

Status Report: Bioenergy in Arkansas

Submitted to

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Executive Summary

Arkansas is a biomass-rich State. Based on the data, assumptions, and calculations presented in this report, estimates were made of current and potential bioenergy production in Arkansas and are presented in Figure 1 (with explanatory notes provided in Appendix 1). The following observations are based on the summary results shown.

- Potential bioenergy production in Arkansas \cong 428,000,000 million (MM) Btu per year.
 - In ethanol equivalents \cong 3,850 MM gallons per year (MGY).
- Current energy production \cong 53,700,000 million Btu per year from \sim 4.04 MM tons.
 - In ethanol equivalents \cong 706 MGY.
 - The vast majority of current bioenergy production – about 85% – is from use of woody residues for cogeneration within the State’s forest products industry.
- Current production is \cong 13% of potential production...i.e., Arkansas has the potential to increase total bioenergy production by about eight-fold.
- A key assumption in the potential production estimate reflects use of 1,000,000 acres for herbaceous cellulosic feedstock production plus 200,000 acres of woody cellulosic feedstock production (and conversion of said feedstocks into bioenergy products).
 - The calculations are based on target crop yields that would likely require high-quality farmland (i.e., said yields would likely not be achievable on marginal lands).
- It is assumed that none of Arkansas’ corn production will be used for in-state production of corn-to-ethanol, given the increasingly unfavorable economics of this biofuel option.
- The estimated ’07 production of biodiesel from oil feedstocks was less than 20 MGY.
 - By the end of 2008 the State’s biodiesel production *capacity* is estimated to be more than 110 MGY, although *actual* production during the year is estimated to be only a small fraction of this amount due to unfavorable economics associated with production of biodiesel from virgin oil feedstocks.
 - In February 2008, virgin soy-oil prices in the U.S. exceeded \$190 per barrel.
- The combined *potential* production of biofuels from the estimated quantities of cellulosic biomass from in-forest residues, dedicated energy crops, and rice straw \cong 2.2 BGY of ethanol equivalents.
 - This amount would constitute approximately 14% of the total national cellulosic biofuels requirement for 2022.

Figure 1: Summary of Current and Future Projected Energy Production from Biomass in Arkansas
(Notes to Figure 1 are provided in Attachment 1)

biomass resource	total biomass production, dry tons per year	total land area, acres x000	potential production				2008 production			notes
			assumed utilization factor for bio-energy	amount, Btu x10 ⁹ per year	MM gallons per year, ethanol equivalents	% of total	portion of assumed utilization factor	amount, Btu x10 ⁹ per year	MM gallons per year, ethanol equivalents	
woody biomass										
in-forest residues	6,123,000		42%	40,100	528	14%		-	-	a
processing residues	5,753,000		51%	45,700	601	16%	100%	45,700	601	b
subtotal	11,876,000			85,800	1,129	29%		45,700	601	
agricultural biomass										
rice straw	6,201,000	1,388	20%	15,900	209	5%		-	-	c
other field residues	6,268,300	4,711	3%	2,700	36	1%		-	-	d
rice hulls	837,000		75%	8,000	105	3%	67%	5,360	71	e
other processing residues	112,500		50%	900	12	0%		-	-	f
subtotal	13,418,800			27,500	362	9%		5,360	71	
first-generation biofuels										
corn (to ethanol)	557,200	170	0%	0	0	0%		-	-	g
soybeans (to biodiesel)	2,992,000	3,055	11%	1,200	16	0%	100%	1,200	16	h
other biodiesel				800	11	0%	50%	400	5	i
subtotal	3,549,200			2,000	27	1%		1,600	21	
cellulosic energy crops										
herbaceous	15,000,000	1,000	100%	228,000	1,350	35%		-	-	j
woody	1,200,000	200	100%	18,200	108	3%		-	-	k
subtotal	16,200,000			246,200	1,458	38%		-	-	
other										
poultry litter	930,000		50%	5,600	74	2%		-	-	l
algae-diesel		50	100%	58,500	770	20%				m
wood pellets	150,000		100%	2,500	33	1%	40%	1,000	13	n
subtotal	1,080,000			66,600	876	23%		1,000	13	
totals	46,124,000			428,100	3,852			53,660	706	

current production / potential production

13%

potential production / current production

8.0

Biomass **feedstocks** of particular interest in Arkansas include soybeans (for biodiesel), woody residues, agricultural residues, poultry litter, and dedicated energy crops. Bioenergy **products** of particular interest in Arkansas include biofuels, thermal energy (for space heating or process heat), and electricity; **biofuels** of particular interest in Arkansas include biodiesel from soybeans and other oil feedstocks, and ethanol (and other biofuels) from cellulosic feedstocks.

Corn-to-ethanol: Several corn-to-ethanol (CTE) projects have been considered in Arkansas during the past few years although, as of January 2008, no commercial-scale CTE production facilities are in operation or are under construction in the State. Despite continued Federal subsidies and the national production requirements set forth in the Federal Renewable Portfolio Standard (RPS) established in 2007—15 billion gallons per year (BGY) by 2015, up from nationwide CTE production in 2007 of approximately 6 BGY—investments in corn-to-ethanol facilities have dropped sharply, reflecting feedstock price increases (in early 2008 market prices for corn rose above \$5.00/bushel, compared to less than \$1.50 in early 2006), continued economic reliance on Federal subsidies, and uncertainties regarding feedstock supplies.

Corn production in Arkansas was 557,000 tons in 2006. Said quantity could produce 61.3 million gallons per year (MGY) at a gross production level of 110 gallons per dry ton, or 14.3 MGY at a net production level of 26 gallons per dry ton (reflecting an energy balance of 1.3:1).

Biodiesel: Soybean production in Arkansas in 2006 was approximately 3 million tons (on approximately 3 million acres), although oil was extracted from less than 20% (the balance was exported in raw form). Without additional crushing capacity, the State's virgin oil production of 38.5 MGY (27 MGY from soybeans, 11.5 MGY from cottonseed) could support production of about 35 million gallons of biodiesel (although most of this oil is already marketed the food industry). The energetics of soybeans is approximately 3.4:1, with gross and net production levels under Delta conditions of about 47 and 29 gallons of biodiesel per acre per year, respectively. The market price for virgin soy oil of \$0.60 per pound (February 2008) equates to a biodiesel feedstock price of \$4.60 per gallon or \$193 per barrel.

Since November 2005, three biodiesel facilities have been established in Arkansas and four more are scheduled for completion in 2008, with a combined production capacity of more than 110 MGY (2008). Total biodiesel production in Arkansas in 2007 was less than 20 MGY. In addition to virgin oils, most of the facilities have targeted other feedstocks such as waste vegetable oil or animal fats. However, as with CTE, biodiesel producers are facing serious economic challenges, reflecting high (and volatile) feedstock prices and uncertainty of supplies. Despite continued Federal subsidies and the national production requirements set forth in the '07 RPS, investments in biodiesel projects have dropped sharply in the past two years. Most of the existing producers have cut back or temporarily ceased production, and the future of the State's fledgling biodiesel industry is uncertain, given the economic challenges facing the industry.

There is increasing interest in biodiesel from algae, and several Arkansas companies are evaluating such technologies. Algae-diesel facilities are capital intensive, but projected yields range from 5,000 to 20,000 gallons per acre per year. At 10,000 gallons per acre per year (net), 50,000 acres of algal-biodiesel production would meet 56% of the State's current petro-diesel consumption of 1.07 BGY¹ (compared to over 17,000,000 acres of soybeans...almost three times the total existing agricultural farmland in Arkansas' Delta region).

Cellulosic biofuels: Interest in cellulosic biofuels has risen significantly in recent years, as evidenced by: a) grant support from the U.S. Department of Energy (DOE) in eleven cellulosic biorefineries during January 2007~February 2008 exceeding \$500,000,000 and b) the cellulosic biofuel requirement set forth in the '07 RPS (over 15 BGY by 2022).

Four Arkansas-based companies are actively interested in cellulosic biofuels; two of these companies are participating in DOE-supported commercial-scale cellulosic biorefinery projects (one in Florida, the other in Georgia). Feedstocks of particular interest for such activities in Arkansas include in-forest residues, rice hulls, rice straw, and dedicated cellulosic energy crops. Based on the agronomic yield estimates discussed herein, one million acres of herbaceous energy crops could produce approximately 1,350 MGY of cellulosic ethanol.

Electricity and/or thermal energy: Primary options for biomass-to-electricity in Arkansas include co-firing (e.g., in coal-fired boilers) and co-generation. Approximately half of the woody residues generated by the State's forest products industries are used as boiler fuel for on-site co-gen (with the balance used for other purposes...un-used woody processing residues are estimated to be less than one percent of production). Current biomass cogeneration by the State's forest products industry is about 48×10^{12} Btu per year...roughly equivalent to the energy output from a 420 MW coal-fired powerplant.

Additional electricity and/or thermal energy could be generated by use of other residues (e.g., in-forest residues, agricultural residues) and/or dedicated energy crops. Based on the agronomic yield estimates discussed herein, one million acres of herbaceous energy crops could generate approximately 2,200 MW of power. Electrical/thermal energy could also be made from poultry litter (although this would probably be limited to centralized systems, since farm-scale litter-fired units have not been demonstrated to be feasible). Using half of the litter produced in the State could support approximately 46 MW of electric generating capacity.

Biomass feedstocks: Whereas essentially all of the woody processing residues (e.g., sawdust) are already being used, in-forest residues (IFR) constitute a major potential resource for Arkansas. An estimated 6.1 million tons (dry matter basis) of in-forest residues are produced per year in Arkansas. The net usable IFR (reflecting logistical and ecological factors) is estimated at 2.6 million dry tons per year, which equates to 528 MGY (at 90 gallons per dry ton).

The predominant agricultural biomass resources in Arkansas are rice straw and rice hulls, consisting of 6.2 and 0.8 million tons per year, respectively. Approximately fifty percent of hulls produced in Arkansas are used for on-site cogen; the balance is used by the poultry industry for bedding. Test harvests of rice straw have identified logistical issues that need to be addressed, and both straw and hulls have high ash content (mostly silica).

There is continuing interest in Arkansas in poultry litter, the only significant animal-derived biomass feedstock in the State. Although no farm-scale litter-fired energy systems are commercially available, off-farm centralized litter-to-energy systems exist (a 50 MW litter- and woody residue-fired powerplant began operation in Minnesota in 2007). Roughly fifty percent of the 930,000 dry tons per year of litter produced in Arkansas could support a 46 MW powerplant.

Cellulosic energy crops represent an enormous potential resource for Arkansas, given the large agricultural acreage and favorable growing conditions in the Delta region. Yield is paramount for economic feasibility of energy crops production, but the current lack of yield data for energy crops under Delta conditions creates uncertainties and risks that will constrain commercial-scale investments. Some research efforts were recently initiated in the Delta to gain production experience and obtain agronomic data; those efforts need to be expanded to include additional test locations and additional candidate crops..

From an **environmental** perspective, bioenergy systems offer a number of benefits over fossil-based systems. In particular, closed-loop biomass energy systems could have a significant impact on the State's carbon balance...production of herbaceous energy crops on one million acres of farmland in the Delta could avoid over 22 million tons per year of CO₂.

Next steps: More information is needed regarding algae-based biodiesel production systems, including potential CO₂ sources, feedstock production, processing, and economics. More agronomic data is needed for cellulosic energy crops (particularly under Delta conditions), as are strategies for establishing large-scale commercial production operations. The carbon/GHG benefits of bioenergy systems in Arkansas—both current and future—should be assessed (which should be of considerable interest to the Governor's Commission on Global Warming). The potential opportunities for co-firing of biomass with coal need to be evaluated (using residues and/or dedicated crops). The potential for expanding markets for wood pellets needs to be evaluated, given the potential opportunities for displacing propane as fuel for heating poultry houses by wood pellet-fired furnaces (and by furnaces using corn or other biomass feedstocks). Given the significant economic changes that have occurred in the energy space during the past five years (as well as increasing pressures on the poultry industry to reduce land application of litter in the northwest Arkansas region), the economics of off-farm centralized litter-to-energy systems should be re-evaluated.

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Appendix 1: Notes to Figure 1 - Summary of Current and Future Projected Energy Production from Biomass in Arkansas

Appendix 2: Notes to Notable Recent Bioenergy Activities in Arkansas

Appendix 3: Excerpted Executive Summary – Winrock’s April 2004 Biodiesel report

Appendix 4: State Energy Consumption Estimates from EIA

Appendix 5: State Energy Price and Expenditure Estimates from EIA

Appendix 6: Biomass Resources in Arkansas – January 2008 update

Appendix 7: Supporting Calculations: Comparative Analysis of Biofuels Production Options

Appendix 8: Outline of State Actions – Energy Supply – Governor’s Commission on Global Warming

Appendix 9: Program Rules: Arkansas’ 2007 Alternative Fuels Development Program

Attachment 1: Biodiesel Production in Arkansas

1. Recent Bioenergy Activities in Arkansas

Arkansas is a biomass-rich State. Bioenergy has long been used in Arkansas: at small scale for residential heating , (using cordwood) and at large scale by the forest products industry (primarily for cogeneration at processing facilities). For economic and environmental reasons, interest in bioenergy systems and technologies has surged during the past few years. Notable bioenergy-related activities and events that have occurred in Arkansas during the past four years are shown in Figure 2; notes are provided in Appendix 2.

Figure 2: Notable Recent Bioenergy Activities in Arkansas

	2004	2005	2006	2007	notes
WT's biodiesel production study completed	■				1
Federal biodiesel support program established		■			2
Federal Energy Act of 2005 enacted		■			3
AR biomass resources assessment updated		■			4
FutureFuels began producing biodiesel		■			5
Potlatch bioenergy feasibility study		■	■		6
Patriot Biofuels began producing biodiesel			■		7
AEDC's Bioenergy Policy Council			■	■	8
Arkansas Bioenergy Workshop convened			■		9
BRI's team received DOE biorefinery award				■	10
Tyson-Syntroleum JV: Dynamic Fuels				■	11
Federal Energy Act of 2007 enacted					■
AR's biofuels grant program implemented					■
AR Commission on Global Warming begins					■

Mr. Chris Benson is Director of the Arkansas Energy Office (AEO).² In mid-2007, the AEO hired Ms. Jenny Ahlen to serve as fulltime coordinator for renewable energy activities. The Arkansas Energy Office is part of the Arkansas Economic Development Commission (AEDC).

2. Commercial Bioenergy Products

2.1 Ethanol

The two basic options for ethanol production in Arkansas are corn or cellulosic feedstocks.

2.1.1 Corn-derived ethanol

557,000 tons (dry matter basis) of corn were produced in Arkansas in 2006 – down 25% from 745,000 tons in 2003 (produced on 170,000 acres, with average yields of 4.38 tons/acre [147 bushels/acre]).³ Numerous corn-to-ethanol projects have been considered during the past few years in various locations across the State, both using locally-produced corn, as well as corn imported from other states. However, as of January 2008, no commercial-scale corn-to-ethanol production facilities are in operation or under construction in Arkansas.⁴

The Energy Policy and Security Act of 2007 continued Federal economic support for corn-derived ethanol; the legislation also expanded and extended the Renewable Fuels Standard (RFS), which sets forth required production levels of certain types of renewable liquid transportation fuels, including an increase in corn-derived ethanol from 5 billion gallons per year (BGY) in 2007 to 15 BGY in 2015 – refer to §3.3.1 for more details regarding RFS.

However, there are widespread concerns regarding corn-to-ethanol (CTE) production:

- The economics of CTE production are reliant on Federal support, and it is widely held that this situation will continue (i.e., CTE production is not projected to become economically feasible without subsidies).⁵ As a result, the investment frenzy in CTE during the past few years has cooled significantly.
- The increased demand for corn for fuel has increased prices for feed and food corn which, in turn, has increased prices of corn-based food products worldwide (e.g., poultry and livestock products in the U.S., tortillas in Mexico).⁶ Market prices in early '08 were above \$5.00/bushel (compared to ~\$4.00/bu in early '07).
- The energetics of CTE production systems are low...typically considered to be about 1.3 to 1, including energy credits allocated to co-products (primarily DDG, or distillers dried grains).⁷
- The environmental aspects of CTE are increasingly considered unfavorable and unacceptable from the perspective of global climate change. Two reports, issued and widely circulated in January 2008, underscore these concerns.⁸

2.1.2 Cellulosic ethanol

Substantial efforts and investments are underway worldwide to develop and commercialize processing technologies for converting cellulosic feedstocks into ethanol (and other biofuels and other energy products). Various conversion technologies are now being deployed, some with significant federal assistance (e.g., through DOE's cellulosic biorefinery program).⁹ As of January 2008, five [known] companies active in the emerging cellulosic biofuels industry:

- **Bioengineering Resources Inc:** Based in Fayetteville, BRI (a privately held company) has developed a proprietary three-step process: gasification of the cellulosic feedstocks, followed by fermentation of the syngas into ethanol by patented microbes, followed by production of anhydrous ethanol using distillation and a molecular sieve. The company has a operational pilot plant and was selected as the technology provider for Alico Inc (LaBelle, FL), one of the recipients of DOE's first round of cellulosic biorefinery awards.¹⁰
- **FutureFuels Corporation:** Based in Batesville, Future Fuels was the first company to produce biodiesel in Arkansas. Future Fuels, purchased by a group of private investors in October 2006 (previously a part of Eastman Chemical Company), has a stated intent to produce and market cellulosic-derived biofuels and has existing plant resources that can be readily redirected to cellulosic processing. The company intends to construct a cellulosic pretreatment demonstration facility; as of January 2008, construction had not begun.¹¹
- **Potlatch Corporation:** In 2005 Potlatch (with assistance from Winrock International and the University of Arkansas - School of Forestry) investigated the potential for establishing a cellulosic processing facility using Fischer-Tropsch adjacent to its existing paper mill at Cypress Bend in southeast Arkansas.
- **Price Companies' Biostock Services:** Based in Monticello, Price Companies Inc was established in 1965 as a lumber, logging, and sawmilling operation. In the 1980s, Price expanded into contract chipping mill services, and now operates nineteen forest produces processing facilities nationwide. Biostock focuses on feedstock acquisition, pre-processing, and delivery, and was selected as the feedstock supplier for Range Fuels, Inc (Broomfield, CO) one of the recipients of DOE's first round of cellulosic biorefinery awards (the project is located in eastern Georgia, using in-forest residues as its primary cellulosic feedstock).¹²
- **Colusa Biomass Energy Corporation:** Based in California, the company has a patented technology for converting cellulosic feedstocks into ethanol. Colusa is particularly interested in rice straw and rice hulls, and has been looking at potential project opportunities in Arkansas.

2.2 Biodiesel

2.2.1 Overview

Biodiesel processing technology is well-established (“off-the-shelf”) and can utilize a variety of feedstocks, including virgin oils (e.g., soybean-derived oil, cotton seed-derived oil), animal fats, and waste vegetable oils. Soybeans contain approximately 20% oil by weight, and Arkansas produced 2.99 million tons (dry matter basis) of soybeans in 2006 (from 3.05 million acres).¹³

In theory, 100% of Arkansas’ soybean production could produce about 126 million gallons per year (MGY) of biodiesel, i.e., approximately 13% of statewide petro-diesel consumption of 1.07 BGY. In actuality, less than 20% of Arkansas’ soybeans are crushed in-state (Total crushing capacity in Arkansas is ~30 MGY), with the balance of the soybeans being shipped overseas in raw form (i.e., with no value-added processing). Combined with 11.5 MGY of cotton seed oil, Arkansas’ total virgin oil production of 41.5 MGY could produce about 41 MGY of biodiesel...except that almost all of that virgin oil is already consumed by food-grade oil markets.

Thus, any biodiesel producer sourcing virgin oil in Arkansas would either have to compete with this established, premium-priced food-grade market or obtain the feedstock from some newly established or expanded crushing facility. In fact, this additional demand for oil as biodiesel feedstock has resulted in higher prices for virgin oil (not just in Arkansas, but nationwide). On top of the historic price volatility of virgin oils, the economics of virgin oil has created havoc for the State’s fledgling biodiesel industry.

In April 2004, Winrock International published a report “Establishing Biodiesel Production Facilities in Arkansas...a Pre-feasibility Assessment,” which concluded that:¹⁴

“...increased production and consumption of biodiesel appears highly desirable, given the numerous associated economic, environmental, and energy security benefits for Arkansas and the United States. However, as noted above, it is unlikely that substantial increases in consumption or production will occur without public sector support or intervention.”

Approximately six months later, a national biodiesel support program was enacted, providing incentive payments of up to \$1.00 per gallon of biodiesel. About one year later, Arkansas’ first biodiesel production facility came online.

The executive summary of Winrock’s April 2004 biodiesel report is included herein as Appendix 3.

2.2.2 Challenges facing the biodiesel industry

Since November 2005, three biodiesel facilities have been established in Arkansas and four more are scheduled for completion in 2008, with a combined production capacity of 120 million gallons per year. However, as with corn-to-ethanol, there are significant concerns regarding soybeans-to-biodiesel operations:

- As described above, the economics of biodiesel production and sales have been volatile and, ultimately, unfavorable, despite continuation of federal subsidies.¹⁵ As of January 2008, actual biodiesel production in Arkansas was only a fraction of potential capacity, with most of the facilities either producing less, temporarily shut down or facing delayed start-up.
- Access to feedstocks is a fundamental concern to the State's biodiesel producers, and has led to intense competition for [limited] non-virgin feedstocks such as animal-derived fats or waste vegetable oil, resulting in price escalation of the feedstocks (which are of inferior quality compared to virgin oils and were initially anticipated to cost significantly less than virgin oils).
- As with corn-to-ethanol, environmental concerns regarding oilseed-to-biodiesel production systems have escalated (associated primarily with land use). For Arkansas, low soybean crop yields (on average, less than one ton per acre per year, dry matter basis) equate to low energy yield (less than thirty gallons per acre per year *net*). However, offsetting this concern somewhat is the net energy balance of soybeans-to-biodiesel, which is substantially more favorable than that of corn-to-ethanol...typically about 3.4 (compared to 1.3 for CTE).¹⁶

2.2.3 Biodiesel from algae

DOE and others have been evaluating algae as a source of oil (for further processing into biodiesel) for decades. Recent energy prices have led to rapidly increasing in this biofuel option, particularly given the estimated energy production per unit of land and time...5,000 ~ 20,000 gallons per acre per year (compared to around 50 for biodiesel from soybeans).¹⁷ If actual (net) production of, say, 10,000 gallons/acre/year could be realized, then only 100,000 acres¹⁸ of algal-biodiesel production would be required to meet 100% of the State's current petro-diesel consumption of 1.07 BGY.

Despite uncertainties regarding the technical viability and economic feasibility of algal-diesel production (there is limited specific data available within the public domain regarding algae-to-biodiesel), substantial interest and investment is underway worldwide in such systems.¹⁹ There are several companies in Arkansas that are actively evaluating algal-biodiesel, with some claiming to be close to commercial deployment. Given the sig-

nificant production potential, this technology warrants serious consideration as a large-scale clean energy pathway for Arkansas.

A more detailed discussion of biodiesel production, distribution, and marketing in Arkansas is set forth in Attachment 1.

2.3 Cellulosic biofuels

2.3.1 Why should we be interested in cellulosic?

As noted in §2.1.2, several Arkansas companies have already initiated specific pursuits of cellulosic biofuels, and numerous additional expressions of interest have been conveyed to the Arkansas Energy Office and Winrock International during the past two years. However, widespread deployment of cellulosic biofuels projects is still considered contingent on satisfactory demonstration of technical and economic viability at commercial scale—a process which is now underway nationwide.⁸

Interest in cellulosic biofuels in Arkansas is driven by:

- The federal RPS requirement of 15 BGY of cellulosic biofuels by 2022;
- The expected favorable economic and environmental benefits;
- Recent advancements in cellulosic processing technologies;
- The abundance of cellulosic residues in the State;
- The significant potential for production of dedicated lignocellulosic energy crops, given the large agricultural land base in Arkansas (14.4 million acres, or 43% of the total land area in the State);²⁰
- The high projected energy yields (gallons/acre/year) compared to other biofuels options (with the potential exception of algae-biodiesel); and
- Recent deployment of commercial-scale cellulosic projects, including high-dollar support from the U.S. Department of Energy (DOE) for biorefineries.
 - In February 2007, DOE awarded six grants totaling \$385 million to help deploy commercial-scale biorefinery projects using cellulosic feedstocks.²¹
 - In January 2008, DOE awarded four more grants totaling \$114 million to help deploy smaller-scale biorefinery projects using cellulosic feedstocks.²²
 - In February 2008, DOE awarded \$34 million to support four projects focused on enzymatic conversion of cellulosic feedstocks into ethanol.²³

2.3.2 Cellulosic feedstocks²⁴

Types of cellulosic feedstocks available (or potentially available) in Arkansas are shown in Figure 3. Biomass residues and energy crops are further discussed below. Key criteria for feedstock selection include:

- access to the material,
- reliability of supply,
- quality (i.e., physical and chemical characteristics),
- energy attributes,
- seasonality,
- acquisition cost,
- location (which equates to cost of transport to the processing facility), and
- other logistical considerations (e.g., the extent to which existing equipment can be used to produce and harvest the material).

Figure 3: Types of cellulosic feedstocks in Arkansas

<i>Category / subcategory</i>	<i>examples</i>
residues / byproducts	
woody	
in-forest	harvesting slash
processing	sawdust
agricultural	
field	rice stubble, wheat straw
processing	rice hulls, gin trash
animal agriculture	
manure	poultry litter
other	processing byproducts
waste streams	
storm debris	woody debris
municipal	biosolids, waste paper
other	landfill gas
dedicated energy crops	
annual	energy sorghum
perennial	
herbaceous	switchgrass, miscanthus, giant reed
woody	hybrid poplar, willow

2.3.2.1 Residues

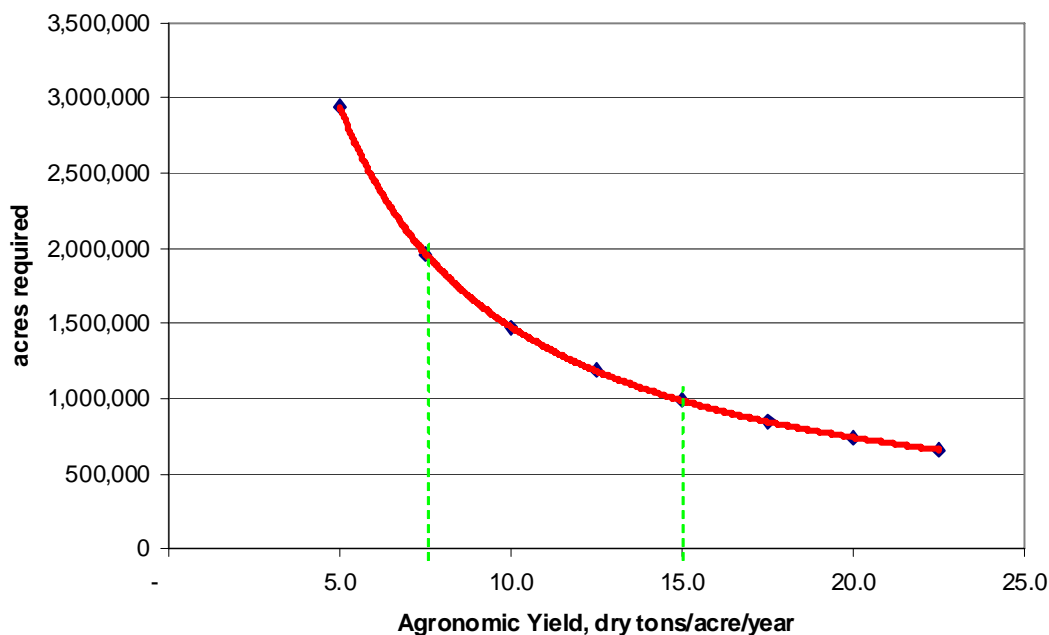
- As shown in §3.2, total “usable” biomass residues in Arkansas are estimated at 13 million tons per year (dry matter basis).²⁵
- Converting, say, 30% of these residues into biofuels could produce about 350 million gallons per year of (at an estimated gross processing yield of 90 gallons per dry ton).
- Most of the woody processing residues generated in Arkansas are already being used for cogeneration by the forest products industry²⁶—any bioenergy project targeting such residues would likely result in substantial price increases.
- In-forest residues are considered by some to be the most attractive biomass residue resource in Arkansas (given the large quantities, geographic distribution, year-round availability, and expected relatively low cost). However, there are some concerns that pursuit of such materials could result in price increases in wood chips for existing fiber markets.

