Prospects for Biofuels in Alabama: A Synthesis of Expert Opinion

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INTRODUCTION

Proponents of biofuels often promise the industry will be an economic boon to rural communities around the country. Alabama has the potential to become a national leader in the developing biofuels industry due to the presence of abundant timber resources (71 percent of the state is in commercial forest) and the ability to produce switchgrass and other sources of biomass. This report presents an evaluation of opportunities and constraints to commercial biofuels production based on interviews with and data collected from scientists, entrepreneurs, policy makers, and owners of both forest and farm land. The experience of rapid increases in corn-based ethanol production in the Mid-west demonstrates that a new energy industry can have both positive and negative consequences. There are lessons to be learned from the experience of the Mid-west, but the prospects for biofuels development in Alabama and the South are far different because this region's bioenergy industry will be based on cellulosic feedstocks to produce second generation biofuels as well as a range of other chemical products and byproducts.

Because the scientific basis of this new industry is just being established, there is at present no commercial production of second generation bioenergy whose impact can be examined. And yet many people believe that development of bioenergy will have a transformative impact over the next decade. To the extent that this is correct, we believe now is the time to systematically examine what these impacts might be. The best way to approach this question is through what is known as a "Delphi study" where information is solicited from individual experts representing a wide variety of fields and who are engaged in development efforts or who are likely to become centrally involved as stakeholders in this new industry. Scientists and policy makers would be examples of individuals with detailed knowledge of technical developments and policy initiatives that may shape development of this new industry, while farmers and forest landowners represent the type of stakeholder who will be directly affected.

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The importance of input from a variety of sources was highlighted by Meyer and Hinrichs (2007:1), who note that the "exuberant projections of government officials, some scientists and other proponents" are in contrast with the "more equivocal responses by farmers and landowners to the emerging agricultural biofuels sector."

Development of a new biomass-based energy industry will affect land use patterns, employment opportunities, and income generation. A prospective assessment of impacts can provide useful information to researchers, developers, and policy makers, and ensure consideration is given to rural economic and community development as this new industry develops. The fact that biomass to supply this new industry will come from rural areas is no guarantee that people living in rural areas will benefit from this development. The Land Grant mission includes promotion of rural economic and community development, and the present study was motivated in large part to provide preliminary consideration to the connection between bioenergy and such development. Successful biofuels development could provide an economic boon to Alabama farmers and other rural landowners—including those with limited resources—by creating a market for perennials like switchgrass or thinnings or other small diameter timber. Our work focuses on Alabama, but we believe our findings have at least regional implications given the extent of the South's forest and agricultural resources.

Our research is exploratory in nature given that the biofuels industry is at an early stage of development and its long-term effects cannot yet be evaluated. Such assessments at the outset are of vital importance to shaping the future direction of the biofuels industry so that appropriate technologies, production practices, and organizational strategies can be designed to ensure economic viability and social sustainability. At this early stage of development, it is unclear whether the benefits of biofuels development will be concentrated among large producers who enjoy economies of scale in access to technologies and markets, or to what extent other potential producers, including limited resource producers, might also benefit. Biofuels are not the first new industry to affect rural economies, and there are lessons to be learned from the history of technological innovations (e.g., farm mechanization) and shifts in production systems (e.g., from row cropping to pine plantation in much of Alabama and the South) (Hartsell and Johnson 2009). We also are sensitive to the all-pervasive nature of energy in contemporary society as well as the potentially disruptive impact on global food supplies of converting grains to energy (Pimentel et al. 2009; Tokar 2006).

Biomass-derived fuels offer the potential for a revolutionary break from a petroleum-based economy dominated by a handful of corporate actors. Feedstocks are dispersed geographically and in ownership, representing a challenge to centralized control. These and other factors suggest that, compared to large petroleum refineries, biofuel production facilities will be relatively small in scale and dispersed across the landscape. The scale factor opens the possibility of a more decentralized energy economy.

The focus of this report is liquid transportation fuels, but biomass can be used to generate other forms of bioenergy, such as electricity. Biomass can be combusted directly to produce heat or supply power, though net efficiency for electricity generation is low (Wang et al. 2008). Sawmills and pulp and paper mills usually burn manufacturing waste to power a boiler and produce thermal energy to dry lumber. Biomass can also be converted into a synthesis gas, which is then co-fired with coal in a combustor or combusted to produce steam (Wang et al. 2008). High-quality syngas, Wang et al. (2008) state, can be fed into gas engines or turbines directly to generate power. In addition to generating energy, the chemical complexity of cellulosic feedstocks makes possible the simultaneous production of both energy and valuable specialty chemicals. This diversity of products from cellulosic feedstocks is one reason for excitement among scientists and entrepreneurs when evaluating the economic potential of the emerging bioenergy industry.

Many energy experts believe that the technologies and feedstocks used in today's biofuel production are just the beginning and that the path toward energy security and sustainable fuel alternatives will be much broader and encompass much more advanced technology (ACES 2007). Yet little attention has been paid to the social and cultural impacts of the biofuels industry on rural U.S. communities. A thorough analysis would involve addressing issues spanning a wide range of fields including ecology, energy policy, economics, land use and tenure, technology, local governance, public understanding and behavior, industry structure, resource dependency, education and outreach, and governmental incentives and imperatives.

Legislative Environment

Federal and state governments are promoting alternative energy in all its forms through legislative measures as well as high-profile grants designed to attract industry and build confidence in the economic feasibility of new technologies. Some legislation has been passed setting mandates; for example, by the end of 2010, all gasoline sold in Florida is to have 9 to 10 percent ethanol by volume. In Alabama, says a consultant for the Department of Agriculture and Industries, lawmakers are not comfortable setting mandates, but their commitment is no less strong. Resolutions have passed encouraging use of biofuels by school systems and state departments, and in 2007, the state legislature formed the Permanent Joint Legislative Committee on Energy to develop bills to encourage production and utilization of renewable energies.

Nationwide, millions of dollars have been awarded to projects designed to use renewable resources for energy and boost industrial development. The federal government has issued grants worth hundreds of millions of dollars to private companies developing second-generation technologies. States have awarded smaller grants to universities and municipalities to foster industrial development through research and through community use of and support for renewable energy.

At the federal level, the Food, Conservation and Energy Act of 2008 (the Farm Bill) has several programs designed to fulfill needs of biomass-based fuel and electricity industries. The Farm Bill introduced significant new provisions in support of cellulosic ethanol development, both in terms of feedstock and fuel production. The content of the Farm Bill highlights contemporary priorities and demonstrates the attention policy makers are paying to bioenergy and, specifically, to second generation biofuels. While the blender's credit for corn-based ethanol was reduced from $0.51

to $0.45 per gallon, cellulosic ethanol producers are to benefit from a production tax credit up to $1.01 per gallon. Biorefinery assistance is available in the form of grants for 30 percent of the costs of demonstration scale plants and loan guarantees for commercial scale plants up to $250 million per plant. Unlike previous federal policy initiatives, the 2008 Farm Bill provides incentives for biomass producers. Through the Biomass Crop Assistance Program (BCAP), producers will be paid 75 percent of the costs of establishing perennial crops (including switchgrass and timber) for farmers and nonindustrial forestland owners who have supply contracts with cellulosic ethanol producers. In addition, the USDA will make matching payments up to $45 per ton for each ton of cellulosic biomass delivered to a conversion facility for a period of two years. Criteria to determine who will benefit from these program funds include the anticipated economic impact, opportunity for biomass producers and local investors to participate in ownership of the facility, participation opportunities for beginning and socially disadvantaged farmers and ranchers, as well as the impact on soil, water, and related resources.

Under the Bioenergy Program for Advanced Biofuels, a limitation has been set on funds available to larger producers of biofuels. Not more than 5 percent of the total payments can be made available to facilities with capacity greater than 150 million gallons per year. The Farm Bill includes a Biodiesel Fuel Education Program to fund nonprofits and educational institutions to conduct educational programs and provide technical support. Legislation also calls for a comprehensive study of biofuels, including their effects on the price of fuel, land prices, land use, and environmental changes. There is to be a comparative analysis of corn ethanol to other biofuels and the feasibility of converting corn ethanol plants to make biodiesel or cellulosic ethanol. The 2008 Farm Bill appears designed to promote the rapid expansion of cellulosic ethanol production through reducing risks and subsidizing both producers of feedstocks and those who will produce the ethanol from cellulosic feedstocks. This bill, and others like it, can provide an important kick-start to the bioenergy industry, allowing producers entry to markets.

Social Impacts

Some authors stress that examining the social impacts of large projects is equally important, if not more so, as assessing environmental impacts (Biopact 2007b). Unanticipated or unintended social and economic changes or perceptions can lead to withdrawal of public support and failure of such projects (Mol 2007). Careful attention to the social, economic, and environmental impacts of bioenergy projects is important to ensure that “a particular project fits into the dense cultural and social fabric of local communities” (Biopact 2007b).

Much of the available literature on the impacts of cellulosic biofuels development has focused on the potential positive impacts of such development. Keoleian and Volk (2005), for example, focused attention on the environmental and social benefits of willow biomass crops used as feedstock for bioenergy. They argued that willow biomass crops could provide an alternative source of income for farmers willing to diversify their farm crops. Community businesses and power plants can create mutually beneficial relationships as money generated by locally produced energy is spent locally. Keoleian and Volk argued further that more jobs could be created by this form of energy production than by fossil fuels or other renewable forms. Improvements in the refinery process, the authors say, could increase the value of willow biomass even more. Baral and Guha (2004) made similar statements regarding the production of short-rotation woody crops as an approach to promote growth of rural economies. Halvorsen, Barnes, and Solomon (in press) report that a cellulosic ethanol plant producing 20 million gallons per year would generate $45 million in gross state product in the upper Mid-west, but note these figures depend on government subsidies and the availability of investment capital for a largely unproven industry.

In the Mid-west, corn-based ethanol has been a boon to many small towns, in some cases even reversing out-migration trends of young people (Campbell 2007). About half of the ethanol plants in the U.S. in 2007 were farmer-owned, accounting for 30 to 40 percent of industry capacity (Campbell 2007; Urbanchuk 2007; Widenoja 2007). The positive economic impact on a farming community can be considerable when producers benefit not only from supplying feedstock but also from the value added in converting that feedstock to ethanol. Farmer-owned refineries, Morris states, should be considered "a powerful economic development engine" (2006:4). They benefit the farmer by providing some protection against a volatile commodities market; if the price of corn drops, some of that loss is cushioned by increased profits (due to lower production costs) in the sale of ethanol, Morris says. Local ownership benefits communities by ensuring that more of every dollar spent on ethanol (as opposed to petroleum-based fuel) stays in the economy. Financing, marketing, and administrative roles are more likely to be filled locally if farmers operate the facility (Campbell 2007). Recent developments have led to consolidation within the corn ethanol industry and the gradual reduction in numbers of farmer-owned biorefineries (Campbell 2007; Widenoja 2007). The average size of a plant has risen to more than 100 million gallons per year, demanding larger investments, mainly from outside investors. The changing ownership structure may have important impacts on local communities if the new owners change business practices and become less involved in community affairs.

Hoffman and Flora (2008) use the community capitals framework of Flora and Flora (2004) to assess the industry/rural community dynamic and examine the social impacts a corn ethanol plant has had on a small Iowa town. The authors discovered that social and political capital were major driving forces behind the development and construction of the ethanol plant, with community leaders playing significant roles. Yet, the authors noted, respondents did not say the plant was highly integrated into the local community. Existing financial capital (in the form of local investors) and built capital (especially highway and rail access) also had roles leading to the construction of the facility, and were a factor in the company's decision to locate there. Authors also note the plant's unique ownership structure as a factor in its success; the plant had a high number of local shareholders. The plant had positive impacts on cultural capital and presented new opportunities for economic development because of increased infrastructure. The authors note, however, that although the plant provided aid to schools through taxes, it had no direct involvement in educational programs and had little impact on the community's overall human capital.

METHODS

Research for this report was conducted from October 2007 to June 2009. Secondary data for this study came from reading electronic newsletters and trade journals, corporate websites, and other materials cited in the reference section. A systematic review of literature of the social, technical, and policy context of the biofuels industry helped inform the interview guide. Primary data was collected through a "Delphi approach" (Breiner, Cuhls, and Grupp 1994) to utilize the knowledge of expert respondents involved in development of biofuels. In this approach, each expert is given the opportunity to independently express his or her opinion based on personal and professional experiences and training. The Delphi approach is, we believe, well suited to evaluating future trends related to novel technological developments. Among our respondents have been researchers, state policy makers, biofuels producers, landowners, and representatives of a variety of state and industry organizations.

More than 20 expert interviews were conducted. Information was also collected by attending workshops, seminars, and conferences organized for biofuels distributors, feedstock producers, and academic researchers. Table 1 demonstrates the number of respondents by type of expert and type of data collection method. The number of individuals from whom data was gathered (via interviews and speeches) totaled more than 80. The interviews were open-ended and semistructured, allowing respondents to explore in depth issues they believed to be particularly important or regarding which they had particular expertise. In most instances, interviews took place in the respondent's workplace and lasted an average of one and a half hours (with a range of approximately 30 minutes to two hours). Notes taken during the interviews were written up and fleshed out within a day.

