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Assessing the rural development potential of lignocellulosic biofuels in Alabama

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ABSTRACT

We examine the potential rural development impacts of a highly decentralized system of feedstock production, biorefining, and consumption of locally-produced lignocellulosic biofuels in Alabama, a heavily forested state in the southeastern United States. Primary data based on in-depth interviews and public presentations by experts were used to establish a realistic scenario for development of a lignocellulosic biofuels industry in Alabama. Based on these data, we applied an input–output model to illustrate economic impacts of establishing six biorefineries, each with an annual capacity of 189 dam^3. We applied this same model to analyze the impact of one biorefinery of that size on a set of rural counties in west Alabama, a region characterized both by abundant timber resources and persistent rural poverty. Research findings reveal a high potential for economic development and job growth, especially in the logging sector and in rural regions of the state. The trajectory of this development and distribution of benefits from this incipient industry will depend on federal, state and local policies. We identify types of policies that would simultaneously encourage growth of this industry and ensure that those who live in areas where production and refining operations take place benefit from this development.

1. Introduction

More than thirty years ago President Jimmy Carter termed energy policy "the moral equivalent of war" [1]. Only in the last few years has there been a significant federal effort in support of alternative energy, with lignocellulosic biofuels coming to play a major role. The U.S. Energy Independence and Security Act of 2007 established a goal of producing 136 hm^3 of renewable fuels annually by 2022, with 79.5 hm^3 of this total coming primarily from lignocellulosic feedstocks [2–4]. The Food, Conservation and Energy Act (the "Farm Bill") of 2008 included tax credits, loan guarantees, and subsidies for establishing perennial crops available to farmers and non-industrial forestland owners who have supply contracts with biomass conversion facilities [5,6]. Unlike previous federal policy initiatives, the 2008 Farm Bill provides incentives for biomass producers and limits the percentage of federal funds that go to large-scale biorefineries. Criteria to determine who will benefit from these program funds include anticipated economic impact, opportunity for biomass producers and local investors to participate in ownership of the biorefinery, and participation opportunities for beginning and socially disadvantaged farmers and ranchers. These criteria shift benefits away from corporate actors and create economic space for development of a locality-based lignocellulosic energy production and distribution system.

In the context of these federal policy initiatives, we examine the rural development implications of producing liquid

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transportation fuels from lignocellulosic feedstocks in Alabama, a heavily forested state in the southeastern United States (Fig. 1). Alabama has 9.3 million hectares of timberland [7] with a total volume in 2000 of 883.5 million cubic meters of live trees [8]. In addition, Alabama has 771,000 ha in production as grassland pasture and range [9] suitable for production of perennial grasses that could be used as lignocellulosic feedstock.

The focus of our work is on Alabama, but we believe our findings have implications for other states in the southeastern United States (including Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia) which share similar resource endowments (80 million hectares of timberland and 55 million hectares of grassland pasture and range) [7,9]. This resource base makes the South a logical center for development of a significant lignocellulosic energy industry [10].

As the starting point of our analysis, we use interviews with experts from a range of backgrounds to identify a realistic development scenario for an emerging lignocellulosic biofuels industry in Alabama. Based on our expert-defined scenario, we document potential rural development impacts with special reference to landowner income, employment generation, and increased tax revenues that could be generated by this prospective industry. We say “prospective” because, as of this writing, there are no commercially viable lignocellulosic biorefineries producing liquid transportation fuels in operation in the United States, though several are under construction. The consensus of expert opinion reviewed below is that this industry will become commercially viable and that government policies and economic incentives will speed development of lignocellulosic biofuels. In our view, now – as this new industry is in its infancy – is the time to start considering the consequences of such development in a state and region characterized by both abundant natural resource endowments and persistent rural poverty [11,12]. Such assessments at the outset can contribute to public debate regarding how energy production and use can be used to address questions ranging from global climate change to community development.

After briefly discussing our data and methods, we describe the resource base available to support a lignocellulosic biofuels industry in the South and the economic and logistic factors that will determine that industry’s structure. We next utilize an input–output model to estimate potential rural development impacts both for Alabama as a whole and for a 12-county region in west Alabama characterized by abundant timber resources and persistent rural poverty. We follow with a discussion of the relative merits of a decentralized industry structure and a description of potential resource limitations that may raise environmental concerns as the lignocellulosic biofuels industry expands.

