Economic impacts of woody biomass utilization for bioenergy in Mississippi

Gustavo Perez-Verdin
Donald L. Grebner
Ian A. Munn
Changyou Sun
Stephen C. Grado

Abstract

This study examined the economic impacts of woody biomass utilization for bioenergy conversion in Mississippi. Analysis of economic impacts was organized around three groups of events: (1) recovery of logging and thinning residues, (2) electricity generation from cofiring systems, and (3) construction and operation of biofuel facilities. Input–output analysis was used to simulate economic impacts in terms of gross output, value-added, and employment. Cost information and woody biomass inventories were obtained from the literature, a statewide forest inventory, and Impact Analysis for Planning (IMPLAN) database. Results showed that the single activity of recovery of all available logging and thinning residues would create a considerable number of jobs and stimulate the rural economy with more resources coming to local industries and households. Due to construction and operation costs, economic impacts of biofuels were higher than biopower. However, biofuels reported the lowest employment and value-added multipliers of all three groups. This may be due, in part, to equipment and materials manufactured outside of the state. It is expected that as technology, equipment, and human capital were gradually attracted to the area, the multiplicative effect and expenditure retention should increase. These results can help decision-makers evaluate Mississippi's potential for future bioenergy development.

Concerns over energy security, environmental health, and economic development have generated increasing interest in the search for alternative sources of fuel supplies (Bartuska 2006). Woody biomass, the fibrous and generally inedible portions of stems and branches of plants, is one alternative energy supply source because it is renewable, abundant, and can reduce greenhouse gas emissions (Hamelinck et al. 2005, USDE 2006, Solomon et al. 2007). Cellulose and hemicellulose, the main compounds of woody biomass, are made of energy-rich sugars that can be converted to ethanol through hydrolysis and fermentation procedures (USDE 2006). Alternatively, biomass can be used as a feedstock to produce electricity replacing fossil fuel-fired power plants.

Woody biomass for bioenergy conversion is obtained from a diverse and widespread resource base which includes low-value forest products such as logging residues and thinning of overstocked stands, among other sources (Perlack et al. 2005). Frequently, this material is left on-site, piled, and burned at additional cost, or left on-site for decomposition and incorporation into soil nutrients. As pressure for green energy develops, there has been a strong interest in utilizing this material for bioenergy conversion. A significant number of studies have evaluated the potential of woody biomass for fuels, electricity, and heat generation (e.g., Giampietro et al. 1997, Graf and Koehler 2000, CEC 2001, Solomon et al. 2007). A

The authors are, respectively, Postdoctoral Research Associate, Associate Professor, Professor, Assistant Professor, and Professor, College of Forest Resources, Mississippi State Univ., Mississippi State, Mississippi (gperez@cfr.msstate.edu, dgrebner@cfr.msstate.edu, imunn@cfr.msstate.edu, csun@cfr.msstate.edu, sgrado@cfr.msstate.edu). The authors would like to thank the Sustainable Energy Research Center and Forest and Wildlife Research Center (FWRC) at Mississippi State Univ. for funding this project. We are grateful to Dr. Anwar Hussain for his invaluable help in manuscript review and IMPLAN simulations. Preliminary results were presented at the 2008 SOFEW conference at Savannah, Georgia. We thank attendees for insightful comments. This manuscript has been registered as FO370 by the FWRC, Mississippi State Univ. This paper was received for publication in May 2008. Article No. 10487.

Forest Prod. J. 58(11):75–83.

question remains about the economic impacts that recovery of logging residues for use as a feedstock to bioenergy would have on a state's economy. These impacts, generally estimated in terms of expenditures, taxes, and employment, have not been well-documented due to the incipient market development and low-scale commercial production (CEC 2001, REMI 2006, Gan and Smith 2007).