Typed notes from all interviews, personal correspondence, speeches, and presentations were imported into qualitative data analysis software (MAXQDA 2007). Use of this software allowed the authors to organize the material in such a way that it could be analyzed. The primary software features used to analyze data were hierarchical coding and text retrieval. Text was coded into various topics. Each document

Table 1. Delphi Approach: Number and Type of Experts by Type of Data Collection Method

	Data collection method	
Type of expert	Interviews or personal correspondence	Speeches or presentations
Grower (farmer, forestland owner)	0	6
Organization (nonprofit or governmental)	13	24
Industry (producer, distributor, consultant)	6	17
Policy maker (politician, lobbyist)	3	4
Researcher (university faculty)	5	24
Total	**27**	**75**

was coded according to what kind of expert provided the data (grower, organization representative, industry representative, policy maker, or researcher). In total, more than 900 segments of text were coded. Codes with the highest number of text segments assigned to them were "feedstock availability," "industry structure–distribution and consumption," "industry structure–refineries," "feedstock–type–woody biomass–residues," "industry structure–preproduction logistics," "policy–incentives," and "rural development." These topics represent the issues experts recognize as being of high importance or in need of further investigation.

Table 2 demonstrates the number of experts in each category who provided information or spoke about coded topics. Growers appear most concerned about feedstock logistics, industry structure, and policy. Based on the number of coded text segments assigned to them, industry structure was the topic of greatest interest. Organization representatives display the widest range of interests, perhaps because experts come from a number of different sectors, many of which address multiple issues of interest to our research. Industry structure and feedstock type yielded the highest number of expert responses. Industry representatives' interests were largely focused on industry structure, with interest also expressed in feedstock type and conversion technologies. Policy makers mostly spoke about policy and industry structure. Researchers also display a wide range of interests, perhaps reflective of the range of disciplines they represent. Researchers spoke most often, however, about feedstock type.

FIRST GENERATION BIOFUELS

Biofuels are liquid transportation fuels derived from biomass. Biomass is organic matter that can be converted into different forms of energy. Sources of biomass include trees, living plant material, agricultural and forestry residues, animal waste, the organic components of municipal and industrial wastes, and agricultural and aquatic crops. Biofuels are made through biochemical or thermochemical processes. Through these processes, the raw materials found in feedstock—compounds such as

Table 2. Number of Experts Who Provided Information on Coded Topics

	Expert type				
Code grouping	Grower (N=6)	Organization (N=29)	Industry (N=22)	Policy maker (N=5)	Researcher (N=25)
Conversion technology	0 (0)[1]	4 (14)	9 (41)	0 (0)	8 (32)
Environment	0 (0)	6 (21)	1 (5)	2 (40)	8 (32)
Feedstock–logistics	3 (50)	13 (45)	5 (23)	1 (20)	11 (44)
Feedstock–type	2 (33)	15 (52)	10 (45)	1 (20)	18 (72)
Industry structure	3 (50)	18 (62)	17 (77)	4 (80)	10 (40)
Infrastructure	0 (0)	7 (24)	2 (9)	2 (40)	3 (12)
Landowners/ limited-resource	1 (17)	10 (34)	2 (9)	1 (20)	2 (8)
Policy	3 (50)	13 (45)	7 (32)	4 (80)	7 (28)
Pulp and Paper	1 (17)	4 (14)	4 (18)	1 (20)	3 (12)
Rural development/ municipalities	0 (0)	13 (45)	5 (23)	3 (60)	7 (28)

[1] Number in parenthesis is percent of experts who mentioned coded topic.

sugar, starch, and cellulose—are converted into a usable form for the production of energy. The two most common forms of liquid bioenergy produced in the U.S. are biodiesel and ethanol, made through biochemical processes. These represent “first generation” biofuels because they rely on existing technology that has been proven commercially.

Biodiesel

Biodiesel is an ester and can be used not only as a fuel for vehicles, but also as a heat source in domestic and commercial boilers. The National Biodiesel Board, a trade association, estimates that more than 460 million gallons of biodiesel were produced in 2007, up from only 600,000 gallons in 1999 (National Biodiesel Board 2008). Feedstocks for biodiesel include soybeans, canola, cotton seed, sunflower seed, mustard seed, algae, safflower, animal tallow, and used cooking oil. The growing demand for alternative fuels, however, has forced the prices of many oil crops to go up, making the production of biodiesel less profitable (ACES 2007).

Biodiesel is made through a base catalyzed process of transesterification. Oils are extracted from crops through either mechanical press extraction or solvent extraction. The seed meal remaining from the mechanical extraction process (in which oil is removed as oil seeds are crushed) can be used as animal feed. The solvent extraction method extracts a greater amount of the oil and with a higher degree of purity, but is more expensive. The process begins by first dissolving the oil with a solvent, then distilling the oil to separate it from the solvent. The solvent condenses and can be reused in the extraction process (“Biofuel Technologies” 2007). Methyl esters (biodiesel) are produced when oils are reacted with methanol in the presence of a catalyst (U.S. Department of Energy 2007; “Biofuel Technologies” 2007). Through this process, glycerin is also produced—about 10 pounds for every 100 pounds of biodiesel (U.S. Department of Energy 2007). Most diesel engines do not require modifications to run on biodiesel. For engines built prior to 1993, hoses and the fuel pump filter may need to be changed (Lawson 2007). Biodiesel is sold in a range of blends—from B5 (5 percent biodiesel, 95 percent petroleum) to B100 (100 percent biodiesel)—but is usually sold in a blend of 20 percent biodiesel and 80 percent petroleum.

In 2007 Alabama was rated fourth in the nation for biodiesel production (Shirek 2007). At that time, the production capacity of the state was 95 million gallons per year, with another 60 million gallons per year of production capacity under construction. Alabama was the top-rated state in the Southeast, followed by Georgia and Tennessee ranked at 12 and 13, respectively.

Ethanol

Ethanol is an alcohol made from biomass high in carbohydrates. Feedstocks for ethanol include corn, sorghum, wheat, barley, rice, potatoes, sugar cane, and sugar beets. Sugar crops, such as sugar cane and sugar beets, are easier to convert into alcohol. Brazil, the world’s second leading producer of ethanol, uses sugar cane as its primary feedstock. Most of the ethanol produced in the U.S. is made from yellow feed corn (ACES 2007).

Ethanol is usually made through a fermentation and distillation process. Ethanol can be used as a high-octane alternative fuel or as an additive to gasoline, though its energy content is about two-thirds of that found in gasoline. Because they contain oxygen, ethanol molecules make gasoline burn more completely, reducing tailpipe emissions considered harmful (Wu 2007). The Renewable Fuels Association, a trade group for the ethanol industry in the U.S., estimates that approximately 6.5 billion gallons of ethanol were produced in 2007, compared to 175 million in 1980 (Renewable Fuels Association 2008).

Ethanol is most commonly produced through a biochemical, wet milling process. Through this process, the feedstock (usually grain) is steeped and broken down into its components: starch, germ, and fiber. Enzymes are used to convert starch crops to sugars. (Some crops, such as sugar cane, already contain fermentable sugars and are easier to convert.) With the addition of yeast, the sugars are fermented in the presence of air. The resulting solution, known as beer, is distilled to separate the alcohol from water, solids, and chemical byproducts, producing an 80- to 95-percent solution of ethanol (Wu 2007; “Biofuel Technologies” 2007). The solution can be further purified. The solids remaining from the process contain nutrients that can be used as livestock feed.

Most commercially available vehicles cannot use fuels with high levels of ethanol, like E85 (which is 85 percent ethanol and 15 percent gasoline), because of the alcohol content. Engines in flex fuel vehicles (FFVs) are designed to withstand the corrosive effects of E85 and can run on any mixture of gasoline and ethanol (up to 85 percent by volume) (U.S. Department of Energy 2007). Lower ethanol blends (up to 10 percent ethanol by volume) are commonly mixed in with gasoline and can be transported, stored, and dispensed through existing infrastructure. Due to its corrosive nature, E85 requires separate infrastructure. Because ethanol cannot be incorporated into existing refineries or transported through existing pipelines, its growth has been hampered and its availability to markets outside the Mid-west limited (Etter 2007).

SECOND GENERATION BIOFUELS

First generation biofuels have broken ground, created interest in renewable fuel sources, and proven the concept of biomass-derived liquid fuels. Though corn-based ethanol and oil-based biodiesel have been established commercially, because of the limited feedstock supply available, it is unlikely these forms of biofuels will be sufficient to meet consumer demand and ambitious governmental mandates of the future. Researchers and investors are increasingly turning toward second generation biofuels—fuels made from more readily and widely available renewable sources—such as woody biomass. There is real potential in these fuels, but feasibility is dependent on technological development and on questions of scale.

Ethanol can be produced from a wide range of sources, including sugar cane, corn, and wood. The production process is most simple with sugars, slightly more complex with corn or other starches, and more complex with cellulosic feedstocks. Both sugars and starches go through processes of fermentation and distillation, the only difference being a pre-treatment step where starches are broken down into constituent sugars (Figure 1). In the dry mill process, corn is first ground into a fine powder and liquefied into a mash. In wet milling, starch is separated from other constituent elements by soaking the grain in water or a dilute acid solution. From there with both processes enzymes are added to break down starch into sugars, followed by fermentation, distillation, and dehydration.

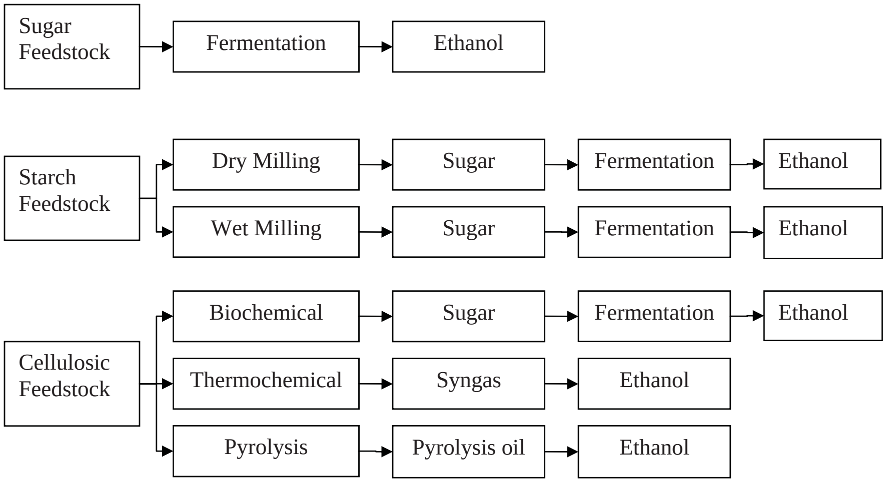
Cellulosic Ethanol

Cellulosic biomass is more abundant and considered more renewable than traditional ethanol feedstock crops, such as corn and sugar cane. Growing this biomass requires fewer fossil-fuel derived inputs (like nitrogen fertilizer) and its production into ethanol yields fewer carbon dioxide emissions than the corn-based process (ACES 2007). Feedstocks used to make cellulosic ethanol include trees, perennial grasses, wood waste, waste paper and packaging, pulp sludge, and agricultural residues (such as corn stover). Though cellulosic biomass has the potential to be a more efficient, environmentally friendly feedstock for ethanol production, the challenge lies in figuring out a cost-effective way to break down the complex structure of the rigid cell wall and to scale up conversion technologies to a commercial level.

Compared to corn, cellulosic feedstocks present more of a challenge to those who want to produce ethanol. In traditional ethanol production from corn, only the kernel is used, but in cellulosic ethanol production all of the biomass can be used to generate energy (ACES 2007). Cellulosics are made up of three basic elements. Cellulose and hemicellulose are the source of energy for ethanol production. The third element, lignin, makes up between 10 and 20 percent of the biomass and must be removed so that it does not interfere with the production of sugars. Lignin acts as glue, chemically bonding the components (cellulose and hemicellulose) of woody fibers together and giving plants their hardness. Lignin complicates the chemical processing of cellulosic ethanol, but has value as a source of energy to generate electricity to run the processing facility. It can also be burned to heat fermentation tanks (Wu 2007), or be processed into high value specialty chemicals. Cellulosic feedstocks themselves generally are more difficult to handle than grain. Trees are heavy, bulky, and must be chipped or ground to a uniform size before further processing. Switchgrass and agricultural residues are less dense than wood and have their own harvest, transportation, and storage challenges. In particular, both of these potential feedstocks have seasonal availability so that processors would need to either provide storage or utilize alternative feedstocks during extended periods of the year.

As shown in Figure 1, there are three basic approaches to processing cellulosic feedstocks. The biochemical process involves use of dilute sulfuric acid to break down hemicellulose into simple sugars. Hemicellulose is relatively easy to break down compared to cellulose, but the sugars are more difficult to ferment. Cellulose is more difficult to break down into sugars, but after it is broken down, the sugars are easy to ferment. Once sugars from cellulose and hemicellulose have been produced, they are fermented, distilled, and dehydrated. This approach is best suited to processing a single stream of feedstocks to achieve peak efficiencies. This is so because the enzymes used to break down cellulose into sugars are tailored for specific feedstocks.