2. Materials and methods

The challenge of studying the impact of lignocellulosic biofuels development is that there are as yet no impacts to observe. This industry is “incipient” [13], in the process of being invented, with considerable uncertainty regarding feedstocks, industrial processes, and ownership structure. To understand the industry’s likely contours and dimensions, we turned to researchers, legislators and policymakers, corporate investors, and leaders of non-governmental organizations to identify likely development scenarios. In addition to these interviews, we attended and took detailed notes of speeches and presentations made by individuals we defined as experts in 14 workshops, seminars, and conferences held in Alabama between 2007 and 2009 that were organized to promote production and consumption of biofuels. Input from a total of 85 individuals was obtained from 22 face-to-face interviews, three phone interviews, and 88 public presentations at biofuels conferences in Alabama. In some cases, additional input was provided by expert respondents through personal correspondence, usually in the form of email exchanges.

We adopted several strategies to identify experts for purposes of this study. We started at our home university, Auburn University, where significant research on biomass and bioenergy is underway. Using what is known as the “snowball approach” where initial contacts are asked to identify additional contacts, we expanded our list of expert respondents to include academic researchers, people in state agencies with responsibility for biofuel development, and private sector

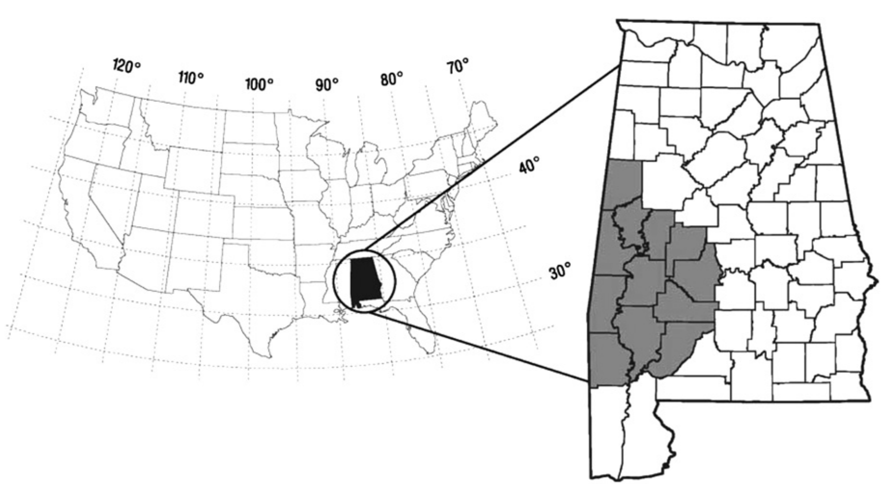

Fig. 1 – Alabama and region covered by input–output model.

investors. We also read local, state and regional newspapers, went to corporate websites, and attended conferences and meetings to identify individuals who in our judgment had expert knowledge of biofuels development.

Twelve of our respondents (eight of whom we interviewed face-to-face) serve as technical advisors to Alabama's Permanent Joint Legislative Committee on Energy Policy. This Committee was formed in 2007 to develop legislation and policies that would promote development and use of Alabama's renewable energy sources. The process we used for identifying experts was quite separate from that used to mobilize technical assistance by the Committee, but the fact that there was substantial overlap increased our confidence that the perspectives and judgments of our experts represented the state of knowledge and understanding.

In Table 1, we classify our expert respondents as representing non-industrial private forestland (NIPF) owners, organizations, industry, policymakers, and researchers. All but 5 percent of Alabama's forestland is privately owned, and NIPF owners account for 78% of this total [8]. Information from NIPF owners came from presentations made at conferences and meetings. We did not conduct individual interviews with NIPF owners because a parallel effort made it clear that most NIPF owners in Alabama had limited knowledge regarding biofuels development but were eager to participate in any new industry that would expand markets for their timber [14].

Respondents from "organizations" represented a variety of governmental and non-governmental organizations with interests in biofuels development, including the Alabama Clean Fuels Coalition, the Alabama Forestry Association, the Alabama Forestry Commission, and the Alabama Department of Economic and Community Affairs. Respondents from industry included representatives of Range Fuels (a company building a lignocellulosic ethanol plant in neighboring Georgia), representatives of Catchlight Energy (a joint venture between Weyerhaeuser and Chevron), and a consultant with the Ethanol Promotion and Information Council. Policymakers included a lobbyist, a state legislative Representative, and an adviser to the Undersecretary for Agriculture for Research, Education and Economics of the U.S. Department of Agriculture. Researchers were largely university faculty from a range of disciplines, including engineering, forestry, and agronomy.