The study objectives were to describe the main economic impacts of developing bioenergy and to specifically quantify the economic impacts on Mississippi's economy of logging residue recovery, electricity generation from woody biomass, and construction and operation of a biofuel facility. The paper begins with a brief review of basic concepts of bioenergy and input-output models, which are the basis for economic impacts simulations. It then presents a case study using data for the state of Mississippi to analyze preliminary economic impacts and closes with a summary and conclusions.

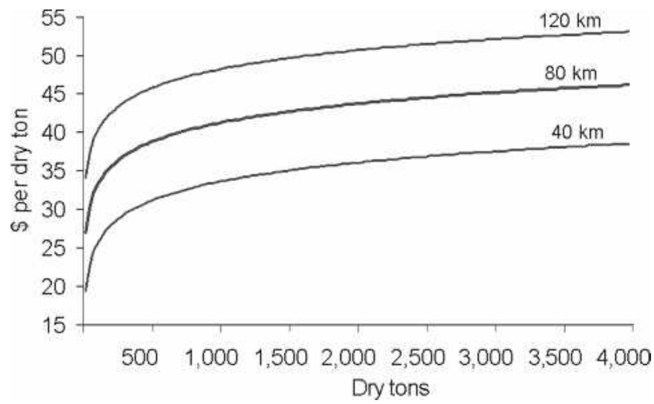

Figure 1. — Adjusted cost curves of woody biomass feedstocks for three procurement distances in Mississippi (Source: Grebner et al. In press).

Background

Bioenergy is solar energy stored via photosynthesis in organic matter. While this definition implies plant-converted energy, the concept also includes animal and food processed wastes (Perlack et al. 2005). Electricity (biopower), liquid fuels (biofuels), and heat generated from biomass are examples of bioenergy. The first two are largely considered for commercial scale development due to existing processing capacity and an increasing demand for residential and industrial uses (Cook and Beyea 2000, Gan and Smith 2006, Solomon et al. 2007). Electricity generated from biomass operates in a similar way as fossil fuel-based plants. Instead of fossil fuels, however, biomass is direct-fired in a boiler to produce high-pressure steam that rotates a turbine, which in turn is connected to an electric generator. The majority of power plants are direct-fired systems, but some plants use a combination of coal and biomass feedstocks, a process called cofiring (NREL 2007). Cofiring systems have demonstrated that combining coal and biomass for electricity generation increases boiler efficiency, reduces fuel costs, and significantly decreases emissions of nitrates and fossil carbon (Demirba 2003). Typically, the same power plants that generate renewable electricity also yield useful steam and heat in combined heat and power. It is expected that the combined share of biomass and other non-hydropower renewable electricity for the next 30 years will increase from 2.2 to 4.3 percent of total generation (EIA 2006).

Biofuels are liquid or gaseous fuels produced from biomass feedstocks. Bioethanol, biodiesel, biogas, and hydrogen fuel are some examples of biofuels. Bioethanol and hydrogen fuel are produced through microbial fermentation of sugar, starch, and cellulosic materials. Biodiesel is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking grease. Biogas is produced through anaerobic digestion of volatile organic matter. Ethanol is the most common biofuel produced from cellulose and hemicellulose (NREL 2007). Ethanol has been in the center of political debates as it was announced as a serious alternative fuel to displace 30 percent of U.S. current gasoline use by 2030 (USDE 2006). Current technology, based on dilute acid pretreatment and fermentation, can produce up to 80 gallons of ethanol from one dry ton of woody biomass (Hamelinck et al. 2005). To meet the 2030 goals, it would be necessary to produce 60 billion gallons of cellulosic ethanol a year, which requires one billion dry tons of woody biomass in supplies. Nationwide studies estimated that current woody biomass potential is about 1.3 billion dry tons per year, of which 73 percent comes from agricultural residuals (Perlack et al. 2005). This amount is enough to cover the 2030 energy goals.