Figure 1. Ethanol production paths (highly simplified).



By-products of the fermentation process can be sold, such as carbon dioxide to the beverage industry or gypsum as a soil amendment (Cassidy and Ashton 2007).

The process involved in the biochemical production of ethanol is complex and expensive. Scientists are searching for new ways to make the technology more commercially available, such as figuring out how to process cellulose and hemicellulose together or genetically modifying plants to make their cell walls easier to break down (Wu 2007). Some think the answer lies in discovering new enzymes (in bacteria, fungi, and other microbes) better suited to cellulosic crops. These new technologies, however, must be able to "be scaled up in an economically sound way" (Wu 2007:121).

Because of the high costs of enzymes and restrictions of pretreatment processes, many respondents believe there is more potential in thermochemical conversion of biomass. The key advantage of the thermochemical approach is that a wide range of feedstocks can be used because the process does not involve the use of specialized enzymes. One thermochemical technology is gasification. This process involves the combustion of biomass at a high temperature (between 1,112 and 1,832 degrees Fahrenheit), under conditions of limited oxygen, turning the solids into a synthesis gas (Cassidy and Ashton 2007). This "syngas" is then passed through catalysts and converted into ethanol (Badger 2002). Pyrolysis is another processing option where cellulosic biomass is heated at high temperatures in the absence of oxygen to produce pyrolysis oil (also known as bio-oil or biocrude), which can be further processed into ethanol or other liquid transportation fuels. The material residue, char, can be used to help fuel the process.

Biocrude

Like their petroleum-based counterparts, biofuels can come in crude form, which is made from biomass and can be later refined to make a variety of products. Biocrude, also known as bio-oil, offers refiners options concerning what the final product will be, whether it's gasoline, butanol, diesel, or other fuels. Biocrude is of particular interest to major oil companies because it can use existing refining and distribution systems ("BTL Biocrude" 2008). The potential to produce a broad range of transportation fuels from biomass has created opportunities for oil giants to pair up with leaders in other industries, such as timberland and agriculture, to meet energy demands without compromising food supplies. Some examples of these relationships include ConocoPhillips teaming with Archer Daniels Midland (an agricultural processor and the biggest U.S. ethanol producer), and Chevron joining forces with Weyerhaeuser (a forest products company) (Gutierrez 2007). Yet the widespread application of the technology to produce biocrude has been limited because of "limited uses and difficulty in downstream processing" (Wang et al. 2008:574).

Biocrude can be produced through thermochemical conversion. Through fast pyrolysis, biomass is sent through a high-heat reactor (about 932 degrees) and rapidly transformed into a vapor (Cassidy and Ashton 2007). No combustion of the material occurs because there is no oxygen. The cooled vapor is condensed and chemically recollected into a liquid form. Again, resulting by-products (such as char) can be sold for commercial uses.

ALABAMA FEEDSTOCKS

Feedstock availability was identified by many of our respondents as a key issue needing to be addressed in establishing an economically viable biofuels industry. One respondent describes the perfect biomass feedstock: immediately available, high yield with low input, easy and quick to establish, native and non-invasive, easy and cheap to harvest, easy and cheap to dry, easy and cheap to store, good wildlife habitat, and profitable for growers. Though there is no one feedstock at this time that possesses all these characteristics, there are potential sources. One of the first factors to consider with feedstock is whether it grows well in a particular environment and climate. Feedstock sustainability is an important factor in biofuel production, with multiple components. "You not only need to be able to grow a variety of different crops, you need to be able to sustain them," one respondent says. Sustainability issues include land, fertilizer, water resources, weather, disease, food demands, and economic feasibility. In general respondents expect conversion processes will follow available feedstocks: "We don't grow corn well in the South; we grow trees and biomass well, so that may be where our niche is."

In the following sections, we discuss feedstocks for both first and second generation biofuels.

Alabama Feedstocks for First Generation Biofuels

The two most common feedstock sources for biofuel in the U.S. today are corn (for ethanol) and soybeans (for biodiesel). Both crops have been criticized as feedstock sources because of the high level of inputs required and because their use for fuel production diverts arable land from food crops. However, both are heavily subsidized as food crops and, as Johnson et al. (2007) point out, farmers producing alternative crops do not receive subsidies or crop insurance.

In Alabama, the production of both corn and soybeans has dropped drastically in the past several decades (Table 3). Alabama was ranked 30th in the nation for corn-for-grain production in 2007, producing 0.2 percent of the nation's total crop (USDA NASS 2008). In a state that imports additional feed corn to support a thriving poultry industry, many respondents expressed their doubts about whether Alabama can supply an adequate amount of corn to support an ethanol industry. Yet the increasing demand for ethanol in East Coast driving markets—and the costs associated with transporting the fuel—has spurred the development of an ethanol industry in the South. Producers are comparing the costs of importing finished ethanol with the costs of importing corn and producing fuel locally. For now, corn is the primary feedstock for ethanol production in the South, but it is viewed by many as a transition technology. As other forms of conversion emerge, researchers and investors expect cellulosic ethanol to become the industry focus in the South.

One respondent suspects that farmers wanting to get into feedstock production would grow soybeans, which require less fertilizer and cost less to produce than corn. Presently, much of the soybean feedstock used in Alabama's biodiesel production plants is brought in from out of state. (Alabama was ranked 26th in the country for 2007 soybean production.) "I don't foresee us growing enough soybeans to furnish what we need" to fully support a biodiesel industry on Alabama feedstocks, he says, "but we can grow a lot." He says that soybean producers' perception of the biofuels industry and the feedstock market is "cautiously optimistic."

Perhaps the most significant determinant of whether farmers will be able to support a burgeoning biofuels industry will be crop prices. In late 2007, the price of soybeans was high—pulling in $9 to $9.50 per bushel. But farmers remember 20 years ago, "so they're not going to just jump back in there too fast," a respondant says. Also, although the prices are good right now for soybeans and corn, the 2007 drought took its toll on producers. Farmers, the respondent says, were dealing with the "psychological problem of having a poor product (because of the drought) during a time of high prices." Drought influences certain decisions: "They're not going out and buying a lot of equipment." He believes the price spike for soybeans is probably temporary. He expects soybean prices will follow trends of corn prices with an initial spike in value, but then as the market responds, a decline, settling above average, but not remaining at that peak. "It will level back out at some point," he says, but given normal conditions, the price of soybeans won't go all the way back down to the initial values.

Another respondent, interviewed in fall 2007, felt differently, saying that farmers need to realize that these high prices are long-term. "If you're (already) farming,

Table 3. First Generation Feedstocks in Alabama

Feedstock	State rank 2007 [1]	Production level 2007 [1]	Production level 1997 [2]	Production level 1987 [2]	Percent change 1987-2007
Corn (bushels)	30	22,120,000	21,750,000	18,000,000	22.9
Soybeans (bushels)	26	3,780,000	8,500,000	10,440,000	-63.8

Source: [1]USDA NASS (2008). [2]USDA NASS (2009).

you're already benefitting" from higher crop prices, except those in the poultry industry. During that interview, he said the price of corn had gone from $2.40 to $4.00; soybeans were over $10; and wheat had gone from $2.00 to about $8.00. All these prices impact one another, as well as other commodities. The respondent says, "If you bid one thing up, everything else is going to have to catch up," or else acreage will all switch over to one crop. But he believes shifts in demand and the market create a lot of opportunities. For example, in the Black Belt, "instead of low-value hay, you could be producing high-value soybeans," he says. The respondent also believes that if the price is high enough, "there are no barriers to entry to corn production." And because of high crop prices, there won't be the same economies of scale that there have been. "At $10 beans, you can afford to have no combine and 100 acres."

In terms of growing these traditional feedstocks, the South cannot compare to places like Iowa with its deep layers of fertile soil. But, one respondent states, "there's other stuff we can grow that we need to explore," like sugarcane, sweet sorghum, and sweet potatoes. These crops can be turned into fuel through existing conversion technologies. Farmers around Alabama have experience and expertise in growing these feedstocks. The respondent says, "If you pick some regionally appropriate feedstocks (and the expertise is in place), . . . why not exploit that?" The biofuels boom and the demand for soybeans and corn have put unanticipated pressure on the market.

One respondent has heard that industry is interested in sorghum as a feedstock, but that in order for sorghum to be profitable for farmers, they would probably need to devote thousands of acres to production. Another respondent has made test batches of ethanol from a variety of sources, including sugarcane and sorghum. These sugar crops do not have to be cooked and converted the way starch products do, eliminating not only costs, but time. Because the stalks of sorghum are much thinner than the stalks of sugarcane, it can be harvested with the same equipment that is used to harvest hay, the respondent says. Sorghum can also be sent directly through a press, she says, whereas sugarcane must first be stripped of its leaves. Sorghum also has a much shorter maturation cycle, getting two crops a year as opposed to one every 16 months for sugarcane. The respondent gave some of the by-product of sorghum-based ethanol to her cows: "They loved it; they thought it was great."

The sweet potato is the subject of study at Tuskegee University for its potential as a feedstock for ethanol. A professor of agriculture and environmental engineering says that a lot of research is being conducted internationally on sweet potatoes, which are consumed elsewhere at much higher rates than in the U.S. The sweet potato, he says, is a "regionally appropriate" crop, more so than other crops used as ethanol feedstocks. Another respondent has made ethanol from sweet potatoes, using many that were unfit for regular consumption.

Canola can be pressed for its oil and converted into biodiesel. The crop yields about 170 gallons of oil per acre (in comparison to soybeans' 58 gallons), says a plant science professor, who lists a number of benefits of canola: it is a profitable alternative to wheat as a viable winter crop in Alabama; it can be double-cropped with soybeans; government programs are in place to support growth; costs can be offset by co-products (like oilseed meal); community-based biodiesel plants may be feasible; and most years, canola is higher-priced than wheat.

Algae, which is not controlled by the commodities market like other feedstock sources, is also being explored as a possible source of oil by Auburn University researchers and PetroSun Inc. ("Algae BioFuels" 2007; "Alabama Grant" 2007). Algae grows in shallow ponds, feeding off of carbon dioxide, wastewater, and agricultural and industrial waste. Some believe algae farming could revitalize some of the state's poorest regions. They say catfish ponds, exposure to sun, and climate found in the Black Belt make the region an ideal location for large-scale production of algae.

Woody Biomass for Second Generation Biofuels

Woody biomass is the most immediately-available feedstock in Alabama. In 2007, the state ranked second in the nation for commercial forest land, with 22.6 million acres (USDA NASS 2007). An expert knowledgeable of the forest products industry states that timber growth in Alabama exceeds removals by over 19 percent: "That's a great situation; it means that we've got surplus resource that's available for other uses, whether it be the conventional industry or for bioenergy." Between 1945 and 2002, Alabama experienced a 22.3 percent increase in total forestland (Southeast Agriculture & Forestry Energy Resources Alliance 2009). There are 900 million dry tons of standing woody biomass in the state's forests—equivalent to 2.5 million barrels of oil—says one respondent. Wood's potential goes beyond the forests, says a research director at an energy research center in North Dakota, talking about gasification technologies. Wood is readily available in the form of branches and wood waste; a small municipality of 25,000 people could supply a gasification facility. "The cool thing about wood is that there appears to be a fairly decent sustainability to that, not only in our forests, but in our municipalities." Forest biomass sources include thinnings, non-traditional species, plantations, natural stands, and stands damaged by extreme weather (such as hurricanes or tornadoes). The bioenergy sector allows for these resources to be considered higher value than they may otherwise. Seventy percent of Alabama is forested and some parts of the state, such as South Alabama, are accumulating standing timber because of recent paper mill closures. Table 4 displays figures for the state's inventory of timberland and biomass. Though there is a significant amount of raw material, little is known about how much of the timber in the state would be available for use as a biofuel feedstock if cellulosic technologies become viable. Current timber supply models may not reflect actual availability and timberland owner objectives must be accounted for. So must other industries that utilize the state's forest resources.

A recent study in Lee County, Alabama, does provide some basis for optimism among proponents of bioenergy that family forest landowners would be willing to supply biomass for energy. Paula (2009) reported that more than three-quarters of all family forest landowners would be willing to supply biomass for energy production.

Table 4. Forest-based Feedstocks in Alabama[1]

Feedstock	2007 inventory	2000 inventory	1990 inventory	Percent change 1987-2007
Timberland (million acres)	22.5	22.9	21.9	2.66
Gross biomass (million tons)	734.5	761.3	735.9	-0.19

[1]USDA Forest Service FIA.

Moreover, those who answered in the affirmative represented ownership of 92 percent of all family forestland in Lee County. Family forestland owners in Alabama own two-thirds of all forestland in the state (Hartsell and Johnson 2009).

A variety of factors must be considered when determining the feasibility of harvesting woody biomass, including topography and soil types. Favorable attributes include available biomass (6 to 7 dry tons per acre says a forest biology and ecology professor), access to and availability of infrastructure, gentle topography, resilient soils, even-aged stands (allows for easier harvesting), high wood density, machine maintenance, and production costs of felling, skidding, and chipping. Silvacultural practices (such as thinning) could help boost desirability of typically low-value biomass. Disadvantages of harvesting residual material for bioenergy include removal of nutrients and possibilities of erosion or sedimentation.