Interview guides were tailored for each face-to-face interview based on the respondent's area of expertise. We used existing literature to help develop interview guides for our interviews. Interview guides contained open-ended questions, which encouraged respondents to elaborate on their answers. Interviews typically lasted from 45 to 60 min, though they ranged from 30 min to nearly 2 h. Data from public presentations were gathered in settings that did not provide for such dialog between respondent and researcher. We included data from such presentations because, in our view, they provided valuable insight expanding our understanding of the issues that knowledgeable individuals found to be important in shaping the potential future of a lignocellulosic biofuels industry. Several people we interviewed also spoke at conferences we attended, so the views of these individuals are, to some extent, over-represented in Table 1. This double counting did not materially affect the range or relative importance of issues raised by our respondents. Moreover, our interviews with these individuals covered a wider range of topics than any individual respondent covered in their presentations.

Data from interviews and public presentations were entered into a qualitative data analysis software program [15]. Use of this software allowed the authors to identify common patterns and central concerns. The hierarchical category system of the software was used to organize coded information based on subject matter. Analysis of secondary data (from journals, industry publications, and other bioenergy-related literature) helped form the basis of these subject groupings. Once all material was input and coded based on subject matter and type of expert, text retrieval was used to extract needed information. Table 2 provides an overview of logistical and other concerns raised by our respondents and illustrative quotes from different types of respondents.

We used secondary data to develop an input–output model to estimate the economic impact of establishing six 189 dam^3 lignocellulosic biorefineries in Alabama. Our expert respondents identified this as a reasonable refinery size for reasons to be described in more detail below. The number of refineries was identified based on current consumption levels of gasoline and diesel fuels in Alabama [16] as a proportion of

Table 1 – Percentage of experts who voiced concerns about coded topics.

Code grouping	Expert type				
	Non-industrial private forestland owner ($N = 6$)	Organization leader ($N = 29$)	Industry leader ($N = 22$)	Policymaker ($N = 5$)	Researcher ($N = 23$)
Conversion technology	0	14	41	0	35
Environment	0	21	5	40	35
Feedstock-logistics	50	41	23	20	39
Feedstock-type	33	52	45	20	78
Industry structure	50	62	77	80	43
Infrastructure	0	24	9	40	13
Landowners/limited-resource	17	34	9	20	9
Policy issues	50	45	32	80	26
Pulp and Paper	17	14	18	20	13
Rural & municipal Development	0	45	23	60	26

Table 2 – Major logistical issues and concerns raised by experts.

Issues	Questions raised by and asked of experts	Sample quotations (Type of expert)
Preproduction logistics		
Feedstock	• What kind of feedstock is best? • Are landowners willing to grow/sell feedstock? • What is "highest and best" use for material?	"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)
Equipment	• Is equipment scale-appropriate? • Can it handle material/demand?	"You can't drag a tree top through the mud and expect your chipper to last." (Organization leader)
Infrastructure	• What are transportation and storage requirements (for feedstock and fuel)? • Is transportation sector prepared for demand?	"If you had better rail access, the river dredged … all of these are going to have to be improved if (feedstock) production is going to increase to any great degree." (Organization leader)
Refinery logistics		
Production scale/Location	• What size will refineries be? • How will they be dispersed geographically?	"Cellulosic plants will (likely) be smaller and more dispersed than we see with the corn plants." (Industry leader)
Competing industries	• Will pulp and paper mills become producers ("integrated" refineries)? • How will competition for material impact prices?	"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 leader)
Ownership	• How will oil companies be involved in production or distribution of fuels (and byproducts)? • Will grower-owned cooperatives have a role?	"(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)
Distribution and consumption		
Supply chain	• How will supply chain differ from current system? • How will end product reach consumers? • What role will producers play in distribution?	"Cellulosic plants will have a strong competitive advantage … they will be able to deliver directly to the retail and fleet sites … it bypasses a lot of the traditional supply chain." (Industry leader)
Marketing/Demand	• Will there be enough consumer 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 leader)
Policy	• How will mandates affect competition for material? • Will federal policy create an unlevel playing field?	"What's the impact of BCAP on pulp mills? … There's tremendous potential to distort the market." (Researcher)

national consumption, and the state's share of projections established by the RFS (Renewable Fuels Standard) within the Energy Independence and Security Act of 2007.