2.3.2.2 Energy crops

- The potential amount of biomass production from dedicated energy crops = agronomic yield *times* crop acreage.
- As with food, feed, and fiber crops, the importance of agronomic yield for energy crops is paramount. Figure 4 illustrates acreage requirements for dedicated energy crops vs. potential production of one billion gallons of biofuels.²⁷
- For example, Production of 1 BGY of ethanol from herbaceous energy crops at an agronomic yield of 15 dry tons per acre per year²⁸ would require 990,000 acres.²⁹
- In contrast, an agronomic yield of 7.5 tons/acre/year³⁰ would require 1,960,000 acres...half the yield requires twice the acreage.
- For comparison purposes, production of 1 BGY of ethanol equivalent from soybeans-to-biodiesel (i.e., 650 MGY of soy-diesel) would require 22 million acres.³¹

Figures 5 and 6 further illustrate the significant anticipated benefits of net energy production of bioenergy from dedicated energy crops; each include a comparison to equivalent energy production from soybeans [to biodiesel]. The various boxes in Figure 5 are all roughly to scale. The relative sizes of the circles in Figure 6 are roughly to scale.

Figure 4: Crop Acreage Requirements vs. Agronomic Yield for production of 1 BGY from cellulosic energy crops



2.3.3 Will deployment of cellulosic-based systems really happen?

There is widespread skepticism regarding the technical/economic feasibility of cellulosic conversion technologies primarily because, to date, no commercial-scale operations have been established. However, billions of dollars have been invested by both the public and private sectors during the past few decades to move cellulosic processing technologies from the lab to commercial reality, and interest (and investments) in such systems has risen dramatically within the past three years.

Just within the past twelve months, the U.S. Department of Energy has invested over \$500 million to support initial deployment of commercial projects using cellulosic feedstocks (this figure does include private sector investments in those projects and in other projects currently being deployed without public support). Results from these recently initiated commercial-scale endeavors should be available within about three years; those results will provide an important basis for go/no-go investment decisions in subsequent biorefinery projects. Given the significant increases in interest, investment, and deployment efforts currently underway worldwide, there is little doubt that production of energy products from cellulosic feedstocks will happen, and the emerging industry is on track for rapid growth.

Figure 5: Production land required to produce 450 MGY of petroleum-derived diesel (equivalent) for different production options and yields

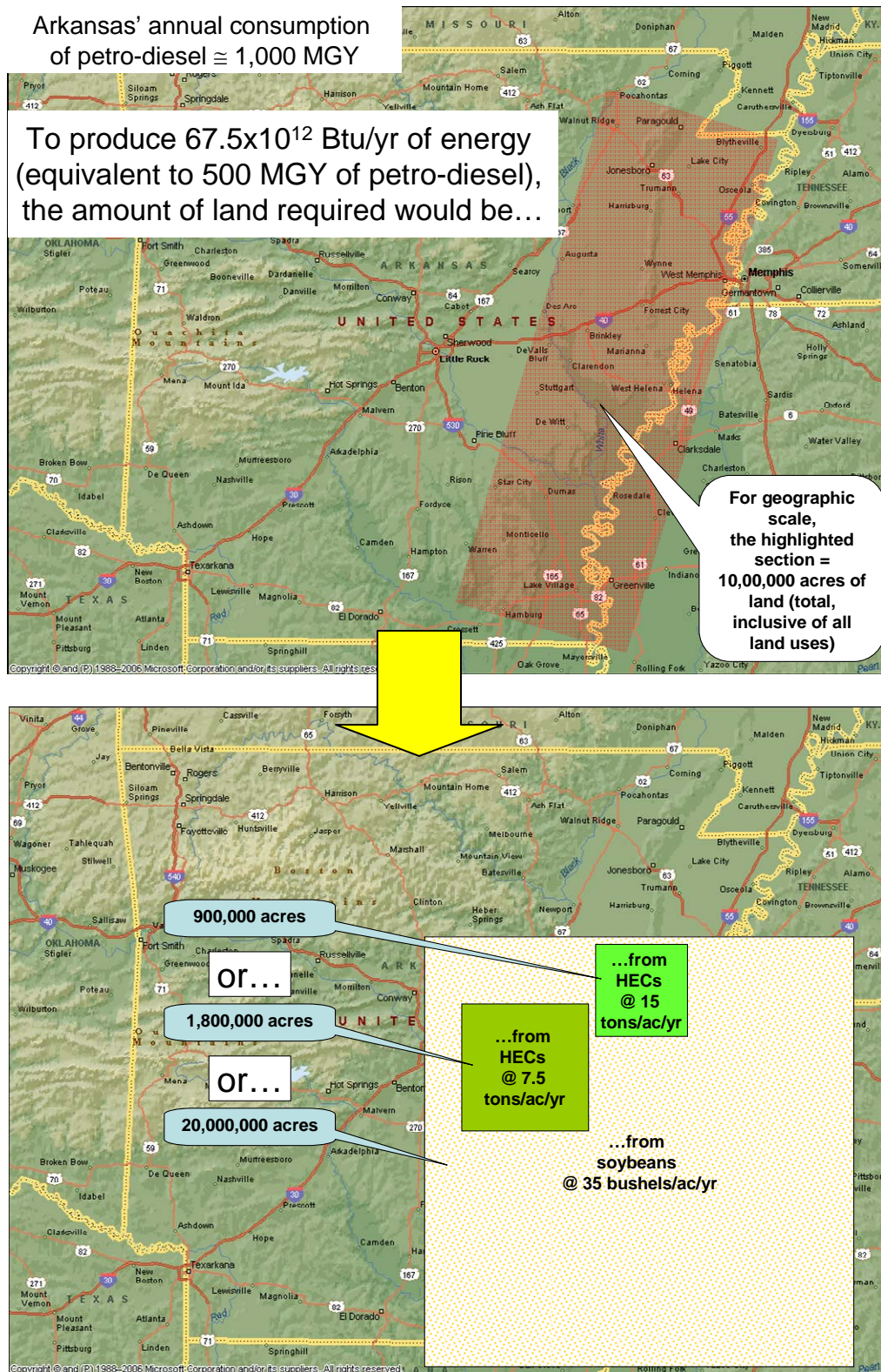
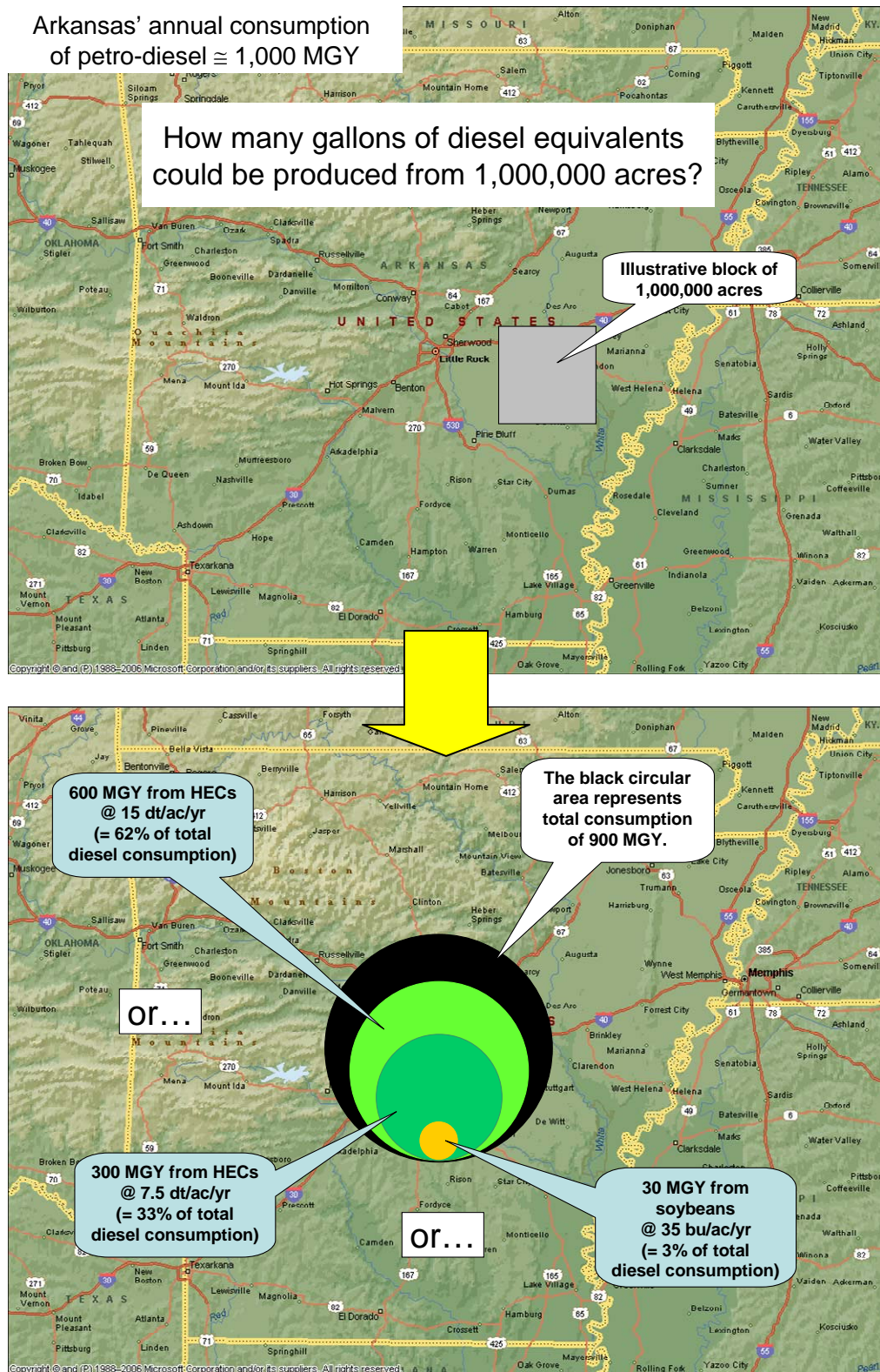


Figure 6: Biofuels production (in gallons of petroleum-derived diesel equivalents) from 1,000,000 acres of farmland for different production options and yields

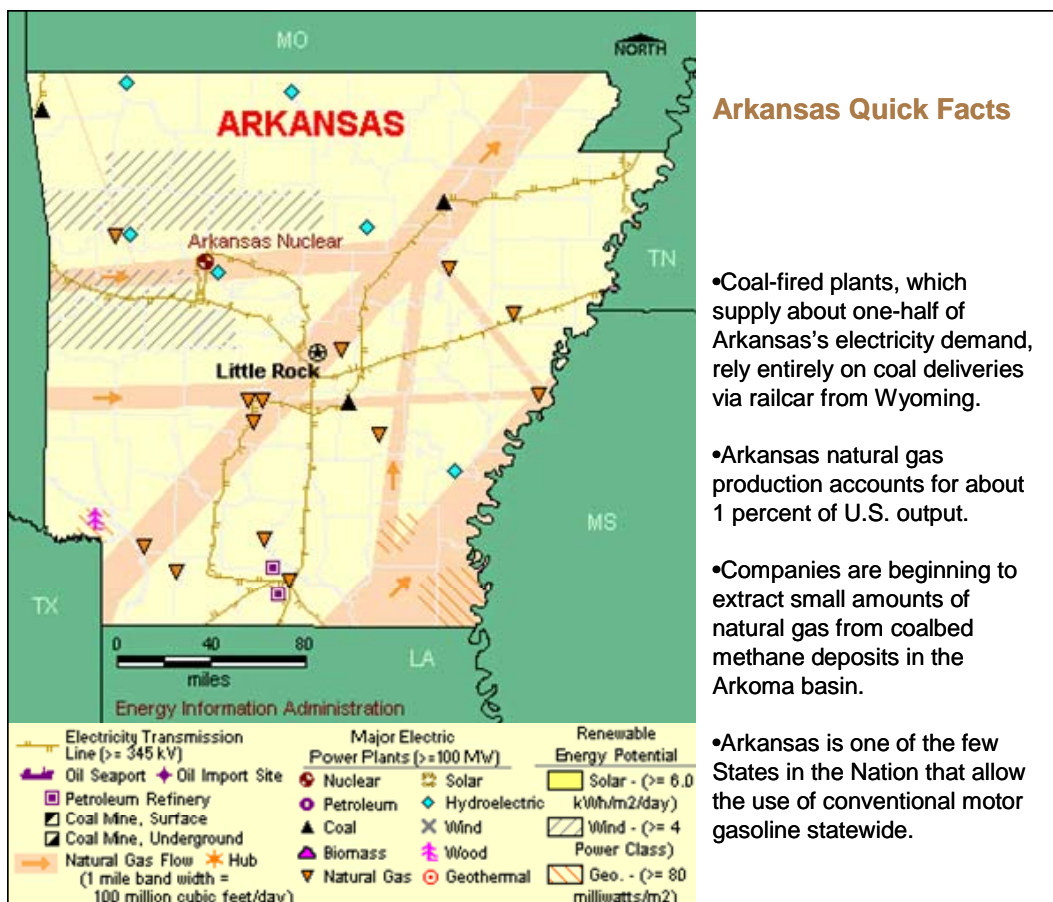


2.4 Electricity

According to the Energy Information Administration (EIA), electricity generating capacity in Arkansas in 2006 was 14,507 megawatts (MW), 26.5% of which was from coal.³² Total generation in 2006 was 52.2 million megawatt-hours (MWh),³³ 19.3% of which was produced by “Independent Power Producers & Combined Heat and Power”. The EIA data does not specifically identify biomass-derived generation, although 3.3% of production was listed as generated from “Other Renewables.”

The simplistic map within EIA’s Energy Profile of Arkansas shows no biomass-fired powerplants and one wood-fired powerplant located in the southwest (presumably the Domtar paper mill in Ashdown [purchased from Georgia-Pacific in 2001]³⁴) – refer to Figure 7.³⁵ However, there are numerous forest products processing facilities in Arkansas that use substantial quantities of woody residues for on-site co-generation—presumably the output from these biomass-fired systems is not reflected in the EIA’s [net] electricity data.

Figure 7: Energy Overview Map of Arkansas (EIA)



Until recently, the State had surplus installed generating capacity; that situation is changing, and utilities are now considering planning for additional generation capacity to meet growing demand for power in Arkansas (in addition to deployment of various energy efficiency programs within the electricity sector).³⁶

2.4.1 Co-firing:

There are three utility-owned coal-fired plants in Arkansas, with one more under construction and one more undergoing permitting:

- Entergy Arkansas Inc's Independence facility (1,678 MW) near Newark.
- Entergy Arkansas Inc's White Bluff facility (1,640 MW) near Pine Bluff.
- Southwestern Electric Power Co's Flint Creek facility (528 MW) near Gentry.
- Dynegy Inc's Plum Point facility (665 MW) near Osceola (under construction).
- Southwestern Electric Power Co's Turk facility (600 MW) near Fulton (construction is pending approval of permits by the Department of Environmental Quality).

The possibility exists, at least in theory, for co-firing biomass at some of these coal-fired powerplants in Arkansas. However, no known co-firing tests have been performed at, nor specific co-firing discussions undertaken with, these facilities/utilities. Nonetheless, the possibility exists, and co-firing could be an attractive option for displacing some coal with biomass and reducing carbon emissions (particularly through co-firing of closed-loop biomass).

2.4.2 Co-generation and stand-alone power generation

In addition to co-firing, options for electricity production from biomass feedstocks in Arkansas include co-generation or stand-alone power generation.

- Co-generation ("co-gen") at large forest products processing facilities (having on-site demand for both thermal and electrical energy) has been economically feasible for many years, as evidenced by the numerous residue-fired co-gen facilities across the State.
- Historically, stand-alone power generation (with export of the power to the grid) using biomass feedstocks has not been able to compete economically with low-cost fossil fuels in Arkansas. However, those economic conditions are rapidly changing nationwide, given:
 - Increasing demand for electricity (requiring more generating capacity);

- Increasing concerns regarding environmental impacts associated with fossil fuels, particularly CO₂ as the principal greenhouse gas (GHG); and
- Increasing costs of fossil fuels, reflecting increasing supplies vs. constant (or decreasing) supplies.

There is widespread expectation within the utility sector that Federal CO₂ emissions regulations are forthcoming, and the investment community expects such emissions to cost \$20~\$40 per ton of CO₂.³⁷ Along with the Federal Production Tax Credits, these changing economic conditions have set the stage for economically attractive stand-alone biomass power generation projects in some locations in the U.S., and there may be future opportunities for such projects in Arkansas.

2.4.2.1 Using residues

- Most (almost all) of the sawdust and other woody processing residues generated in Arkansas are already used as “boiler fuel” (for on-site cogen) within the forest products industry.³⁸ Thus, no significant quantities are considered available for new or expanded energy generation using these feedstocks without economic disruption to the existing markets for woody residues.
- Approximately fifty percent of the rice hulls generated by rice mills in Arkansas are being used for on-site cogeneration. Essentially all of the hulls not being used for energy are being used as bedding material by the State’s poultry industry.³⁹
- There has been some interest in using rice straw as a feedstock for bioenergy production, primarily given the relatively high straw production¹—estimated at 5.1 dry tons per acre, with total estimated annual production in Arkansas at 7.04 MM tons per year.⁴⁰
- In 2005 a study was conducted in Jackson County to evaluate the feasibility of harvesting rice straw for bioenergy production. The primary technical barriers were limited field access due to weather conditions and technical problems associated with feedstock pre-processing (reflecting the high silica/ash content of rice straw).
- The cost of feedstock harvesting was estimated at \$27 per dry ton. No follow-on commercial project has been pursued to date.⁴¹
- As of January 2008, other than the on-going use of rice hulls for on-site thermal energy at several rice mills, no other agricultural residues are known to be used for energy generation in Arkansas.

¹ As discussed in §3.2, *gross* production figures should be discounted by ~60% to obtain *net usable* production, reflecting the estimated portion of field stubble that can be sustainably removed, based on ecological considerations.

2.4.2.2 Using poultry litter

For over fifteen years there has been interest in using litter as an energy feedstock, both at farm-scale and for relatively large, centralized, litter-to-energy power-generating options. Although, as of January 2008, no such systems have been commercially deployed in Arkansas (at either farm-scale or centralized), there is on-going interest in and some continuing research efforts underway regarding use of litter as an energy feedstock. Refer to §2.7.2 and §3.4 for more information regarding litter-related issues and options.

2.4.2.3 Using biogas or landfill gas

Biogas, a medium energy density fuel (35%~65% methane content), is produced from anaerobic digestion of liquid feedstocks such as slurried manure.

- In 1993, Winrock International (with funding support from DOE and the Arkansas Energy Office), installed a floating cover on an anaerobic lagoon for biogas capture at a commercial swine farrowing farm in central Arkansas. The project successfully demonstrated and quantified biogas recovery.
- The City of Little Rock's Fourche Creek Wastewater Treatment Plant has been using digesters for treatment of and energy generation from sewage sludge since the early nineties. The biogas is used in an engine/generator to produce electricity to help operate the wastewater treatment plant.⁴²
- The economics of biogas generation, recovery, and utilization are site-specific and subject to economies of scale. Experienced expertise is needed for digester system design to ensure effective performance and minimize upsets. Several companies specializing in digester design and/or biogas recovery/utilization can be located through internet searches, including RCM Digesters, the company that provided technical assistance to Winrock on the swine lagoon project in central Arkansas.⁴³

Landfill gas (LFG) is produced as a result of anaerobic digestion of the organic fraction of the buried garbage within landfills. In January 2006, an LFG system was dedicated at the Two Pine Landfill in Jacksonville, AR.⁴⁴

2.4.2.4 Using dedicated energy crops

Dedicated cellulosic energy crops could be used as feedstock for thermal/electrical production at co-gen or stand-alone facilities (or for co-firing at coal-fired powerplants). Refer to §2.3.2.2 for more discussion regarding dedicated energy crops.

2.5 Process heat

In general, production of thermal energy from biomass feedstocks entails substantially higher system efficiency than electricity generation, leading to more favorable economics of thermal energy from biomass vs. electricity. Thus, installation of bioenergy systems adjacent to existing thermal loads is generally considered strategically attractive for siting bioenergy systems.

One example of the potential for generating process heat from biomass is at FutureFuels. The company has three relatively small coal-fired boilers for generating thermal energy for on-site use, and has considered using biomass feedstocks to displace some of the coal.

2.6 Space heating

2.6.1 Residential/small commercial

Cordwood is still widely used as a fuel for space heating in Arkansas (in fireplaces, stoves, inserts, and small furnaces). EIA's Residential Sector Energy Consumption Estimates (1960~2004) shows '04 cordwood consumption at 1.94 trillion Btu statewide, which equates to an average per capita consumption of about 130 pounds per year (down from over 1,400 pounds per person in 1960). Lynndale Manufacturing Inc, based in Harrison, is a manufacturer of cordwood-fired furnace systems for residential/light-commercial applications.⁴⁵

- Packaged cordwood is widely available from many retail locations; prices in northwest Arkansas are in the range of \$5.00 per 0.75 cubic foot package, which equates to a net energy cost to the consumer of \$36 per Btu.⁴⁶
- Bulk cordwood is commonly available in northern Arkansas (January 2008) for roughly \$100 per cord (in rural areas, near a supply location), which equates to a net energy cost to the consumer of about \$4.40 per MM Btu.⁴⁷

Pellet-fired appliances have increased in popularity over the years.

- Compared to cordwood, pellet-fired stoves and fireplaces are more convenient and have significant environmental benefits, and are often more economical.
- Premium grade wood pellets are now widely available in northern Arkansas (January 2008); Prices in Fayetteville are ~\$4.10 per 40-pound bag, which equates to a net energy cost to the consumer of \$16.60 per MM Btu.⁴⁸ Where possible, use of pellets in bulk form is more economical (pellets in bulk form can be managed using existing storage and handling equipment; delivered costs range from ~\$110/ton to ~\$160/ton, depending on the transport distance from the pellet mill).

2.6.2 Poultry farms

Propane fuel for space heating is the single greatest operating expense for poultry growers. Propane prices have risen sharply in recent years, reaching in late 2007 what are widely considered to be critical levels in terms of economic viability of poultry production. As a result, there has been increasing interest within the poultry industry in biomass-fired furnaces for meeting most of the space heating needs within poultry houses, thereby displacing most of the propane. Refer to §3.4 for additional discussion regarding this topic.

2.7 *Wood pellets & densified biomass products*

2.7.1 Woody feedstocks

Relative to raw biomass, densified biomass products (e.g., pellets, cubes, briquettes) have improved handling and combustion characteristics (thereby expanding utilization options and reducing emissions) and have increased energy density (thereby enhancing transport economics).

As of February 2007, there are four known woody biomass densification operations in Arkansas:⁴⁹

- **Balcones Resources:** Based in Austin, TX, with an operation in Little Rock, Balcones manufactures fuel cubes from organic waste streams, including waste paper.⁵⁰
- **Fiber Resources:** Based in Pine Bluff, the company has been manufacturing wood pellets since 1990. The company's premium-grade wood pellets, made from oak residues and marketed nationwide, are marketed primarily for use in pellet-fired stoves and fireplaces.⁵¹ The company also produces a range of flavored pellets for pellet-fired barbecue appliances.⁵²
- **Biowood:** Based in Monticello, the company began making premium-grade wood pellets from kiln-dried oak flooring residues in January 2007; the company has a product marketing agreement with Pennington Seed
- **FutureFuels:** The specialty chemical company in Batesville established a premium-grade wood pellet operation in 2007.⁵³

2.7.2 Litter feedstocks

As a fuel, pelletized poultry litter has significant advantages over raw litter (e.g., uniform moisture content, improved characteristics for handling and combustion, higher energy density). However, litter's high ash content (typically ranging from 15% to 24% by weight) makes it expensive to pelletize, and the resulting pellets still have much higher ash content (and have lower energy content) than other densified biomass fuels.⁵⁴

A litter pelletizing facility near Bentonville in northwest Arkansas intermittently produced litter pellets during the past seven years; as of February 2008, the facility was not in operation. Although the company's products were targeted at fertilizer and soil amendment markets, the litter pellets were successfully used for combustion tests in a pellet-fired furnace demonstration system during 1997~1998 by the University of Arkansas. Refer to §3.4 for additional discussion regarding poultry litter as a fuel.

3. Additional Discussion

3.1 Energy-related data for Arkansas

Key sources providing some energy-related information and data for Arkansas include:

- Energy profile of Arkansas, from the U.S. Department of Energy's Energy Information Administration (EIA).
http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=AR
- State Energy consumption Estimates from EIA.
http://www.eia.doe.gov/emeu/states/sep_use/notes/use_print2004.pdf
- The section regarding Arkansas is included as Appendix 4.
- State Energy Price and Expenditure Estimates from EIA.
http://www.eia.doe.gov/emeu/states/sep_prices/notes/pr_print2004.pdf
- The section regarding Arkansas is included as Appendix 5.
- *2007 Arkansas Energy Data Profile*; prepared by the Walton College of Business, University of Arkansas, for the Arkansas Energy Office; Nov07.
http://www.arkansasedc.com/business_development/energy/files/PDF/Energy%20Data%20Profile%202007.pdf

3.2 Biomass resources

3.2.1 1994 – The first assessment

Arkansas' first biomass resource assessment was prepared by Winrock International in 1994. The report, prepared with support from DOE and the Arkansas Energy Office (and available in hard copy only), was based in large part on 1992 USDA Agricultural Census data. The results, presented by county in both tabular and graphical formats, identified and quantified biomass in four principle categories:

- Forest resources (in-forest residues, processing residues)
- Agricultural resources (field residues, processing residues)
- Animal biomass (manure, litter)
- Municipal (e.g., biosolids, urban green waste, storm debris, waste paper)

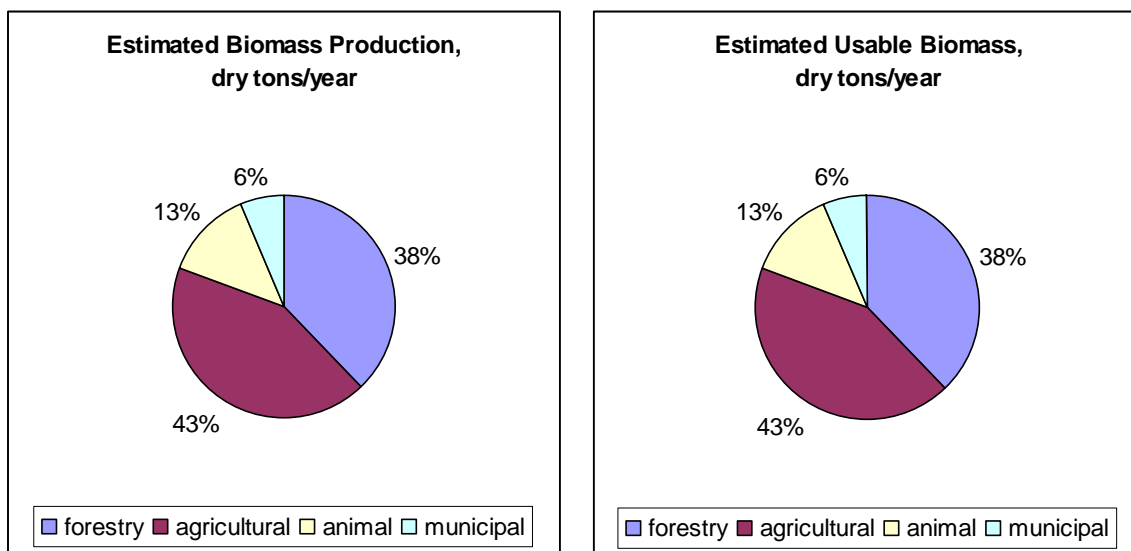
3.2.2 2005 update

The data (and some of the factors used to convert production data into residue data) were updated in 2005 (based on production data set forth in the 2002 agricultural census), with support by DOE (through the Southern States Energy Board) and the Arkansas Energy Office. The results have been available at the AEO's website.