However, at the moment, available resources appear to outweigh available market opportunities. One forestland owner says that the forest products industry is harvesting much less timber—10 million tons a year less pulpwood and roundwood—than it was ten years ago. "(But) we've got more land growing trees, so the essence of all this is you've got to have more markets for wood; more demand for wood." Because there is so much wood and so little demand, he says, $10 or $12 per (50 percent moisture) ton "is realistic in today's market, but where I would need to be is $18 to $19 per ton, which is what we used to get." Realistically, though, pulpwood is the product class biomass will likely compete for, which sells well below stumpage rates for higher-quality timber. At $10 to $12 per ton, the forestland owner said he would not even consider clear cutting: "If that's all I could get for wood, I wouldn't even be in the business. . . . You're sacrificing income down the road (if you clear cut)."

As shown in Table 5, there was a wide variation in responses to questions about what kind of feedstock is best suited to development of cellulosic-based biofuels in the South. The feedstocks most touted by experts giving public presentations were residues, especially harvesting residues. These experts spoke often about the amount of residues that gets "left behind" in forests and the potential benefits landowners can experience from clearing this material out. But in personal interviews other experts were much less optimistic about residual material. They stated that the logistics are not favorable for harvesting residues.

Experts question whether the cost of recovering limbs and tree tops from logging harvests would be a viable strategy. Collecting residues from the forest floor is not economically feasible, says a division director with the Alabama Forestry Commission. "You can't bring in a million dollar chipper (to collect residues)," he says, "You can't drag a tree top through the mud and expect your chipper to last." However, research in Biosystems Engineering at Auburn University is being directed towards development of in-woods chipping systems, so the technical and economic viability of using harvest residues remains at this time an open question.

According to the Forest Products Development Center, Alabama generates 4.3 million dry tons of logging residues annually. Even if harvesting residues were recovered, the vice-president of the Alabama Forestry Association estimates that only about 500,000 dry tons would be available on an annual basis for bioenergy

Table 5. Experts' Perspectives on Feedstock Availability by Type

Type of feedstock	Negative perception		Positive perception	
	Points	Quotes	Points	Quotes
Timber	• Short-rotation timber expensive to establish • Loss of future market opportunities • Requires years of growth before ROI	"You're sacrificing income down the road (if you clear cut for current prices)." (Grower) "All of this (demand from competing markets) is drawing from that same forest resource." (Organization)	• Growth exceeds removals • Slow demand in other markets • Harvest and transportation infrastructure in place	"We can grow trees fast. It's probably what we do best." (Organization) "Competition for raw material is something that's part of the fabric of this (forest products) industry." (Organization) "(They're saying) pulpwood is a thing of the past." (Organization)
Harvesting residues	• Difficult to recover residues • Equipment not set up to handle • Loss of soil nutrients	"Thinning would be a nightmare." (Organization) "You can't bring in a million dollar chipper (to collect residues)." (Organization) "Unless times get a whole lot tougher (loggers will not invest that time and effort)." (Organization)	• Material not utilized • Can be used as part of timber stand improvement practices • Reduce risk of wildfires	" (It's) a great way to reduce competition, increase growth on the good trees, and also look for better markets down the road." (Organization) "There's a great opportunity for that (logging) system to recover even more . . . because there's a tremendous amount of material in the waystream we're not capturing now." (Organization)
Manufacturing residues	• Currently used by mills to generate power • Other markets use residues (pellets, poultry bedding)	"All the mill residues that are generated right now are used." (Organization)	• Potential for "higher-value" use • Provide new revenue stream for mills • Potential for retrofitting of mills to make other products	"There's a lot that's being traded on the open market that would be able to compete with that for a higher use, so that's extreme material that could be tapped into (for bioenergy)." (Researcher)

consumption. Additional volume could be available as timber stands are thinned. Landowners interested in thinning their stands (to encourage healthy growth) and in getting rid of underbrush (because it is aesthetically pleasing and deters fires) may not get paid much per ton, but those with knowledge of tree growth and stand health would understand the benefits of getting rid of the material. Active management can also preserve wildlife and help discourage pests and disease.

The director of the Alabama Loggers' Association believes that a market for forest residues may offer operators a chance to use that resource and recover equity from other parts of their operations. He notes that thinning a densely planted tract is "a great way to reduce competition, increase growth on the good trees, and also look for better markets down the road." Being able to sell thinnings for cellulosic ethanol production would increase the options forestland owners have to manage their timber.

Alabama has a strong wood products manufacturing industry and, despite decline in recent years, is still home to a number of pulp and paper mills, sawmills, plywood mills, and other industrial users of timber. Respondents say these existing industries help situate the state to be a leader in woody biomass-based biofuels. The structure for a cellulosic-based biofuels industry is yet to be determined, but one significant advantage to a technology that utilizes the region's wood resources is that a delivery infrastructure is already in place for a resource the region is very familiar with. There are well-established systems for growing, harvesting, and transporting wood. Potential sources include direct harvesting for biofuel, logging residues, land clearings, fuel wood, residues from forest management, and urban wood wastes.

In recent years, industrial actors have sold off virtually all of their timberlands to timber investment management organizations and real estate investment trusts (Bliss et al. 2008). Because the wood products industry no longer controls the flow of fiber to their mills, cellulosic ethanol producers will be free to compete in an open market for feedstock. Cellulosic ethanol producers will be in competition not only against the traditional forest products industry, but also against those within the bioenergy sector. This includes buyers directly burning woody biomass for process heat, to produce electricity, or who make wood pellets for export to Europe as a thermal energy source. The potential of a cellulosic-based fuel industry must be evaluated in the context of these competing markets, all vying for part of the same forest resource.

Despite its availability, there are some negative characteristics of woody biomass, largely associated with the logistics of transportation. A research engineer who has examined harvesting of biomass for bioenergy highlights some of these challenges: mill turnaround times, logging capacity, productivity levels, high horsepower requirements, short-term employment, opportunity costs, lack of experience with government contracts, and overall expense. Other unfavorable characteristics of woody biomass are high moisture content, low energy density, and low bulk density. One unknown is in what form refineries will want the material delivered. Different technologies may have different requirements; for example, because of the high heat transfer rates involved in pyrolysis, the feedstock must be in a fine form (less than a quarter inch) (Cassidy and Ashton 2007). An Extension specialist in forestry recommends that chipping become standardized prior to emergence of a bioenergy industry in the state so that landowners can meet market demand of different companies.

Few experts spoke much about using timber for biofuel production perhaps because there may be a poor public perception of cutting trees for fuel. However, experts felt that landowners are likely to be willing to sell to whomever can give them the most for their timber regardless of whether the trees become paper or fuel.

Perennial Grasses/Herbaceous Species

Although soil productivity in the Southeast is generally low, abundant rainfall and a long growing season favor growth of herbaceous species. They have good potential as sources of biomass for a number of reasons: crops can be sown and harvested with traditional equipment, they contain suitable chemical composition for conversion processes, they can benefit from seasonal rotations, and they are flexible and can be used in other ways, such as silage or for livestock grazing (Bransby et al. 1989).

Perennial grasses have been heralded by many as an important feedstock with significant ecological benefits. Perennial grasses recycle nitrogen, require low inputs, have extensive root systems that control soil erosion, have high resistance to pests and disease, grow in a variety of climates and on marginal lands, and provide habitat for wildlife (Jensen et al. 2007; Johnson et al. 2007). At present the market in the South for perennial grasses as a bioenergy feedstock is not well developed (Jensen et al. 2007), and, therefore, there is no significant large-scale production. Primary motivations for those growing switchgrass have been the crop's soil conservation characteristics. Significant opportunity costs are associated with switchgrass, which takes three years to produce an adequate yield. Farmers growing switchgrass annually in the Southeast may be able to produce 6 to 8 tons per acre (Jensen et al. 2007). Based on models he has created in the past, one agronomy and soils professor says start up costs run about $200 an acre to establish switchgrass. Once established, it requires some "minimal" fertilization to continue producing, he says. The costs of maintenance and harvesting are low, but so too are the revenues.

The market value of biomass is likely to be in the range of $30-50 per ton, perhaps even more. If we assume 8 tons at $50, gross revenues would be $400 per acre. This may be an attractive proposition for marginal farmland, but, as one respondent noted, "It's going to be bidding for the same acres corn and soybeans are." Landowners will need to calculate the benefits of this crop compared to corn, soybeans, or other higher-value uses of land. One expert on switchgrass has looked at the science behind growing the crop, as well as the economic and technological investments required. He is considering ways farmers can save money through certain techniques or use of existing equipment to harvest. Techniques, such as using a silage chopper to field-chop the grass, can make growing switchgrass for fuel production more feasible. However, another respondent notes, it is important to convince farmers of this; demonstrate to them that they can adapt existing equipment and techniques to make the process affordable.

Another expert, a biosystems engineer, is hesitant to espouse switchgrass as a promising feedstock for Alabama's small producers. He says that there are logistical challenges regarding the supply chain for switchgrass. The costs of harvesting and, especially, transporting the biomass may not be economically feasible for some farmers. “I think there’s still some hurdles to get over (with respect to) the supply chain,” he says. He believes it will be a challenge for the small subsistence farmer to invest in the equipment necessary to transport switchgrass. He doesn’t rule out the possibility of there being a market; his concern is over whether a profit can be made by certain producers. “I can envision a system where there are people with large equipment” who can be contracted out, he says. But at the end of the transaction “is there going to be anything [money] left for that landowner?” Even if conversion technologies are commercialized, farmers may not want to sell their crop to make fuel; they may get more money by selling switchgrass to erosion control processors for use as mulch than selling it as a biofuel feedstock. “You’ve got to look at those other markets,” the respondent says, when considering potential available feedstock.

Agricultural and Manufacturing Residues

Many studies have emerged disputing the ecological value of crop-based biofuels. They posit that the energy required to grow, harvest, transport, and convert such crops to fuel negates any energy saved by using a “renewable” feedstock source. Authors of these studies often urge industry to avoid relying on crops and turn instead to forestry and agricultural residues. Novozymes North America, the largest supplier of enzymes to the ethanol industry, has focused efforts on creating enzymes for production of ethanol from these residues (including corn stover), from fiber streams from grain processing, and from the fibrous waste products of sugarcane. An engineer for the company says that the “enzyme cocktail” used for crop residues is likely to be different from those used on woody plants. The differences might be minimized through pre-treatment, but the fundamental differences still remain. Novozymes has focused on residues, he says, because in the short-term, “this is where we see the movement in the market.”

Most expert respondents we interviewed doubted that agricultural crop residues would become an important feedstock for cellulosic ethanol in the South. Alabama produced approximately 391,000 dry tons of crop residues in 2007, compared to Missouri’s more than 6 million tons (Southeast Agriculture & Forestry Energy Resources Alliance 2009). The general decline in row crop agriculture in the South means that, compared with other regions, the availability of corn stover and other crop residues is relatively inconsequential. Between 1945 and 2002, Alabama experienced a 54.8 percent decline in total croplands (Southeast Agriculture & Forestry Energy Resources Alliance 2009). Many respondents believe that residues cannot supply the amount of biomass that some studies claim (e.g., Perlack et al. 2005). Moreover, farmers “are not going to be very amenable to selling their crop residues,” says one respondent, because they understand the importance to soil nutrition and erosion control. Studies have revealed the importance of residues and their role in soil and erosion maintenance, and many farmers have adopted conservation techniques utilizing those residues. On the other hand, Johnson et al. (2007) suggest that recommendations for sustainable harvest rates of stover could be established that account for erosion risk and maintaining soil organic carbon.

Residues from wood products manufacturing, such as sawdust and shavings, also may be utilized for energy production. The director of the Forest Products Development Center at Auburn University notes that there is an active market for such residues and that they would be available if the price was right. The Forest Products Development Center estimates that Alabama generates approximately 7.8 million dry tons of forest products manufacturing residues annually (in form of bark, chips, sawdust, and shavings). Those experts giving public presentations touted the amount of “waste” material produced annually by forest products companies, and the potential benefits of using it for a “higher” purpose. But in personal interviews other experts stated that all manufacturing residues are already being utilized. According to the executive vice-president of the Alabama Forestry Association (AFA), less than 1 percent of the wood waste produced by wood products manufacturers remains unutilized. The Southern Bioenergy Roadmap estimates that in 2007 industrial mills in Alabama generated 6.6 million tons of residues and states that “[O]ver 90 percent of all mill residues are currently used for fiber byproducts or fuel for on-site operations, so there is limited opportunity for expanded use” (Southeast Agriculture & Forestry Energy Resources Alliance 2009:44). Pulp and paper mills, for example, often generate all or nearly all of their own electricity and sometimes generate enough to sell electricity to the grid. Increasing prices of natural gas and fossil fuels will encourage full utilization of available raw materials. Residues from forests and products manufacturing are also used for fiber for pulp and panels and for mulch (Jackson 2007). Because of these competing uses, cellulose waste will likely only make up a small percentage of the feedstock for ethanol production. The AFA vice-president expects that cellulosic ethanol producers trying to procure biomass will have to “get it out of the woods.”