Input–output (I–O) analysis is a method of accounting for and representing the purchases and sales of goods and services among firms as part of their production processes and purchases and sales of products between firms and final consumers. The model representing this economic activity consists of a set of simultaneous equations that depicts average production functions for industries in a region based on census data collected at the national and local levels. The assembled data provide a description of how the economic sectors of a region interact. Manipulation of the matrix of simultaneous equations yields a predictive model (the multiplier model) that provides information on how a change in production for a particular sector in the economy elicits production changes in all the sectors that provide it with inputs (its suppliers) as well as the sectors that provide the suppliers with inputs (the suppliers to the suppliers). The multiplier is a concise way of describing the aggregate of this activity for a sector within a given region. A sector that purchases more of its inputs locally (within the region) stimulates a higher level of local production than a sector that imports its inputs from outside the region. As a result, that sector will likely have higher multipliers. In the conduct of most standard I–O analyses, various multipliers are constructed to predict the effect of total output, employment, wages, and business taxes that occur as a result of production changes in a regional economy.

3. Lignocellulosic feedstocks in Alabama

A wide variety of feedstocks can be used to produce lignocellulosic biofuels, including perennial grasses (miscanthus and switchgrass) and wood in its various forms (logs, wood chips, residues from harvesting or manufacturing operations). The near unanimous consensus among our expert respondents was that wood would provide the initial feedstock for development of a lignocellulosic biofuel industry. Despite the presence of a large forest products industry in the state, timber growth has exceeded removals since at least 1982 and between 1990 and 2000 the area classified as timberland increased by 4.5 percent [8]. Roundwood harvests of both softwood and hardwood species in Alabama have experienced a ten year decline beginning in the mid-1990s [17].

Switchgrass may emerge as an important feedstock but few land owners are likely to convert their land to perennial grasses before biorefineries and markets are in place. Wood will be the feedstock of choice because of its availability, rapid growth due to abundant rainfall and long growing seasons, and the existence of well-established systems for growing, harvesting, transporting, and marketing wood. None of our respondents felt that residues from corn or other crops would provide an important source of feedstock given the relatively small area devoted to row crops in the region [9].

There was, however, little consensus among our respondents regarding which type of woody biomass would be used. Some took the view that harvest residues would be an important feedstock for biofuel refineries. Harvest residues are made up of tree tops and limbs and woody underbrush left after tree stems ("roundwood") are removed. Proponents argue that use of harvest residues would provide land owners additional revenue and facilitate replanting. Many of these same experts claimed that wood residues from manufacturing (e.g., saw mills) would be available for production of biofuel. Other respondents were much less optimistic, pointing out that the costs of collecting and transporting harvest residuals with current technologies makes this prospect uneconomic and that manufacturing residues already are being utilized. Less than one percent of residues from the forest products industry are unused [17]. Given these data, we base our analyses of lignocellulosic feedstock supply on the availability of roundwood. In Alabama, 49 percent of all roundwood harvests are used for the production of wood pulp for the manufacture of paper products, while 37 percent is used for saw logs. The remaining 14 percent is used for veneer, composite panels, or other industrial uses [17]. Markets for pulpwood and composite panels are most likely to be affected by demand for biofuels as saw logs and veneer logs attract premium prices.

From Table 1, we see that feedstock logistics and availability were major concerns among our experts. Wood is a heavy and bulky material and costs of harvest and transport are significant. Our respondents spoke at length about the need to locate biorefineries in close proximity to the resource, often using pulp and paper mills (which furnish their facilities from within an 80 km radius) as a likely model for biorefineries. Our experts also discussed the existence of established markets for pulp and paper, dimensional lumber, plywood, oriented strand board, and other wood products, and that biorefineries would have to compete against these products. The general consensus among respondents was that biorefineries would increase competition in wood markets, which generally have softened over the past decade. Respondents noted that land owners are suffering from depressed prices and looking for more attractive markets.