3.2.3 2007 update

Some of the data has been further updated as part of this bioenergy assessment (in coordination with the University of Arkansas). The agricultural data reflects 2006 NASS data, and the forestry data reflects 2006 data from the US Forest Service's Forest Inventory and Analysis (FIA) program⁵⁵ and 2007 severance tax data from the Arkansas Forestry Commission. The municipal and animal biomass data sets have not been updated. Graphics of the summary results of the updated assessment of biomass resources in Arkansas are set forth in Figures 8 & 9. A summary table of biomass residues in Arkansas is set forth in Figure 10. Additional information is provided in Appendix 6.

Figures 8 and 9: Summary of Biomass (Residue) Resources in Arkansas



- NASS' 2007 Agricultural Census is expected to be available by about June 2008, at which time the agricultural and animal biomass data and calculations could be further updated.
- Source data resolution continues to be limited to county level due to USDA's disclosure rules, although location-specific feedstock production analyses based on NASS'

microdata set would be more meaningful to project developers and others trying to evaluate specific potential bioenergy opportunities.

- Estimated usable (sustainably removable) quantities of in-forest residues, poultry litter, rice straw, and other agricultural field residue in Arkansas are shown in Figures 11, 12, 13, and 14, respectively.

Figure 10: Summary Data regarding Biomass (Residue) Resources in Arkansas

	Production Quantity, tons/year (1)	Estimated Usable Quantity, tons/year (1)	Usable / Total Production
Forestry			
in-forest residues			
softwoods	2,385,000	1,567,000	66%
hardwoods	3,738,000	2,594,000	69%
primary milling residues			
pine	4,339,000	1,836,000	42%
hardwoods	1,414,000	598,000	42%
sub-total forestry	11,876,000	6,595,000	56%
Agricultural			
field residues			
Corn	557,200	185,000	33%
Cotton	540,000	109,500	20%
Rice	6,201,000	1,678,000	27%
Sorghum	92,000	-	0%
Soybeans	4,351,000	-	0%
Wheat	728,100	65,300	9%
processing residues			
Cotton	112,500	112,500	100%
Rice	837,000	837,000	100%
sub-total agriculture	13,418,800	2,987,300	22%
Animal manure			
Cattle manure			
beef	2,114,000	0	
dairy	138,000	0	
Swine manure			
hogs & pigs for breeding	12,000	0	
other swine	14,000	0	
Poultry			
broilers	1,325,000	1,325,000	100%
layers	142,000	142,000	100%
replacement pullets	46,000	46,000	100%
turkeys	281,000	281,000	100%
sub-total agriculture	4,072,000	1,794,000	44%
Municipal			
biosolids	41,000	21,000	50%
other biomass	1,992,000	1,494,000	75%
sub-total municipal	2,033,000	1,515,000	75%
Total biomass	31,399,800	12,891,300	41%

(1) dry matter basis (0% m.c.)

Figure 11: In-forest Residues in Arkansas

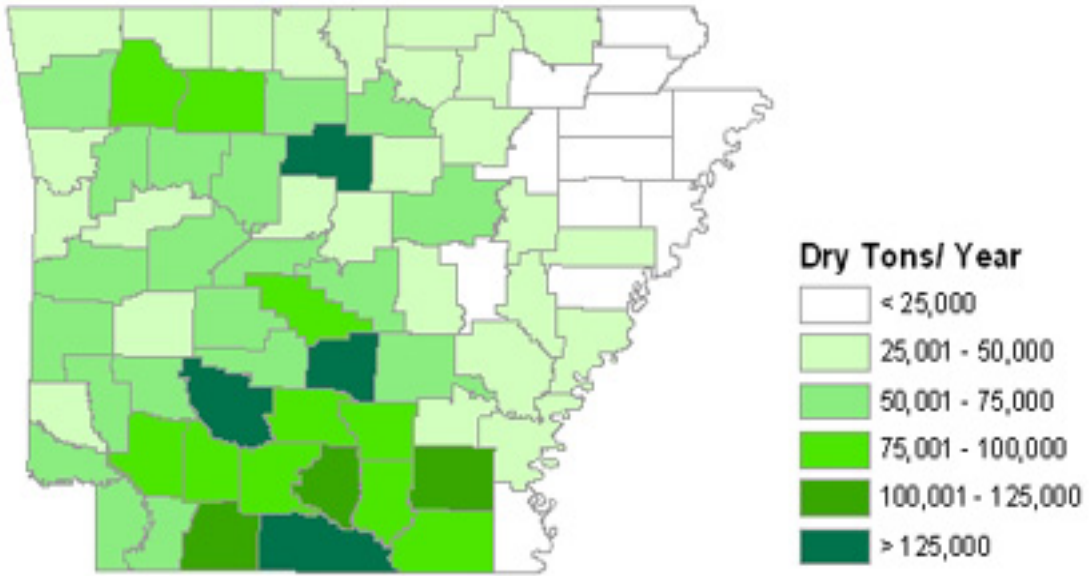


Figure 12: Poultry Litter in Arkansas

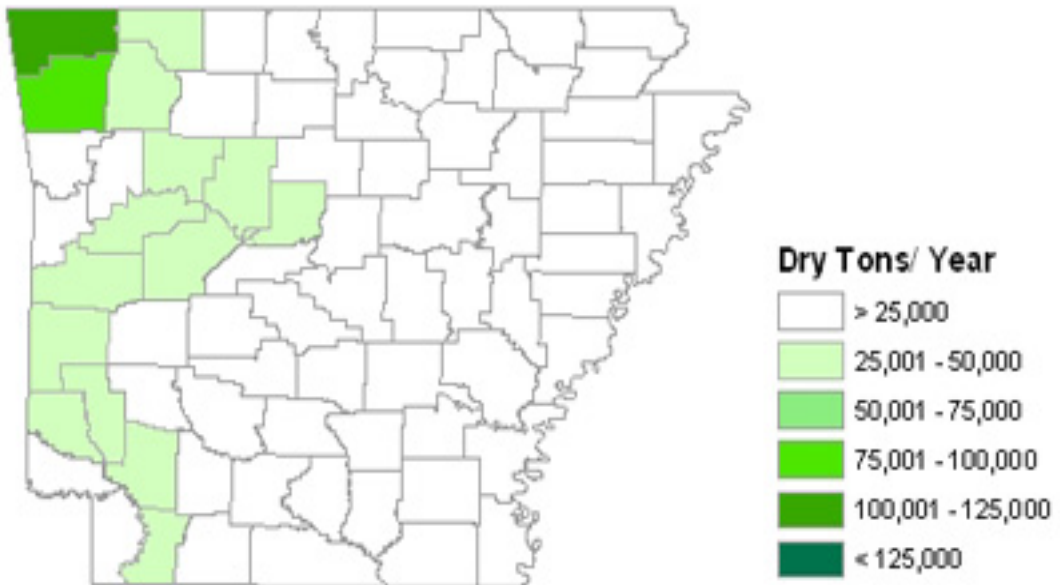


Figure 13: Rice Straw in Arkansas

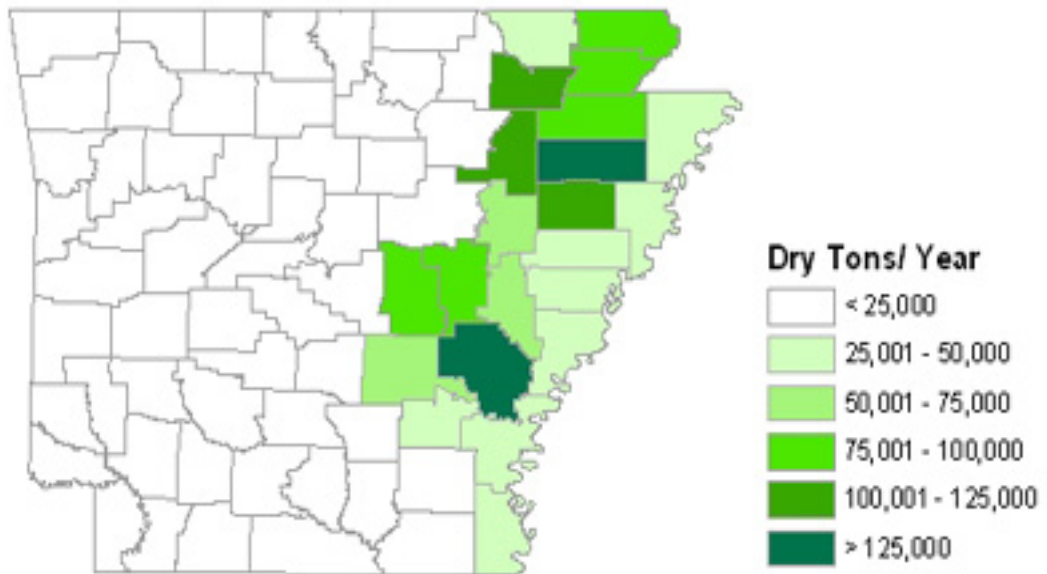
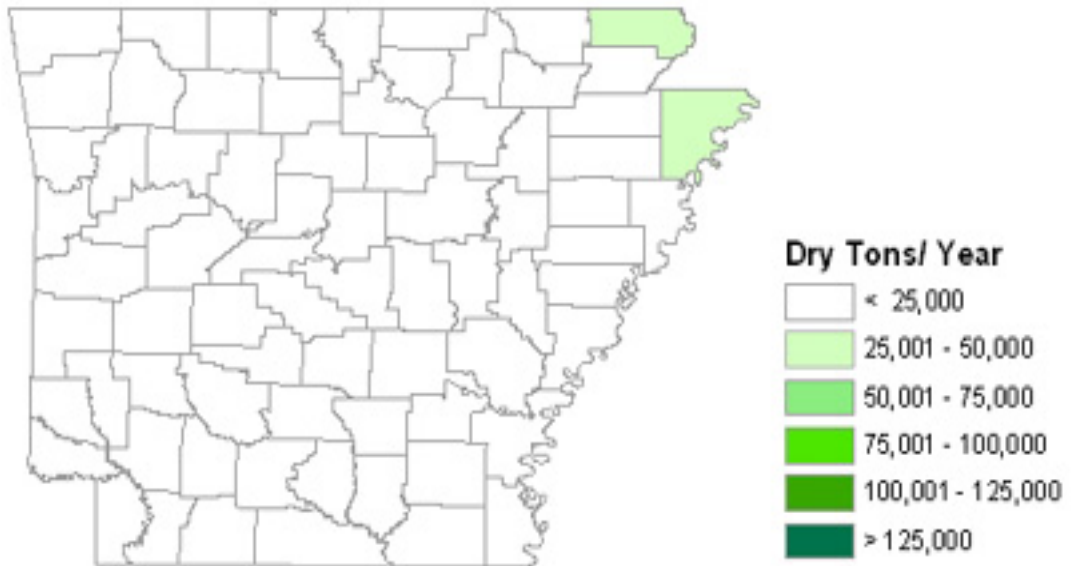


Figure 14: Other Agricultural Field Residues in Arkansas



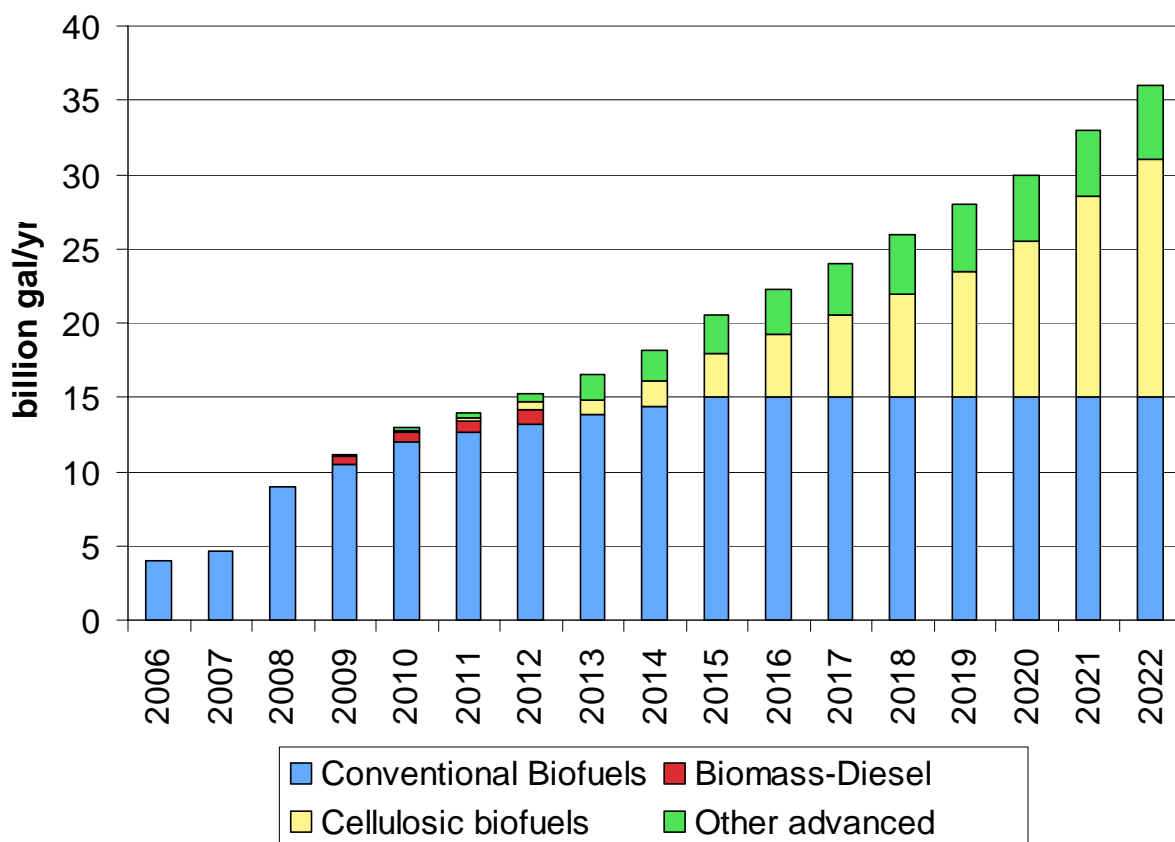
3.3 Biofuels

3.3.1 Federal Renewable Portfolio Standard (RPS)

The Energy Independence and Security Act of 2007 (HR6) established nationwide production requirements for certain biofuels through 2022.

- As shown in Figure 15, the RPS entails a 3-fold increase (relative to 2007 production levels) to 15 BGY by 2015 of corn-derived ethanol production.
- Also as shown in Figure 15, the RPS entails a ramp-up of cellulosic biofuels (anticipated to be primarily cellulosic ethanol) beginning in 2011 to over 15 BGY by 2022.

Figure 15: National Renewable Fuels requirements under the 2007 RPS



3.3.2 List of retail purchase locations

A list of retail locations around the State where biofuels can be purchase by consumers is maintained by the Arkansas Farm Bureau:

http://www.arfb.com/commodity_marketing/biodiesel/

The Arkansas Oil Marketers Association (AOMA – www.aoma.org) is involved in transport, distribution, and storage of biofuels in the State. As such, OAMA and its members are concerned about:

- biofuel supplies (e.g., seasonal variations in wholesale supplies);
- biofuel quality (e.g., cloud point of biodiesel and the ability to ensure that fuels meet ASTM/EPA specifications);
- logistics specifically related to biofuels (e.g., biodiesel requires separate storage /tankage prior to blending and generally requires tank heating during winter periods);
- reporting and other regulatory requirements (e.g., EPA requires RINs⁵⁶ to track biofuels sales, which encompass significant levels of paperwork on the part of biofuel distributors/blenders);
- perceived problems (e.g., cold-start problems, potential voidance of engine warranties); and
- cost.

The above-noted concerns regarding biofuels have led to some reluctance on the part of the existing oil marketing industry in Arkansas to embrace biofuels. The bottom line is that the economic margins realized by biofuels blenders, distributors, and marketers must be sufficiently high to offset the real or perceived concerns and additional costs associated with biofuels.

3.3.3 Energetics analyses

A topic of significant concern regarding biofuels production is the energetics associated with each biofuel, i.e., the amount of fossil energy equivalents consumed (directly and indirectly) during the production of a gallon of a given biofuel. For example, several energetics analyses of corn-derived ethanol have concluded that 1.0 gallon of fossil fuels [ethanol equivalents] is consumed during the production of about 1.3 gallons of ethanol. Thus, the net energy balance is 1.3/1.0, or 1.3.

Such energetic analyses are complicated, particularly when considering embedded energy. A recommended portal into the world of energetic analyses of biofuels can be found at the Institute for Local Self Reliance's website, prepared by Dr. David Morris, Vice President of the nonprofit organization based in Minneapolis.

<http://www.newrules.org/agri/netenergy.html> ILSR also maintains a list of current topics of discussion regarding biofuels and bioenergy in its Democratic Energy section:

<http://www.newrules.org/de/index.html>

3.3.4 Simple comparison of biofuels production

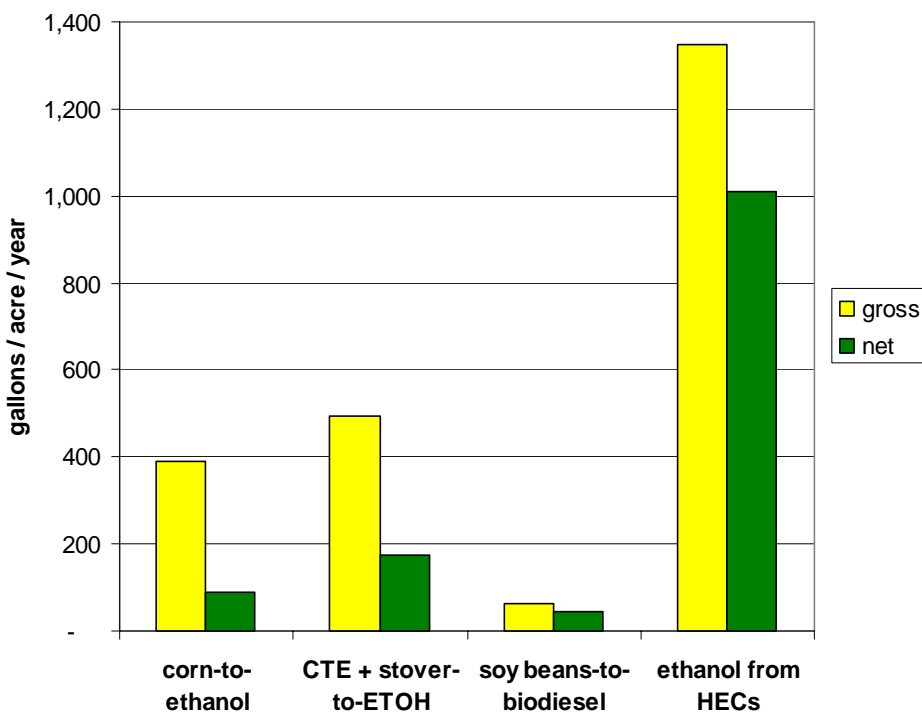
In addition to ethanol, cellulosic feedstocks can be used to make a variety of biofuels, including hydrocarbon-derived equivalents (e.g., renewable gasoline and renewable diesel).

3.3.4.1 Biofuels options and crop yield

A comparative analysis of gross and net energy production (in gallons per acre per year) from corn-to-ethanol, soybeans-to-biodiesel, and dedicated cellulosic energy crops to ethanol is shown in Figure 16 (for which crop yield figures for corn and soybeans are based on 2006 USDA data; the crop yield estimate for herbaceous energy crops is based on extrapolated results from test plots in other locations around the country). The four options shown in Figure 16 entail:

- Corn-to-ethanol (CTE), using traditional fermentation processes.
- Traditional CTE, plus cellulosic conversion of the corn stover into ethanol.
- Soybeans-to-biodiesel (using virgin soy feedstocks via esterification).
- Ethanol from dedicated herbaceous energy crops using cellulosic processes.

Figure 16: Comparative Analysis of Biofuels Production Options



The supporting assumptions and calculations are shown in tabular format in Appendix 7. While the graphic clearly illustrates the potential advantage of using Arkansas' land resources to produce biofuels from dedicated herbaceous energy crops (HECs), a key assumption within the HEC calculations is an assumed agronomic yield of fifteen tons (dry matter basis) per acre per year.

While this yield is substantially higher than the current nationwide average yield of 8 tons/acre/year commonly cited for switchgrass,⁵⁷ such a yield is considered achievable under Delta conditions because:

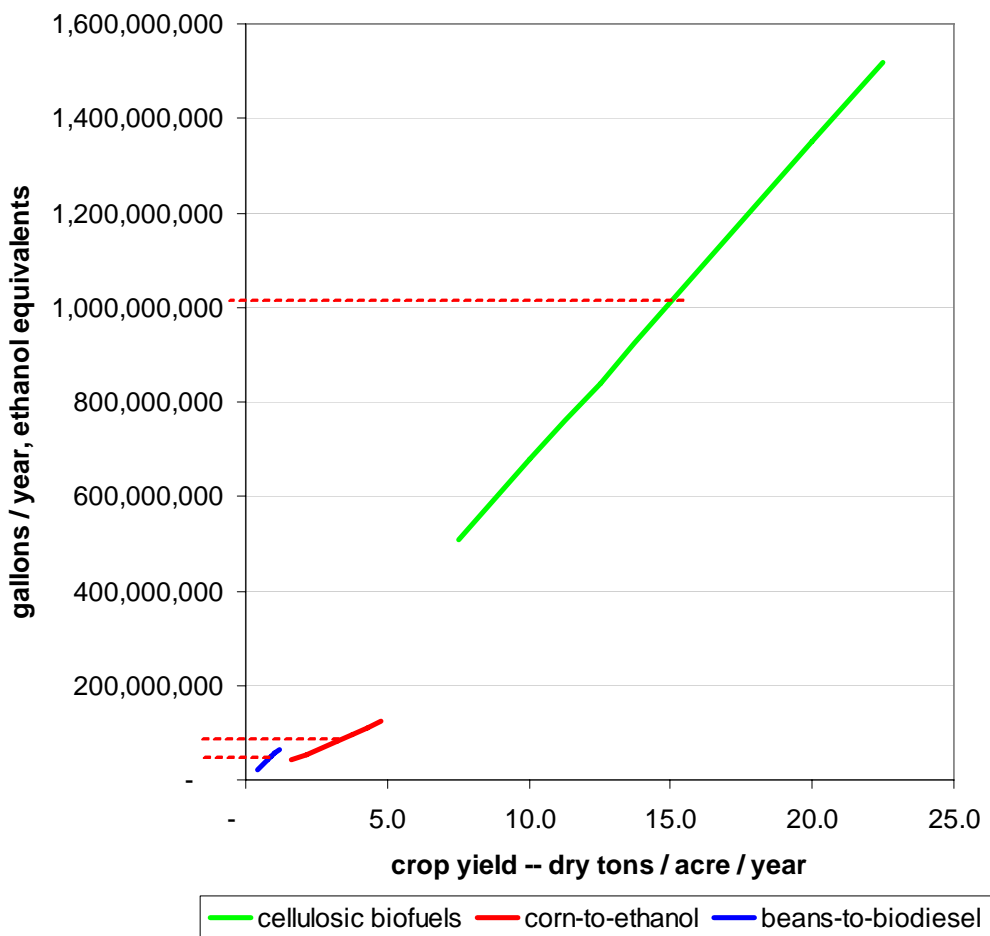
- Growing conditions in the Delta region are typically above average.
- Yields of switchgrass in the range of 15 dry tons/acre/year have been attained under above-average conditions in other locations.⁵⁸
- Yields of other energy grasses (e.g., miscanthus, napier grass, giant reed) have been shown to exceed those of switchgrass at several side-by-side research locations. One such set of trials is at the University of Mississippi in Starkville, where yields in the range of 17~19 dry tons/acre/year have been obtained for miscanthus during the past few years.⁵⁹ Another such set of trials were undertaken during 2000~2004 in Jacksonville, FL, where giant reed significantly outperformed switchgrass and other perennial grass/woody crops.⁶⁰
- Investment of public and private resources into agronomic research will almost certainly lead to significant future improvements in yield and other desired characteristics of energy crops (as has been the case with hundreds of food, feed, and fiber crops during the past century).

The importance of crop yield cannot be over-emphasized. Figure 17 illustrates the impact of agronomic yield on net biofuel production on one million acres for the three basic biofuel options. For each option, a curve depicts the production range—in net gallons per acre per year of ethanol equivalents—equating to a fifty percent (+/- 50%) yield variation. Even at 50% yield reduction for herbaceous cellulosic energy crops and a 50% yield increase for soybeans or corn, the “2nd generation” cellulosic biofuel option substantially outperforms the “1st generation” corn-to-ethanol or soybeans-to-biodiesel options. Several important observations can be made from the calculations and graphics presented herein:

- Potential production of cellulosic biofuels options is substantially more attractive than 1st-generation biofuels.
- The agronomic yield of cellulosic energy crops is paramount (as it is with all commercial agricultural crops).

- Highest attainable yields equates to the most efficient utilization of land resources.
- Additional efforts and resources are needed to evaluate cellulosic feedstock production in Arkansas, particularly in the Delta region.

**Figure 17: Net Biofuels Production vs. Agronomic Yield
(on 1,000,000 acres of crop production)**



3.3.4.2 Future production of cellulosic feedstocks in Arkansas

As discussed in the previous section, there is enormous potential opportunity for producing dedicated cellulosic feedstocks in the Delta region. Looking ahead over the next few decades: as demand for energy (particularly energy for vehicles, which is the most valuable and expensive form of energy) continues to increase while supplies continue to diminish (or, at best, remain constant), there will be an increasing need to identify and embrace the most resource-efficient options for producing renewable transportation fuels.

Given the vast agricultural resources of Arkansas' Delta region (e.g., over 7 million acres of active cropland), the State has an excellent opportunity to position itself as a major producer of ag-derived energy. Moreover, large-scale production and processing of cellulosic feedstocks could lead to levels of capital infusion and economic benefits that could transform the entire region.

But such a commercial bioenergy industry in the Delta will only occur if private project developers are able to put together viable projects and obtain financing. And, while there are substantial capital resources now being invested in bioenergy activities worldwide, capital resources will only flow to specific projects if perceived risks are within acceptable tolerance levels.

At this time the unknowns associated with cellulosic feedstock production in the Delta region create uncertainties (i.e., risks) that constrain investment. Thus, the key to embracing the future of bioenergy in the Delta is to invest the necessary resources now to address those uncertainties and pave the way for deployment of commercial bioenergy projects in the region.

3.3.4.3 Key uncertainties that need to be addressed

- **Yield:** As discussed in §3.3.4.1, agronomic yield is critical and, to date, there is almost no yield data available for cellulosic crops under Delta conditions. In 2007 the University of Arkansas began planting switchgrass on several test plots in eastern Arkansas.⁶¹ Resources are needed to expand those efforts...more species, more test plots, and more field-scale plantings.
- **Landowner participation:** A key issue facing establishment of cellulosic production systems will be farmers' willingness to plant perennial crops (herbaceous or woody). Perennial crops entail considerable capital cost and typically take 2 or more years before generating revenues. Plus, alternate markets for harvested biomass are limited (or non-existent). And, commercial processing facilities will require long-term supply contracts (necessary for those facilities to obtain financing). Finally, there would be no annual planting flexibility with perennial crops, and there would be a cost associated with eliminating the crop and replanting traditional/alternate crops (assuming that the farmer could break the long-term supply contract).

On the other hand, production of perennial biomass crops would essentially eliminate the growers' crop marketing risks and offer long-term economic security. And, of course, net revenues from biomass crop production will need to be economically attractive to the producer/landowner (compared to other crop options, taking into account reduced risk factors).