CONSTRAINTS TO A BIOFUEL INDUSTRY IN ALABAMA

In this section we review constraints that may affect development of a biofuels industry in Alabama, starting with feedstock availability. Also included in this discussion will be infrastructure, economies of scale, industry structure, land usage, feedstock ownership, and environmental concerns.

Feedstock Availability

Many questions were raised by experts regarding logistical challenges of steps in the supply chain prior to actual biofuel production. While Table 6 demonstrates the wide variety of questions and issues raised, the biggest concern expressed regarding feedstock was availability.

While most interview respondents were optimistic about landowners’ willingness (assuming prices competitive with existing markets could be paid), they all stressed that feedstock availability, and landowner willingness in particular, are areas in need of further research if there is any hope for future industry development. When beginning operations, fuel production facilities consider a number of factors regarding feedstocks, including accessibility, costs, and sources of feedstock, as well as financing options available for feedstock. Fuel producers, regardless of their final product, face a challenge in building a feedstock supply system. First generation biofuels producers will need to import a portion (and probably a high portion) of their feedstocks from other regions. The industry, when looking for sites to locate plants, wants to know that a continuous feedstock supply will be in place. However, before investing time and money in equipment, land, and agricultural inputs, growers want a guarantee that someone will buy their feedstock. Respondents say that strengthening the state's farming infrastructure and

Table 6. Issues and Concerns Raised by Experts About Preproduction Logistics

Issues	Questions	Sample quotes (Type of expert)
Source of feedstock	• Who will own the land (private landowners, corporations)? • Where will they be located?	"The people developing these plants, they don't want to sit there without some guarantee that they're going to get the raw material." (Researcher) "A lot will be (determined by) the timberland ownership around the plant." (Industry)
Availability of feedstock	• Will landowner be willing to sell material? • What other markets will be in competition for resource?	"There's a disconnect in that question: Is the landowner willing to give me that stover? . . . What is realistically available?" (Researcher) "(The forestry commission) has never modeled that aspect of what's out there (and available)." (Organization)
Transportation of feedstock	• What form will feedstock be? • What distance will plants be willing to travel?	"The main problem with cellulosic is that it's not dense enough, so transporting it is going to be a problem." (Organization)
Type of equipment	• Can equipment handle demand? • Is equipment scale-appropriate?	"All these kinds of things have to be decided: . . . how much it's going to cost and how things are going to work together and how to efficiently use all of the pieces." (Researcher)
Impact on equipment	• Will material damage equipment? • Where will equipment be used?	"You can't drag a tree top through the mud and expect your chipper to last." (Organization)
Farming infrastructure	• Will irrigation be needed? • What kind of storage requirements?	"(The growers) cannot go into this without being able to guarantee a crop. . . . You have to start rebuilding that infrastructure." (Organization)
Transportation infrastructure	• Can rural roads handle increase in truck traffic? • What transportation method will end product require?	"The transportation of ethanol and B100 are issues that our infrastructure does not address right now." (Policy maker)
Legal infrastructure	• Will regulations interfere with production or distribution? • How will mandates or RPS impact future industry development?	"(The existence of a law prohibiting transport of ethanol) seems like a little bitty thing, but taken as a whole, it's an important thing." (Policy maker) "Carbon credits—what's that going to do to any possible markets?" (Organization)

developing farmer education and outreach programs can help bridge the gap between fuel producers' wants and farmers' needs.

Because the South cannot support high-level production of first generation feedstocks the way the Mid-west can, studies are being conducted to identify alternatives. But few studies offer any indication as to whether alternative feedstocks are or will be realistically available to fuel producers in the future. Supply models often ignore landowner willingness in their projections, says one respondent: "There's a disconnect in that question; is the landowner willing to give me that stover?" Even with the abundance of forestland in Alabama, there are concerns about the availability of second generation feedstocks as well. Large oil companies considering commercialization of thermochemical technologies (like gasification and pyrolysis) want a guaranteed, continuous supply of woody biomass, says a biosystems engineer. Though biomass is available year-round, seasons do affect the energy content of wood as it is left to dry. Models show that there are approximately 4.3 million dry tons of logging residues in Alabama and 7.8 million dry tons of manufacturing residues generated on an annual basis (Muehlenfeld 2007). What these models don't demonstrate is whether that material would be available to refineries—and at what cost. According to an Assistant State Forester, the Alabama Forestry Commission is concerned about whether these kinds of data may be too optimistic about what the state has to offer. While he would like to see industry come to Alabama, he worries that overestimations of available biomass may mislead landowners into thinking there is greater potential for a market to emerge than is realistic.

One respondent points out that in the South, the forest products industry has learned to live with many unknowns, like weather, and the region would be prepared to handle supplying an emerging cellulosic-based biofuels industry. One way to ensure a steady feedstock supply is through contracts. According to one respondent, companies building plants are interested in putting short-term contracts in place to ensure a steady feedstock supply. Farmers also express interest in contracts: "Contracts lend stability," says one farmer, "And, of course, it has to have flexibility built into it because conditions change quickly." Such contracts may not be an option for long-term crops, like poplar trees and switchgrass, that require several years' growth and effort before any return on investment is seen. There is difficulty in convincing farmers to take that kind of risk without knowing where the industry will be in several years.

Infrastructure

Infrastructure was another concern voiced by many experts, especially organization representatives familiar with challenges rural communities currently face in attracting industry (Table 2). One respondent stressed a need for government monies to be used to strengthen the state's farming infrastructure, specifically providing irrigation systems for Alabama farmers. "People are so focused on the 'gee whiz,' the science of (biofuels)," he says, "but the real world is much different." He says that developing a biofuels industry is not like flipping a switch; the South is not going to approach the task in the same way states like Iowa have: "The Mid-west has not lost as much of their infrastructure as the South, so it was a little easier for them to jump into ethanol production." Much of the infrastructure related to row crop production has been lost in the last several decades.

Farmers lack on-farm storage capacity and have few facilities that will accept high volumes of raw material. This lack of infrastructure, and the lack of irrigation systems or ways to store water, is affecting farmers' ability to enter the biofuels feedstock market. A respondent says: "(The farmers) cannot go into this without being able to guarantee a crop. . . . You have to start rebuilding that infrastructure." Another respondent says that there are companies who need feedstock and landowners with farmland: "In the middle there's got to be that infrastructure. . . . The infrastructure is going to be that lift" to get people to make investments and put their land back into agricultural production.

Investors and fuel production companies are looking to put their money in places they know can support a growing industry and new technologies. The transportation sector is not prepared to handle a heavy feedstock market right now; rail capacity is full and rivers cannot handle heavy barge traffic: "All of these things are going to have to be improved if production is going to increase to any great degree." Better usage and availability of the water ways, as well as improving the industrial road systems servicing rural Alabama will be needed to support a burgeoning industry, respondents say. Though, one respondent notes, conversion technologies may determine the way in which material is transported. For example, biomass may need to be ground down to a finer form or baled prior to transporting.

Economies of Scale and Industry Structure

Infrastructure will affect economies of scale and industry structure. Industry structure in Alabama will differ from that of the Mid-west, where many large ethanol plants have been built alongside rows of corn. How and where biofuels are produced will be greatly impacted not only by feedstock availability, but also by emerging technologies and whether the fuel is used locally. The most viable feedstock-to-plant production system has yet to be determined. Which system may be most viable for a community is influenced by a number of factors: availability of feedstock and labor, harvesting and conversion processes, existing industry and workforce development, product marketability, and economic incentives and assistance.

Perhaps the biggest question about a biofuels industry is not "When" or "How" but "Where?" Few doubt whether a biofuels industry will emerge or whether benefits will be experienced. But what people don't know is who will experience those benefits and where they will live. If we get answers to many of the questions asked in Table 7, we may have a better idea of where refineries will locate and which cities and towns may stand to gain from this development. Based on responses of interview participants, the biggest factor in refinery location is transportation of both the feedstock and the end product. Though the majority of the feedstock is likely to be located in rural areas, the majority of the demand will come from urban areas. Most respondents stated that feedstock will probably need to be sourced from within 50 miles of the refinery (similar to pulp and paper mills). Another topic of interest was the potential for pulp and paper mills to become integrated forest products biorefineries, retrofitting their existing facilities to produce other cellulosic-based products, including biofuels. Those respondents familiar with the forest products industry felt strongly that this is the direction the industry may go, but were unsure about what specific technologies would be used or what economic impacts this development would have on communities.

Table 7. Issues and Concerns Raised by Experts About Refinery Logistics

Issues	Questions	Sample quotes (Type of expert)
Distance to market	• Who will purchase end product? • How will product be transported?	"However and wherever you make (the fuel), it still has to be moved (to the market)." (Policy maker)
Scale of production	• What size will refinieries be? • How will they be geographically dispersed?	"Cellulosic plants will (likely) be smaller and more dispersed than we see with the corn plants. Economies of scale rule and they are bunched in the Mid-west." (Industry)
Competition for raw material	• What other nearby industries will be competing for same resource?	"It's a level playing field issue. . . . It's not in anybody's best interest to over-harvest the resource." (Organization) "You've got to look at those other markets." (Researcher)
Integrated forest products biorefineries	• Will pulp and paper mills produce biofuel? • What changes will be required?	"(The pulp and paper industry) knows how to grow, harvest, transport, and process renewable biomass." (Researcher) "A pulp and paper mill is (already) a biorefinery because it takes material, breaks it down, and produces paper. . . . I do think we're headed in that direction." (Organization)
Supply chain	• Who will collect and transport raw material, and how? • What will be role of growers, custom companies, or others?	"(It's) better to aggregate the material than (everyone separately) try to haul it by truck." (Organization) "If you keep it in fewer hands, you can control it better, probably increase (grower) profitability." (Grower)
Capital investment required	• How much will facilities cost? • Who will make investments?	"You're not just willy nilly going to come in and stick that kind of money in the ground." (Organization) "It's expensive to build an ethanol plant; I don't care what your design." (Policy maker)

In Alabama, it is likely that a production system for cellulosic-based fuels will mirror the pulp and paper industry, with landowners growing the feedstock, custom companies harvesting and transporting the biomass, and production companies converting the raw material into an end product. "Each one does what he does best," explains a forestland owner. There is a lot of bulk involved in biomass production for fuel; and because of the high weight-to-value ratio, transportation costs quickly become a factor in economic viability. Control, says one farmer, will lie in the hands of whoever can collect and transport the feedstock in the most cost-effective way. But, he says, if the process is kept in fewer hands, farmers could probably control it better and increase profitability.

Pulp and paper mills have been called "first generation" biorefineries and they have the potential to become producers of cellulosic ethanol themselves. The infrastructure is in place, one respondent says, for pulp and paper mills to become integrated forest products biorefineries. Some changes can be made to equipment that can turn a facility into one that produces a whole spectrum of products, including paper and transportation fuel. This, he says, is the long-term vision of the American Forest and Paper Association as part of its "Agenda 2020." He says the individual technologies have been proven, but that connecting the various technologies together has not, and doing so is likely to be very costly. But, he says, "I do think we're headed in that direction." In fact, the respondent sees more potential for cellulosic ethanol production to occur as part of integrated biorefinery operations than as individual production facilities.

The director of the Alabama Center for Paper and Bioresource Engineering says that the pulp and paper industry is facing "increasingly difficult prospects of long-term success." He says that this is due to lower domestic demand for products (like newsprint) and lower labor costs found in overseas markets. Stringent environmental restrictions in the U.S. also hamper mills' abilities to turn a profit. The Center's director says that in order to stay in business and prevent even more job loss, mills in the rural South need to create new sources of revenue by meeting energy needs. Fiber loss in a mill can reach as much as 25 or 30 percent; mills can eliminate their sludge (waste material consisting of rejected fiber) and provide a revenue stream by making ethanol through a process of hydrolysis and fermentation. About 75 gallons of ethanol can be produced from a dry ton of sludge and an average mill can expect to produce about 2.5 million gallons per year. A capital investment to become a producer of ethanol would run less than $10 million, but would likely involve private equity since most mills are strapped for cash. Mills could also be involved in gasification of their waste, producing syngas, which could then be used to produce liquid fuel or to power mill operations. While these new technologies probably wouldn't create a large number of employment opportunities, they would help create new skill sets for workers and possibly higher paying jobs.

One disadvantage that many pulp and paper mills would have to overcome is their geographic isolation from major markets. Most (though not all) mills in the South are located in rural areas, far from major urban centers. Primary criteria for siting a paper mill are availability of abundant water and access to abundant supplies of timber. Not surprisingly, then, the costs of transportation are likely to shape the location of cellulosic ethanol production facilities. These costs in turn will be influenced by the availability of feedstocks, the nature of transportation infrastructure, and access to retail markets. Cellulosic ethanol production is likely to occur where an optimal combination of these three factors are present.