Mississippi's bioenergy potential

Mississippi's forests cover approximately 20 million acres, and each year they generate more than $1 billion worth of timber and related forest products (Munn and Tilley 2005). The forest products industry, which consists basically of four sectors: logging, solid wood products, pulp and paper, and wood furniture manufacturing, on average processes 1.3 billion cubic feet of roundwood and by-products per year (Howell et al. 2005, MAFES 2007). In 2001, all sectors combined were responsible for more than 54,000 direct jobs, roughly 3.7 percent of the State's total employment, and its impact on the economy was about $13 billion (Munn and Tilley 2005). Wood furniture contributed 44 percent of the direct jobs, followed by the solid wood products industry (28%), pulp and paper (13%), and logging and miscellaneous forest products (15%). Grebner et al. (In press) estimated the availability and production costs of woody biomass in Mississippi's 82 counties. Their results showed that about four million dry tons of woody biomass can be produced every year in the state (**Fig. 1**). The material consists of logging residues, small diameter trees, urban waste, and mill residues. They also indicated that logging residues, the largest feedstock, can be produced at $40 per dry ton and small-diameter trees at $49 per dry ton, for a 50-mile procurement radius.

To process these supplies, it is necessary to know where exactly feedstocks are located and how much it will cost to transport the material to a manufacturing facility. Region-specific studies are necessary to account for variation in cost and availability of woody biomass. Generally, the best facility location is conceived as the place which significantly reduces production costs (i.e., a site close to feedstocks). Once site location is identified and availability and production costs are estimated, a next step is to analyze the economic impacts on a state's economy of processing woody biomass. The economic impacts can be analyzed in terms of various socio-economic indicators such as gross output, value-added, employment, and taxes (CEC 2001; Gan and Smith 2007), and input-output models are often used in the appraisal. This type of evaluation would help decision-makers evaluate and develop strategic energy transformation centers in the state.

Methods

To estimate economic impacts of bioenergy development, this study used the Impact Analysis for Planning (IMPLAN) model developed by MIG, Inc. and the USDA Forest Service. The IMPLAN model, based on input-output (I-O) analysis, consists of a nationwide matrix and estimates of sector activity for final demand, final payments, industry output, and employment for each county in the Unites States. New databases, which include 509 economic sectors, are annually developed using U.S. Census Bureau, U.S. Department of Commerce, Bureau of Economic Analysis, and other government-based information.

Input-output models

I-O models trace commodity flows from producers to intermediate and final consumers (Schaffer 1999). Industries produce goods and services for final demand and purchase raw material from producers. Producers, in turn, purchase goods and services from other industries. This process continues until *leakages* from the region stop the cycle (Schaffer 1999). The total industry purchases of commodities, services, employee compensation, value-added, and imports are in the end equal to the value of the commodities produced. I-O models also provide multipliers that estimate the relationship between the initial effect of a change in final demand and the total effects of that change (Miller and Blair 1985). The effects, which can be direct, indirect, or induced, describe the change of output for each and every local industry caused by a one dollar change in final demand and, typically, they are estimated in terms of output, value-added, and employment (Rickman and Schwer 1995). Gross output represents the total value of production; value-added is total output minus costs of purchased inputs and represents the amount of money available for disbursement, either in the form of wages, owner compensation, or taxes; and employment includes the number of full- and part-time jobs in the sector (Munn and Tilley 2005).

Direct effects measure changes associated with the immediate impacts in the level of production of an economic activity. Indirect effects are the production changes from various rounds of interindustry respending. For instance, a cellulosic ethanol plant requires a considerable amount of chemical and biological materials such as sulfuric acid and *cellulase* enzymes to process woody biomass. Changes in sales, jobs, and income in the cellulosic ethanol industry are direct effects. Changes in sales, jobs, and income in the chemical industry represent indirect effects of changes in ethanol production. The chemical industry, in turn, requires inputs from other industries that represent another round of indirect effects. Indirect effects disappear gradually until leakages stop the cycle. Induced effects are the changes in economic activity resulting from household spending of income earned directly or indirectly as a result of bioenergy conversion. Cellulosic ethanol and chemical industry employees spend their earned income for housing, food, transportation, insurance, health, and education. The sales, income, and jobs that result from household spending of added wage, salary, or proprietor's income are induced effects. The magnitude of this ripple effect is captured in multipliers (Tilley and Munn 2007).