Strategies are needed to address this chicken-or-egg dilemma...planting of dedicated energy crops will likely not proceed without adequate assurance of a market (i.e., a biomass processing facility), but a biomass processing facility will likely not be able to secure financing and be constructed without adequate assurance of feedstock supply. To lay the groundwork for embracing a large-scale bioenergy industry in Arkansas using dedicated cellulosic crops, efforts are needed to develop implementation strategies (e.g., creation of biomass production cooperatives) that can effectively address this dilemma.

3.3.4.4 Other locations for producing cellulosic feedstocks in Arkansas

Other regions in Arkansas also have potential for energy crop production:

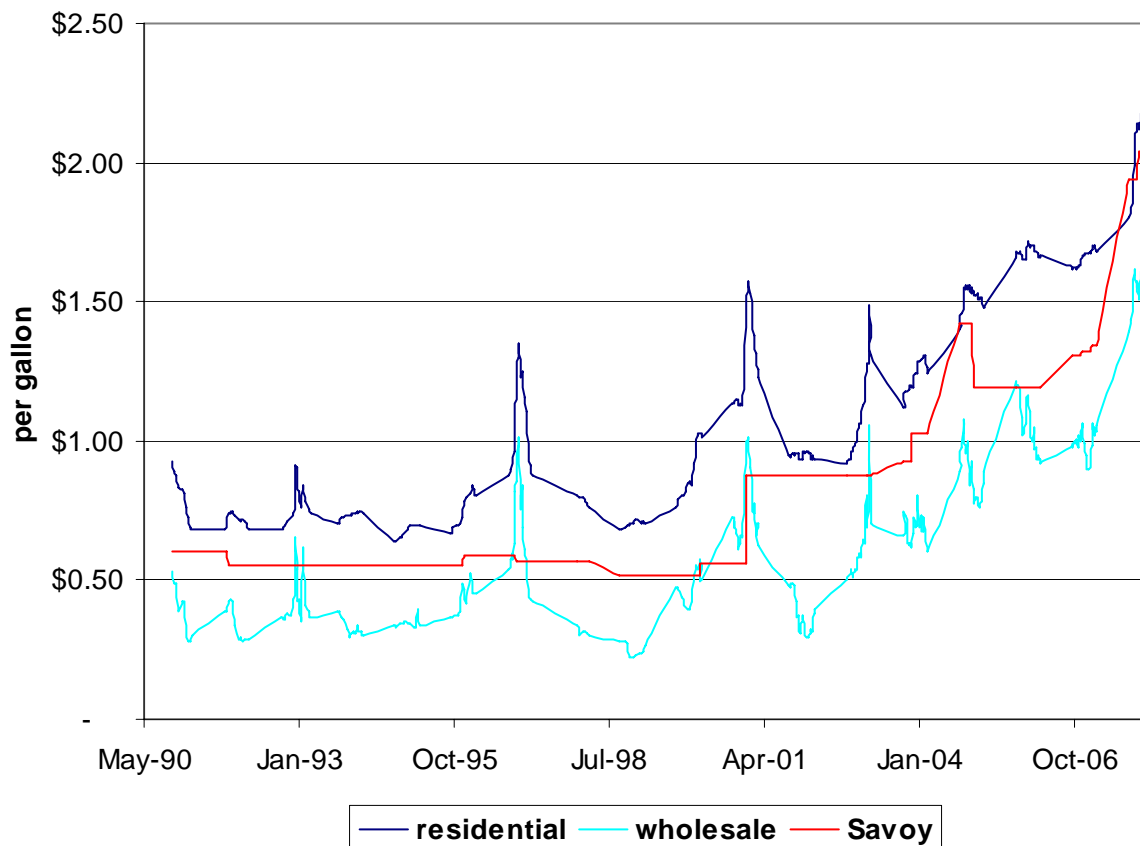
- **Forestlands:** In addition to in-forest residues from active timberlands in southern and northern Arkansas, the potential exists for establishing dedicated woody crops. While yields are expected to be significantly lower for such stands compared to, say, herbaceous crops on Delta soils, land and production costs are also expected to be much lower, so that the net economics of woody crops may be attractive.
- **Pasturelands** in areas of concentrated animal agriculture: Due to environmental concerns, there are increasing pressures to reduce land application of poultry litter and liquid manure streams from confined feeding operations. In certain areas, restricted land application of these materials may result in decreased grazing and/or a need to reduce accumulated levels of certain nutrients (e.g. phosphorus). Production of energy crops may be an attractive option for many such lands, in that herbaceous energy crop production could provide an alternate land use option and revenue source to landowners (i.e., instead of running cattle) as well as means of remediating certain soils.⁶²

3.4 Heating poultry houses

Propane for space heating is the single greatest operating expense for poultry growers, and propane prices have risen dramatically in recent years—refer to Figure 18.⁶³ As a result, the industry is looking for ways to reduce propane consumption, with emphasis on:

- **Energy efficiency practices**, such as house sealing and insulating (applicable to both traditional curtain houses and those converted to tunnel ventilation).
- **Alternative heating systems**, e.g. use of biomass-fired furnaces; in particular, there has been considerable interest during the past year in using corn-fired furnace systems.

Figure 18: Propane Prices in Northwest Arkansas⁶⁴



3.4.1 Litter-fired furnaces

There is continuing interest in litter-to-energy systems, both on-farm and centralized. For on-farm applications (for which growers must purchase and operate the system), a commercially-feasible litter-fired system must meet four essential criteria:

- **Technically viable:** all aspects of the system (e.g., feedstock storage, handling, and in-feed; combustion; controls; ash management) must be proven.
- **Environmentally acceptable:** recognizing the high levels of impurities in litter, this would apply to feedstock handling, ash handling, and air emissions.
- **User-friendly:** most poultry growers do not have the time or desire (or ability) to work with a pre-commercial technology; for poultry farms, a “black box” type product is needed that is reliable and entails minimal effort by the grower for operation (and maintenance).
- **Economically feasible:** the system must be affordable (and finance-able).

The attractiveness of converting litter to usable energy on the farm is obvious...avoid transporting the litter elsewhere, and reduce (or avoid) the various concerns associated with land application of the litter (although most poultry growers still consider litter a farm asset, and the material's agronomic benefits are well demonstrated). For at least fifteen years, numerous efforts (and significant investments—both public and private) have been made to develop a farm-scale litter-fired energy system that would meet the threshold criteria noted above.

Most systems have focused on thermochemical processes (primarily combustion, but also gasification and pyrolysis), although some have pursued anaerobic digestion (which entails taking dry litter—typically about 25% moisture content—and adding water to create a slurry feedstock for the digester). To date there have been no significant successes, and it now appears unlikely that *any* farm-scale system can be developed that would meet the first three criteria *and* the final criterion (i.e., economically feasible).

3.4.2 Centralized litter-to-energy

Several studies during the past ten years have concluded that a centralized (off-farm) litter-to-energy system provides the most attractive option for managing surplus litter in areas of concentrated poultry production.⁶⁵ The technical feasibility of litter combustion is well-demonstrated: Fibrowatt has been operating litter-fired systems in the UK since the early 90s, and in 2007 FibrowattUSA completed construction and began operating a 50MW litter-fired power generating facility in Minnesota.⁶⁶ Key criteria to consider regarding a centralized litter-to-energy system:

- **Feedstock quality:** The processing system must be designed and operated to accommodate the variability in physical and chemical characteristics of poultry litter, as well as the feedstock's high alkali levels which can lead to slagging, corrosion, etc.
- **Feedstock quantity:** For project financing, investors/lenders need sufficient confidence in long-term supplies of feedstocks (at a minimum to cover the period of debt service).
- **Facility size:** Since these systems are subject to economies of scale, larger systems tend to be more economically feasible than smaller systems.
- **Thermal energy demand:** A thermal demand (e.g., steam use at an adjacent poultry processing facility) is a more energy efficient (and economically attractive) pathway for biomass-derived energy than electricity, so such siting options should be considered.
- **Sale of electricity:** Unless the facility is co-located with a sufficient on-site power load, the litter-derived power would likely be sold to an electric utility under a long-

term Power Purchase Agreement. The economics of such enterprises are highly sensitive to the transaction price. Litter-derived electricity is also eligible for Federal support under the \$45 Production Tax Credit (PTC) program, which is currently worth approximately \$20 per megawatt-hour.

- **Emissions:** A centralized facility can afford to incorporate emissions controls systems that are beyond the scope of farm-scale systems.
- **Ash management:** Essentially all of the minerals in litter (e.g., phosphorus) are captured in the ash from a thermochemical process, which provides opportunities for beneficial use of the nutrient-rich material. For example, in the UK Fibrowatt further processes its litter-derived ash and markets it as Fibrophos.⁶⁷

3.4.3 Corn-fired furnaces

Another heating option being considered by some growers in the northwest Arkansas region is use of a corn-fired furnace system. Two corn-fired furnace manufacturers (both based in Iowa) have been promoting their products to poultry farms during the past year.⁶⁸ To date, approximately thirty furnaces have been installed on at least five poultry farms in the region. A preliminary assessment of such systems undertaken by BioEnergy Systems LLC in January 2008 indicates that the economic feasibility of such units is highly sensitive to several key variables, including [displaced] propane prices, amount of propane displaced, [fuel] corn prices, furnace system efficiency, and furnace system service life. Comparing fuel costs for space heating options shows:⁶⁹

- **Propane:** \$23.55/MMBtu (@ \$2.10/gallon and 98% system efficiency)
- **Corn:** \$19.62/MMBtu (@\$5.00/bushel and 65% system efficiency)
- **Wood pellets:** \$15.57/MMBtu (@\$170/ton and 65% system efficiency)

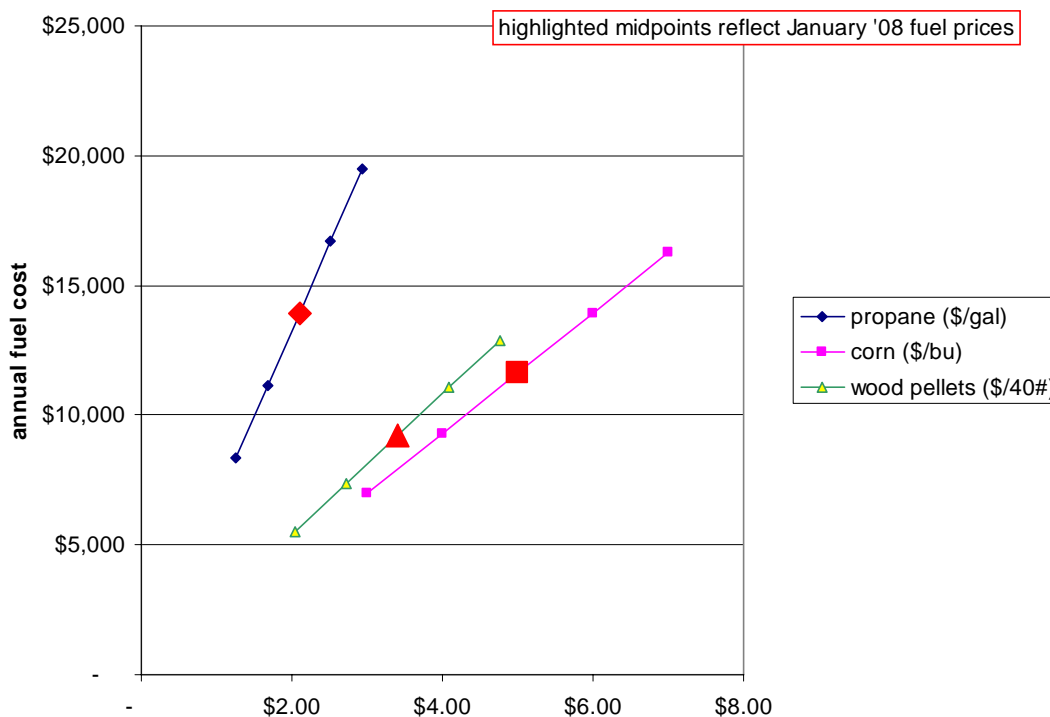
3.4.4 Pellet-fired furnaces

Pellet-fired furnaces and boilers are available from numerous manufacturers in the U.S. (many vendors advertise that their units can burn pellets or corn), although few are suitable for poultry farm applications without significant modification. But, all else being equal, pellets are preferred over corn as fuel because of higher energy content and lower ash content. In 1995 Winrock (with grant funds from DOE and AEO and in coordination with the RC&D program) installed two pellet-fired furnaces on poultry farms in northern Arkansas. In 1998 the University of Arkansas installed a pellet-fired furnace system at house #3 at its Savoy research farm. Numerous lessons were learned from these experiences regarding design and operation of such systems. Fundamentally, the technical vi-

ability of using pellet-fired systems was validated, and other benefits were demonstrated—including the bird growth benefits of “dry heat.”⁷⁰

Figure 19 shows the net heating cost for varying prices for propane, corn, and wood pellets for heating poultry houses (the price ranges shown for each fuel reflect January 2008 prices +/- 40%). Given the technical viability (from past demonstrations) and economic attractiveness (as indicated in figure 19) of wood pellets compared to other fuels, wood pellet fuel should be re-evaluated as a fuel to displace propane for heating poultry houses in Arkansas and the region.⁷¹

Figure 19: Comparison of Annual Fuel Costs for Heating a Poultry House
(refer to the legend for x-axis units)



3.4.5 Energy efficiency improvements

Traditional poultry barns incorporate plastic sheeting for sidewalls (“curtain houses”) and are notoriously energy inefficient. Sealing/insulating the house walls/ceilings has proven to be an effective means of reducing fuel costs for space heating.⁷² An Arkansas company, BioBased Technologies,⁷³ has developed a range of sealants and insulation products made from soybeans. Another Arkansas company, Ag-Tite,⁷⁴ a BioBased licensee, has been applying the soy-based products in poultry houses throughout the United States.

The company claims these energy efficiency improvement practices often have a simple payback of less than one year.

3.4.6 Funding support

For financial support for on-farm energy-related improvements, poultry growers have considered the 9006 program, which is administered thru USDA's Rural Development (RD) program (the 9006 program is funded thru the Energy Title of the Farm Bill). The 9006 program can provide up to 25% grant funds and/or a 25% loan guarantee in support of the initial cost of the energy efficiency improvements or renewable energy system (e.g., corn-fired or pellet-fired furnace system).

Based on discussions with the RD office in Little Rock, past applications for 9006 funds for energy efficiency improvements have required a farm energy audit be conducted (or a similar analysis for renewable energy systems resulting in a farm energy "report") before funds are awarded, and it is anticipated that the program rules will be changed to also require such an audit for applications for renewable energy systems. A specific protocol for poultry farm energy audits (or energy reports) is needed to avoid the relatively high cost of "one-off" assessments and to expedite the process for the region's growers.

3.5 *Environmental & policy matters*

3.5.1 Carbon-neutral (closed-loop) bioenergy options

As discussed in §2.3.2.2, dedicated production of energy crops (woody or herbaceous) and conversion of the harvested biomass into usable energy constitutes carbon-neutral energy generation. This approach was formally recognized at the Federal level in 1992 through the inclusion of closed-loop biomass as a qualifying option for Production Tax Credits for renewable electricity generation.

This same *zero-net-carbon-emissions* environmental benefit could apply to dedicated production and use of biomass to produce thermal energy and/or biofuels. For example, production of cellulosic feedstocks exclusively for conversion into [renewable] liquid transportation fuels would constitute a carbon-neutral energy production system, whereby every unit of CO₂ emitted during fuel consumption would be fully offset through conversion of atmospheric CO₂ into biomass via photosynthesis during crop growth. Thus, production and utilization of dedicated cellulosic biomass energy crops offers a significant pathway for GHG reduction and global climate change mitigation, and Arkansas is well-positioned to be a world leader in such systems.

From a greenhouse gas perspective, closed-loop biomass energy systems could have a significant impact on the State's carbon balance. With reference to the example cited in §1.3.2.2, production of herbaceous energy crops on one million acres of farmland in the Delta could avoid over 22 million tons per year of CO₂.⁷⁵

3.5.2 Governor's Commission on Global Warming

With the signing of Act 696 of the Arkansas 86th General Assembly (HB2460), Governor Mike Beebe established the Governor's Commission on Global Warming. By design the Commission represents a wide diversity of views and perspectives with members coming from business, industry, environmental groups, and academia. Seventeen of the twenty-one members of the Commission are appointed by the Governor and two members each are appointed by the President Pro Tempore of the Arkansas State Senate and by the Speaker of the Arkansas House of Representatives.⁷⁶

The Commission is charged with setting a "global warming pollution reduction goal" for Arkansas and a "comprehensive strategic plan for implementation of the global warming pollution reduction goal." The Act sets several study and evaluation requirements and requires a final report be provided to the Governor by November 1, 2008. The final report of the GCGW will offer findings to the Eighty-Seventh General Assembly on which state action can be based.

The Commission includes five technical working groups:⁷⁷

- Agriculture, Forestry, and Waste
- Energy Supply
- Residential Commercial & Industrial
- Transportation & Land Use
- Cross-Cutting Issues

A Catalog of State Actions was compiled to serve as a framework for discussion for the Energy Supply working group.⁷⁸ An outline of the Catalog is provided in Appendix 8.

The Catalog of State Actions compiled for the Agriculture, Forestry, and Waste working group includes the following primary topics:

- Agriculture - Production of Fuels and Electricity
- Agriculture - Livestock
- Agriculture - Crop Production

- Agriculture - Land Use Change
- Agriculture - Farming Practices
- Forestry – Production of Fuels and Electricity in Forestry
- Forestry – Biomass Protection and Management
- Forestry – Wood Products and Waste
- Waste Management – Waste Management Strategies
- Waste Management – Landfill Gas Strategies
- Waste Management – Wastewater Activities

Neither the Energy nor the Agriculture Catalogs specifically recognize closed-loop (carbon-neutral) bioenergy options (i.e., energy produced from dedicated energy crops). Given the significant potential win-win opportunities for Arkansas through production of carbon-neutral biomass energy, these options should be recognized and incorporated into the Commission's process.

3.5.3 Carbon sources

No lists of carbon sources or quantified carbon emissions *per se* were located for Arkansas for this assessment, although it may be possible to make certain estimates from the EIA consumption and/or generation data shown in Appendices 2 and 3, respectively. It is presumed, however, that such lists will be compiled through the Climate Commission's efforts (within the Energy Supply working group).

3.5.4 State bioenergy policies and programs

- In 2006, a Bioenergy Policy Council was established by AEDC. The Council's reports were prepared in advance of the 2007 legislative session and are available from the AEO.
- In part as a result of the work of the 2006 Bio Bioenergy Policy Council, a grant program was established in 2007 to support biofuels production and distribution. Program rules are provided in Appendix 9. More information can be obtained from the Arkansas Energy Office or at <http://www.arkansasrenewableenergy.org/bioenergy/incentives.htm>.
- In 2007 the University of Arkansas prepared an assessment of bioenergy policies in Arkansas compared to surrounding states. As of January 2008 that report had not been publicly released.

4. Future efforts needed regarding Bioenergy in Arkansas

4.1 *Dedicated cellulosic energy crops*

Develop and deploy a program to help stakeholders and beneficiaries (e.g. farmers, landowners, and other members of the agricultural sector; project developers, technology providers, and investors; public decision makers) better understand and appreciate the benefits of (and opportunities associated with) dedicated crops

- Estimate key potential economic, environmental, and energy security benefits;
- Identify key issues associated with implementation;
- Assess landowner participation options for cellulosic operations;
- Evaluate and quantify where feasible the anticipated environmental benefits;
 - E.g., carbon emissions offsets, carbon sequestration, wildlife habitat, support of prairie restoration efforts, sustainable agricultural systems;
- Evaluate policy considerations and needed support;
- Assess logistical and infrastructural issues and options for bioenergy product marketing;
- Estimate the economic benefits of a robust cellulosic bioenergy program in Arkansas; and
- Coordinate regionally: Given the commonalities of growing conditions in the Delta region (i.e., the lower Mississippi River alluvial valley), multi-state efforts could result in synergistic approaches towards large-scale commercial pursuits.

4.2 *Quantify the carbon benefits of bioenergy options for Arkansas*

Estimate potential fossil energy offsets, carbon sequestration levels, and greenhouse gas reduction levels through expanded bioenergy production in Arkansas, with emphasis on closed-loop feedstock production and conversion. Such information would be of considerable value to the recently-established Governor's Commission on Global Warming..

4.3 *Grand Prairie restoration*

Assess the potential for synergy between cellulosic feedstock development and efforts to restore portions of the Grand Prairie.

4.4 Surplus litter management options

Numerous significant economic changes have occurred since previous efforts were undertaken (during the 2001~2003 timeframe) to evaluate the economic feasibility of off-farm, centralized litter-to-energy options. Re-assessment of such options is particularly needed since no viable farm-scale litter-fired systems have been developed and since there are increasing pressures to embrace surplus litter management options within sensitive watersheds.

4.5 Farm energy audit program for poultry growers

Develop and deploy a farm energy audit program targeted at poultry growers. Audits should encompass both energy efficiency improvements and bioenergy heating options.

4.6 Algae-to-biodiesel

Assess the status of current production & processing technologies. Assess the potential scope of production in Arkansas from widespread commercial deployment. Assess key issues, barriers, and mitigation strategies for commercialization.

4.7 Wood pellets

Assess the opportunities for expanding commercial production of pellets and other densified biomass products in Arkansas, given the numerous potential markets for such products (e.g., utility co-firing, displacing propane for heating poultry houses, residential space heating).

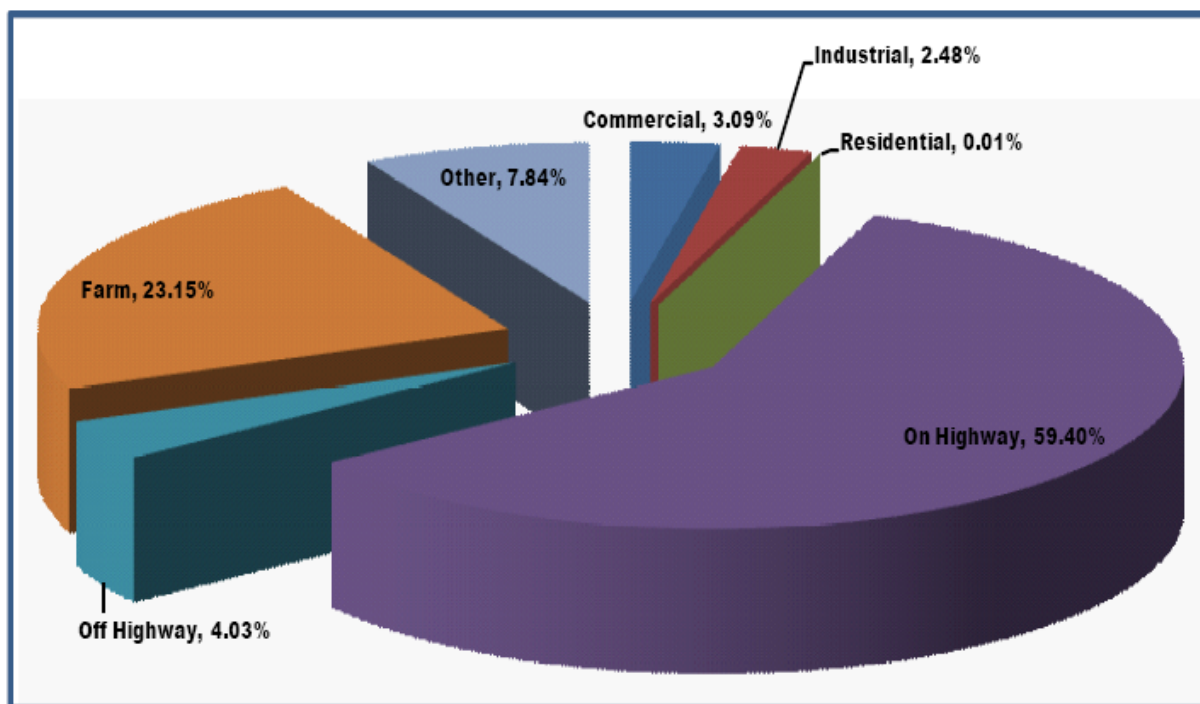
4.8 Co-firing

Assess the opportunities for co-firing biomass with coal, including both residues (e.g., in-forest residues) and dedicated energy crops.

5. End Notes

¹ Source: *Arkansas Energy Data Profile 2007*; pg 29;
http://www.arkansasedc.com/business_development/energy/files/PDF/Energy%20Data%20Profile%202007.pdf

2005 Arkansas Distillate Fuel Sales by End-Use



Notes:

-Total Distillate Fuel Sales was 1,066,157 thousand gallons

-Sales of distillate fuel oil have been adjusted at the PAD District level. Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration

² Refer to: http://arkansasedc.com/business_development/energy/ and
<http://www.arkansasrenewableenergy.org/bioenergy/bioenergy.html#overview>

³ Source: USDA National Agricultural Statistics Service <http://www.nass.usda.gov/>

⁴Two forthcoming corn-to-ethanol production facilities near Arkansas include:

- a) a 60 MGY corn-to-ethanol facility located in Vicksburg, MS; the project is a joint venture between Ergon Refining Inc. and Bunge North America. Refer to:

<http://www.vicksburgpost.com/articles/2006/10/27/news/news01.txt> and
<http://www.vicksburgpost.com/articles/2008/03/16/news/news04.txt> ; and

- b) a 110 MGY corn-to-ethanol facility located in Lake Providence, LA; the project, using a dry-mill process, is being developed by BioEnergy International LLC, based in Quincy, MA. Refer to: <http://www.vicksburgpost.com/articles/2008/03/16/news/news04.txt> and <http://www.bioenergyllc.com/projects.htm> .

⁵ *Economics of Ethanol*; Purdue University; Dec06.
<http://www.ces.purdue.edu/extmedia/ID/ID-339.pdf>

⁶ The Rising Tide of Corn: Ethanol-Driven Demand Felt Across the Nation; Washington Post; Jun07.
<http://www.washingtonpost.com/wp-dyn/content/article/2007/06/14/AR2007061402008.html>

⁷ A net energy balance of 1.3 means that 1.3 gallons of ethanol are produced for each gallon (in ethanol equivalents) of fossil energy consumed during feedstock (corn) production, transport, and processing into ethanol...i.e., the net energy production is 0.3 gallons of corn-derived ethanol per gallon of fossil-equivalent energy consumed.

⁸ For additional information, refer to:
<http://blogs.wsj.com/environmentalcapital/2008/01/23/more-bad-news-for-ethanol/> and
<http://www.npr.org/templates/story/story.php?storyId=18800996>

⁹ In February 2007, DOE announced six awards totaling \$385M in Federal funding for cellulosic ethanol plants: <http://www.energy.gov/news/4827.htm>

In January 2008, DOE announced four awards totaling \$114M in Federal funding for “small-scale” cellulosic ethanol plants:

http://www1.eere.energy.gov/biomass/news_detail.html?news_id=11549

¹⁰ Refer to: <http://www.brienergy.com/pages/process01.html> and
http://www.energy.gov/media/Alico_One_pager.pdf

¹¹ Refer to: <http://www.futurefuelcorporation.com/biofuels/>

¹² Refer to: <http://www.pricebiostock.com/index.html> and
http://www.energy.gov/media/Range_Fuels_One_pager.pdf

¹³ source: USDA National Agricultural Statistics Service.

¹⁴ For more information, refer to:

http://www.winrock.org/us_programs/files/Winrock_US_AR_biodiesel_final_report.pdf and
http://www.biodieselmagazine.com/article.jsp?article_id=624

¹⁵ For more information, refer to: <http://www.nwanews.com/adg/Business/209452/>

¹⁶ For more information regarding the energetics of biofuels, refer to:

<http://www.newrules.org/agri/netenergy.html>

¹⁷ *A Look Back at the U.S. Department of Energy's Aquatic Species Program—Biodiesel from Algae*; National Renewable Energy Laboratory; Jul98.

http://www1.eere.energy.gov/biomass/pdfs/biodiesel_from_algae.pdf

Algaculture @ Wikipedia: <http://en.wikipedia.org/wiki/Algaculture>

Oilgae – Oil from Algae...a comprehensive website on the subject: <http://www.oilgae.com/>

Algae Biodiesel: New Feedstocks for Biodiesel Production; General Atomics; Nov06.