Transportation and supply chain issues dominated discussions with experts about distribution and consumption of biofuels (Table 8). Experts made it clear, however, that the structure of the biofuels industry will be drastically different from that of traditional, petroleum-based fuels. The general consensus was that, due to transportation constraints of both feedstock and fuel, smaller, distributed facilities will likely emerge. There is some disagreement about how the fuel will be transported (whether by barge, rail, or trucks), but most expect smaller facilities will be established to meet the demands of local markets. Consumer demand is another big unknown, however. Most respondents felt that while ethanol does not have a big market in the South, if mandates are established (for example, requiring 10 percent blends), this could change. Almost all experts felt, however, that the real future lies in the production of fuels that require no changes to current infrastructure, such as gasoline or diesel made through renewable processes.

Table 8. Issues and Concerns Raised by Experts About Distribution and Consumption

Issues	Questions	Sample quotes (Type of expert)
Supply chain	• How will end product reach consumers? • What role will producers play in distribution?	"Cellulosic plants will have a strong competitive advantage because they will be able to deliver directly from their plant via a truck to the retail and fleet sites that use a blender pump and have dedicated ethanol storage. . . . It bypasses a lot of the traditional supply chain." (Industry) "Producers don't want to—and don't need to—be distributors." (Organization)
Consumer demand	• Will there be enough demand? • How much demand can be sustainably supported?	"(The supply/demand issue) is a huge piece of the puzzle that's going to constrain (commercialization)." (Organization) "There's no way we can use all the ethanol we're capable of producing." (Organization) "Despite the huge momentum that ethanol has grown, that's not our perfect biofuel." (Researcher)
Transportation	• How will end product be transported? • How will transportation needs impact industry structure and vice versa?	"Cellulosic plants will (likely) be smaller and more dispersed. . . . This allows for simpler consolidation of fuel volumes to be shipped in very large unit trains to terminals." (Industry) "You need to be where the barge traffic is." (Organization)
Infrastructure	• Is the infrastructure in place to transport and/or store large volumes of biofuel? • How might lack of infrastructure constrain commercialization or marketing of product?	"If you've been making green gasoline through a hydrocarbon process, well now you're just replacing petroleum-based with renewable-based, and all the (current) infrastructure can be used." (Researcher) "The infrastructure in the United States (for gasoline) has been around for a hundred years. . . . Suddenly trying to slip in ethanol or biodiesel—it's been a little difficult." (Researcher)
Policy	• What mandates may impact industry? • How will mandates and RPS affect demand?	"One of the things we all have basically agreed with . . . is the subject of mandates. We are not at a place in (Alabama) to set mandates." (Policy maker) "(Mandates) are coming at us like a freight train." (Researcher) "Terminals (in mandated markets) don't want to try and consolidate bulk ethanol from numerous small cellulosic plants, many of which may not even be on rail lines." (Industry)

Second generation biofuels facilities probably should be located in areas where they do not compete directly with pulp and paper mills. As one respondent noted, growers will get the best price for their material in the form of pulpwood; refineries may not be able to compete with pulp and paper mills willing to pay more for the same biomass. Facilities may also benefit more by locating closer to the market for ethanol or other fuel, closer to more populous areas compared to the rural location of most pulp and paper mills. Transportation costs would be reduced and refineries may have an edge over companies that ordinarily service the regions through pipelines. Other geographic considerations include proximity to major highways or water sources. The map displayed in Figure 2 shows where pulp and paper mills are located as well as highways and major fuel markets. Currently, the majority of mills in Alabama are located in the Southwest portion of the state.

One possibility is that of satellite facilities, which would be smaller-scale production plants that utilize raw material found within a limited distance. Or the raw material can be collected from various "concentration yards," then shipped by rail to a central plant. "(It's) better to aggregate the material than try to haul it by truck," says a division director with the Alabama Forestry Commission. Whatever system is developed to get the raw material to the production facility will affect how landowners—and which ones—will benefit.

Land Usage and Feedstock Ownership

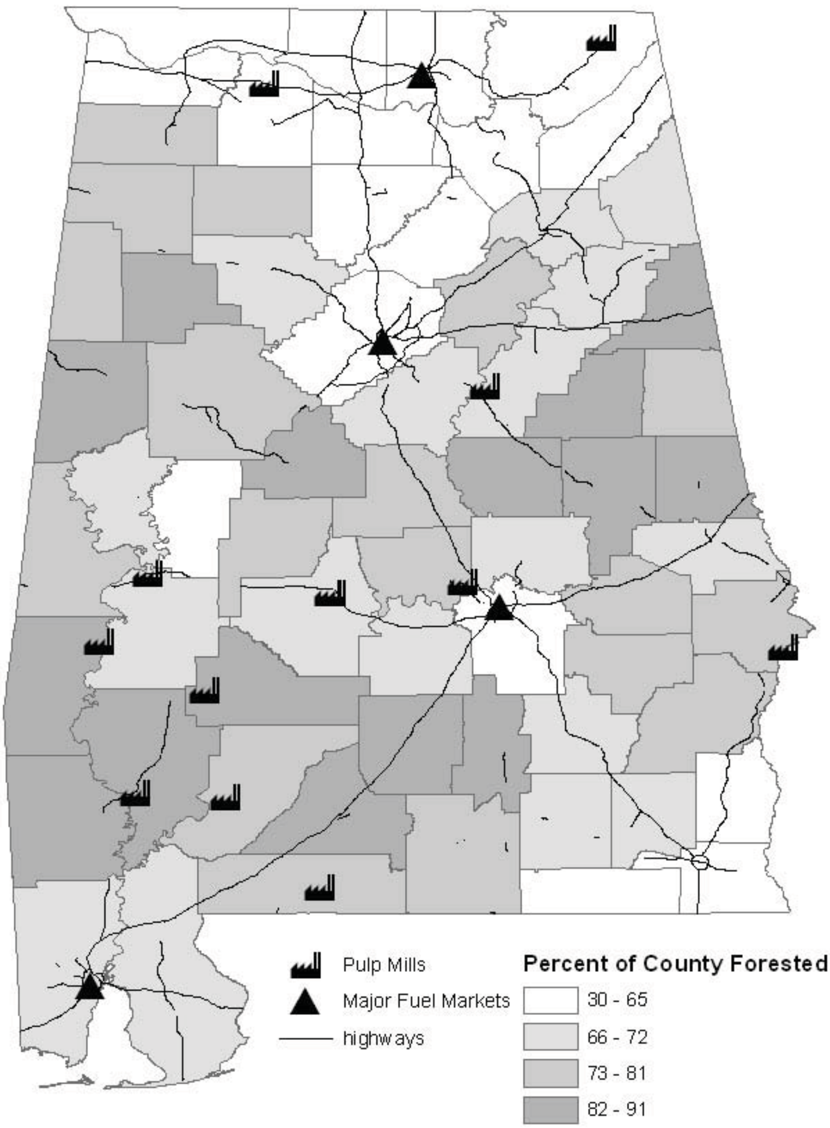
Few if any prospective biofuel producers will be integrated (growing and transporting feedstocks and converting them into fuel). Most likely, the biofuels production system will involve myriad landowners growing the feedstock. Non-industrial private forestland (NIPF) owners own the majority (69 percent) of all forestland in the South (Wear and Greis 2002). This category of owners broadly encompasses individuals (farmers and family forestland owners) and corporate entities that do not own wood-based manufacturing facilities. Included in the NIPF category are individuals who own less than 10 acres as well as individuals, partnerships, and corporations that own thousands of acres. In Alabama, 95 percent of the forests are privately owned by families and the forest industry (Langholtz et al. 2007). One expert on the forest products industry in Alabama states that ownership of woody biomass feedstock for bioenergy applications is likely to be roughly proportional to existing harvests. The private non-industrial sector is expected to produce the majority of cellulosic feedstocks, followed by private institutional ownerships, then the public sector. Experts expect private institutional landowners to be most aggressive in pursuing cellulosic opportunities and to engage in silvicultural practices.

Respondents doubt that owners of small tracts of forestland will have a significantly higher number of market opportunities than are currently available. If cellulosic ethanol plants can pay more per dry ton than the traditional market, it will be only an incremental increase, not substantially more. The harvesting technology and the production costs will be the same, and because it costs so much in fuel to get all the harvesting equipment to the landowner's property, it's difficult to justify going to those small acreages. However, the more competition that is in place, the more facilities will pay for the raw material. And more money in the marketplace may lend flexibility to loggers to collect material that before was uneconomical. So if the price rises high enough, small landowners may be able to get loggers out to their property. A higher demand for raw material may indirectly impact landowners by putting more money into their pockets.

One respondent noted that forest stakeholders are interested in forming landowner cooperatives. Many farmers own forestland and state agencies or farmer interest groups may be well-positioned to facilitate the creation of such co-ops. Owners of Conservation Reserve Program lands may also be interested in forming co-ops. Those in the business of procurement often try to buy timber from smaller tracts that are adjacent to larger tracts or to company lands. If several landowners in close proximity to one another enter into a contract together, it would be economical for harvesters to procure from smaller acreages.

The recent increase in commodity prices and the potential for development of cellulosic ethanol production is having an impact on land values. Respondents believe

Figure 2. Locations of pulp mills, highways, major fuel markets, and forested areas.



that much of the land currently in grass or in the Conservation Reserve Program will go back into production. In 1985, the Conservation Reserve Program was implemented to remove land from agricultural production and place it into conservation. With this emerging market for biomass, some of the CRP lands may be put into row crops and some may be put into trees as cellulosic feedstock. In Alabama, approximately 491,587 acres are enrolled in the Conservation Reserve Program (Jackson 2007). In 1995, approximately 53 percent of the state's CRP lands were in trees and 45 percent in grasses (Onianwa et al. 1999). A 2005 study estimated that CRP lands in Alabama could produce annually 2.7 million dry tons of switchgrass and 1.9 million dry tons of willow and hybrid poplar (Jackson 2007). According to Jensen et al. (2007), switchgrass is eligible for CRP payments as long as it is not harvested more frequently than once every three years.

Until now, one respondent says, increasing land prices in Alabama have largely been driven by recreational uses, but with the prospects of the biofuels industry, land prices may increase further. Land value will vary by region and may depend on the price of oil. There may be some leveling off, but if crop values stay high, so will land values. "If there's money to be made, that will drive the price up," says a respondent. Rising land values give landowning farmers more financial security. And, if land prices are high enough, some may decide to get out of the business altogether. Another respondent has an opposing view and doesn't expect the emerging biofuels industry to have a great impact on land prices. There are few places in Alabama that are strictly agricultural and prices appear driven more by development. He predicts that a biofuels boom would more likely impact rental prices for farmland.

Despite the potential for land values to rise and feedstock markets to open up, not all landowners may be so quick to jump on the biofuels bandwagon even in the economically deprived parts of the region. "There's a lot of people in West Alabama who are really not interested in getting back into agriculture," says one respondent. People consider the risks of putting land back into production, he says, and many choose instead to rent out land to hunters. There is little risk involved in leasing hunting land—no equipment to buy and the landowner still gets paid even if no wildlife are killed. These competing land uses need to be considered when assessing how much land and feedstock would be available to support a biofuels industry.

Respondents state that in order for the biofuels industry to be economically viable, financial incentives will need to be in place to give a jump start—both to growers and to fuel producers. Growers stressed that incentives are needed to provide a safety net to those planting long-term crops (like switchgrass) for which there is currently little or no market. Landowners also said that if an active market was in place and they had someplace to sell their material to, incentives would not be necessary. They emphasized that putting money into research and development for conversion technologies would help lessen growers' reliance on incentives by providing a more stable market. The Executive Director of the Alabama Loggers' Association says that incentives could help fund not only cellulosic-based fuel production, but generation of electricity as well: "I think there's a need, particularly in that arena, to bring a comfort zone to those who are going to have to be putting the money up and provide investment opportunities for people to take that kind of risk. . . . We've got trees in the ground, we're cutting them everyday, we just need to find a market—that market we don't have."

Environmental Concerns

Few environmental concerns were raised by our respondents, many of whom have likely placed higher priority on creating a more marketable environment to attract commercial producers. We are aware that concerns have been expressed by some environmental groups, including the Dogwood Alliance, a leading voice for the protection of southern forests. Their concerns are that rapid expansion of a biomass-based energy industry could lead to deforestation, undermining ecological integrity and the economic and social viability of communities dependent on forest ecosystems (Quaranda n.d.). Among the dangers they foresee are the possible expansion of industrial pine tree plantations and the increased clear cutting of both plantations and natural forests. They argue that deforestation would contribute to increased greenhouse gas emissions because well-managed natural forests remove and store carbon. The Dogwood Alliance has been engaged in a long-term campaign critical of the pulp and paper industry, which utilizes roughly half of all timber harvests in the region, and sees cellulosic ethanol as another threat to southern forests. They argue further that no research has been done to support the view that cellulosic biofuel will have positive social, economic, or environmental benefits.

This is not the place to debate these issues, and they are presented here to alert readers that there is another view, which is in contrast to the more positive and even enthusiastic stance taken by most of the people we interviewed. The prevailing view was that Alabama possesses abundant timber resources and that landowners would benefit from the opening of new markets for timber. Data on forest resources in the state confirm that Alabama's forest resources have expanded, both in area and in volume of timber, during the past half century (Hartsell and Johnson 2009), but it is also true that Alabama and the South as a whole have experienced rapid increases in harvesting when economic conditions encouraged this to occur (Walker 1991).