Willingness of forestland owners to sell timber for biofuel production was another issue of concern raised by some of our experts, though most were confident that feedstocks would be available if prices paid were competitive with existing markets. Not all forestland owners pursue timber production as their primary management objective. Among alternative objectives of land owners are hunting and other forms of recreation, aesthetic enjoyment, and ecological stewardship [18,19]. However, "People are going to grow what the market wants," said one respondent, noting that everything from closing pulp mills to the Kyoto Protocol and potential carbon credit markets will impact availability. "You'll see land owners do what is necessary to meet market demand." One forestland owner remarked "What does the world need more of today? Is it fuel or is it paper? It looks like it is fuel and I would be pleased to sell my wood to anybody who will do something legal with it and make me the most money." This same landowner went on to say "I love the pulp and paper industry, but it's changed and we have to change with it." These views were confirmed by Paula [14], who found that roughly one out of four forestland owners were unwilling to sell timber or harvest residues for energy, but these owners represented a relatively small fraction (8 percent) of total forestland.

4. Prospects for decentralization of energy production and supply

Our current liquid fuel system is based on large oil refineries linked to consumption centers via pipeline. Technical and economic considerations associated with the production and supply of biomass and the transport of ethanol are likely to result in a more decentralized system of energy production and distribution. As our respondents pointed out, biomass has a high weight/value ratio so that transportation costs quickly become a factor in economic viability of a biorefinery. The consensus among our respondents was that this factor favors construction of numerous relatively small biorefineries rather than a few large facilities. Technical and infrastructural constraints limit the shipping of ethanol through conventional pipelines so that transportation costs will encourage product use near the biorefinery. A distributed system of biofuel refineries may lessen the importance of long-distance transport of biofuels, and in any event some portion of biofuel production will be consumed in local markets. The placement of biofuel refineries where both adequate feedstocks and markets intersect (major urban centers, interstate highways) would increase the likelihood that local production would be consumed locally.

Capital costs for establishing a lignocellulosic biorefinery will determine whether local ownership (as distinct from ownership by oil majors or other large corporations) will be economically feasible. Annual capital production costs for a corn-based ethanol plant are said to run 530 $ m^{-3}, so that a 189 dam^3 plant would require investment of $100 million [20,21]. Investment costs for lignocellulosic ethanol biorefineries have been estimated to be half again as much, (i.e., $150 million for 189 dam^3 capacity). Crooks [22] argues that "Given the scale of investment and the role of intellectual property in lignocellulosic biofuel, the farmer-owned business model may struggle to find its place in this emerging segment of the industry." Greer [23] argues that adopting a modular design might make it possible to develop lignocellulosic biorefineries with far lower capital investment costs. We have heard presentations made by operators of smaller, modular lignocellulosic biorefineries in Alabama who claim small biorefineries can be established for well under $10 million. One of our respondents was investing in a facility with total capital investments in the range of $3 million for a small commercially viable biorefinery. The question of capital requirements cannot at this time be answered given the rapid pace of development in conversion technologies. The question is important as it will be a major factor in determining the type of actor (e.g., local entrepreneur or major energy corporation) that establishes a dominant ownership position within this new industry.

In the Mid-west, the cooperative-ownership model has proved successful for corn ethanol refineries, though a process of industry consolidation followed this initial local development path [20]. Most of our respondents expect big oil companies will play a major role; not just in the distribution of biofuels, but also in production. This is not surprising given the watchful presence of oil majors such as Chevron (through their joint venture with Weyerhaeuser) who

Table 3 – Potential wood demand to produce 189 dam^3 of biofuels per year in Alabama using two efficiency scenarios.

	Scenario #1	Scenario #2
Efficiency (dm3/t of green biomass-50% moisture)	139.6 dm^3/t	243.4 dm^3/t
Supply of green wood needed to operate one 189 dam^3 biofuel refinery for one year	1.4 Mt	0.77 Mt
Supply needed to operate one 189 dam^3 biofuel refinery for one year, expressed as percent of total Alabama roundwood harvests	2.2 percent	1.3 percent

Sources: [3,20,21].

are positioning themselves to invest once different technologies have had a chance to prove themselves [24]. This strategy avoids the costs and risks associated with technological experimentation and early commercial development, mirroring the process that has led to consolidation of the corn ethanol industry.

5. Rural development potential of lignocellulosic bioenergy in the south

There are several ways that lignocellulosic biofuels development can contribute to rural development opportunities in the South. In this section we make a preliminary effort toward understanding these potential benefits and consider how to ensure that some if not most benefits reach rural communities within this region.