<http://www.bbibiofuels.com/biofuelsworkshop/2006/docs/speakerpapers/west/bww/BWW06-10-Bierer.pdf>

Algal biodiesel debut by Solazyme Inc; Biofuels, Bioproducts, & Biorefining; Jan08.

<http://www.biofpr.com/view/MTAyNjQzL05XLzUxL251bGw=/newsDetail.html>

¹⁸ 100,000 acres would represent less than 1.5% of the 6 million acres of active agricultural land in the Arkansas Delta region.

¹⁹ *Shell Dips into Algae Biodiesel*; Business Week; Dec07.

http://www.businessweek.com/globalbiz/content/dec2007/gb20071212_433535.htm?campaign_id=rss_daily

²⁰ Source: USDA Economic Research Service. <http://www.ers.usda.gov/StateFacts/AR.htm>

²¹ Refer to: <http://www.energy.gov/news/4827.htm>

²² Refer to: <http://www.energy.gov/news/5903.htm>

²³ Refer to: <http://www.energy.gov/news/6015.htm>

²⁴ The more technically accurate term is lignocellulosic (reflecting the three basic constituents of biomass: cellulose, hemi-cellulose, and lignin), although the term “cellulosic” is more widely used, particularly in reference to Federal production mandates and economic support programs.

Also, for the purposes of this discussion, the category has been expanded to reflect a wide spectrum of biomass resources available (or potentially available) in Arkansas that are not commonly associated with cellulosic bioenergy production (e.g., animal processing byproducts).

²⁵ Total usable residues are less than total residue production, reflecting limitations on the portions of agricultural field residues and in-forest residues that can be sustainably removed from ecological perspectives. The factors vary according to source, as further discussed in §3.2.

²⁶ Utilization of essentially all of the woody processing residues produced in Arkansas—i.e., there are no significant un-used woody residues—is a widely recognized fact within the state’s forestry products industry. As depicted in the graphic in the lower-right portion of page 7 of the report “*Arkansas’ Timber Industry—An Assessment of Timber Product Output and Use, 2002*” by the U.S. Forest Service (Resource Bulletin SRS-99), it is estimated that 51% of the woody residues produced in Arkansas are used for industrial fuel, with less than 1% “not used.”
<http://www.srs.fs.usda.gov/pubs/8968>

²⁷ In ethanol equivalents, based on gross processing yield of 90 gallons per dry ton.

²⁸ Considered a reasonable assumption, given the yields of 17~18 tons per acre per year for miscanthus on test plots during the past few years at Mississippi State University in Starkville.

²⁹ At an average processing yield of 90 gallons per dry ton.

³⁰ DOE’s estimated average yield for switchgrass in the United States is 8 tons/acre/year (per the Billion Ton report).

³¹ Based on USDA’s average soybean yield in Arkansas of 35.1 bushels/acre/year (@ 15% m.c.).

³² Source: Arkansas Electricity Profile; Energy Information Administration; 2006.
http://www.eia.doe.gov/cneaf/electricity/st_profiles/arkansas.html

³³ At 85% capacity factor, 7,451 MWh per year would be generated per MW of capacity.

³⁴ Encyclopedia of Arkansas History & Culture: Ashdown (Little River County).
<http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=921>

³⁵ Source: EIA’s Energy Profile – Arkansas.

³⁶ *Rip Van Winkle Wakes Up in Arkansas: Our Energy Efficiency Story*; Sandra Hochstetter, Commissioner Emeritus – Arkansas Public Service Commission; Nov07.

http://www.epa.gov/cleanenergy/documents/southeast-meeting/sandy_hochsetter_rip_van_winkle_pp.pdf

³⁷ *Bank of America Puts a Price on Carbon*; Wall Street Journal; Feb08.

<http://blogs.wsj.com/environmentalcapital/2008/02/13/bank-of-america-puts-a-price-on-carbon/>

³⁸ Refer to: <http://www.prmenergy.com/Projects/Co-Generation.htm>

³⁹ Rice hulls are produced by four companies at five rice mills in eastern Arkansas (<http://www.usarice.com/about/suppliers.cgi>) and have low moisture content (typically 7~11%, wet basis). However, the suitability of hulls as fuel is diminished by the material's high ash content (typically 16~22% by weight), of which about 85% is silica.

⁴⁰ As with rice hulls, rice straw has high ash content (up to 22%), primarily consisting of silica; refer to: http://www.pustaka-deptan.go.id/rkb/knowledgeBank/troprice/Rice_Straw_.htm

⁴¹ The feasibility study report is available from the Ozark Foothills RC&D office.

⁴² Refer to: <http://www.lrwu.com/locations.asp#3>

⁴³ Refer to: <http://www.rcmdigesters.com/>

⁴⁴ Refer to: http://www.house.gov/list/press/ar02_snyder/pr_060110_energyindependence.html

⁴⁵ Refer to: <http://www.arkweb.com/lynndale/index.html>

⁴⁶ Based on the following assumptions: 50 lbs/cu ft bulk density, 20% moisture content, 8,100 HHV, 55% system efficiency.

⁴⁷ Based on the following assumptions: 128 cu ft per cord, 50 lbs/cu ft bulk density, 20% moisture content, 8,100 HHV, 55% system efficiency.

⁴⁸ Based on the following assumptions: 8% moisture content, 8,400 HHV, 80% system efficiency.

⁴⁹ *Renewable Fuel's Appeal Growing*; Nancy Cole - Arkansas Democrat-Gazette; Nov06.
<http://www.nwanews.com/adg/Business/172827/>

⁵⁰ Refer to: http://www.balconesresources.com/pages/fuel_tech.html

⁵¹ Regarding Fiber Resources, refer to: <http://www.heatresource.com/index.html>

Regarding wood pellet appliances, refer to the Pellet Fuels Institute:

<http://www.pelletheat.org/2/index/index.html>

⁵² Refer to: <http://www.bbqrsdelight.com/index.html>

⁵³ Refer to: <http://www.futurefuelcorporation.com/biofuels/pellets.php>

⁵⁴ *Physical Characteristics of Pellets from Poultry Litter*; ASABE; Aug07.
<http://asae.frymulti.com/request.asp?JID=5&AID=16916&CID=can2004&T=2>

⁵⁵ For more information regarding forest biomass in Arkansas, refer to the “*Forest Inventory & Analysis Factsheet, Arkansas 2005*” by the U.S. Forest Service; December 2006.
<http://srsfia2.fs.fed.us/states/ar/AR%202005%20Factsheet.pdf>

⁵⁶ RIN = Renewable Information Number, which is the reporting mechanism established by EPA to measure progress against the RPS requirements. For more information about RINs, refer to Appendix 2.

⁵⁷ *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*; USDA & DOE; April 2005.
http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

⁵⁸ *Biofuels from Switchgrass: Greener Energy Pastures*; Oak Ridge National Laboratory.
<http://bioenergy.ornl.gov/papers/misc/switgrs.html>

⁵⁹ Personal communications with Dr. Brian Baldwin, Associate Professor and Plant Scientist, Mississippi State University.

⁶⁰ Personal communications with Jacksonville Electric Authority.

⁶¹ Personal communications with Dr. Chuck West, Agronomist – University of Arkansas.

⁶² For example, production and use of certain grasses (e.g., switchgrass) instead of traditional forage crops (e.g., fescue) on pasturelands in, say, the Illinois River in northwest Arkansas could mitigate potential runoff (through elimination of cattle grazing and year-round production of a perennial grass crop) and simultaneously reduce soil-phosphorus levels (through uptake of the nutrients by the energy crop and subsequent capture of the nutrient in the form of high-nutrient-density ash, produced through thermochemical conversion of the biomass into usable energy).

⁶³ Savoy is the University of Arkansas' commercial-scale broiler research facility, located west of Fayetteville; the prices shown for Savoy are the prices paid for propane by the broiler farm.

⁶⁴ Data source for residential and wholesale prices: DOE EIA
http://tonto.eia.doe.gov/oog/info/twip/twip_propane.html#prices

Data source for Savoy (the location of the broiler research facility): University of Arkansas.

⁶⁵ This assumes that there insufficient land-application markets within economic hauling distance for the litter; in turn, this assumes that land application of the litter as a soil amendment/fertilizer is, where economically and environmentally feasible, the highest and best use of litter.

⁶⁶ The Fibrominn facility also uses other agricultural and woody biomass feedstocks; refer to:
<http://www.fibrowattusa.com/>

⁶⁷ Refer to: <http://www.fibrofos.co.uk/>

⁶⁸ Refer to: http://www.biomass-furnace.com/corn_burner.html

And refer to: <http://www.sarcornfurnace.com/600Rocketthumbinfo.html>

⁶⁹ The assumed energy content of the fuels are: propane = 91,000 Btu/gallon; corn: 7,000 Btu/lb (dry matter basis); wood pellets = 8,400 Btu/lb (dry matter basis).

⁷⁰ Dry heat refers to the low humidity environment within a poultry house resulting from heat provided by a biomass-fired furnace (particularly with the products of combustion vented externally); in contrast, water vapor—the primary product of combustion from propane-fired furnaces—is released inside the house. There is empirical evidence that, through reduced in-house ammonia levels resulting from reduced humidity levels, dry heat reduces mortality, improves feed conversion, and shortens grow-out time. Specific efforts are needed to scientifically quantify these benefits, and such data should be of particular interest to integrators since bird growth performance benefits would directly accrue to the integrators and not to the growers.

For more information regarding use of pellet stoves for heating poultry houses, contact:

Dr. Tom Costello, Biological and Agricultural Engineering Department, University of Arkansas (Fayetteville campus). <http://www.baeg.uark.edu/627.php>

Richard Drewry, Coordinator – Northwest Arkansas Resource Conservation and Development Council (RC&D): http://www.ar.nrcs.usda.gov/contact/rcd_contacts.html

⁷¹ Costs shown reflect fuel costs only and do not reflect amortized capital costs or other operating costs and reflect 100% displacement of propane by corn or pellets (in reality, target displacement for such systems would be in the 80%~85% range).

⁷² Refer to: <http://ag-tite.com/support-files/ausept06newsletter.pdf>

⁷³ Refer to: <http://www.biobasedtechnologies.com/>

⁷⁴ Refer to: <http://www.ag-tite.com/>

⁷⁵ Calculations assume that all of the biomass is used to produce electricity and displace coal; calculations are based on the following assumptions: 1.0 million acres of energy crops; 15 dry tons/acre/year agronomic yield; 8000 Btu/pound energy content of the biomass; 3823 pounds of CO₂ emissions per ton of coal (ref: <http://www.eia.doe.gov/oiaf/1605/factors.html>); 10,377 Btu/pound average energy content of coal (www.eia.doe.gov). These calculations do not reflect soil carbon sequestration that would be realized through conversion of traditional cropland to perennial herbaceous crops.

⁷⁶ Refer to: <http://www.arclimatechange.us/index.cfm>

⁷⁷ Refer to: <http://www.arclimatechange.us/twg.cfm>

⁷⁸ Refer to: <http://www.arclimatechange.us/ewebeditpro/items/O94F15547.pdf>

Appendix 1: Notes to Figure 1 – Notable Recent Bioenergy Activities in Arkansas

- 1. WI's biodiesel production study completed:** Winrock's study "*Establishing Biodiesel Production Facilities in Arkansas...a Pre-feasibility Assessment*", published in April 2004, concluded that "...increased production and consumption of biodiesel appears highly desirable, given the numerous associated economic, environmental, and energy security benefits for Arkansas and the United States. However, as noted above, it is unlikely that substantial increases in consumption or production will occur without public sector support or intervention." The excerpted executive summary of the report is shown in Attachment 1; the full report is available from Winrock International – U.S. Programs. Refer to: http://www.winrock.org/us_programs/files/Winrock_US_AR_biodiesel_final_report.pdf
- 2. Federal biodiesel support program established:** The "American Jobs Creation Act of 2004" (HR 4520) significantly elevated Federal support for the nation's biodiesel industry. Refer to: http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo_2005analysispapers/ajca.html
- 3. AR biomass resources assessment updated:** With support from DOE, the Arkansas Energy Office commissioned an update of the Arkansas Biomass Resources Assessment (originally prepared by Winrock International in 1995); the data covers agricultural, forestry, poultry & livestock, and municipal residues, all at county-level resolution (most of the residue data was based on '02~'04 production data from USDA-NASS; some of the data was further updated [by Winrock] during December '07 ~ January '08; it is anticipated that the data will be again updated after the results of the '07 NASS agricultural census become available (by mid 2008); the results are available in both tabular and graphical formats at AEO's website: http://arkansasedc.com/business_development/energy/?page=bioenergy
- 4. Future Fuels began producing biodiesel:** Future Fuels Corporation (previously Eastman Chemical) began producing biodiesel in Batesville, Arkansas. As a result of ongoing facility expansions, the company expects to reach 60,000,000 gallons/year biodiesel production capacity by mid-2008. Refer to: <http://www.futurefuelcorporation.com/biofuels/>
- 5. Potlatch bioenergy feasibility study:** Potlatch Corporation, with assistance from Winrock International, began evaluating a commercial-scale bioenergy production operation to be located adjacent to the company's existing paper mill in southeast Arkansas. Using a variety of cellulosic feedstocks, the Project would produce several biofuels products as well as thermal energy for displacing natural gas used for paper production. For more information, refer to: <http://ir.potlatchcorp.com/phoenix.zhtml?c=100877&p=irol-newsArticle&ID=802348&highlight=> (note: the confidential study is not available to the public.)
- 6. Patriot Biofuels began producing biodiesel:** In April 2006, Patriot, based in Stuttgart, AR, began operations with a 3,000,000 biodiesel production capacity; the company plans to increase capacity to at least 13 MM GPY; refer to: <http://www.patriotbio.com/index.php>
- 7. AEDC's Bioenergy Policy Council:** In anticipation of Arkansas' 2007 Legislative Session, the Arkansas Economic Development Authority in early 2006 established a Bioenergy Policy Council; the Council's recommendations, supported by a Technical Advisory Council also

convened by AEDC, became available to lawmakers in late 2006. For more information, contact the Arkansas Energy Office: http://arkansasedc.com/business_development/energy/

8. **Arkansas Bioenergy Workshop:** With supporting funds from DOE (through SSEB), the workshop was organized and convened by the Arkansas Energy Office, the University of Arkansas, and Winrock International. Refer to: <http://www.uark.edu/ua/biomass/> or <http://deltafarmpress.com/news/060921-arkansas-biofuels/>
9. **BRI's team received DOE biorefinery award:** Bioengineering Resources Inc, a private bioenergy company based in Fayetteville, Arkansas, is the technology provider for one of DOE's biorefinery awards in 2007; BRI has developed a proprietary two-step process for converting biomass into ethanol: gasification, followed by microbial conversion of the syngas within an aqueous solution. The lead company for the project is Alico, Inc., a large landowner and farming operation in south Florida. Refer to: <http://www.energy.gov/news/4827.htm>
10. **Tyson announces Dynamic Fuels JV:** Tyson Foods Inc, based in Springdale, AR, entered into a joint venture with Syntroleum Corporation to establish a synthetic fuels production facility in Louisiana using Tyson's animal processing byproducts as feedstocks. Refer to: <http://www.tyson.com/Corporate/PressRoom/ViewArticle.aspx?id=2748>
11. **Federal Energy Act of 2005 enacted:** One of the more notable outcomes of this legislation (HR6 – Energy Independence and Security Act of 2007) was an expanded and extended Renewable Fuels Standard, which established annual mandates for production of certain categories of biofuels. Refer to: http://energy.senate.gov/public/_files/RL342941.pdf
12. **AR's biofuels grant program implemented:** In November 2007, the Arkansas Agriculture Department began implementing a grant program to support biofuels production, processing, and distribution. The \$20M program was established by the '07 Arkansas legislature (Act 873). Refer to: <http://aad.arkansas.gov/Topics.htm>
13. **AR Commission on Global Warming:** The 2007 Arkansas Legislature created, as part of Act 696, the Global Warming Commission. The 21-member commission will study issues related to global warming and devise a comprehensive plan to address the problem. Seventeen members were appointed by the governor, and two each by the House speaker and the Senate president pro tem. Refer to: http://www.eere.energy.gov/state_energy_program/project_brief_detail.cfm/pb_id=1168 and <http://www.arkleg.state.ar.us/scripts/ablr/committees/ARcommittee3a.asp?ccode=988> and <http://www.arclimatechange.us/ewebeditpro/items/O94F15276.pdf>

Appendix 2: Excerpted Executive Summary from Winrock's April 2004 Biodiesel Report

Biodiesel is a renewable liquid fuel made from a variety of materials such as soybean-derived oil, waste cooking oil, or animal fat. Biodiesel production technologies are well-known and readily available, although new techniques are still being developed. Biodiesel can be used in existing diesel engines without modification, most commonly used as B2 (2% biodiesel, 98% petro-diesel). Production and consumption of biodiesel can lead to economic, environmental, and energy security benefits, and there is increasing interest in using biodiesel in the United States and in Arkansas...as of April 2004 there are thirty suppliers of biodiesel in the State but no biodiesel production facilities.

The objectives of this report were to assess the potential feasibility of establishing a biodiesel production facility(s) in Arkansas and identify potential strategies that could lead to deployment of such facilities. This report has two principal components: this overview report prepared by Winrock International (with emphasis on economic/financial perspectives and policy considerations) and a more in-depth assessment prepared by Frazier Barnes & Associates (with emphasis on feedstocks, processing, and biodiesel markets) which is incorporated as Attachment A.

Current demand for biodiesel in Arkansas is estimated to be less than 200,000 gallons per year; annual consumption would increase to about 18,000,000 gallons of biodiesel if all diesel users switched to B2. That level of consumption could support the establishment of at least one large biodiesel production facility in the State.

But biodiesel is currently more expensive than petro-diesel. For example, recent pre-tax prices in eastern Arkansas were \$2.75 per gallon for pure biodiesel and \$1.22 per gallon for petro-diesel. Even at these prices, a B2 blends cost only \$1.25 per gallon...just 3¢ per gallon more than petro-diesel.

Due to the relatively high price of pure biodiesel, it is unlikely that there will be significant increases in consumption of biodiesel unless current conditions change. And it is unlikely that economic conditions will change for biodiesel without public sector intervention. One public policy option is to provide direct financial support for biodiesel production and/or consumption such as incentive payments or tax credits. In fact, the State of Arkansas has several support programs in place for biodiesel, including a 10¢ per gallon production tax credit, as well as a B20 school bus-biodiesel demonstration project. However, in the opinion of the authors of this paper, additional support will be required to stimulate large-volume consumption of biodiesel *and* reduce risks for potential investors in biodiesel plants to acceptable levels.

Mandating consumption of biodiesel is an alternate strategy for realizing the various benefits associated with biodiesel production and consumption without incurring any public sector costs or requiring any complex or costly public sector support programs. At a premium of 1.5¢ per gallon above petro-diesel, purchase of B2 would entail an additional cost of about \$13,500,000 per year above current diesel expenditures in Arkansas. Coupled with long-term purchase commitments, this level of demand for biodiesel would almost certainly be sufficient to achieve satisfactory financial performance and acceptable risk levels necessary for investments biodiesel production facilities to move forward within the state of Arkansas.

Additional considerations for a potential biodiesel production facility in Arkansas include:

- **Feedstocks:** At least initially, use of virgin oil feedstocks would minimize variability in feedstock quality (compared to waste vegetable oil or rendered fats) and associated processing challenges. Subject to economic feasibility, other feedstocks could later be used after processing expertise has been attained.
- **Processing:** In addition to conventional processing (transesterification), other techniques should be evaluated (e.g., use of additives). As with most value-added agricultural processing operations, larger-size facilities would benefit from economies of scale, and the ability to utilize multiple feedstocks would provide greater system flexibility.
- **Markets:** Since 100 gallons of virgin oil yield approximately 90 gallons of biodiesel and 10 gallons of glycerin (using transesterification), biodiesel producers need to also develop markets for the glycerin byproduct. New or expanded markets for glycerin will be needed as biodiesel production increases in the United States in order to minimize the potential for drops in glycerin market prices due to increased production of the material.

In conclusion, increased production and consumption of biodiesel appears highly desirable, given the numerous associated economic, environmental, and energy security benefits for Arkansas and the United States. However, as noted above, it is unlikely that substantial increases in consumption or production will occur without public sector support or intervention. Mandating consumption of biodiesel may be the most attractive strategy for stimulating increased biodiesel production, although additional efforts are needed to fully assess the full spectrum of public sector support/intervention options available to policy makers and determine the most desirable and feasible courses of action.

Appendix 3: State Energy Consumption Estimates from EIA

Table 8. Residential Sector Energy Consumption Estimates, Selected Years, 1960-2004, Arkansas

Year	Coal ^a	Natural Gas ^b	Petroleum				Wood ^a	Geothermal	Solar/PV ^d	Retail Electricity Sales	Net Energy	Electrical System Energy Losses ^e	Total
			Distillate Fuel ^a	Kerosene ^a	LPG ^{a,c}	Total				Million Kilowatthours		Million Kilowatthours	
	Thousand Short Tons	Billion Cubic Feet	Thousand Barrels				Thousand Cords			Million Kilowatthours		Million Kilowatthours	
1960	0	33	24	62	2,831	2,918	969	--	--	1,339	--	3,312	--
1965	0	37	43	63	3,420	3,527	667	--	--	2,333	--	5,572	--
1970	0	60	70	147	6,552	6,769	417	--	--	4,321	--	10,460	--
1975	0	49	161	128	5,162	5,451	430	--	--	7,751	--	18,640	--
1980	1	47	152	0	2,142	2,294	102	--	--	10,227	--	24,659	--
1985	(s)	40	1	31	2,083	2,114	192	--	--	8,936	--	20,585	--
1990	(s)	39	(s)	20	1,851	1,871	158	--	--	10,558	--	24,423	--
1995	0	41	2	14	1,497	1,513	229	--	--	12,417	--	28,207	--
1996	0	46	1	12	1,490	1,503	238	--	--	12,934	--	29,420	--
1997	(s)	42	1	19	1,577	1,596	117	--	--	12,990	--	29,437	--
1998	(s)	38	1	15	1,169	1,184	104	--	--	14,339	--	32,529	--
1999	(s)	36	1	36	3,027	3,064	110	--	--	14,045	--	32,136	--
2000	0	42	1	25	2,686	2,711	118	--	--	14,871	--	33,833	--
2001	0	37	1	24	2,823	2,848	111	--	--	15,104	--	R 33,970	--
2002	(s)	39	9	20	2,112	2,140	113	--	--	15,527	--	34,786	--
2003	0	38	4	16	1,743	1,763	119	--	--	15,598	--	R 34,649	--
2004	(s)	35	6	11	1,934	1,951	122	--	--	15,619	--	34,766	--

Trillion Btu

1960	0.0	34.4	0.1	0.4	11.4	11.9	19.4	0.0	0.0	4.6	70.2	11.3	81.5
1965	0.0	36.5	0.3	0.4	13.7	14.3	13.3	0.0	0.0	8.0	72.2	19.0	91.2
1970	0.0	60.0	0.4	0.8	24.8	26.0	8.3	0.0	0.0	14.7	109.1	35.7	144.8
1975	0.0	48.3	0.9	0.7	19.2	20.8	8.6	0.0	0.0	26.4	104.2	63.6	167.8
1980	(s)	46.6	0.9	0.0	7.9	8.8	2.0	0.0	0.0	34.9	92.3	84.1	176.4
1985	(s)	40.9	(s)	0.2	7.5	7.7	3.8	0.0	0.0	30.5	82.9	70.2	153.1
1990	(s)	39.5	(s)	0.1	6.7	6.8	3.2	^f 0.1	^f 1.3	36.0	^f 86.9	83.3	^f 170.2
1995	0.0	44.6	(s)	0.1	5.4	5.5	4.6	0.1	1.3	42.4	98.4	96.2	194.7
1996	0.0	47.5	(s)	0.1	5.4	5.5	4.8	0.1	1.2	44.1	103.2	100.4	203.6
1997	(s)	43.0	(s)	0.1	5.7	5.8	2.3	0.1	1.2	44.3	96.8	100.4	197.2
1998	(s)	39.1	(s)	0.1	4.2	4.3	2.1	0.1	1.1	48.9	95.7	111.0	206.7
1999	(s)	36.9	(s)	0.2	10.9	11.2	2.2	0.2	1.0	47.9	99.3	109.6	209.0
2000	0.0	43.2	(s)	0.1	9.7	9.8	2.4	0.2	0.9	50.7	107.1	115.4	222.6
2001	0.0	37.7	(s)	0.1	10.2	10.3	2.2	0.2	0.7	51.5	102.7	R 115.9	R 218.6
2002	(s)	41.2	(s)	0.1	7.6	7.8	2.3	0.2	0.6	53.0	105.0	118.7	223.7
2003	0.0	39.9	(s)	0.1	6.3	6.4	2.4	0.3	0.4	53.2	102.7	118.2	220.9
2004	(s)	36.3	(s)	0.1	7.0	7.1	2.4	0.3	0.3	53.3	99.7	118.6	218.3

^a The continuity of these data series estimates may be affected by changing data sources and estimation methodologies. See the Technical Notes for each type of energy.

^b Includes supplemental gaseous fuels.

^c Liquefied petroleum gases.

^d Solar thermal and photovoltaic energy. Includes small amounts consumed by the commercial sector that cannot be separately identified. See Section 5 of the Technical Notes for explanation of estimation methodology.

^e Incurred in the generation, transmission, and distribution of electricity plus plant use and unaccounted for electrical system energy losses.

^f There is a discontinuity in this time series between 1988 and 1989 due to the expanded coverage of renewable energy sources beginning in 1989.

R = Revised data.

-- = Not applicable.