Perhaps the main ecological concern raised was how industrial production would affect water resources. Says one respondent talking about the relationship between water resources and a burgeoning biofuels industry in need of feedstock, "Those issues are out there and they are inextricably tied together . . . and become even more important in the rural part of the state." He says if the state is to be a high producer of feedstock (especially first generation), the government needs to be "pretty darn sensitive" about how it handles water issues. Withdrawal of water for irrigation is extremely low in Alabama, even compared to other states in the South, limiting the state's ability to compete in the feedstock commodities market. According to one water quality scientist, some people question whether Alabama leaders have the political will to establish a water plan. One respondent would like to see incentives made available to farmers to help provide irrigation systems.

One water expert notes that rising energy costs directly affect irrigation costs. Irrigation energy requirements include construction to provide the water (in the form of dams, reservoirs, etc.), pump and pipe systems to move the water, and systems to disperse the water. One respondent says: "We have plenty of water. It just comes through at the wrong time," so farmers need storage facilities to help make the most of the water that's available to them. Educational efforts and technical assistance could help farmers effectively manage water resources and be aware of how their practices affect water quality (for example, nitrate runoff).

No one voiced concerns over environmental impacts of conversion processes, probably because this is still a big unknown. Not only do we not know what processes will win out, but we don't know what environmental impacts would be experienced by commercial-scale implementation of these processes. Few experts spoke about the possibility of clear cutting or using timber, probably because the thought of cutting down trees to fuel cars is a bit taboo. It is easier to tout the environmental benefits of using residues than to address the possible ecological impacts of cutting timber.

Aside from water issues, other environmental concerns have been raised in the literature. Internationally, many of the environmental concerns highlighted in the literature are related to large-scale production of biofuel feedstocks (such as palm oil or sugarcane) in developing countries where land and labor are cheap. Environmental concerns surrounding production of feedstocks in the U.S. include use of pesticides, nitrate runoff into water supplies, and increased demands for water as drought-tolerant crops, like wheat in the Mid-west, are replaced by corn and soy (Tokar 2006).

Academic research teams have conducted lifecycle analyses of ethanol production and dispute claims about the net energy gain of such processes (Tokar 2006). Numerous researchers and authors state that when agricultural inputs—such as petroleum-based fertilizers, pesticides, and herbicides—and energy inputs—such as harvesting, processing, and transportation—are taken into account, there is a net loss of energy in production of corn-based ethanol (Nicholls and Campos 2007). Farming biomass on a large scale requires heavy equipment to harvest the crops, transportation to refineries, and processing into fuel—all activities that require energy and emit greenhouse gases (Wu 2007). Pimentel and Patzek (2005) conducted a study in which they analyzed all the energy inputs of various feedstocks to determine the net gain (or loss) in energy. The authors considered both energy and economic expenditures associated with agricultural as well as procedural inputs (such as labor and irrigation). They conclude that not only is corn-based ethanol production environmentally destructive, but it is uneconomical as well. The authors draw similar conclusions for other feedstocks.

The U.S. Department of Energy (2007), however, has a different standpoint. It says that because of changes and improvements in farming techniques and conversion technologies, the energy required to produce ethanol has decreased over the last 20 years. According to the DOE, corn-based ethanol today delivers up to 67 percent more energy than is required to produce it. The Department says that cellulosic ethanol is even more efficient, delivering four to six times more energy than is required to produce it.

In the United States, Wallace and Palmer (2007) warn of the dangers of high-input low-diversity (HILD) agricultural systems created by production and cultivation of biofuel feedstocks. The authors state that large-scale monocultures produced for biofuels, including corn, oil palms, and switchgrass, require large inputs of fertilizer, pesticides, and irrigation water. Also, HILD systems cause land use to shift away from agricultural production of food and animal feed. Even collecting agricultural residues for production of biofuel has its environmental critics. Crop residues such as corn stover and wheat straw, which can be harvested for cellulosic ethanol, revitalize soil and prevent erosion, which is caused by wind or rainfall ("Biofuels and the Environment" 2007; Biopact 2007a). Stover also replaces nutrients, sequesters carbon, and improves soil water relations (Biopact 2007a; Johnson et al. 2007).

Environmentalists have expressed concern about the possibilities of genetic engineering used to increase yields of energy crops. Many scientists—both those who have published in the literature as well as those who provided data for this study—view genetic modification of trees and grasses as one tool in helping to supply an abundance of biomass to an emerging biofuels industry. Although the benefits of cellulose-based fuels have been touted by many, commercially available conversion methods remain elusive. The challenge is finding an economically feasible way to separate plants into their components—cellulose, hemicellulose, and lignin—in order to turn the cellulose into fuel. Lignin chemically bonds the components of the cell wall, making it difficult for enzymes to reach the cellulose and break down the simple sugars inside. Genetic engineers have discovered a way, however, to reduce the lignin found in trees—in some cases by as much as half (Pollack 2007). A reduction in lignin could make the conversion process easier by eliminating steps and reducing costs by 10 cents per gallon of ethanol.

Environmentalists are concerned that making such alterations could reduce the structural stiffness of plants and leave them vulnerable to pests. They are also worried that modified trees could establish themselves in the wild, a concern not found with modified row crops, which need care from farmers. Wind could carry pollen—and genetic traits—across hundreds of miles into the wild. Evaluating the long-term consequences of genetic modification is also difficult because of the long life spans of trees. Proponents of using genetically modified trees for fuel argue that there are many benefits to growing such trees: they help to fight global warming by absorbing carbon dioxide and they can be cut whenever needed (instead of harvested only at certain times like row crops). Those in favor of growing modified trees in plantations say that doing so would cut down on the need to harvest trees found in natural forests.

Genetically modified plants are grown throughout the nation; federal records demonstrate that genetically modified crops have been grown in about 296 locations in Alabama since 2004 (Raines 2007). Such crops, which require federal permits and oversight, are often altered to be resistant to herbicides. The two most common biofuel feedstocks in Alabama, soybeans and corn have been engineered to resist damage from insects. ArborGen, a company jointly owned by International Paper, MeadWestvaco, and New Zealand-based Rubicon, is the only known company in the U.S. to be vigorously pursuing genetic engineering of forest trees (Pollack 2007). The company is developing eucalyptus with a 10- to 20-percent reduction in lignin. Other researchers are looking for ways not to reduce lignin, but to alter the types of alcohol that comprise lignin, perhaps making its extraction process easier.

Governmental policies and sustainability initiatives could play a role in mitigating negative environmental impacts. The Global Forest Coalition calls for northern countries to reduce energy consumption and invest instead in solar and wind energies (Global

Forest Coalition et al. 2006). Wallace and Palmer espouse the cultivation of low-input high-diversity (LIHD) mixed perennial grasslands. However, in order for farmers and ethanol producers to benefit from LIHD, the authors state that incentives must be carefully implemented to encourage cultivation of such feedstocks.

Despite the stated negative impacts of large-scale operations, organizations generally appear supportive of small-scale, local production of feedstocks. Biofuels may be most advantageous in local applications, as in farmers using crop wastes to fuel farm machinery, or automobiles running on fuel produced from restaurant waste oil (Tokar 2006). Global Forest Coalition et al. (2006) states, "Certain small-scale and strictly regulated sustainable forms of biofuel production can be beneficial at the national level." Based on its recent study of the sustainability of biofuels, Bank Sarasin, a banking institution based in Switzerland, favors the use of local raw materials, instead of stock from developing countries (Baue 2006). The organization also prefers ethanol over biodiesel because of the wide range of raw materials it can use and because it yields better carbon reductions.

Given the voracious nature of energy demand, there is some concern (though not voiced by respondents) of overharvesting forest or other resources.

CONTRIBUTIONS OF A BIOFUEL ECONOMY TO RURAL DEVELOPMENT

Rural development and revitalizing small towns in Alabama are priorities of agencies and organizations statewide. Legislation introduced in early 2008 proposed extra incentives for biofuel produced in "favored geographic areas." One respondent says that extra incentives like this are understandable given the nature of doing business in rural areas where transportation costs are higher. Yet it may be those very limitations placed by high transportation costs that make higher numbers of small towns likely to benefit from a bioeconomy. In the South, woody biomass is the most immediately available feedstock for conversion into fuel (liquid or thermal). If cellulosic ethanol technologies advance and a viable industry develops, the cost of transporting feedstock is likely to limit the economic impact to a small radius (roughly 50 miles) from the refinery. Similarly, the challenges associated with transporting ethanol itself mean that biorefineries need to be located near retail outlets. These factors argue in favor of a distributed energy system. Large biorefineries are likely to face dis-economies of scale if they draw biomass and ship ethanol greater distances than smaller facilities. These factors combined suggest a relatively decentralized network of production and distribution systems compared to the petroleum-based liquid fuels system. Because the essential feedstock—biomass—is owned by a wide range of actors, the benefits of energy production offer the potential for a wider distribution of benefits compared to our current petroleum-based system.

The introduction of additional market demand for woody biomass is likely to have a positive impact on the income of forestland owners and in the process drive up land values. Production of switchgrass, soybeans, and other energy crops could have a similarly positive impact on farm incomes and land values. There will be winners and losers from these changes, but the net impact is likely to be positive in part because recent sales of timberland by forest products industries are creating new ownership opportunities in Alabama and elsewhere. Landownership and, therefore, the economic benefits associated with biomass production will continue to be concentrated, but there are also large numbers of smaller tracts whose owners could share in these gains.

Capital costs for establishing biorefineries will determine whether local ownership (as distinct from ownership by larger corporations or oil companies) will be economically feasible. Though farmer-owned ethanol refineries have proved successful in the corn-rich Mid-west, local ownership faces challenges in the South, where cellulosic material is the most likely source of raw material. States Crooks, “Given the scale of investment and the role of intellectual property in cellulosic biofuel, the farmer-owned business model may struggle to find its place in this emerging segment of the industry” (2007:40). A question on many of our experts’ minds is whether cooperative-ownership opportunities will be available for growers of cellulosic feedstock (Table 9). Because of high capital costs and low investor confidence, however, the general consensus was that there will be few opportunities for growers to be actively involved in the production of biofuels. Most expect big oil will play a major role, not just in the distribution of biofuels, but also in the production.

Some respondents expressed concern about whether the biofuels industry holds the answer. One respondent says that landscapes have changed over the last hundred years, that the crops grown in the South cannot compete with those in the Mid-west,

Table 9. Issues and Concerns Raised by Experts About Refinery Ownership

Issues	Questions	Sample quotes (Type of expert)
Role of oil companies	• How will oil companies be involved in production or distribution of biofuels? • How will their involvement affect distribution of benefits?	"The oil refining people can bring a lot to the table for biofuels. . . . (Political interest in biofuels) has generated enormous confidence in the private sector." (Researcher) "These two sectors (oil and biofuels) have viewed each other as competitors up until now and finally they are starting to merge, and that’s going to make us move much faster." (Researcher)
Role of grower-owned cooperatives	• Will growers be involved in biofuel production? • What kind of time and financial investment would be required?	"(I would be interested) only if it makes money. . . . It depends on the nature of the process and the investment required." (Grower) "(Biofuel producers) don’t want to license their technology out to anybody else so I don’t even know whether the option of grower co-ops is going to be available." (Researcher)
Role of investors	• Who will invest? • Will investors be local?	"Right now there’s probably not too much opportunity for (traditional investors) because they’re way too conservative." (Researcher)

and that the timber industry requires less labor, leading to depopulation. He asks, “Is an energy economy, is a bio-based economy going to turn it around anymore than any other pipe dream we’ve had?” Depending on the skill level requirements of positions created by production plants, some employment opportunities may be generated or they may maintain the status quo. One major determining factor in how small towns in Alabama will be affected economically is whether investors see a bright future for production in the state. Aside from the natural resources available, the state is ripe with human resources as well.

Farmers and landowners don’t have the strong lobbying powers enjoyed by the petroleum industry, and often lack a way to communicate their needs. Yet state policy makers and members of the Permanent Joint Legislative Committee on Energy have voiced their hopes for and concerns about reinvigorating economically depressed areas of Alabama through a bioeconomy. One state representative says committee members are especially concerned about how West Alabama will be impacted by the new interstate system planned for the region. He says that biofuel production plants need to benefit those in whose communities these plants are located. He compares these concerns to those he talked about when addressing forestry and pulp and paper groups recently. Discussing million-dollar paper mills built in places like Camden, (in the Black Belt’s Wilcox County), the Representative said, “But what else is around? There’s poverty; there’s dirt, a blinking light, and a gas station.”

In the more economically depressed areas of the state, there are many landowners of small tracts, 50 acres or less. These landowners have typically struggled to meet market needs, whether they produce agricultural crops or grow timber. Many of the state’s Black Belt counties have stronger sales of catfish, broilers, and cattle than row crops. Respondents say economies of scale are not favorable to small landowners who want to grow row crops for biofuel feedstock. “A farmer with 50 acres is going to have to grow a high value crop on a per-acre basis to support a family,” one respondent says. In order to profit from row crops like corn and soybeans, farmers would probably need to own more than 1,000 acres because machinery and systems (like irrigation) are so expensive. “You’ve got to have large production to justify the costs to purchase and run a machine like (a combine).”