Various types of multipliers have been developed to measure the effects (i.e., direct, indirect, and induced) and the economic activity analyzed (i.e., output, value-added, employment, and income) (Rickman and Schwer 1995). I-O multipliers include Type I, Type II, Type III, and social account matrices (SAM). Differences among all multipliers involve the type of effects being analyzed and the way that induced effects are computed. For instance, Type SAM multipliers are estimated by adding direct, indirect, and induced effects and dividing by the direct effects. Induced effects are based on information in the social account matrix. Type SAM multipliers usually are preferred to other types of multipliers because they account for social security and tax leakages, institutional savings, and interinstitutional transfers (Rickman and Schwer 1995). IMPLAN generates multipliers for output, value-added, employment, and income. Output multipliers measure total impact of selling industries of each dollar brought by purchasing industries. Value-added multipliers are a measure of economic output that eliminate interindustry sales and, therefore, reflect the amount of output added by each industry. Employment multipliers are defined as the ratio of the number of employees over one million of dollars of output (Schaffer 1999). Income multipliers are the ratio of household income to output or total changes in output over total changes in income (Miller and Blair 1985, Schaffer 1999).

Few studies have analyzed the economic impacts of woody biomass utilization in terms of employment, output, and value-added since bioenergy development is relatively new. Gan and Smith (2007) estimated cobenefits of woody biomass for electricity generation in East Texas. They found that about 1.3 million dry tons could be used to generate 2,400 MWh of electricity in coal-fired power plants. They also reported that about $352 million would be generated as total output and 1,340 jobs would be created. Their study, however, did not provide specific information about costs and industry sectors actually included in the simulations. In a conjoint study developed by Michigan Tech University and Regional Economic Models, Inc. (REMI) in the Great Lakes Region, it was found that bioethanol can bring considerable economic impacts, including population migration and value-added, due to construction and operation of processing facilities (REMI 2006). This study, based on dynamic input-output models, simulated three scenarios for ethanol production as a function of plant capacity. The greatest impacts were found for the construction and operation of a 52-million gallon ethanol plant (REMI 2006).

Classification of bioenergy impacts

The analysis of economic impacts of woody biomass for bioenergy conversion was organized around three groups of events: (1) recovery of logging and thinning residues, (2) electricity generation from cofiring systems, and (3) construction and operation of biofuel facilities. The first group, recovery of logging residues and thinning, involved the procurement of wood in the form of tree tops and branches, and the chipping, loading, and transporting of raw material to a processing facility. Transportation costs were estimated for a 50-mile supply radius, which included 2 miles of in-woods hauling. The total cost of recovery of logging residues and thinning was estimated at $151.7 millions per year (Grebner et al. In press). This number was used in IMPLAN simulations. To avoid conflicts in woody biomass allocation to any type of bioenergy, the effects of collecting all woody biomass supplies were simulated independently of the other two groups.

The second group involved operation of existing processing facilities to convert woody biomass into biopower. Due to technical considerations, derived from incipient markets, it was difficult to estimate investments and input requirements for modifications, operation, and maintenance of biopower plants. Following Gan and Smith (2007), it was assumed that biopower was somewhat similar to electricity generation from fossil fuel power plants. Though possibly unrealistic, this assumption was based on the feasibility that existing power plants can also be used for cofiring systems and on similarities of per-unit production costs of initial investments between biomass-fired systems and coal or other fossil fuel-fired plants (Hughes 2000, Gan and Smith 2007). Thus, the analysis of biopower did not consider new plant construction and the impact analysis was conducted by replacing coal as the primary feedstock with woody biomass. As of 2006, according to the Energy Information Administration (EIA), there were 17 power plants operating in Mississippi that may use coal and wood for electricity generation with a production capacity of 2,800 MW (17% of the state capacity) (EIA 2007). As expected, not all woody biomass supplies would be sufficient to meet power plant demands, especially if part of the material was diverted for biofuels conversion. Woody biomass was perceived as an alternative to reduce problems associated with fossil fuels consumption, but it was not expected to completely solve fossil-fuel dependency.