(s) = Btu value less than 0.05 or physical unit value less than 0.5.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 9. Commercial Sector Energy Consumption Estimates, Selected Years, 1960-2004, Arkansas

Year	Coal ^a	Natural Gas ^b	Petroleum						Hydro-electric Power ^d	Biomass ^a	Geothermal	Retail Electricity Sales	Net Energy	Electrical System Energy Losses ^e	Total ^f
			Distillate Fuel ^a	Kerosene ^a	LPG ^{a,c}	Motor Gasoline	Residual Fuel ^a	Total				Million Kilowatthours		Million Kilowatthours	
	Thousand Short Tons	Billion Cubic Feet	Thousand Barrels						Million Kilowatthours			Net Energy	Million Kilowatthours		
1960	0	17	14	38	500	151	103	806	0	--	--	1,161	--	2,872	--
1965	0	28	24	39	604	127	88	883	0	--	--	1,834	--	4,379	--
1970	0	39	40	90	1,156	181	41	1,508	0	--	--	2,789	--	6,752	--
1975	0	33	92	79	911	143	1,077	2,302	0	--	--	4,382	--	10,538	--
1980	5	31	112	132	378	162	437	1,221	0	--	--	5,326	--	12,842	--
1985	1	27	829	84	368	119	0	1,400	0	--	--	5,848	--	13,471	--
1990	(s)	25	298	1	327	142	0	769	9	--	--	6,681	--	15,455	--
1995	0	27	301	5	264	29	0	599	0	--	--	7,771	--	17,654	--
1996	0	31	291	5	263	29	(s)	588	0	--	--	8,063	--	18,340	--
1997	(s)	29	270	5	278	28	0	582	0	--	--	8,236	--	18,664	--
1998	(s)	28	358	7	206	29	0	600	0	--	--	8,910	--	20,212	--
1999	(s)	28	260	4	534	28	0	827	0	--	--	9,064	--	20,737	--
2000	0	33	376	4	474	29	0	883	0	--	--	9,472	--	21,551	--
2001	0	32	593	9	498	30	0	1,131	0	--	--	9,894	--	R 22,253	--
2002	(s)	33	446	4	373	110	0	933	0	--	--	10,035	--	22,482	--
2003	0	32	722	3	308	99	0	1,132	0	--	--	10,568	--	23,475	--
2004	(s)	30	515	17	341	104	(s)	977	0	--	--	10,731	--	23,885	--

Trillion Btu

1960	0.0	17.8	0.1	0.2	2.0	0.8	0.6	3.7	0.0	0.4	0.0	4.0	25.8	9.8	35.6
1965	0.0	28.0	0.1	0.2	2.4	0.7	0.6	4.0	0.0	0.3	0.0	6.3	38.5	14.9	53.4
1970	0.0	39.3	0.2	0.5	4.4	0.9	0.3	6.3	0.0	0.2	0.0	9.5	55.3	23.0	78.4
1975	0.0	33.1	0.5	0.4	3.4	0.8	6.8	11.9	0.0	0.2	0.0	15.0	60.1	36.0	96.1
1980	0.1	30.5	0.6	0.7	1.4	0.9	2.7	6.4	0.0	(s)	0.0	18.2	55.2	43.8	99.1
1985	(s)	27.2	4.8	0.5	1.3	0.6	0.0	7.3	0.0	0.1	0.0	20.0	54.5	46.0	100.5
1990	(s)	25.3	1.7	(s)	1.2	0.7	0.0	3.7	9	0.0	9	22.8	52.3	52.7	105.1
1995	0.0	29.7	1.8	(s)	1.0	0.2	0.0	2.9	0.0	0.8	(s)	26.5	60.0	60.2	120.2
1996	0.0	31.8	1.7	(s)	1.0	0.2	(s)	2.8	0.0	0.8	(s)	27.5	63.0	62.6	125.6
1997	(s)	29.9	1.6	(s)	1.0	0.1	0.0	2.8	0.0	0.6	(s)	28.1	61.3	63.7	124.9
1998	(s)	28.8	2.1	(s)	0.7	0.1	0.0	3.0	0.0	0.5	(s)	30.4	62.7	69.0	131.6
1999	(s)	28.4	1.5	(s)	1.9	0.1	0.0	3.6	0.0	0.6	0.0	30.9	63.5	70.8	134.3
2000	0.0	33.8	2.2	(s)	1.7	0.1	0.0	4.1	0.0	0.6	0.0	32.3	70.8	73.5	144.3
2001	0.0	32.5	3.5	0.1	1.8	0.2	0.0	5.5	0.0	0.6	0.0	33.8	72.3	R 75.9	R 148.2
2002	(s)	34.7	2.6	(s)	1.3	0.6	0.0	4.5	0.0	0.6	0.0	34.2	74.0	76.7	150.8
2003	0.0	33.4	4.2	(s)	1.1	0.5	0.0	5.9	0.0	0.6	0.0	36.1	75.9	80.1	156.0
2004	(s)	31.2	3.0	0.1	1.2	0.5	(s)	4.9	0.0	0.5	0.0	36.6	73.2	81.5	154.7

^a The continuity of these data series estimates may be affected by changing data sources and estimation methodologies. See the Technical Notes for each type of energy.
^b Includes supplemental gaseous fuels.
^c Liquefied petroleum gases.
^d Conventional hydroelectric power. Does not include pumped-storage hydroelectricity.
^e Incurred in the generation, transmission, and distribution of electricity plus plant use and unaccounted for electrical system energy losses.
^f Small amounts of solar thermal and photovoltaic energy consumed in the commercial sector cannot be separately

identified and are included in residential consumption.
^g There is a discontinuity in this time series between 1988 and 1989 due to the expanded coverage of renewable energy sources beginning in 1989.
R = Revised data.
-- = Not applicable.
(s) = Btu value less than 0.05 or physical unit value less than 0.5.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 10. Industrial Sector Energy Consumption Estimates, Selected Years, 1960-2004, Arkansas

Year	Coal ^a Thousand Short Tons	Natural Gas ^b Billion Cubic Feet	Petroleum									Hydro-electric Power ^e Million kWh	Biomass ^a	Geo-thermal	Retail Electricity Sales	Net Energy	Electrical System Energy Losses ^f	Total
			Asphalt and Road Oil ^a	Distillate Fuel ^a	Kero-sene ^a	LPG ^{a,c}	Lubri-cants ^a	Motor Gasoline	Residual Fuel ^a	Other ^{a,d}	Total				Million kWh		Million kWh	
	Thousand Barrels																	
1960	14	108	1,003	1,055	465	1,183	269	431	315	1,892	6,614	0	--	--	3,161	--	7,819	--
1965	6	134	1,295	1,057	283	1,141	163	485	291	2,807	7,522	0	--	--	4,883	--	11,661	--
1970	0	162	2,104	1,962	584	1,798	231	291	191	2,830	9,992	0	--	--	6,333	--	15,328	--
1975	40	132	2,276	2,841	480	2,715	308	169	3,634	3,017	15,440	0	--	--	5,994	--	14,416	--
1980	296	126	2,770	3,544	439	2,122	268	51	1,438	3,975	14,608	0	--	--	10,946	--	26,392	--
1985	379	109	1,263	4,273	41	1,076	244	630	726	2,433	10,687	0	--	--	9,049	--	20,846	--
1990	256	127	495	2,424	17	1,202	274	416	214	1,843	6,886	9	--	--	10,126	--	23,424	--
1995	325	140	1,246	4,041	20	1,416	262	449	204	1,798	9,436	0	--	--	14,483	--	32,900	--
1996	348	144	975	3,393	9	1,317	254	454	116	7,182	13,700	0	--	--	15,139	--	34,436	--
1997	296	152	1,012	3,997	10	1,171	268	472	21	7,679	14,630	0	--	--	15,632	--	35,426	--
1998	287	149	859	3,816	17	915	281	648	3	7,540	14,079	0	--	--	16,066	--	36,446	--
1999	324	140	1,023	3,528	13	1,955	284	549	17	7,530	14,899	0	--	--	16,680	--	38,163	--
2000	382	132	1,017	4,026	4	3,269	280	550	9	7,382	16,536	0	--	--	17,268	--	39,288	--
2001	437	124	536	4,589	19	2,741	256	936	203	5,701	14,980	0	--	--	16,734	--	R 37,637	--
2002	422	120	2,608	4,347	5	1,507	253	999	46	5,802	15,567	0	--	--	16,887	--	37,831	--
2003	417	112	1,810	5,173	2	1,113	234	1,071	188	6,097	15,688	0	--	--	16,942	--	37,634	--
2004	415	107	884	5,583	1	1,143	237	1,257	446	6,708	16,259	0	--	--	17,322	--	38,556	--

Trillion Btu

1960	0.4	112.1	6.7	6.1	2.6	4.7	1.6	2.3	2.0	11.3	37.4	0.0	17.7	0.0	10.8	178.3	26.7	205.0
1965	0.2	134.2	8.6	6.2	1.6	4.6	1.0	2.5	1.8	16.8	43.1	0.0	21.6	0.0	16.7	215.7	39.8	255.5
1970	0.0	162.8	14.0	11.4	3.3	6.8	1.4	1.5	1.2	16.9	56.6	0.0	25.8	0.0	21.6	266.7	52.3	319.0
1975	0.9	131.7	15.1	16.5	2.7	10.1	1.9	0.9	22.8	17.5	87.6	0.0	27.1	0.0	20.5	267.7	49.2	316.9
1980	6.3	125.1	18.4	20.6	2.5	7.8	1.6	0.3	9.0	22.5	82.8	0.0	50.3	0.0	37.3	301.9	90.1	391.9
1985	8.1	110.9	8.4	24.9	0.2	3.9	1.5	3.3	4.6	13.7	60.5	0.0	58.9	0.0	30.9	269.3	71.1	340.4
1990	5.8	128.3	3.3	14.1	0.1	4.4	1.7	2.2	1.3	10.5	37.6	9	66.9	9	34.6	273.2	79.9	353.1
1995	7.8	151.8	8.3	23.5	0.1	5.1	1.6	2.3	1.3	10.4	52.6	0.0	77.5	0.0	49.4	339.2	112.3	451.4
1996	8.4	148.0	6.5	19.8	0.1	4.8	1.5	2.4	0.7	39.3	74.9	0.0	82.2	0.0	51.7	365.1	117.5	482.6
1997	7.0	153.9	6.7	23.3	0.1	4.2	1.6	2.5	0.1	42.2	80.7	0.0	84.0	0.0	53.3	378.9	120.9	499.8
1998	7.0	153.1	5.7	22.2	0.1	3.3	1.7	3.4	(s)	41.4	77.8	0.0	79.4	0.0	54.8	372.1	124.4	496.5
1999	7.9	142.1	6.8	20.6	0.1	7.1	1.7	2.9	0.1	41.1	80.2	0.0	79.4	(s)	56.9	366.6	130.2	496.8
2000	9.6	134.8	6.7	23.4	(s)	11.8	1.7	2.9	0.1	40.2	86.8	0.0	80.6	(s)	58.9	370.8	134.1	504.8
2001	10.9	125.5	3.6	26.7	0.1	9.9	1.6	4.9	1.3	31.5	79.5	0.0	R 64.1	(s)	57.1	337.0	R 128.4	R 465.5
2002	10.5	126.3	17.3	25.3	(s)	5.4	1.5	5.2	0.3	32.1	87.2	0.0	R 70.2	(s)	57.6	351.7	129.1	480.8
2003	10.1	118.1	12.0	30.1	(s)	4.0	1.4	5.6	1.2	33.8	88.1	0.0	70.4	(s)	57.8	R 344.6	128.4	R 473.0
2004	10.1	112.1	5.9	32.5	(s)	4.1	1.4	6.6	2.8	37.1	90.5	0.0	70.6	(s)	59.1	342.4	131.6	473.9

^a The continuity of these data series estimates may be affected by changing data sources and estimation methodologies. See the Technical Notes for each type of energy.
^b Includes supplemental gaseous fuels.
^c Liquefied petroleum gases.
^d "Other" is the subtotal of 16 petroleum products. See a full description in the Technical Notes, Section 4, "Other Petroleum Products."
^e Conventional hydroelectric power. Does not include pumped-storage hydroelectricity.
^f Incurred in the generation, transmission, and distribution of electricity plus plant use and unaccounted for electrical system

energy losses.
⁹ There is a discontinuity in this time series between 1988 and 1989 due to the expanded coverage of renewable energy sources beginning in 1989.
R = Revised data.
kWh = Kilowatthours. -- = Not applicable.
(s) = Btu value less than 0.05 or physical unit value less than 0.5.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 11. Transportation Sector Energy Consumption Estimates, Selected Years, 1960-2004, Arkansas

Year	Coal ^a	Natural Gas ^b	Petroleum								Ethanol	Retail Electricity Sales	Net Energy	Electrical System Energy Losses ^d	Total ^e
			Aviation Gasoline ^a	Distillate Fuel ^a	Jet Fuel ^a	LPG ^{a,c}	Lubricants ^a	Motor Gasoline	Residual Fuel ^a	Total		Million Kilowatthours		Million Kilowatthours	
	Thousand Short Tons	Billion Cubic Feet	Thousand Barrels								Thousand Barrels	Million Kilowatthours	Net Energy	Million Kilowatthours	
1960	(s)	9	177	926	2,237	309	274	14,093	3	18,019	0	0	--	0	--
1965	(s)	11	482	1,703	2,094	434	305	17,310	36	22,364	0	0	--	0	--
1970	0	13	293	3,383	2,204	692	300	21,985	5	28,862	0	0	--	0	--
1975	(s)	12	254	6,410	1,995	679	308	27,299	11	36,957	0	0	--	0	--
1980	0	11	275	6,699	2,035	205	432	26,276	0	35,922	0	0	--	0	--
1985	0	8	86	7,690	2,030	147	393	25,857	0	36,203	^f 19	0	--	0	--
1990	0	9	125	9,722	1,693	83	442	28,438	0	40,503	146	0	--	0	--
1995	0	11	143	12,569	1,179	51	422	31,644	0	46,008	9	0	--	0	--
1996	0	13	121	13,066	1,534	45	410	31,599	0	46,775	1	0	--	0	--
1997	0	12	135	13,582	1,539	42	433	32,684	0	48,414	0	0	--	0	--
1998	0	10	122	14,345	1,527	33	453	32,585	0	49,065	0	0	--	0	--
1999	0	9	118	13,824	4,575	457	458	33,120	0	52,552	0	0	--	0	--
2000	0	9	93	14,346	4,868	93	451	32,719	0	52,570	0	0	--	0	--
2001	0	9	183	15,633	1,036	89	413	32,280	0	49,634	0	0	--	0	--
2002	0	8	118	16,811	794	54	408	32,995	0	51,180	0	0	--	0	--
2003	0	9	103	16,075	822	47	377	33,173	0	50,597	0	0	--	0	--
2004	0	8	129	17,189	722	51	382	33,266	0	51,740	0	(s)	--	(s)	--

Trillion Btu

1960	(s)	9.5	0.9	5.4	12.0	1.2	1.7	74.0	(s)	95.2	0.0	0.0	104.7	0.0	104.7
1965	(s)	11.4	2.4	9.9	11.2	1.7	1.8	90.9	0.2	118.3	0.0	0.0	129.7	0.0	129.7
1970	0.0	13.5	1.5	19.7	11.9	2.6	1.8	115.5	(s)	153.0	0.0	0.0	166.5	0.0	166.5
1975	(s)	12.2	1.3	37.3	10.8	2.5	1.9	143.4	0.1	197.3	0.0	0.0	209.4	0.0	209.4
1980	0.0	11.4	1.4	39.0	11.0	0.8	2.6	138.0	0.0	192.9	0.0	0.0	204.2	0.0	204.2
1985	0.0	8.3	0.4	44.8	11.0	0.5	2.4	135.8	0.0	195.0	^f 0.1	0.0	^f 203.4	0.0	^f 203.4
1990	0.0	8.7	0.6	56.6	9.2	0.3	2.7	149.4	0.0	218.9	0.5	0.0	228.1	0.0	228.1
1995	0.0	12.5	0.7	73.2	6.7	0.2	2.6	165.0	0.0	248.4	(s)	0.0	260.8	0.0	260.8
1996	0.0	12.9	0.6	76.1	8.7	0.2	2.5	164.8	0.0	252.9	(s)	0.0	265.8	0.0	265.8
1997	0.0	11.8	0.7	79.1	8.7	0.2	2.6	170.4	0.0	261.7	0.0	0.0	273.5	0.0	273.5
1998	0.0	10.5	0.6	83.6	8.7	0.1	2.7	169.8	0.0	265.5	0.0	0.0	276.1	0.0	276.1
1999	0.0	9.2	0.6	80.5	25.9	1.7	2.8	172.6	0.0	284.1	0.0	0.0	293.3	0.0	293.3
2000	0.0	9.0	0.5	83.6	27.6	0.3	2.7	170.5	0.0	285.2	0.0	0.0	294.2	0.0	294.2
2001	0.0	8.9	0.9	91.1	5.9	0.3	2.5	168.2	0.0	268.9	0.0	0.0	277.8	0.0	277.8
2002	0.0	8.4	0.6	97.9	4.5	0.2	2.5	171.8	0.0	277.5	0.0	0.0	285.9	0.0	285.9
2003	0.0	9.0	0.5	93.6	4.7	0.2	2.3	172.7	0.0	274.0	0.0	0.0	283.0	0.0	283.0
2004	0.0	8.0	0.7	100.1	4.1	0.2	2.3	173.5	0.0	280.9	0.0	(s)	288.9	(s)	288.9

^a The continuity of these data series estimates may be affected by changing data sources and estimation methodologies. See the Technical Notes for each type of energy.

^b Includes supplemental gaseous fuels. Transportation use of natural gas is gas consumed in the operation of pipelines, primarily in compressors, and, since 1990, is also natural gas consumed as vehicle fuel.

^c Liquefied petroleum gases.

^d Incurred in the generation, transmission, and distribution of electricity plus plant use and unaccounted for electrical system energy losses.

^e Beginning in 1993, ethanol blended into motor gasoline is included in both "Motor Gasoline" and "Ethanol," but is

counted once in the "Total."

^f There is a discontinuity in this time series between 1980 and 1981 due to the expanded coverage of renewable energy sources beginning in 1981.

-- = Not applicable.

(s) = Btu value less than 0.05 or physical unit value less than 0.5.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 12. Electric Power Sector Consumption Estimates, Selected Years, 1960-2004, Arkansas

Year	Coal Thousand Short Tons	Natural Gas ^a Billion Cubic Feet	Petroleum				Nuclear Electric Power	Hydroelectric Power ^e	Biomass ^f	Geothermal	Solar/PV ^g	Wind	Electricity Net Imports ^h	Total
			Residual Fuel ^{b,c}	Distillate Fuel ^{b,d}	Petroleum Coke ^b	Total								
	Thousand Barrels				Million Kilowatthours		Million Kilowatthours				Total			
1960	0	47	118	1	0	119	0	992	--	0	0	0	0	--
1965	0	68	38	(s)	0	38	0	1,080	--	0	0	0	0	--
1970	0	107	698	8	0	705	0	2,160	--	0	0	0	0	--
1975	0	32	4,365	62	0	4,427	4,874	3,433	--	0	0	0	0	--
1980	1,774	59	3,106	180	0	3,285	7,833	1,695	--	0	0	0	0	--
1985	12,302	11	8	12	0	21	9,889	4,434	--	0	0	0	0	--
1990	11,836	32	15	140	0	155	11,282	3,655	--	0	0	0	0	--
1995	13,216	33	15	94	0	109	11,658	3,218	--	0	0	0	0	--
1996	14,467	34	81	97	0	179	13,357	2,797	--	0	0	0	0	--
1997	13,772	25	27	100	0	127	14,208	3,516	--	0	0	0	0	--
1998	14,276	41	100	179	0	279	13,097	3,117	--	0	0	0	0	--
1999	14,974	40	92	167	0	260	12,920	2,694	--	0	0	0	0	--
2000	14,866	35	293	67	0	360	11,652	2,370	--	0	0	0	0	--
2001	15,110	26	1,340	82	0	1,421	14,781	2,548	--	0	0	0	0	--
2002	14,165	42	180	69	0	249	14,559	3,436	--	0	0	0	0	--
2003	14,310	56	382	71	0	453	14,689	2,655	--	0	0	0	0	--
2004	15,318	40	742	62	0	805	15,450	3,643	--	0	0	0	0	--

Trillion Btu														
1960	0.0	48.4	0.7	(s)	0.0	0.7	0.0	10.7	0.0	0.0	0.0	0.0	0.0	59.8
1965	0.0	67.6	0.2	(s)	0.0	0.2	0.0	11.3	0.0	0.0	0.0	0.0	0.0	79.1
1970	0.0	107.9	4.4	(s)	0.0	4.4	0.0	22.7	0.0	0.0	0.0	0.0	0.0	135.0
1975	0.0	32.2	27.4	0.4	0.0	27.8	53.7	35.7	0.0	0.0	0.0	0.0	0.0	149.4
1980	30.2	60.4	19.5	1.0	0.0	20.6	85.4	17.6	0.0	0.0	0.0	0.0	0.0	214.2
1985	211.7	12.0	0.1	0.1	0.0	0.1	105.0	46.3	0.0	0.0	0.0	0.0	0.0	375.2
1990	206.9	32.7	0.1	0.8	0.0	0.9	119.4	38.0	0.0	0.0	0.0	0.0	0.0	397.8
1995	229.5	33.4	0.1	0.5	0.0	0.6	122.5	33.2	0.0	0.0	0.0	0.0	0.0	419.2
1996	251.7	34.8	0.5	0.6	0.0	1.1	140.3	28.9	0.0	0.0	0.0	0.0	0.0	456.8
1997	239.8	25.4	0.2	0.6	0.0	0.8	149.1	35.9	0.0	0.0	0.0	0.0	0.0	451.0
1998	247.7	41.4	0.6	1.0	0.0	1.7	137.4	31.8	0.0	0.0	0.0	0.0	0.0	459.9
1999	259.1	41.1	0.6	1.0	0.0	1.6	135.0	27.6	0.0	0.0	0.0	0.0	0.0	464.3
2000	258.0	35.3	1.8	0.4	0.0	2.2	121.5	24.2	0.0	0.0	0.0	0.0	0.0	441.2
2001	263.1	27.1	8.4	0.5	0.0	8.9	154.4	26.3	0.0	0.0	0.0	0.0	0.0	479.8
2002	244.8	43.1	1.1	0.4	0.0	1.5	152.0	35.0	0.0	0.0	0.0	0.0	0.0	476.4
2003	243.5	58.2	2.4	0.4	0.0	2.8	153.1	27.2	7.1	0.0	0.0	0.0	0.0	491.9
2004	260.1	41.3	4.7	0.4	0.0	5.0	161.1	36.5	2.4	0.0	0.0	0.0	0.0	506.4

^a Includes supplemental gaseous fuels.

^b The continuity of these data series estimates may be affected by changing data sources and estimation methodologies. See the Technical Notes for each type of energy.

^c Prior to 1980, based on oil used in steam plants. Since 1980, residual fuel includes fuel oil nos. 4, 5, and 6 and residual fuel oils.

^d Prior to 1980, based on oil used in internal combustion and gas turbine engine plants. Since 1980, distillate fuel includes fuel oil nos. 1 and 2, kerosene, and jet fuel.

^e Conventional hydroelectric power. Includes pumped-storage hydroelectricity, which cannot be separately identified, from 1960 through 1989.

^f Wood and waste.

^g Solar thermal and photovoltaic energy.

^h Electricity traded with Canada and Mexico.

ⁱ There is a discontinuity in this time series between 1988 and 1989 due to the expanded coverage of renewable energy sources beginning in 1989.

-- = Not applicable.

(s) = Btu value less than +0.05 and greater than -0.05 or physical unit value less than +0.5 and greater than -0.5.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Appendix 4: State Energy Price and Expenditure Estimates from EIA

Table 2. Residential Sector Energy Price and Expenditure Estimates, Selected Years 1970-2004, Arkansas

Year	Primary Energy								Retail Electricity	Total Energy ^b
	Coal	Natural Gas	Petroleum				Wood	Total ^b		
			Distillate Fuel	Kerosene	LPG ^a	Total				
Prices in Nominal Dollars per Million Btu										
1970	—	0.75	0.93	1.40	1.84	1.81	0.71	1.06	6.82	1.88
1975	—	1.12	2.40	2.80	3.51	3.44	1.39	1.80	9.35	3.82
1980	2.97	2.49	6.54	—	8.77	8.54	3.57	3.45	15.58	8.10
1985	3.19	4.35	10.33	7.18	8.46	8.43	4.04	4.97	21.91	11.38
1990	2.70	5.06	7.69	6.75	10.78	10.72	3.53	5.83	23.64	13.51
1991	2.81	4.89	7.11	6.38	12.15	12.07	3.38	5.76	23.75	13.59
1992	2.69	5.06	4.99	5.82	10.66	10.56	3.09	5.66	24.27	13.72
1993	2.73	5.31	5.68	5.75	9.91	9.87	3.02	5.75	24.24	13.62
1994	2.83	5.59	5.38	4.29	10.00	9.96	2.93	6.03	23.66	13.80
1995	—	5.05	5.20	3.97	10.26	10.16	2.87	5.52	23.40	13.56
1996	—	5.77	5.84	4.49	12.14	12.04	3.29	6.31	22.78	13.65
1997	2.72	6.58	5.56	6.18	11.29	11.20	3.27	7.06	22.86	14.50
1998	2.81	6.68	4.46	3.01	10.03	9.89	2.84	6.93	22.00	14.84
1999	1.01	7.09	4.89	3.02	10.51	10.37	2.92	7.77	21.76	14.69
2000	—	7.29	8.40	7.83	14.70	14.60	4.38	8.58	21.85	15.01
2001	—	9.90	7.15	6.17	15.59	15.46	4.17	10.97	22.61	16.95
2002	2.72	8.50	6.43	5.56	12.54	12.40	3.81	9.02	21.26	15.32
2003	—	9.82	9.07	7.86	15.16	15.04	4.54	10.43	21.23	16.15
2004	3.26	11.23	10.66	9.94	17.38	17.28	5.18	12.06	21.58	17.25
Expenditures in Million Nominal Dollars										
1970	—	45.1	0.4	1.2	45.6	47.2	2.3	94.5	100.5	195.1
1975	—	54.2	2.2	2.0	67.4	71.7	4.6	130.5	247.4	377.8
1980	0.1	115.9	5.8	—	69.0	74.8	2.8	193.6	543.7	737.3
1985	(s)	177.9	(s)	1.3	63.5	64.8	6.0	248.7	667.9	916.6
1990	(s)	199.9	(s)	0.8	72.3	73.1	4.4	277.4	851.7	1,129.1
1991	(s)	202.2	(s)	0.5	73.5	74.0	4.4	280.6	891.6	1,172.2
1992	(s)	201.2	0.3	0.2	57.9	58.4	4.2	263.9	864.6	1,128.5
1993	(s)	244.9	(s)	0.3	61.0	61.4	5.7	312.0	972.8	1,284.8
1994	(s)	237.2	(s)	0.2	60.6	60.8	5.3	303.3	939.9	1,243.2
1995	—	225.3	0.1	0.3	55.7	56.0	5.1	286.5	991.4	1,277.8
1996	—	274.1	(s)	0.3	65.3	65.7	6.1	345.9	1,005.3	1,351.1
1997	(s)	283.0	(s)	0.7	64.4	65.1	3.0	351.1	1,013.1	1,364.2
1998	(s)	261.6	(s)	0.3	42.4	42.6	2.3	306.6	1,076.4	1,383.0
1999	(s)	261.7	(s)	0.6	115.1	115.7	2.5	379.9	1,042.9	1,422.8
2000	—	314.7	(s)	1.1	142.4	143.6	4.0	462.4	1,108.5	1,570.9
2001	—	373.1	(s)	0.8	159.1	159.9	3.6	536.7	1,165.4	1,702.1
2002	(s)	350.2	0.3	0.6	95.7	96.6	3.4	450.2	1,126.3	1,576.5
2003	—	392.5	0.2	0.7	95.9	96.8	4.2	493.5	1,129.8	1,623.3
2004	(s)	407.9	0.3	0.6	121.6	122.5	4.9	535.4	1,149.9	1,685.2

^a Liquefied petroleum gases.

^b There are no direct fuel costs for geothermal, photovoltaic, or solar thermal energy.

— = No consumption.

(s) = Value less than 0.05 million nominal dollars.

Note: Expenditure totals may not equal sum of components due to independent rounding.

Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 3. Commercial Sector Energy Price and Expenditure Estimates, Selected Years 1970-2004, Arkansas

Year	Primary Energy										Retail Electricity	Total Energy ^c
	Coal	Natural Gas	Petroleum					Biomass ^b	Total ^c			
			Distillate Fuel	Kerosene	LPG ^a	Motor Gasoline	Residual Fuel			Total		
Prices in Nominal Dollars per Million Btu												
1970	—	0.52	0.86	0.77	1.23	2.74	0.42	1.37	0.71	0.64	6.07	1.58
1975	—	0.90	2.29	2.32	2.64	4.60	1.75	2.23	1.39	1.25	8.60	3.08
1980	1.89	2.29	6.25	5.51	5.54	9.93	3.33	5.24	3.57	2.80	14.74	6.73
1985	2.12	4.06	6.13	7.18	9.00	8.80	—	6.95	4.04	4.67	19.06	9.95
1990	1.99	4.43	5.47	6.75	9.80	8.86	—	7.55	2.98	4.81	20.40	11.65
1991	1.86	4.28	4.79	6.38	10.67	8.81	—	7.46	2.93	4.59	20.34	11.58
1992	1.86	4.35	4.45	5.82	10.05	8.69	2.00	6.73	2.67	4.59	20.76	11.78
1993	1.88	4.36	4.32	5.75	9.63	8.56	2.08	6.25	2.76	4.54	20.60	11.44
1994	1.78	4.49	4.00	4.29	8.63	8.62	—	5.63	2.64	4.59	20.07	11.47
1995	—	3.77	4.09	3.97	9.04	8.75	—	5.97	2.45	3.95	19.96	11.09
1996	—	4.56	4.91	4.49	10.01	9.42	2.79	6.86	2.86	4.73	19.71	11.33
1997	1.80	5.16	4.68	6.18	10.24	9.32	—	6.97	2.75	5.30	19.84	12.00
1998	1.70	5.03	3.58	3.01	9.17	7.99	—	5.17	2.34	5.03	17.31	11.02
1999	1.76	5.29	4.24	3.02	9.48	8.51	—	7.20	2.01	5.48	17.16	11.20
2000	—	5.31	6.78	7.83	12.56	11.20	—	9.38	3.14	5.73	17.49	11.13
2001	—	7.70	6.00	6.17	13.45	10.60	—	8.59	2.72	7.79	18.30	12.72
2002	1.87	6.69	5.58	5.56	11.27	10.38	—	7.87	2.78	6.80	16.82	11.45
2003	—	7.29	6.81	7.86	12.63	11.72	—	8.36	^R 3.50	7.43	16.23	11.63
2004	1.88	8.47	9.16	9.94	15.40	13.97	4.57	11.29	3.81	8.82	16.53	12.69

Expenditures in Million Nominal Dollars												
1970	—	20.6	0.2	0.4	5.4	2.6	0.1	8.7	(s)	29.3	57.8	87.1
1975	—	29.7	1.2	1.0	8.9	3.5	11.9	26.5	0.1	56.2	128.6	184.8
1980	0.2	69.9	4.1	4.1	7.7	8.5	9.2	33.5	0.1	103.6	267.8	371.4
1985	(s)	110.5	29.6	3.4	11.9	5.5	—	50.4	0.1	161.1	380.4	541.5
1990	(s)	112.1	9.5	0.1	11.6	6.6	—	27.8	0.5	140.4	465.1	605.5
1991	(s)	113.0	7.2	0.1	11.4	3.7	—	22.4	0.5	136.0	480.4	616.4
1992	0.1	110.9	7.4	0.2	9.6	3.2	0.1	20.5	0.5	132.0	478.8	610.7
1993	(s)	128.1	9.0	0.2	10.5	1.3	(s)	20.9	0.8	149.8	512.5	662.3
1994	(s)	125.6	8.9	0.1	9.2	1.3	—	19.5	0.8	145.9	510.2	656.1
1995	—	112.0	7.2	0.1	8.6	1.3	—	17.2	0.8	130.1	529.4	659.4
1996	—	145.2	8.3	0.1	9.5	1.4	(s)	19.4	0.9	165.5	542.4	707.9
1997	(s)	154.0	7.4	0.2	10.3	1.4	—	19.2	0.6	173.8	557.4	731.1
1998	(s)	144.8	7.5	0.1	6.8	1.2	—	15.6	0.4	160.8	526.2	687.1
1999	(s)	150.1	6.4	0.1	18.3	1.3	—	26.1	0.5	176.6	530.7	707.4
2000	—	179.5	14.8	0.2	21.5	1.7	—	38.2	0.7	218.4	565.1	783.5
2001	—	249.8	20.7	0.3	24.2	1.7	—	46.9	0.8	297.5	617.8	915.3
2002	(s)	232.1	14.5	0.1	15.2	5.9	—	35.7	0.7	268.6	575.8	844.4
2003	—	243.5	28.7	0.1	14.1	6.0	—	48.9	0.9	293.3	585.1	878.4
2004	(s)	264.1	27.5	0.9	19.0	7.5	(s)	55.0	1.0	320.1	605.3	925.4

^a Liquefied petroleum gases.

^b Wood and waste.

^c There are no direct fuel costs for hydroelectric, geothermal, photovoltaic, or solar thermal energy.

R = Revised data.

— = No consumption.

(s) = Value less than 0.05 million nominal dollars.

Note: Expenditure totals may not equal sum of components due to independent rounding.

Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 4. Industrial Sector Energy Price and Expenditure Estimates, Selected Years 1970-2004, Arkansas

Year	Primary Energy															Retail Electricity	Total Energy ^d
	Coal			Natural Gas	Petroleum									Biomass ^c	Total ^d		
	Coking Coal	Steam Coal	Total		Asphalt and Road Oil	Distillate Fuel	Kerosene	LPG ^a	Lubricants	Motor Gasoline	Residual Fuel	Other ^b	Total				
Prices in Nominal Dollars per Million Btu																	
1970	—	—	—	0.28	0.68	0.67	0.77	1.23	5.08	2.74	0.45	0.95	1.00	1.45	0.49	2.78	0.72
1975	—	1.22	1.22	0.68	1.81	2.09	2.32	2.64	7.48	4.60	1.63	2.40	2.19	1.45	1.29	5.18	1.63
1980	—	1.89	1.89	2.24	3.58	4.87	5.51	5.54	14.36	9.93	2.95	6.42	4.99	1.44	3.18	9.15	4.07
1985	—	2.12	2.12	3.65	4.21	6.09	6.36	9.00	17.61	8.80	4.01	7.98	6.61	1.44	4.41	13.74	5.81
1990	—	1.99	1.99	2.86	3.01	5.78	5.71	9.80	14.60	8.86	2.54	8.99	7.10	^e 0.94	^e 3.11	14.94	^e 4.83
1991	—	1.86	1.86	3.01	3.22	5.06	5.39	10.67	16.80	8.81	2.30	7.61	6.97	1.10	3.12	14.79	5.00
1992	—	1.86	1.86	3.11	2.23	4.81	5.04	10.05	18.32	8.69	2.00	9.17	6.03	1.10	3.16	14.71	4.92
1993	—	1.88	1.88	3.27	2.70	4.69	4.61	9.63	18.96	8.56	2.08	7.86	5.77	1.09	3.13	14.21	4.89
1994	—	1.78	1.78	3.21	2.72	4.43	4.03	5.05	19.11	8.62	2.31	8.74	5.37	1.10	3.02	13.48	4.68
1995	—	1.82	1.82	2.56	2.92	4.41	4.08	4.94	19.41	8.75	2.26	9.06	5.26	1.18	2.66	13.22	4.27
1996	—	1.80	1.80	3.20	3.11	5.31	5.20	6.32	20.08	9.42	2.79	6.35	6.10	0.96	3.23	13.09	4.75
1997	—	1.80	1.80	3.66	3.17	5.04	4.48	5.62	17.98	9.32	2.74	5.82	5.69	0.96	3.41	13.03	4.89
1998	—	1.70	1.70	3.40	3.25	3.92	3.23	4.18	19.07	7.99	1.92	4.14	4.57	1.24	3.10	12.20	4.59
1999	—	1.76	1.76	3.39	3.60	4.50	2.88	4.85	16.75	8.51	2.47	5.46	5.33	1.39	3.33	12.09	4.81
2000	—	1.71	1.71	5.13	3.68	7.05	7.70	8.25	17.99	11.20	3.65	7.87	7.65	1.44	4.77	12.32	6.05
2001	—	1.78	1.78	6.30	3.77	6.55	6.92	6.65	19.00	10.60	3.13	6.55	6.93	1.56	5.22	12.98	6.61
2002	—	1.87	1.87	5.35	3.81	5.65	5.40	5.77	22.08	10.38	3.60	6.67	6.17	^R 1.56	^R 4.69	11.77	^R 5.94
2003	—	1.90	1.90	6.60	4.16	6.85	7.99	7.87	27.07	11.72	4.36	7.71	7.43	^R 1.52	^R 5.64	11.84	^R 6.78
2004	—	1.88	1.88	7.69	4.53	9.68	10.09	10.07	29.05	13.97	4.57	9.76	9.88	1.76	7.12	12.18	8.09

Expenditures in Million Nominal Dollars																	
1970	—	—	—	40.7	9.4	7.7	2.6	8.2	7.1	4.2	0.5	7.0	46.6	9.3	96.6	59.1	155.7
1975	—	1.1	1.1	82.3	27.4	34.5	6.3	26.4	14.0	4.1	36.7	31.5	180.9	9.8	274.0	104.4	378.4
1980	—	12.0	12.0	265.8	65.9	100.5	13.7	42.8	23.3	2.7	25.9	107.1	381.9	14.9	674.6	338.3	1,012.9
1985	—	17.0	17.0	314.5	35.3	151.5	1.5	34.7	26.0	29.1	16.8	65.5	360.4	17.5	709.4	391.8	1,101.2
1990	—	11.6	11.6	303.0	9.9	81.5	0.5	42.6	24.3	19.4	2.4	39.9	220.5	^e 39.8	^e 575.0	472.9	^e 1,048.0
1991	—	12.7	12.7	279.7	11.4	59.3	0.6	48.6	25.0	21.0	1.1	26.1	193.1	48.0	533.6	487.5	1,021.1
1992	—	13.2	13.2	320.8	17.4	92.6	0.3	43.1	27.8	20.0	0.1	32.5	233.9	51.9	619.8	520.1	1,139.9
1993	—	14.6	14.6	335.6	26.1	86.7	0.3	48.5	29.3	17.7	1.9	28.2	238.7	60.8	649.6	555.9	1,205.5
1994	—	15.3	15.3	372.5	19.2	81.3	0.4	23.7	30.9	19.2	3.0	31.8	209.4	59.5	656.7	553.1	1,209.8
1995	—	14.1	14.1	325.4	24.1	103.6	0.5	25.3	30.8	20.5	2.1	31.4	238.4	78.1	656.0	582.2	1,238.1
1996	—	15.1	15.1	396.1	20.1	104.8	0.3	30.1	30.9	22.3	1.5	162.0	372.0	66.9	850.1	627.0	1,477.2
1997	—	12.5	12.5	466.7	21.3	117.2	0.3	23.7	29.3	22.9	0.2	168.6	383.5	68.2	931.0	645.6	1,576.6
1998	—	11.9	11.9	411.1	18.5	86.7	0.3	13.8	32.5	27.0	(s)	123.8	302.7	82.8	808.6	623.4	1,432.0
1999	—	14.0	14.0	407.1	24.5	92.3	0.2	34.3	28.8	24.3	0.3	156.2	360.9	92.2	874.2	641.5	1,515.7
2000	—	16.4	16.4	593.8	24.8	164.8	0.2	97.1	30.5	32.1	0.2	223.1	572.7	98.0	1,281.0	674.9	1,955.9
2001	—	19.4	19.4	677.9	13.4	174.5	0.7	65.8	29.5	51.7	4.0	133.1	472.8	82.8	1,252.9	681.1	1,934.1
2002	—	19.5	19.5	584.7	65.9	142.9	0.2	31.4	33.9	54.0	1.0	143.0	472.3	^R 78.2	^R 1,154.7	623.6	^R 1,778.3
2003	—	19.2	19.2	^R 677.6	49.9	206.3	0.1	31.7	38.4	65.4	4.9	174.2	570.9	^R 72.7	^R 1,340.5	631.9	^R 1,972.4
2004	—	19.0	19.0	751.6	26.6	314.1	0.1	41.6	41.8	91.6	11.8	248.4	775.9	72.0	1,618.6	659.7	2,278.3

^a Liquefied petroleum gases.
^b "Other" is the "other petroleum products" category described in Section 4 of the Technical Notes.
^c Wood and waste.
^d There are no direct fuel costs for hydroelectric, geothermal, wind, photovoltaic, or solar thermal energy.
^e There is a discontinuity in this time series between 1988 and 1989 due to the expanded coverage of the use of wood and waste beginning in 1989.

R = Revised data.
 — = No consumption, including cases where adjustments were made. See explanation of adjustments in Section 7 of the Technical Notes.
 (s) = Value less than 0.05 million nominal dollars.
 Note: Expenditure totals may not equal sum of components due to independent rounding.
 Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 5. Transportation Sector Energy Price and Expenditure Estimates, Selected Years 1970-2004, Arkansas

Year	Primary Energy										Retail Electricity	Total Energy ^b	
	Coal	Natural Gas	Petroleum							Total			
			Aviation Gasoline	Distillate Fuel	Jet Fuel	LPG ^a	Lubricants	Motor Gasoline	Residual Fuel				
Prices in Nominal Dollars per Million Btu													
1970	—	—	2.17	1.16	0.72	1.23	5.08	2.74	0.40	2.38	2.38	—	2.38
1975	1.22	—	3.45	2.53	2.01	2.64	7.48	4.60	1.57	4.06	4.06	—	4.06
1980	—	—	9.02	6.70	6.34	5.54	14.36	9.93	—	9.11	9.11	—	9.11
1985	—	—	9.99	6.56	5.96	10.34	17.61	8.80	—	8.24	8.24	—	8.24
1990	—	—	9.32	7.87	5.90	11.31	14.60	8.86	—	8.55	8.55	—	8.55
1991	—	—	8.71	7.64	5.01	13.66	16.80	8.81	—	8.43	8.43	—	8.43
1992	—	—	8.54	7.69	4.52	13.15	18.32	8.69	—	8.42	8.42	—	8.42
1993	—	—	8.24	7.65	4.45	12.89	18.96	8.56	—	8.33	8.33	—	8.33
1994	—	4.20	7.96	7.58	4.30	12.06	19.11	8.62	—	8.27	8.27	—	8.27
1995	—	3.63	8.36	7.43	4.28	12.36	19.41	8.75	—	8.35	8.35	—	8.35
1996	—	3.76	9.29	8.37	5.13	12.90	20.08	9.42	—	9.06	9.06	—	9.06
1997	—	5.14	9.39	8.04	4.69	12.87	17.98	9.32	—	8.87	8.87	—	8.87
1998	—	5.22	8.11	6.98	3.50	11.46	19.07	7.99	—	7.64	7.64	—	7.64
1999	—	4.94	8.81	7.41	4.12	12.74	16.75	8.51	—	7.90	7.90	—	7.90
2000	—	6.01	10.87	10.09	6.61	15.35	17.99	11.20	—	10.50	10.50	—	10.50
2001	—	7.64	11.01	9.63	5.48	14.72	19.00	10.60	—	10.25	10.24	—	10.24
2002	—	4.20	10.72	9.41	5.10	16.09	22.08	10.38	—	10.06	10.06	—	10.06
2003	—	5.02	12.42	10.58	6.20	17.33	27.07	11.72	—	11.37	11.36	—	11.36
2004	—	6.56	15.13	12.87	8.30	19.21	29.05	13.97	—	13.63	13.62	16.53	13.62

Expenditures in Million Nominal Dollars													
1970	—	—	3.2	22.8	8.5	3.2	9.2	316.9	(s)	363.9	363.9	—	363.9
1975	(s)	—	4.4	94.4	21.7	6.7	14.0	658.9	0.1	800.2	800.2	—	800.2
1980	—	—	12.5	261.3	70.0	4.2	37.6	1,370.7	—	1,756.4	1,756.4	—	1,756.4
1985	—	—	4.4	293.7	65.7	5.5	42.0	1,195.7	—	1,607.0	1,607.5	—	1,607.5
1990	—	—	5.9	445.4	54.5	3.4	39.2	1,323.6	—	1,872.0	1,876.6	—	1,876.6
1991	—	—	6.3	443.0	48.8	3.9	40.3	1,317.9	—	1,860.2	1,863.1	—	1,863.1
1992	—	—	6.6	445.2	28.0	2.9	44.8	1,319.0	—	1,846.5	1,848.5	—	1,848.5
1993	—	—	5.6	478.5	25.2	3.2	47.2	1,351.4	—	1,911.1	1,911.1	—	1,911.1
1994	—	0.1	6.3	542.1	39.0	5.5	49.8	1,370.9	—	2,013.6	2,013.7	—	2,013.7
1995	—	0.1	6.0	543.9	28.5	2.3	49.7	1,444.7	—	2,075.1	2,075.3	—	2,075.3
1996	—	0.2	5.7	637.0	44.6	2.1	49.9	1,552.1	—	2,291.3	2,291.5	—	2,291.5
1997	—	0.3	6.4	636.3	40.9	2.0	47.2	1,587.2	—	2,320.0	2,320.3	—	2,320.3
1998	—	0.4	5.0	583.6	30.3	1.4	52.4	1,356.2	—	2,028.9	2,029.3	—	2,029.3
1999	—	0.5	5.2	597.1	106.8	21.0	46.5	1,468.3	—	2,245.0	2,245.5	—	2,245.5
2000	—	0.7	5.1	843.4	182.4	5.2	49.2	1,908.7	—	2,993.9	2,994.6	—	2,994.6
2001	—	1.0	10.1	876.6	32.2	4.7	47.6	1,783.3	—	2,754.6	2,755.5	—	2,755.5
2002	—	0.6	6.4	921.6	23.0	3.2	54.7	1,783.5	—	2,792.3	2,792.9	—	2,792.9
2003	—	0.8	6.5	990.4	28.9	3.0	62.0	2,024.4	—	3,115.1	3,115.9	—	3,115.9
2004	—	1.2	9.9	1,289.0	34.0	3.5	67.4	2,424.1	—	3,827.9	3,829.1	(s)	3,829.1

^a Liquefied petroleum gases.

^b From 1981 through 1992, total includes ethanol blended into motor gasoline that is not shown in the motor gasoline column for those years.

— = No consumption, including cases where adjustments were made. See explanation of adjustments in

Section 7 of the Technical Notes.

(s) = Value less than 0.05 million nominal dollars.

Note: Expenditure totals may not equal sum of components due to independent rounding.

Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 6. Electric Power Sector Price and Expenditure Estimates by Source, Selected Years 1970-2004, Arkansas

Year	Coal	Natural Gas	Petroleum				Nuclear Fuel	Biomass ^a	Electricity Imports ^b	Total Energy ^{c,d}
			Residual Fuel	Distillate Fuel	Petroleum Coke	Total				
Prices in Nominal Dollars per Million Btu										
1970	—	0.25	0.42	0.46	—	0.42	—	—	—	0.26
1975	—	0.61	1.78	2.22	—	1.79	0.24	—	—	0.72
1980	1.34	2.16	3.34	4.34	—	3.39	0.54	—	—	1.46
1985	1.58	2.82	3.84	5.86	—	4.99	0.77	—	—	1.37
1990	1.61	1.54	2.75	4.94	—	4.72	0.73	—	—	1.32
1991	1.60	1.41	2.72	5.64	—	5.61	0.70	—	—	1.27
1992	1.65	1.53	2.16	4.81	—	4.81	0.64	—	—	1.32
1993	1.70	2.21	2.07	4.58	—	4.47	0.56	—	—	1.29
1994	1.60	1.82	2.62	4.04	—	3.58	0.48	—	—	1.20
1995	1.61	1.70	1.90	4.18	—	3.83	0.52	—	—	1.28
1996	1.50	2.47	2.04	4.53	—	3.35	0.51	—	—	1.26
1997	1.64	2.62	2.87	4.70	—	4.29	0.49	—	—	1.29
1998	1.47	2.24	2.16	3.71	—	3.13	0.50	—	—	1.24
1999	1.46	2.53	1.67	3.29	—	2.69	0.51	—	—	1.27
2000	1.42	4.38	3.99	4.66	—	4.11	0.52	—	—	1.42
2001	0.87	4.29	4.83	6.26	—	4.91	0.51	—	—	1.03
2002	0.84	3.53	2.03	5.50	—	2.95	0.49	—	—	0.99
2003	1.20	4.23	4.65	6.46	—	4.92	0.49	R 0.73	—	1.36
2004	1.23	6.02	4.72	7.29	—	4.90	0.49	0.82	—	1.43
Expenditures in Million Nominal Dollars										
1970	—	27.4	1.8	(s)	—	1.9	—	—	—	29.3
1975	—	19.7	49.0	0.8	—	49.8	12.7	—	—	82.2
1980	40.3	130.1	65.3	4.5	—	69.8	46.0	—	—	286.3
1985	334.0	34.0	0.2	0.4	—	0.6	81.3	—	—	449.9
1990	333.3	50.3	0.3	4.0	—	4.3	87.5	—	—	475.3
1991	333.9	40.1	(s)	4.2	—	4.2	93.1	—	—	471.3
1992	353.0	42.4	(s)	2.7	—	2.7	76.2	—	—	474.3
1993	327.9	48.0	0.1	3.4	—	3.4	80.1	—	—	459.6
1994	342.3	46.6	0.9	2.9	—	3.8	70.5	—	—	463.2
1995	369.8	56.6	0.2	2.3	—	2.5	64.2	—	—	493.1
1996	378.3	85.8	1.0	2.6	—	3.6	72.0	—	—	539.7
1997	393.2	66.6	0.5	2.7	—	3.2	73.7	—	—	536.7
1998	364.5	92.6	1.4	3.9	—	5.2	69.4	—	—	531.8
1999	377.2	104.0	1.0	3.2	—	4.2	68.7	—	—	554.0
2000	366.6	154.4	7.4	1.8	—	9.2	62.7	—	—	592.9
2001	230.1	116.1	40.7	3.0	—	43.7	79.0	—	—	468.9
2002	204.6	152.3	2.3	2.2	—	4.5	74.1	—	—	435.6
2003	R 291.1	246.3	11.2	2.7	—	13.8	74.8	5.1	—	R 631.3
2004	319.0	248.5	22.0	2.6	—	24.7	79.7	2.0	—	673.8

^a Wood and waste.

^b Electricity imported from Canada and Mexico.

^c There are no direct fuel costs for hydroelectric, geothermal, wind, photovoltaic, or solar thermal energy.

^d Electricity imports have replaced electricity net imports used in previous data editions. This change in methodology causes revisions in the total that are not reflected in other columns.

R = Revised data.

— = No consumption.

(s) = Value less than 0.05 million nominal dollars.

Note: Expenditure totals may not equal sum of components due to independent rounding.

Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Table 1. Energy Price and Expenditure Estimates by Source, Selected Years 1970-2004, California

Year	Primary Energy														Electric Power Sector ^{d,e}	Retail Electricity	Total Energy ^d
	Coal			Natural Gas	Petroleum							Nuclear Fuel	Biomass ^c	Total ^{d,e,f}			
	Coking Coal	Steam Coal	Total		Distillate Fuel	Jet Fuel	LPG ^a	Motor Gasoline	Residual Fuel	Other ^b	Total						
Prices in Nominal Dollars per Million Btu																	
1970	0.43	0.96	0.46	0.56	1.26	0.73	1.84	2.80	0.38	1.52	1.80	0.19	1.39	1.21	0.34	4.76	1.74
1975	1.38	0.92	1.32	1.25	2.97	2.04	3.08	4.84	2.38	2.82	3.55	0.21	1.55	2.61	1.82	8.71	3.46
1980	1.97	1.82	1.91	3.54	6.62	6.21	6.09	10.19	4.49	6.60	7.42	0.49	2.74	5.95	3.99	17.16	7.71
1985	—	2.26	2.26	5.01	6.67	6.01	9.71	8.68	4.75	7.98	7.45	0.96	3.30	6.19	R 3.76	22.90	8.89
1990	—	1.89	1.89	4.20	7.50	5.76	10.55	8.57	3.66	6.05	7.24	0.72	1.38	5.59	R 2.21	25.98	9.89
1991	—	1.82	1.82	4.34	7.35	4.80	11.33	8.18	2.57	6.18	6.91	0.67	1.44	5.40	R 2.00	27.70	9.10
1992	—	1.67	1.67	3.97	7.58	4.53	11.09	9.19	1.86	6.39	7.56	0.55	1.30	5.52	1.89	28.38	9.59
1993	—	1.68	1.68	4.02	7.78	4.50	11.80	9.08	2.03	6.40	7.46	0.44	1.11	5.53	1.99	28.50	9.52
1994	—	1.70	1.70	4.13	7.59	4.03	11.64	9.11	2.03	6.33	7.25	0.47	2.48	5.48	1.91	28.78	9.57
1995	—	1.66	1.66	4.22	7.78	4.15	11.31	9.25	2.14	6.28	7.36	0.43	2.53	5.67	1.67	29.15	9.64
1996	—	1.66	1.66	4.32	8.62	4.96	11.58	10.02	2.10	6.50	8.06	0.44	2.13	6.10	1.76	27.85	9.95
1997	—	1.70	1.70	4.69	8.40	4.71	11.68	10.26	3.34	6.35	8.41	0.45	1.47	6.37	2.04	28.04	10.32
1998	—	1.67	1.67	4.39	7.21	3.38	11.15	8.99	2.11	6.03	7.25	0.45	1.44	5.58	R 1.82	26.23	9.29
1999	—	1.63	1.63	4.25	8.28	4.26	11.11	10.50	4.25	5.50	8.43	0.42	1.32	6.20	R 1.89	26.38	9.98
2000	—	1.57	1.57	6.54	10.48	6.91	14.28	12.63	6.24	5.95	10.48	0.45	2.14	R 8.16	4.03	27.81	12.04
2001	—	1.46	1.46	8.78	9.54	5.83	15.74	12.23	5.30	6.24	10.03	0.43	2.20	8.78	6.56	34.60	13.01
2002	—	1.71	1.71	5.21	9.25	5.40	13.85	11.19	5.78	6.42	9.35	0.49	2.31	R 7.17	2.58	36.67	12.24
2003	—	1.71	1.71	R 7.03	10.82	6.55	16.38	13.70	5.90	8.12	11.41	0.46	3.38	R 8.99	3.58	34.12	R 13.55
2004	—	1.82	1.82	7.63	13.58	9.33	19.09	16.02	6.31	8.86	13.67	0.47	3.60	10.48	4.11	33.61	15.12

Expenditures in Million Nominal Dollars																	
1970	25.6	2.7	28.2	1,126.7	283.0	242.7	99.5	3,149.1	161.1	258.6	4,194.0	6.7	55.8	5,411.4	-282.1	1,886.6	7,015.9
1975	67.7	6.9	74.6	2,148.2	719.4	716.0	169.8	6,137.9	1,628.1	521.8	9,892.9	14.4	67.6	12,197.6	-1,553.7	4,328.7	14,972.6
1980	79.8	46.8	126.6	6,063.2	2,390.8	2,199.3	365.8	13,579.1	4,131.7	1,582.3	24,248.9	26.1	99.7	R 30,566.1	R -4,020.1	9,559.9	36,105.9
1985	—	102.4	102.4	9,251.8	2,775.8	2,257.8	608.7	12,195.2	1,953.0	1,510.3	21,300.7	200.4	171.3	R 31,130.8	R -3,586.1	14,143.0	41,687.7
1990	—	159.2	159.2	8,366.4	3,368.4	3,081.3	636.2	13,778.7	1,461.5	1,171.5	23,497.7	249.6	g 203.0	g R 32,612.6	R -2,554.5	18,415.2	g 48,473.4
1991	—	163.1	163.1	8,774.1	3,202.8	2,438.9	593.4	12,833.9	723.1	1,087.6	20,879.6	221.5	205.3	R 30,334.5	R -2,190.1	19,407.9	47,552.2
1992	—	153.3	153.3	8,456.8	3,049.2	2,219.3	579.5	15,245.6	394.4	1,137.3	22,625.3	203.7	197.6	R 31,673.0	R -2,430.2	20,373.0	49,615.9
1993	—	142.4	142.4	8,264.6	2,938.6	2,273.1	496.0	14,726.7	467.8	1,093.7	21,995.9	145.3	150.2	R 30,726.0	R -2,322.7	20,159.6	48,562.9
1994	—	143.6	143.6	9,074.9	3,194.4	2,257.2	564.0	14,652.9	530.0	1,153.3	22,351.8	164.1	340.2	R 32,104.7	R -2,551.0	20,656.4	50,210.0
1995	—	140.2	140.2	8,337.7	3,302.9	2,241.5	476.9	15,127.1	617.7	1,158.2	22,924.3	135.1	305.1	R 31,869.5	R -1,757.9	20,824.8	50,936.4
1996	—	133.3	133.3	8,059.5	3,693.5	2,915.8	390.1	16,641.7	529.2	1,165.0	25,335.3	157.3	248.5	R 33,953.6	R -1,774.0	20,481.5	52,661.2
1997	—	140.9	140.9	9,467.9	3,887.4	2,755.2	347.6	17,266.0	449.1	1,125.0	25,830.4	145.2	165.8	R 35,771.7	R -2,102.0	21,558.1	55,227.8
1998	—	110.6	110.6	9,907.8	3,290.1	2,018.3	416.1	15,465.1	227.8	1,270.7	22,688.2	164.8	152.4	R 33,042.2	R -2,072.4	20,918.7	51,888.5
1999	—	113.4	113.4	9,452.0	3,985.1	2,383.0	457.2	18,485.9	627.3	1,353.0	27,291.5	146.2	152.2	R 37,179.7	R -2,279.3	20,874.4	55,774.8
2000	—	109.9	109.9	15,046.1	5,695.6	4,036.2	585.2	22,567.0	1,321.2	1,346.8	35,552.1	164.9	257.7	R 51,187.7	R -5,695.0	22,904.7	68,397.3
2001	—	98.8	98.8	20,805.6	5,398.6	3,213.4	536.4	22,426.1	838.3	1,448.9	33,861.6	150.3	262.4	R 55,216.8	R -9,656.6	27,459.8	73,020.1
2002	—	120.0	120.0	11,081.2	4,817.3	3,146.2	683.1	21,528.7	1,110.7	1,544.8	32,830.9	175.5	R 310.1	R 44,540.4	R -3,223.1	29,143.3	R 70,460.6
2003	—	118.7	118.7	R 15,307.9	7,644.9	3,702.4	759.8	26,221.1	866.5	1,569.7	40,764.6	172.0	R 389.3	R 56,767.1	R -4,361.9	27,480.7	R 79,885.9
2004	—	125.2	125.2	17,818.1	7,428.0	5,573.8	938.6	31,415.7	1,101.1	1,753.9	48,211.1	148.8	407.8	66,726.2	-5,134.7	28,669.0	90,260.4

^a Liquefied petroleum gases.
^b "Other" includes asphalt and road oil, aviation gasoline, kerosene, lubricants, petroleum coke (industrial and electric power), and the "other petroleum products" category described in Section 4 of the Technical Notes.
^c Wood and waste.
^d There are no direct fuel costs for hydroelectric, geothermal, wind, photovoltaic, or solar thermal energy.
^e Electricity imports are included in this total but not shown separately. Electricity imports have replaced electricity net imports used in previous data editions. This change in methodology causes revisions in the total that are not reflected in other columns.
^f From 1981 through 1992, total also includes ethanol blended into gasoline that is not shown in the motor gasoline

column for those years.
^g There is a discontinuity in this time series between 1988 and 1989 due to the expanded coverage of the use of wood and waste beginning in 1989.
R = Revised data.
— = No consumption, including cases where adjustments were made. See explanation of adjustments in Section 7 of the Technical Notes.
Note: Expenditure totals may not equal sum of components due to independent rounding.
Sources: Data sources, estimation procedures, and assumptions are described in the Technical Notes.