The U.S. Department of Energy [25] estimates that 139.6 dm^3 of ethanol can be produced per tonne of green wood (50% moisture content). Other estimates for higher efficiencies project up to 243.4 dm^3 for that amount of biomass [23]. At the lower efficiency level, one 189 dam^3 lignocellulosic ethanol plant would require roughly 1.4 Mt of green wood per year (Table 3). Bennett [26] provides a similar estimate. At the higher efficiency level, 0.77 Mt of green wood would be required to produce 189 dam^3. One biorefinery of this size would require 2.2% of all roundwood harvests in Alabama using the lower conversion efficiency figure, and 1.3% using the higher conversion efficiency figure (Table 3). We calculated Alabama's annual share of the national biofuels targets and arrived at a figure of 1.134 hm^3, so that six 189 dam^3 biofuels plants would be required for Alabama to "carry its weight." Under this scenario, anywhere from 7.8% to 13.2% of Alabama's roundwood harvests would be routed to biofuels production (Table 3). These figures are based on 2002 harvests [7], and as noted previously, there are indications that timber inventories have increased since then due to a broad but gradual decline in Alabama's forest products industry [17].

Substantial economic impacts would occur with an aggressive program to meet Alabama's share, 1.134 hm^3 annually, of the objectives of the Renewable Fuels Standard. We used IMPLAN [27], an economic input–output (I–O) model, to evaluate the effects of developing a bioenergy sector consistent with the assumptions made above (six 189 dam^3 plants consuming approximately 8.4 Mt of green wood per year). I–O models, and IMPLAN in particular, have been used for several decades to assess the effects of forest management activities on rural communities [28]. Using economic data collected by the Bureau of the Census, the I–O method models the interactions among industries in an economy, detailing the inter and intra industry purchases of inputs and sales of products to other firms (for use as inputs) and to final demand (consumers and exports). We used 2006 IMPLAN data for Alabama to conduct the analysis.

Our modeling assumptions have to do primarily with feedstock delivery. Currently there are no operational lignocellulosic ethanol plants that can be used as models to determine a plant production function. Similarly sized corn ethanol plants employ 30–40 people, but that may not be the right number for this process. Accordingly, the impacts developed here reflect the effects of increased harvesting and transportation to accommodate the increase in demand for wood fiber. We assume a delivery cost equal to the current average cost of delivered pulpwood in the region, 27.56 $\$ t^{-1}$ for a blend of green hardwood and softwood feedstocks [29]. A basic underlying assumption of I–O analysis is that industry capacities are available to accommodate expansion of demand. Since it is anticipated that development of a bioenergy sector will take place over an extended period of time and since the pulp and paper sector in the region has already adjusted capacity downward due to other global competitiveness factors, we do not believe that competition for raw material that may develop between bioenergy and pulp and paper will have a near-term deleterious effect on either sector's ability to produce.

Given the six facility scenario and a conservative wood-to-fuel conversion ratio, 139.6 dm^3 t^{-1} green wood (50% moisture), 8.4 Mt of green wood per year would need to be delivered

Table 4 – Economic effects of increasing timber harvests to provide feedstock to six 189 dam^3 lignocellulosic ethanol plants producing 1.134 hm^3 of ethanol per year – IMPLAN 2006 data Alabama – state level model.

	Direct	Indirect	Induced	Total	SAM* multiplier
Output	$225,000,000	$162,728,000	$59,467,000	$447,194,000	1.99
Jobs	891	1217	558	2666	2.99
Income	$39,245,000	$41,202,000	$17,800,000	$98,200,000	2.50
Indirect Business Taxes	$2,059,000	$3,615,000	$3,590,000	$9,264,000	4.50

*Social Accounts Matrix.

Table 5 – Economic effects of increasing timber harvests to provide feedstock to 1 lignocellulosic ethanol plant producing 50 million gallons (189 dam^3) of ethanol per year – IMPLAN 2006 data multi-county model – west Alabama.

	Direct	Indirect	Induced	Total	SAM* multiplier
Output	$37,500,000	$24,426,000	$4,844,000	$66,770,000	1.78
Jobs	151	152	54	356	2.36
Income	$6,446,000	$5,052,000	$1,299,000	$12,797,000	1.99
Indirect business taxes	$328,000	$487,000	$320,000	$1,135,000	3.46

*Social Accounts Matrix.