A 100-MW electrical generating plant was considered to determine the economic impacts of electricity generation. This power plant required 240,000 tons of coal at 47 percent efficiency (Beér 2007) or 430,000 tons of woody biomass at 35 percent of efficiency (Gan and Smith 2007) to generate 800,000 MWh of electricity per year. Production costs of fuels were estimated at $10.3 million (EIA 2007) for coal and $17.6 million for wood. According to EIA, the delivery price for each MWh of electricity generated in Mississippi was $90 (EIA 2007), which gave $72 million of total output. Since the plant was already in operation, fixed and variable costs were assumed constant and fuel costs accounted for most differences (**Table 1**).[1] The economic impacts of electricity generation from cofiring systems were simulated for various combinations of wood and coal use. Simulations started with 100 percent of wood and 0 percent of coal, then 75 to 25, 50 to 50, 25 to 75, 10 to 90, 5 to 95, and 0 percent wood and 100 percent of coal use. To compare effects, results were standardized in terms of Type SAM multipliers, which were the ratio of total impacts to direct impacts.

A different approach was applied to the third group (i.e., biofuels). The effects of construction and operation of new manufacturing facilities were estimated because there were no cellulosic ethanol processing facilities in existence. Plant construction impacts included employment for the construction industry, and equipment and material purchases. We assumed a plant capacity of 52 million gallons of ethanol per year that would require about 700,000 dry tons of woody biomass annually. Information regarding construction and operation costs of manufacturing facilities was obtained from various sources including California Energy Commission (2001), REMI (2006), Gan and Smith (2007), and Solomon et al. (2007). A plant processing 52 million gallons of cellulosic ethanol per year would need an estimated capital investment of $224 million (**Table 2**) plus other costs to cover feedstocks, enzymes, utilities, maintenance, labor, and administrative fees during the plant lifetime.

Table 1. — Operation costs for a 100 MW power plant.[a]

IMPLAN sector	Cost category	Million $	$/MWh
014	Biomass cost	17.63	21.99
032	Water	0.30	0.38
037	Modification cost	1.89	2.35
269	Annualized charge	14.89	18.58
043	Maintenance	2.66	3.32
427	Insurance	1.77	2.21
460	Ash transport	0.79	0.98
460	Ash disposal	0.31	0.38
10004	Payroll	2.76	3.45
10007	Other property income	6.45	8.05
11003	Federal taxes	10.75	13.41
12003	State taxes	5.16	6.44
	Total	65.36	81.54

[a]Based on a fluid bed combustor, steam turbine cycle, and 100% wood feedstock. Sources: Caywood (1972), Hughes (2000), and Caputo et al. (2005).

Table 2. — Estimated construction costs for a 52-million-gallon cellulosic ethanol manufacturing facility.

Cost category	Million $
Feedstock handling and equipment	11.4
Pretreatment	37.5
Xylose fermentation	9.7
Cellulase production	4.5
Saccharification and fermentation	33.2
Ethanol recovery	6.4
Off-site tankage	6.4
Environmental systems	6.3
Miscellaneous	7.6
Utilities (steam, electricity, water)	80.7
Start-up costs and working capital	20.3
Total capital investment	224.0

Source: Adapted from Solomon et al. 2007, p. 421.