Appendix 5: January 2008 Update – Biomass Resource Assessment

re Forestry residues:

- Milling residues are based on conversion of harvested timber data compiled from Arkansas Forestry Commission in 2005.
- Estimates of in-forest residues were prepared in collaboration with the University of Arkansas School of Forest Resources in Monticello; figures are based on U.S. Forest Service's Forest Inventory & Analysis data. For more information, contact Dr. Matt Pelkki at <http://www.afrc.uamont.edu/sfr/>

re Agricultural residues:

- Estimates are based on 2006 agricultural production data from USDA National Agricultural Statistics Service.
- Assumptions re conversion factors are shown in Table 1 below.
- A summary of estimated agricultural residues is shown in Table 2 below.

re Animal residues:

- Estimates have not been updated since the 2005 update for AEO. Estimates include manure biomass (and poultry litter) but do not include mortality.
- Assumptions re conversion factors are shown in Table 3 below.
- A summary of estimated animal biomass is shown in Table 4 below.

re Animal residues:

- Estimates have not been updated since the 2005 update for AEO. Estimates are based on data from the Arkansas Department of Environmental Quality.

Table 1: Assumptions for Agricultural Residue Calculations

	NASS production reporting unit acronym	average yield as reported by NASS, in reported units	NASS production reporting units	average bulk density as reported (i.e., as harvested)	bulk density units	bulk density source	estimated moisture content as reported (i.e., as harvested)	moisture content source	field residues, % of crop harvested	data source	estimated sustainable field residue removal, % of total residue production	data source
<u>field residues</u>												
corn	BU	146.6 bushels		56 lbs/bu		A	20.0%	E	100%	K	33.2%	K
cotton	BAL	2.2 bales		480 lbs/bale		B	10.0%	F	100%	L	20.3%	K
rice	CWT	68.6 hundred weight (lbs)		100 lbs/CWT		A	12.2%	H	148%	K	40.1%	K
sorghum	BU	88.7 bushels		56 lbs/bu		A	13.0%	I	100%	K	0.0%	K
soybeans	BU	35.1 bushels		60 lbs/bu		A	7.0%	J	145%	K	0.0%	K
wheat	BU	61.2 bushels		60 lbs/bu		A	13.5%	D	153%	K	13.7%	K
									processing residues, % of crop harvested	data source		
<u>processing residues</u>												
rice husk									20.0%	M		
cotton gin trash									20.8%	N		
<u>source references</u>												
A	ASAE Std D241.4 Table 1											
B	USDA/NASS Arkansas Statistical Office: Arkansas Crop Report November 12, 2004											
D	University of Arkansas (http://www.uaex.edu/Other_Areas/publications/PDF/FSA-3066.pdf)											
C	University of Arkansas, November 2004 (http://www.aragriculture.org/cropsoilwtr/wheat/Verification/wrvp0304.asp)											
E	ASAE Std D241.4 Table 2 (average of two entries for "Com, shelled")											
F	estimate derived from recommendations from various on-line sources (e.g.: http://www.nationalcottoncouncil.org/tech/quality/just-build-it.cfm)											
G	ASAE Std D241.4 Table 2 (average of four entries for "Oats")											
H	ASAE Std D241.4 Table 2 (average of two entries for "Rice")											
I	estimate derived from recommendations from various on-line sources (e.g.: http://www.ext.nodak.edu/extpubs/plantsci/crops/ae905w.htm#storability)											
J	ASAE Std D241.4 Table 2 (average of two entries for "Soybeans")											
K	Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply; April 2005; U.S. Department of Energy (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf)											
L	ditto, but considered to be "other" (i.e., 1.0 tons/acre ÷ 1.0 tons/acre)											
M	personal communications with rice milling specialists											
N	based on 100 lbs/bale per Arkansas Agricultural Extension Service, June 2005											

Table 2: Summary of Estimated Agricultural Residues

Commodity				crop produced		residues produced			estimated usable residues		
	Acres	Production quantity	Reported units	Production quantity, "as reported" tons	Production quantity, dry tons (0% m.c.)	Field residues, dry tons	Processing residues, dry tons	Total residues, dry tons	Removable field residues, dry tons	Processing residues, dry tons	Total residues, dry tons
Corn	169,800	24,885,000	Bu	697,000	557,200	557,200		557,200	185,000	-	185,000
Cotton	1,144,000	2,493,600	Bales	600,000	540,000	540,000	112,500	652,500	109,500	112,500	222,000
Rice	1,388,300	95,191,800	CWT	4,760,000	4,183,000	6,201,000	837,000	7,038,000	1,678,000	837,000	2,515,000
Sorghum	42,700	3,787,000	Bu	106,000	92,000	92,000		92,000	-	-	-
Soybeans	3,054,900	107,107,000	Bu	3,214,000	2,992,000	4,351,000		4,351,000	-	-	-
Wheat	299,400	18,335,000	Bu	550,050	475,793	728,108		728,108	65,258	-	65,258
totals	6,099,100	251,799,400		9,927,050	8,839,993	12,469,308	949,500	13,418,808	2,037,758	949,500	2,987,258

Commodity	Field residues		Processing residues		Total residues		% of total residues that are considered usable
	production, dry tons / year	usable quantity, dry tons / year	production, dry tons / year	usable quantity, dry tons / year	production, dry tons / year	usable quantity, dry tons / year	
Corn	557,200	185,000	-	-	557,200	185,000	6.2%
Cotton	540,000	109,500	112,500	112,500	652,500	222,000	7.4%
Rice	6,201,000	1,678,000	837,000	837,000	7,038,000	2,515,000	84.2%
Sorghum	92,000	-	-	-	92,000	-	0.0%
Soybeans	4,351,000	-	-	-	4,351,000	-	0.0%
Wheat	728,108	65,258	-	-	728,108	65,258	2.2%
totals	12,469,308	2,037,758	949,500	949,500	13,418,808	2,987,258	

Table 3: Assumptions for Animal Biomass Calculations

NASS field name:	beef cows & heifers that had calved	milk cows & heifers that had calved	cattle on feed	units	comments
average weight	1,000	1,350	650 lbs per animal		A
# animals per AU	1.00	0.74	1.54		B
# AUs per animal	1.00	1.35	0.65		C
manure production factor, as excreted	62.04	81.40	62.03 lbs/day/1000 lbs of animal		D
manure per AU per day	62.0	81.4	62.0 lbs/day/AU		E
manure per animal per day	62.0	109.9	40.3 lbs/day/animal		F
manure per AU per year	11.3	14.9	11.3 tons/year/AU		G
manure per animal per year, as excreted	11.3	20.1	7.4 tons/year/animal		H
average moisture content	88.1%	88.0%	54.9%		I
manure per animal per year (DMB)	1.3	2.4	3.3 tons/year/animal		J

category	MPF	MC%	herd %	
T1: dairy				
lactating cow	80.00	87.5%	60.0%	K
dry cow	82.00	88.4%	20.0%	K
heifer	85.00	89.3%	20.0%	
wt'd avg	81.40	88.0%	100.0%	
T2: beef cows				L
cow	63.00	88.4%	80.0%	L
heifer	58.20	87.0%	20.0%	
wt'd avg	62.04	88.1%	100.0%	
T4: feeder cattle				K
high forage diet	59.10	51.2%	90.0%	L
high energy diet	88.40	88.4%	10.0%	L
wt'd avg	62.03	54.9%	100.0%	

Comments	
A refer to comments in each cell for assumptions re avg wt per animal per category	L
B = 1000 lbs (i.e., one Animal Unit) ÷ avg animal weight	L
C = average animal weight ÷ 1000	
D manure production factor (MPF): refer to comments in each cell for assumptions re avg wt per animal per category	
E = same as previous line	
F =MPF x # Aus per animal	
G = 'manure per AU per day' x 365 days/year ÷ 2000 lbs/ton	
H = 'manure per animal per day' x 365 days/year ÷ 2000 lbs/ton	
I refer to comments in each cell for assumptions re avg moisture content per animal per category	
J = 'manure per animal per year, as excreted' x (1-'average moisture content')	
K source: USDA NRCS Animal Waste Management Field Handbook, Table 4-5	
L source: USDA NRCS Animal Waste Management Field Handbook, Table 4-8	

Table 4: Summary of Estimated Animal Biomass

Category	# of animals in inventory	wet tons per year ("as excreted")	dry tons per year (@ 0% moisture)	# of production farms	stetwide average # of animals per production farm	statewide average manure production, dry tons/year/farm	statewide average farm size, animals/farm
Cattle manure							
beef	1,571,000	17,792,000	2,114,000	27,000	58	78	58
dairy	58,000	1,156,000	138,000	490	118	282	118
total Cattle	1,629,000	18,948,000	2,252,000	27,490	59	82	59
Swine manure							
hogs & pigs for breeding	52,000	130,000	12,000	500	104	24	104
other swine	92,000	144,000	14,000	710	130	20	130
total Swine	144,000	274,000	26,000	1,210	119	21	119
Poultry							
broilers	180,967,000	5,299,000	1,325,000	3,060	59,140	433	59,140
layers	12,851,000	568,000	142,000	1,910	6,728	74	6,728
replacement pullets	5,735,000	185,000	46,000	590	9,720	78	9,720
turkeys	8,457,000	1,125,000	281,000	460	18,385	611	18,385
total Poultry manure	208,010,000	7,177,000	1,794,000	6,020	34,553	298	34,553
Totals	209,783,000	26,399,000	4,072,000	34,720	6,042	117	6,042
Broiler and Turkey Litter							
	# of birds sold per year	wet tons per year	dry tons per year (@ 0% moisture)	# of production farms		statewide average manure production, dry tons/year/farm	statewide average farm size, animals/farm
broiler litter	1,178,210,000	1,208,000	906,000	3,060	385,036	296	385,036
turkey litter	28,150,000	35,000	25,000	460	61,196	54	61,196

Table 5: Summary of Municipal Biomass

	Quantity, tons/year	% of counties reporting
Paper-type biomass		
Paper-Cardboard OCC	174,084	47%
Paper-News (Regular)	23,686	43%
Paper-Office (White)	11,149	17%
Paper-CPO	179	5%
Paper-Mixed	20,139	23%
Paper-Ledger (Colored)	22	1%
Paper-Other	78,821	25%
total paper biomass	308,080	
Used cooking oil	4,429	3%
Woody-type biomass		
sawdust	936	1%
used pallets	174,027	13%
other	1,359,216	16%
total woody biomass	1,534,178	
Yard waste	144,814	43%
Biosolids	41,273	60%
total municipal biomass	2,032,774	

**Appendix 6:
Supporting Calculations: Comparative Analysis of Biofuels Production Options**

	corn-derived ethanol	corn stover to (cellulosic) ethanol	soy-derived biodiesel	ethanol from herbaceous energy crops	notes
agronomics					
crop yield - bushels/acre/year, as harvested	147	200	35.1	3,530	2
stover to grain yield, by weight		33.2%			
crop yield, lbs/acre/yr, as harvested	8,232	2,733.0	2,106	35,294	
crop yield, tons/acre as harvested	4.1	1.4	1.1	17.6	
assumed moisture content as harvested	15%	15%	15%	15%	3
crop yield, dry lbs/acre/yr	6,997	2,323	1,790	30,000	4
crop yield, dry tons/acre/yr	3.5	1.2	0.9	15	5
gross liquid fuel production					
gallons/bushel	2.7	0.5	1.2	0.4	6
gallons/dry ton of feedstock	110	90	47	90	7
gallons/acre/year	390	105	42	1,350	
gross energy production (only for energy from liquid fuels produced)					
assumed energy content of biofuel, Btu/gal	76,000	76,000	117,000	76,000	8
gross energy production, MM Btu/acre/year	30	8	4.9	103	9
gross energy production, MM Btu/dry ton of feedstock	8.5	6.8	5.5	6.8	
net energy production (only for energy from liquid fuels produced)					
assumed net energy balance	1.3	5.0	3.3	5.0	10
net energy production / gross energy production	23%	80%	70%	75%	11
portion used for system operations	77%	20%	30%	25%	
net energy production, gal/acre/year	90	84	29	1,013	
net energy production, MM Btu/acre/year	6.8	6.4	3.4	77	
net energy production, MM Btu/dry ton of feedstock	2.0	5.5	3.8	5.1	
net energy production - ethanol equivalents					
net energy production, gal/ac/yr	90	84	45	1,010	
net energy production, gal/dry ton of feedstock	26	72	50	67	
net energy production - diesel equivalents					
net energy production, gal/ac/yr	51	47	25	570	
net energy production, gal/dry ton of feedstock	14	41	28	38	

notes

1	density as harvested, lbs/bushel	56	14	60	10
2	estimated average yields in the Delta				
3	wet basis				
4	"dry" means calculated at 0% moisture content				
5	estimated HEC yield from good agronomic conditions with year-round production				
6	approximate averages for each industry				
7	estimated ethanol process yield from cellulosic feedstocks				
8	this reflects only usable energy within the biofuel and does not include other forms of energy that may be simultaneously derived from the same feedstock stream such as thermal and/or electrical energy				
9	based on generally available figures				
10	"net energy balance" reflects the estimated total output of energy in the biofuel per unit of energy required for production & processing (the assumptions are based on generally accepted figures available in the literature) for example, a net energy balance of 1.3 means the enterprise produces 30% more usable energy than is consumed in producing the energy.				
11	These net energy balance figures typically reflect energy credits allocated to non-energy co-products (which is particularly the case for ethanol from corn and biodiesel from soybeans).				
12	typical energy density of petro-diesel =	135,000			
13	assumed average agronomic yields				

**Appendix 7:
Outline of State Actions – Energy Supply – Governor’s Climate Commission**

1. EMISSIONS POLICIES AND OVERARCHING ITEMS
 - 1.1. GHG cap and trade
 - 1.2. Carbon (GHG) tax
 - 1.3. Generation performance standards and/or mitigation requirements for electricity
 - 1.4. Integrated resource planning (IRP)
 - 1.5. Voluntary GHG commitments
 - 1.6. Technology Research & Development

2. RENEWABLE ENERGY AND ENERGY EFFICIENCY
 - 2.1. Renewable and/or Environmental Portfolio Standard (RPS/EPS)
 - 2.2. Grid-based renewable energy incentives and/or barrier removal
 - 2.3. Distributed renewable energy incentives and/or barrier removal
 - 2.4. Green power purchases and marketing
 - 2.5. Combined Heat and Power (CHP) standards, incentives and/or barrier removal
 - 2.6. Pricing strategies to promote renewable energy and/or CHP (e.g. net metering)
 - 2.7. Renewable energy development issues (zoning, siting, etc.)
 - 2.8. Technology-focused initiatives (biomass co-firing, energy storage, fuel cells, etc.)
 - 2.9. Public benefits charge

3. FOSSIL FUEL AND NUCLEAR ELECTRICITY
 - 3.1. Advanced fossil fuel technology (e.g. IGCC, CCSR) incentives, support, or requirements
 - 3.2. New Nuclear Power
 - 3.3. Relicensing/Upgrading Existing Nuclear Power
 - 3.4. Efficiency improvements and repowering existing plants
 - 3.5. Technology-focused initiatives
 - 3.6. FUEL PRODUCTION, PROCESSING AND DELIVERY
 - 3.7. Oil and gas production: GHG emission reduction incentives, support, or requirements
 - 3.8. Natural gas transmission and distribution
 - 3.9. Oil Refining: GHG emission reduction incentives, support, or requirements
 - 3.10. Coal Production: GHG emission reduction incentives, support, or requirements
 - 3.11. Coal-to-liquids Production: GHG emission reduction incentives, support, or requirements
 - 3.12. Low-GHG Hydrogen production incentives and support

4. CARBON CAPTURE AND STORAGE OR REUSE
 - 4.1. CCSR incentives, requirements and/or enabling policies (administration, regulation, liability, incentives)
 - 4.2. R&D for CCSR

5. OTHER ENERGY SUPPLY OPTIONS
 - 5.1. Transmission system upgrading
 - 5.2. Reduction of transmission and distribution line losses
 - 5.3. General distributed generation support (interconnection rules, net metering, etc.)
 - 5.4. Environmental (GHG emissions) disclosure
 - 5.5. Landfill Gas Recovery (see also Waste)
 - 5.6. Waste to Energy (see also Waste)
 - 5.7. N₂O reduction co-benefit
 - 5.8. Smart Grid

Appendix 8:
Program Rules: Arkansas' 2007 Alternative Fuels Development Program

Arkansas Alternative Fuels Development Program

Regulations for Program Administration and Grant Application

A. Purpose

To increase the availability of alternative fuels produced in Arkansas from feedstock processed in Arkansas by making available incentive grants to alternative fuels producers, feedstock processors, and distributors.

B. Authority

The Arkansas Agriculture Department under the *Arkansas Alternative Fuels Development Act* (Act 873 of 2007 (the “Act”)) is to develop and administer the program.

C. General Provisions

Availability of grants is limited to:

1. alternative fuels production and/or facilities located in Arkansas;
2. alternative fuels production and/or investments made on or after January 1, 2007;
3. two million dollars to any one alternative fuels producer in any one fiscal year;
4. two million dollars to any one feedstock processor in any one fiscal year;
5. fifty-thousand dollars for any one alternative fuels distributor at each alternative fuels distributor site in any one fiscal year.

An entity that holds controlling interest in more than one alternative fuels production facility is considered one alternative fuels producer.

An entity that holds controlling interest in more than one feedstock processing plant is considered one feedstock processor.

Persons or entities who are alternative fuels producers and feedstock processors may apply for and receive grant funds under the Act for alternative fuels production and for feedstock processing.

D. Application Procedures and Requirements

1. Application Deadline

Funding decisions are made on the basis of one round of competition. The FY 07/08 application deadline for grants is February 28, 2008. Applications may cover investments made on or after January 1, 2007 or investments proposed to be made before June 30, 2008. The FY 08/09 application deadline is February 28, 2009.

Applications must be submitted in writing to:

Office of the Secretary
Arkansas Agriculture Department
1 Natural Resource Drive
Little Rock, AR 72205

2. Production Incentive Grant Applications

As defined in the Act, “alternative fuels producer” means a business located in Arkansas that uses biomass or other renewable resources, excluding recycled petroleum oils, to manufacture alternative fuels.

Production Incentive Grants may be for capital improvement and/or operations costs.

Capital improvement grants are to assist in the construction, modification, alteration, or retrofitting of alternative fuels production facilities that are located and operated in Arkansas.

Operations costs grants are for the operation of alternative fuels production facilities located and operated in Arkansas. Successful applicants for operations costs grants are eligible for incentive payments of up to twenty cents per gallon of alternative fuel produced.

Alternative fuels producers may apply for and receive grants to fund capital improvements and/or operations costs however, the Arkansas Agriculture Department will not award grants in an amount that exceeds two million dollars to any one alternative fuels producer in any one fiscal year.

I. Narrative Summary

A narrative description of the proposed project is required. The format, style of presentation, and length may vary, depending on the nature of the project. The narrative shall include the following sections:

- Ownership – legal ownership along with the names, titles, contact information, and roles of principal participants in alternative fuel production facility.
- Location – physical address of facility.
- Description of Current Operation – if in operation, describe facility including feedstock processed, current market, production levels (expected gallonage), and cost per unit.
- Intended Use of Grant –
 - For capital improvement grant, describe construction, modification, alteration, or retrofitting of production facility and permitting required. Include pro-forma operating statement, cash flow analysis, projected per unit cost, annual volume anticipated, expected employment and anticipated markets for alternative fuel.
 - For operating cost grant, include operating pro-forma analysis, cash flow analysis, projected per unit cost, annual volume anticipated, expected employment and anticipated markets for alternative fuel.
- Evidence alternative fuel production volume is sustainable.

II. Selection Criteria

In order to achieve certain goals and priorities, applications will particularly be reviewed for the following criteria. Each will receive a weighted score, the maximum of which is indicated. The sum total score of all the criteria will be used to rank competing applications.

o Capital Improvement Grant Criteria:

- (1) Portion of feedstock grown in Arkansas to be used for alternative fuels production. (15 points)
- (2) Portion of feedstock processed in Arkansas to be used for alternative fuels production. (15 points)
- (3) Share of capital investment from equity investors. (10 points)
- (4) Share of equity investment from Arkansas investors. (10 points)
- (5) Suitability of the alternative fuel to be produced for utilization in the Arkansas fuel economy. (10 points)
- (6) Technical capability of the management team. (15 points)
- (7) New jobs and positions added to the Arkansas rural economy. (10 points)
- (8) Evidence company has in place established quality standards and practices. (15 points)

o Operating Costs Grant Criteria:

- (1) Evidence that applicant and facility will be long-term suppliers of alternative fuels to the Arkansas economy. (20 points)
- (2) Evidence that quality of volume for which claim is made met ASTM standards. (15 points)
- (3) Evidence that applicant attempted to maximize use of feedstock grown or processed in Arkansas. (20 points)
- (4) Evidence that applicant has sound marketing plan in place and is attempting to maximize marketing benefits. (15 points)
- (5) Evidence that applicant has a plan in place to maintain costs at competitive levels. (15 points)
- (6) Evidence company has in place established quality standards and practices. (15 points)

III. Request for Payment

Upon notification that an application for a production incentive grant has been approved, successful applicants may request payment by reporting quarterly production on AAD form AFP-01. All requests for payment, regardless of the fiscal year for which the grant was approved, must be submitted to AAD by May 30, 2009 or payment may be disallowed.

IV. Reporting Requirements

Grant recipients agree to report origin and total annual feedstock processed and total gallons of alternative fuel produced by the facility for the five years subsequent to the construction, modification, alteration, or retrofitting being completed. Or, for operating costs grant, beginning with their first request for payment. Reports are to be submitted on AAD form AFP-02 and must be filed each fiscal year by August 31.

3. Feedstock Processor Incentive Grant Applications

As defined in the Act, “feedstock processor” means a business located in Arkansas that uses biomass or other renewable resources, excluding recycled petroleum oils, to manufacture feedstock to be used in the production of alternative fuels.

Grants are to assist in the construction, modification, alteration, or retrofitting of feedstock processing facilities that are located and operated in Arkansas.

I. Narrative Summary

A narrative description of the proposed project is required. The format, style of presentation, and length may vary, depending on the nature of the project. The narrative shall include the following sections:

- Ownership – legal ownership along with the names, titles, contact information, and roles of principal participants in feedstock processing facility.
- Location – physical address of facility.
- Description of Current Operation – if in operation, describe facility including feedstock processed, current market, production levels, and cost per unit.
- Intended Use of Grant – describe construction, modification, alteration, or retrofitting of feedstock processing facility. Include pro-forma operating statement, cash flow analysis, projected per unit cost, permitting requirements, and anticipated markets for feedstock.

II. Selection Criteria

In order to achieve certain goals and priorities, applications will particularly be reviewed for the following criteria. Each will receive a weighted score, the maximum of which is indicated. The sum total score of all the criteria will be used to rank competing applications.

- (1) Suitability of the feedstock to be produced for utilization by Arkansas alternative fuels producers. (10 points)

- (2) Percentage of Arkansas grown crops or other biomass material to be used for processing. (30 points)
- (3) Share of capital investment from equity investors. (20 points)
- (4) Share of equity investment from Arkansas investors. (20 points)
- (5) Technical capability of the management team. (10 points)
- (6) New jobs and positions added to the Arkansas rural economy. (10 points)

III. Reimbursement Procedure

Upon notification that an application for a feedstock processor incentive grant has been approved, successful applicants may request reimbursement of approved expenditures on AAD form FP-01. All requests for reimbursement, regardless of the fiscal year for which the grant was approved, must be submitted to AAD by May 30, 2009 or reimbursement may be denied.

IV. Reporting Requirements

Grant recipients agree to report origin and total annual tonnage of feedstock processed by facility for the five years subsequent to the construction, modification, alteration, or retrofitting being completed. Reports are to be submitted on AAD form FP-02 and must be filed each fiscal year by August 31.

4. Distribution Incentive Grant Applications

As defined in the Act, “Alternative Fuels Distributor” means a business located in the State of Arkansas that distributes alternative fuels or alternative fuels mixtures.

Distribution incentive grants are restricted to capital investments in alternative fuels distribution facilities.

I. Narrative Summary

A narrative description of the proposed project is required. The format, style of presentation, and length may vary, depending on the nature of the project. The narrative shall include the following sections:

- Ownership – legal ownership along with the names, titles, contact information, and roles of principal participants in alternative fuels distribution business.
- Location – physical address of business and distribution site(s).
- Current source of biofuel and monthly volume.
- Intended use of the grant.
- Evidence sufficient to demonstrate grant will improve the statewide supply and distribution of alternative fuels and/or alternative fuels mixtures that are produced in Arkansas.

II. Selection Criteria

In order to achieve certain goals and priorities, applications will particularly be reviewed for the following criteria. Each will receive a weighted score, the maximum of which is indicated. The sum total score of all the criteria will be used to rank competing applications.

- (1) Additional volume of alternative fuels to be added for distribution as result of investment. (25 points)
- (2) Location of investments in regions or areas of the state where distribution is lacking or deficient. (30 points)
- (3) Improving assurance that investment will add to the capability of providing continuous supplies of alternative fuels throughout the year and across the entire state. (30 points)
- (4) Adding to the supply of alternative fuels in locations where there will be significant environmental benefits from use of alternative fuels. (15 points)

III. Reimbursement Procedure

Upon notification that an application for a distribution incentive grant has been approved, successful applicants may request reimbursement of approved expenditures on AAD form AFD-01. All requests for reimbursement, regardless of the fiscal year for which the grant was approved, must be submitted to AAD by May 30, 2009 or may be disallowed.

IV. Reporting Requirements

Grant recipients agree to report total annual amount of alternative fuel stored and/or distributed by distribution site for the five years subsequent to the grants utilization. Reports are to be submitted on AAD form AFD-02 and must be filed each fiscal year by August 31.