to the plants (in total), translating into $225 million of additional sales for the harvesting (logging) sector. At the state level, due to the need for other industries to support expanded production of the logging sector with trucks and machines, fuel, insurance, employees, etc., the round-by-round multiplier effects increase that $225 million to $447 million, nearly doubling the original expenditure for the economy as a whole (Table 4). The scenario projects 2666 new jobs statewide with a large proportion of those directly associated with the logging sector (891). Indirectly, through purchases made by the logging sector and its suppliers, an additional 1217 jobs will be generated, primarily in agricultural and forestry support services (consulting foresters), forest nurseries, wholesale trade, truck and machinery repair and financial services. Induced purchases, or the purchases made by workers spending their new (additional) income on economic goods and services, require that even more (588) jobs be added to accommodate the bioenergy sector's development. Finally, construction of the bioenergy production facilities will also contribute jobs and incomes to the economy in an important (although quite temporary) way. Generally such capital investments are treated separately (outside the I–O framework) from the ongoing activities associated with supplying inputs to the facility into the future [30].

At the state level, numbers like these look good. The state economy is diverse, with 460 of IMPLAN's possible 528 economic sectors represented. For that reason, most purchases of required inputs can be made from firms operating within Alabama and do not have to be imported from other states. However, because we are examining impacts at the state level, changes resulting from our scenario are quite small in a proportional sense relative to the statewide totals for output, employment, incomes and indirect business taxes. In rural areas, where many of the production activities are likely to take place, the effects can be much more important. For example, if we consider a group of counties in west Alabama (Fig. 1) where the economy is much less developed (only 200 of IMPLAN's economic sectors represented, less than half the economic diversity of the state as a whole), the impacts of a single bioenergy plant can be more dramatic (Table 5). Even though the magnitude of the impacts and the multipliers associated with them are considerably smaller at the region level, the relative importance of the changes is significantly greater because base level economic activity is so low. For example, total new jobs generated by a single facility expressed as a proportion of base level jobs in the region is 3 times greater than the similar measure for a 6 facility project undertaken for the state as a whole. This is why the concept of distributed development of this industry is so important. Adding jobs, incomes and indirect business taxes (which can be invested in infrastructure to attract additional development) can have a significant impact on the economic trajectory of rural Alabama. Evaluations of that impact need to focus on how the existing (local) economy will be affected.

6. Discussion

The idea of a decentralized energy economy has many positive attributes [31]. Communities could establish refineries as a public utility, or guarantee loans to local entrepreneurs who would purchase local feedstocks, employ local workers, and supply local demand for fuel. The economic impact of such investments and the multiplier effects of feedstock purchases, employment, and retail sales would benefit local economies.

The logic of lignocellulosic biomass production, refining, and fuel distribution favors a decentralized energy system. To the extent that the refinery process is scalable down to the point where a wide range of communities and other investors can afford entry, major oil companies may not have the same level of control over supply that they enjoy today. Involvement of the oil majors may expedite commercialization of lignocellulosic biofuels, in the long run, but the rural development benefits may be more limited if the oil majors come to dominate biofuels. Major oil companies do have the financial resources to invest in (or buy out) smaller lignocellulosic biorefineries. They also have distribution systems in place to bring the product to market and, absent policy to the contrary, could exclude fuels from other producers from gaining access to important markets. Just as electric power companies purchase electricity from those of their customers who generate power from photovoltaic cells or other sources, so too the oil majors could be required to purchase biofuels from other producers. The key policy objective should be to ensure opportunity will be provided for smaller producers to be part of the new energy production and distribution system. Policies that guarantee open markets and certification systems that set quality standards would be good starting points to ensure the creation of economic space for a wide range of producers.

Two recent papers [32,33] reviewed data from 12 Mid-West states and concluded that counties where corn ethanol refineries were established enjoyed higher incomes and lower rates of unemployment, but that these differences predated the construction of the refineries. These authors concluded that there is no evidence that corn ethanol biorefineries have contributed to alleviation of poverty or unemployment in this region, and that those urbanized centers were relatively prosperous to begin with. These papers suggest that we should be cautious in promising that a lignocellulosic biofuels industry will have widely shared positive impacts in a region as diverse as the South. Along the same lines, Bain [34] and Selfa et al. [35] in this issue caution us to not assume that local control over biofuels will automatically provide local benefit, pointing out how local elites may use their positions to capture public resources to support private ends. As the lignocellulosic biofuel industry gains momentum, there is much to be learned by the experience – much just becoming available in the academic literature – about the social and political impacts of corn ethanol production in the United States and elsewhere.