To perform IMPLAN simulations of biofuel impacts (e.g., on a year-by-year basis), construction costs were annualized to produce an annual charge over the economic lifetime of the plant. This was done by multiplying the total construction cost by a capital recovery factor. The capital recovery factor is a function of variables such as project life, cost of capital, tax rate, depreciation methods, and equipment type (Axelsson et al. 2003). In this analysis, the economic lifetime of the processing facility was established at 15 years and assumed a 10 percent after-tax rate of return on capital investment. Following Solomon et al. (2007), capital recovery factor was set at 20 percent. Thus, the annualized capital charge was estimated at $44.8 million. This amount was distributed into three IMPLAN sectors: manufacturing and industrial buildings (42%), miscellaneous fabricated metal product manufacturing (32%), and other industrial machinery and equipment manufacturing (26%). The spreading of percentages across

[1] See Caputo et al. (2005) for details in construction and operation of wood-fired power plants.

industries was based on a demand study of plant construction and cellulosic ethanol production in the Great Lakes Region of the U.S. conducted by REMI (2006). Operating costs and annualized capital charges were shown in **Table 3** including cost categories under IMPLAN sectoring.

Results

IMPLAN estimates of economic impacts of logging residue recovery, biopower, and biofuels were shown in **Table 4**. The recovery of 4 million dry tons of woody biomass available each year in Mississippi would create 585 direct jobs and generate $152 million of gross output. Another 481 indirect jobs and 646 induced jobs are generated as a result of logging operations. The total value-added, which is the sum of employee compensation, proprietor income, other property income, and indirect business taxes, provides $37.3 million in direct impacts and $23.4 million in indirect impacts. The induced value-added impact (generated due to income earned by employees in direct and indirect business and industries and spent on goods and services) adds another $37 million. Employee compensation and other property income (or profit earned by loggers) accounted for 48 percent and 30 percent, respectively, within total value-added impacts. The multiplier effect indicates that for every dollar worth of initial stimulus in the recovery of logging residues results in an additional $1.62 of value-added. The highest multiplier within total value-added is indirect business taxes (4.42) which include payments of excise and sales taxes by individuals to businesses. These taxes, collected during normal operation of businesses, do not include taxes on profit or income. Similarly, the multiplier for employment, the highest number of all three groups of bioenergy, shows that for every single job directly created, 1.92 jobs are generated elsewhere. The most affected sectors by recovery of logging residues are agriculture and forestry support activities, petroleum refineries, wholesale trade, owner-occupied dwellings, and food services and drinking places, among others.

The economic impacts of operating a 100-MW power plant using woody biomass as a replacement for coal were also shown in **Table 4**. As expected, the impacts were not as high as biofuels because no construction costs were assessed. In this case, electricity generation from wood would directly support 281 direct jobs, produce direct gross output of $64.5 million, and $15 million of direct value-added. Employee compensation (55%) and other property income (27%) had the highest contribution within total value-added. Type SAM multipliers indicated that for every dollar of gross output generated by the power plant, $0.60 worth of indirect and induced output impacts was generated in other industries. Similarly, Type SAM multiplier for employment is 2.25, which indicated that for every job directly created in biopower, 1.25 jobs were created in other industries. The most affected sectors by biopower included logging, maintenance and repair of nonresidential buildings, insurance carriers, agriculture and forestry support, activities, waste management and remediation services, petroleum refineries, and owner-occupied dwellings, among others.

Electricity generation from cofiring systems creates larger economic impacts when wood was the primary feedstock. Overall, impact multipliers for output, employment, and value-added steadily increase as wood replaces coal in power plants. The multiplier for gross output is 1.4 when wood is not used and 1.6 when wood is fired alone. Smaller differences were found for employment and value-added multipliers. The multiplier for employment was 2.1 when coal is the only feedstock and 2.2 when wood is the primary feedstock. The multiplier for value-added is 2.2 when wood is not used and 2.3 when wood is fired alone (**Fig. 2**).

