended to be prescriptive, it should be noted that the TWG did not specify which landfills should implement LFGTE to meet the goals of this option.

Key Uncertainties

One factor of uncertainty with the analysis, as performed above, is the interest rate used for capital expenditures. Table 9-2 displays the effect on the results of this policy option that a 5% and 10% interest rate would have on the results, which are based on a 8% interest rate.

Table 9-2. Sensitivity to interest rate on capital expenditure

Interest Rate	Annualized Capital Cost ($MM/year)	Net Present Value Policy Cost ($MM)	Cost-Effectiveness ($/tCO₂e)
5%	$0.8	–$2.6	–$6.7
8%	$1.0	–$1.1	–$3.0
10%	$1.1	–$0.1	–$0.3

It is assumed that the most likely candidates to use LFG are the sites that currently have regulatory required active collection. Environmental regulation could push other sites into required active collection in the future, either by air rules or solid waste rules. The air division has four federally recognized modeling protocols for predicting air emissions which, in turn, determine who has to have active control and by what year. Those models could change and cause more facilities to become affected. Another possibility also exists that any of the 24 landfills currently in operation could end up “hot” with gas, to the point where solid waste rules could push them into active collection. There is no way to predict this because the geology and historic construction of each site are unique. If a site was ever required to place active collection “doing business as usual,” then at that time it is likely that the site owners would at least entertain the idea of selling gas or energy as a way to offset costs.

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]