Not everyone believes that lignocellulosic biofuels represent a positive development. The Dogwood Alliance, a leading voice for the protection of southern forests, is concerned that rapid expansion of this industry could lead to deforestation, undermining ecological integrity and the economic and social viability of communities dependent on forest ecosystems [36]. Among the dangers they foresee are the possibility that industrial pine plantations would expand, as would clear cutting of both plantations and natural forests. 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 lignocellulosic ethanol as another threat to southern forests. They argue that no research has been done to support the view that lignocellulosic biofuel will have positive social, economic, or environmental benefits.

We are not yet in a position to argue conclusively that the benefits of lignocellulosic biofuels will outweigh all costs, or to understand how the benefits will be distributed. We understand that the answer to these questions may vary from place to place and depend on scale. In the context of Alabama, expanding timber inventories suggests that a significant lignocellulosic biofuel industry can be supported with existing timber resources, and that many timberland owners would appreciate the opening of new markets. This general statement would need to be evaluated more precisely once plans for siting of specific biorefineries are made because social and biophysical impacts will be location specific. Each site is likely to have its own set of unique environmental concerns (endangered species, watershed protection, etc.), and each individual biorefinery will have a local ecological footprint radiating out approximately 80 km, and it is in this zone that the ecological impact should be measured. Based on expanding timberland acreage and inventories, we believe that Alabama is capable of supporting six 189 dam^3 biorefineries, but this assessment would only have validity were we able to evaluate the water and timber resources available to specific site proposals.

Nationally, meeting the annual goal of 79.5 hm^3 of lignocellulosic and other advanced biofuels by 2020 would require a total of 420 biorefineries producing 189 dam^3 per year. Not all will be built in Alabama or the southeastern United States, but given the region's forest resources and existing infrastructure for growing and harvesting timber and a climate well suited to growing of switchgrass and other energy crops, this region is likely to see considerable investment in biorefineries. Given the history of overexploitation of forest resources in the U.S., including in the South [37], concerns regarding environmental impacts of lignocellulosic biofuel development cannot be disregarded.

Even supporters of a lignocellulosic biofuel industry need to recognize that not everyone will benefit equally (or at all) from development of this industry. Some people own large tracts of land and others do not. Some will have financial capital to invest and others will not. Some will reinvest profits in the local community and others will not. These uncertainties should not make us turn away from the potential benefits, but encourage development of policies to ensure that these benefits are widely distributed. In our society, the most common mechanism we have to ensure that those who profit share their good fortune with others is through tax policy.

The question of tax revenues is of central importance in assessing public benefit from a new industry. When the pulp and paper industry made a big push into the South, many mills were given open-ended tax abatements, which left local schools and governments without adequate resources [38]. Investors have become accustomed to requesting tax abatements, and there may be good reasons to do so for a limited time period in the case of biorefineries. Within a reasonable time frame (e.g., five years), however, biorefineries should be expected to contribute their fair share of the local tax responsibilities and thereby provide support to public schools and other important social services.

7. Conclusion

For a variety of economic and technical reasons, the lignocellulosic biofuels industry of the future will have a distinctly local flavor. How the benefits of this industry are distributed will be determined by corporate investment decisions and policies at the state and federal levels, which should create space for local actors to participate in a new energy economy. This space is vital for the rural development potential of biofuels to be fulfilled. By their very nature, major corporations tend to be highly competitive and seek advantage wherever they see potential gain. These tendencies can be moderated for the social good by public policy.

Lignocellulosic biofuels represent a potentially revolutionary break from an oil-based economy dominated by a handful of corporate actors. Non-industrial private forestland (NIPF) owners control the majority of all forestland in Alabama and the southeastern United States. Transportation costs of moving wood favor establishing numerous small biorefineries. Geographically distributed biorefineries with capital investments that could allow local investors or even individual communities to own biorefineries would represent a dramatic decentralization of our current energy economy. Because major oil companies control distribution and retail infrastructure and are investing in bioenergy, they are likely to play a role in the biofuels industry of the future, but they may no longer be the only players. How the benefits from lignocellulosic bioenergy are to be distributed in the future will be a matter determined at least in part by public policy, which can be used to encourage (or not) a more decentralized energy economy.

Lignocellulosic biofuels are not a magic cure for the ills of rural Alabama or the rural South, but they could provide jobs, incomes, and tax revenues that would spur economic growth and reduce poverty. These gains are more likely to occur if we see potential in the future and plan accordingly. To do otherwise would lead to lignocellulosic biofuels becoming simply another extractive industry which would provide little benefit to those who produce and process raw materials into basic commodities.

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