Federal policy will undoubtedly play a large role in determining who will be able to actively participate in an emerging bioenergy industry. Policy is identified in an expert survey conducted by the University of Florida as one of the biggest weaknesses or threats for bioenergy development in the South (Southeast Agriculture & Forestry Energy Resources Alliance 2009). Opinion columns of newspapers in the South voice concerns over proposed legislation, especially bioenergy mandates that many feel put the region at a disadvantage (Brown 2009; Smith and Wise 2009). Industry groups have voiced concerns about the roles and proposed rules of governmental organizations in implementing fuel standards and carbon regulating (Bennett 2009). Experts who provided data for this study echoed concerns found in the literature.

Legislation is a difficult topic to discuss in any detail in a report like this because of the ever-changing nature of the process and its actors. Table 10 demonstrates some of the issues and concerns experts have with proposed or enacted renewable energy legislation. The top concern voiced regarding all legislation is the potential for competition over raw material and how that competition might impact existing users of wood, particularly the pulp and paper industry. While competition is generally considered good news for landowners, there is concern that too much competition could put mills out of business, thus removing more lucrative, higher-paying markets. Mandates are a sensitive subject, and most experts stated they felt we are not yet at a place in Alabama to enforce mandates for either bioenergy or advanced biofuels.

Regardless of business models, industry structure, and policy, increasing demand for timber and energy crops will have a positive effect on prices, which will translate into higher incomes for owners and higher values for their property. This in turn should translate to higher tax revenues for local governments. This could also lead to incentives for more intensive silvicultural and farming practices that result in higher yields. If industrial-scale facilities are built, there will no doubt be multiplier effects on local economies. For example, when a bioenergy facility purchases more biomass from loggers, the loggers have to purchase more equipment, labor, fuel, etc. to do the work. Those input-supplying industries respond by producing more and must likewise purchase more from their suppliers. This process spreads throughout the economy so that eventually many industries have increased their production in response to the demand for more biomass from the logging sector. In Alabama the employment multiplier for the logging sector is approximately three, which means that for every new job generated in the logging sector as a result of this demand, two additional jobs are generated in the economy to support that activity. With the ad-

Table 10. Policy Concerns of Experts

Legislation	Issues or concerns	Sample quotes (Type of expert)
BCAP (Biomass Crop Assistance Program)	• Competition over wood resources • Loss of more lucrative markets for landowners • Discrepancies over what qualifies as "biomass"	"What's the impact of BCAP on pulp mills? . . . There's tremendous potential to distort the market." (Researcher)
RPS (Renewable Portfolio Standard)	• Competition over wood resources • Higher energy prices • South at a disadvantage in comparison to other U.S. regions	"Federal policy can create a very unlevel playing field. . . . (It's) regional warfare." (Organization)
RFS (Renewable Fuel Standard)	• Competition over wood resources • Lack of material • Technology lagging	"The wood isn't there." (Researcher)
Climate change policy	• Competition over wood resources • Higher energy prices • Competition from international buyers of carbon credits and fuel sources	"I expect that we'll see more and more (pellet mills and boiler fuel facilities) over time, particularly as we see climate change legislation." (Organization)

ditional jobs regional incomes grow as do regional business tax receipts, each in its way an important ingredient to successful economic development.

Multiplier effects of bioenergy and their overall socioeconomic impacts can be difficult to measure due to the broad range of associated aspects, including social and environmental factors (Domac et al. 2005). Yet despite the number of less-tangible benefits associated with renewable forms of energy, job creation and regional economic improvement remain the primary incentives for local communities. The bioenergy sector, it has been suggested, could help to stabilize rural populations, in part by creating jobs directly and indirectly. Other macroeconomic effects include the substitution of imports, the security of energy diversification, more consistently priced energy supply, and overall enhanced industrial competitiveness (Domac et al. 2005).

Meeting Local Needs

Though there are financial and logistical challenges, fulfilling local energy needs with local resources can provide a number of benefits. Shuman (1998) demonstrates how communities can become empowered by investing in locally owned businesses and focusing on development that reduces dependence on imported sources of basic needs, like energy. While much of the pro-bioenergy literature discusses the need to become energy independent because of national security issues, there is minimal focus on the need to become energy independent because of the economic and social benefits that may result. Locally owned refineries would not only provide jobs, but the jobs would be more likely to be filled by local workers. Aside from providing employment, facilities could help boost the community's human capital, providing training and new skill sets for their workers. Hiring locally may help to reverse brain drain—outmigration of the brightest and best young people. Local ownership of community-scale refineries would provide a boost to the local economy beyond providing jobs, in the form of tax revenues and the multiplier effect.

It is important, says one bioenergy expert, that when building refineries, their impact on the local environment be considered. Not just emissions and impact on local watersheds, but also land use, farming practices, and other production processes that the refinery may rely on. Shuman (1998) states that "sustainable development" must not only ensure longevity of resources, but rectify ecological damages of the past and address problems of corporate mobility.

Enterprising municipalities around Alabama are taking hold of their energy future and finding creative ways to fulfill needs while utilizing waste resources. Several cities are looking to save energy costs while benefitting the environment by switching their fleets to biodiesel made from used cooking oil collected from local businesses and residents. These programs have also helped reduce sewage maintenance costs as less grease winds up in the pipes. Hoover is working with Gulf Coast Energy in Livingston to turn wood waste collected by the city into ethanol, which the city fleet can use in its flex fuel vehicles. State departments and agencies also have projects in place, helping to raise awareness of biofuels and hoping to appeal to industry. The state motor pool uses E85, the port authority uses biodiesel, and in June 2007 a bill was passed making the Alabama Department of Agriculture and Industries Center for

Alternative Fuels part of state law. The Center serves as a repository of information on biofuels for Alabama consumers and farmers. The Soybean Producers (a division of Alabama Farmers Federation) are working with the Alabama Clean Fuels Coalition to encourage fleet managers of school bus systems to make the switch to biodiesel. The visibility of these kinds of public projects helps to demonstrate the practicality of alternative energy use and helps build a market, say respondents.

Needs can be met on an even smaller scale with on-farm bioenergy systems. On-farm biodiesel processing equipment can range from a couple thousand dollars (for a 20-gallon system) to tens of thousands for higher-capacity setups. The high cost of petroleum-based fuels certainly offers an incentive for farmers, who have numerous diesel-run equipment to operate, to produce fuel themselves. Biodiesel can also be used to heat poultry houses. On-farm biodiesel systems make sense, says one respondent, because farmers can see a quick return on their investment. Some factors that need to be considered, however, are availability of oil, cost of methanol, labor requirements, storage capacity, and what is to be done with byproducts (such as glycerin).

DISCUSSION

Respondents stress that no single technology and no single biomass will be the answer to biofuel production on a commercial scale. "These are going to be incremental steps. There's absolutely no silver bullet," says one respondent. Says a scientific advisor to the Undersecretary of Agriculture: "We're going to need silver buckshot. We're going to need a lot of technology." A distributed energy system reliant on an array of technologies and feedstocks is a "complete 180" from what we know now, he says. Because of this break from "tradition," there is going to be resistance. A lot of unknowns are going to have to be dealt with. Standards will need to be established and the public educated about the benefits of this new system. Greater collaboration between sectors could help ease such a transition.

The bioenergy sector has received an enormous response in the last several years and respondents note there has been a significant amount of crossover among various agencies, organizations, and governmental entities, all trying to further a bioeconomy in Alabama. Though one respondent says the state has "a lot of growing pains to go through," he remains optimistic about what the biofuels industry could mean for Alabama farmers: "It's exciting to know farmers could actually get a decent price (for their crops) . . . without having to go to town and get a second job." He says a bio-based energy industry could have positive impacts on the environment, national security, and economic development. "If we stay the course, . . . we could revitalize row crop agriculture." But, he stresses, improvements in infrastructure are key to building up a biofuels industry and improving rural communities.

Respondents expressed doubt over whether farmers and landowners are willing to invest time, money, and energy into producing feedstock for an unproven industry, but said education and outreach programs can help quell growers' concerns and facilitate interest and participation in the industry. Outreach efforts should not focus on issues restricted to a bioenergy sector, but on topics affecting farming on a broader spectrum. Topics respondents mentioned included crop rotation, irrigation, use of cover crops, double cropping, business management and administration, on-farm fuel production systems, small-scale cooperative-run fuel production facilities, internet availability and use, and programs for younger or beginning farmers.

CONCLUSION

Alabama lacks the appropriate infrastructure and soil types to support substantial production of first generation biofuels. While row crop agriculture may get a boost from a bioeconomy, the state's real potential lays in second generation fuels that can utilize the South's strong resource base of forest and pasture lands. At this point, there are many unknowns associated with feedstock logistics, though experts we interviewed believe that delivery systems for woody biomass will closely mirror those currently in use to supply pulp and paper mills. Logistics for switchgrass or other cellulosic feedstocks have no such contemporary model.

Experts interviewed for this study agreed that a need exists for more research on conversion technologies. Expert opinion varied regarding whether chemical or thermal processes would come to dominate second generation biofuels development, but there was agreement that the type of feedstock used to supply the process would determine the answer to this question. Chemical processes might work well with homogenous feedstocks, while thermal processes may be better suited where diverse feedstocks are used. Attention must also be paid to how the rights to those technologies are owned. Major oil companies will undoubtedly play a role in this emerging industry, but several of our respondents would like to see intellectual property remain in the hands of local producers. Respondents were referring to exploratory efforts and proprietary technologies developed by two local entrepreneurs.

Vertical integration of companies and absentee ownership may reduce potential benefits to local producers and communities. There is a need for comparative evaluation of different industry structures to determine their impact on locally retained jobs, profits, and tax revenues that would build stronger and more economically viable job markets in rural communities.

Bioenergy's greatest potential for rural communities may not be in attracting industry and large refineries (and lots of jobs), but in creating small numbers of jobs in more places to help towns meet their own energy needs through local-level utilization of existing resources. Multiplier effects may be more wide-reaching from the creation of a handful of jobs in many places versus a higher number of jobs in fewer places.

Policy—both at state and federal levels—will play a crucial role in determining the direction of a bioenergy industry in Alabama. Legislation has already begun to shape each step in the process of biofuel manufacturing—from providing payments to growers with contracts, to regulatory mechanisms setting mandates for market consumption. In a state so heavily dependent upon the forest products industry, careful attention must be paid to statutes that create an uneven playing field.

Many unanswered questions remain about the environmental impacts of both growing and harvesting biomass for bioenergy purposes as well as impacts of commercial-scale conversion of those materials. Lifecycle analysis mechanisms used in regulatory processes need to consider these unique ecosystems and technologies.

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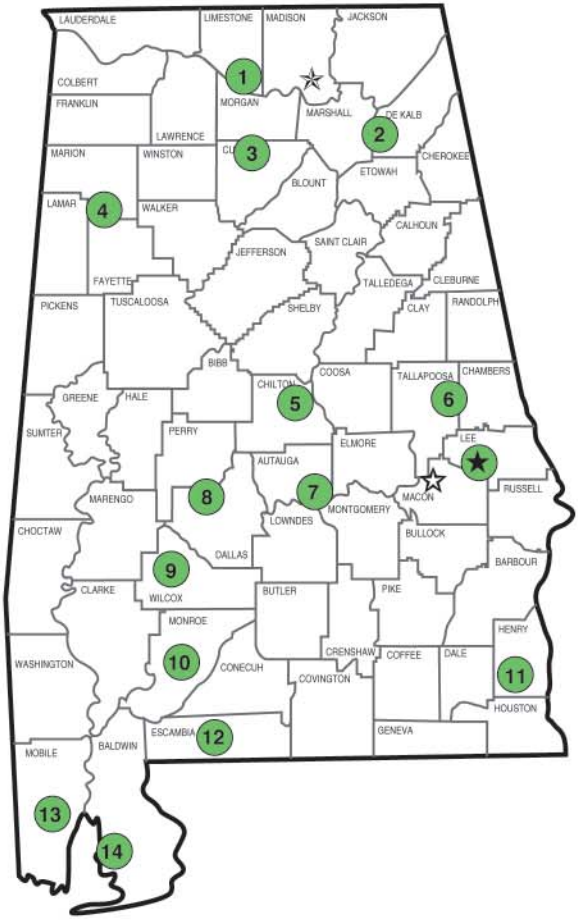
With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the state has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

- ★ Main Agricultural Experiment Station, Auburn.
- ✯ Alabama A&M University.
- ☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Research and Extension Center, Belle Mina.
2. Sand Mountain Research and Extension Center, Crossville.
3. North Alabama Horticulture Research Center, Cullman.
4. Upper Coastal Plain Agricultural Research Center, Winfield.
5. Chilton Research and Extension Center, Clanton.
6. Piedmont Research Unit, Camp Hill
7. Prattville Agricultural Research Unit, Prattville.
8. Black Belt Research and Extension Center, Marion Junction.
9. AU Natural Resources Education Center, Camden
10. Monroeville Agricultural Research Unit, Monroeville.
11. Wiregrass Research and Extension Center, Headland.
12. Brewton Agricultural Research Unit, Brewton.
13. Ornamental Horticulture Research Center, Spring Hill.
14. Gulf Coast Research and Extension Center, Fairhope.