The economic impacts of construction and operation of an ethanol plant were also shown in **Table 4**. Considerable expenditures are immediately lost from the State, due to temporary workforces and the importation of equipment and services not currently available in Mississippi. Regional purchase coefficients (RPC) were determined based on the knowledge of industries acquiring resources within the area, but in some cases they were based on IMPLAN default estimates. These leakages represent about 21 percent of direct output. Overall, 1,756 jobs would be created from biofuels conversion (52-million-gallon plant) and would generate $242.7 million of total gross output. Total value-added was estimated at $86.4 million with employee compensation (58%) and other property income (23%) having the highest

Table 3. — Estimated operation costs and annualized capital charges for a 52-million-gallon cellulosic ethanol manufacturing facility.

IMPLAN sector	Cost category/industry	Million $/year	$/gallon
Operation costs			
014[a]	Feedstock procurement	29.04	0.56
030[a]	Electricity	−4.94[b]	−0.10
032[a]	Water	0.22	0.00
043	Maintenance	7.75	0.15
151	Enzymes	11.57	0.22
154	Other chemical materials (sulfuric acid, lime, nutrients)	5.73	0.11
427[a]	Insurance and property taxes	3.93	0.08
444[a]	Consulting services	2.36	0.05
455[a]	Overhead	8.54	0.16
460[a]	Gypsum disposal	0.56	0.01
Annualized capital charges[c]			
037	Manufacturing and industrial buildings	18.80	0.36
255	Miscellaneous fabricated metal product manufacturing	14.40	0.28
269	Other industrial machinery and equipment manufacturing	11.59	0.22
Labor, profit, and taxes			
10005[a]	Payroll	2.85	0.05
10007[a]	Other property income	18.20	0.35
11003[a]	Federal taxes	2.97[d]	0.06
12003[a]	State taxes	14.15	0.27
	Total production cost	147.72	2.83

Source: Adapted from Solomon et al. 2007, p. 422.
[a]Regional purchase coefficients (RPC) for these events were assumed to be 100%. All other cost categories used IMPLAN default estimates. An RPC of 100% means that additional demands are fully met by local production.
[b]Industry by-products (e.g., lignin) are recycled for electricity generation.
[c]Based on a capital recovery factor of 20%; economic lifetime of 15 years; and 10% after-tax rate of return on capital investment.
[d]Federal taxes include a $0.51/gallon discount (subsidy).

Table 4. — Economic impacts of three groups of bioenergy development in Mississippi.

Group	Economic impacts Direct	Indirect	Induced	Total	Type SAM multiplier[a]
1. Recovery of logging residues					
Gross output (M$)	151.75	68.46	62.28	282.49	1.86
Total value-added (M$)	37.27	23.45	37.07	97.78	2.62
Employee compensation (M$)	13.28	12.52	21.16	46.95	3.54
Proprietors income (M$)	9.91	4.13	2.35	16.39	1.65
Other property income (M$)	12.87	5.46	10.73	29.07	2.26
Indirect business taxes (M$)	1.22	1.34	2.82	5.38	4.42
Employment (number of jobs)	585	481	646	1,712	2.92
2. Biopower(100-MW plant)					
Gross output (M$)	64.47	16.27	22.68	103.42	1.60
Value-added (M$)	14.98	6.42	13.54	34.94	2.33
Employee compensation (M$)	7.95	3.41	7.73	19.09	2.40
Proprietors income (M$)	2.60	0.85	0.85	4.30	1.66
Other property income (M$)	3.74	1.69	3.92	9.35	2.50
Indirect business taxes (M$)	0.70	0.47	1.03	2.21	3.13
Employment (number of jobs)	281	115	236	631	2.25
3. Biofuels (52-million gallon plant)					
Gross output (M$)	150.11	35.91	56.71	242.74	1.62
Value-added (M$)	38.11	14.55	33.74	86.41	2.27
Employee compensation (M$)	23.11	7.69	18.97	49.77	2.15
Proprietors income (M$)	7.78	1.89	2.14	11.81	1.52
Other property income (M$)	6.14	3.91	9.98	20.03	3.26
Indirect business taxes (M$)	1.08	1.08	2.64	4.80	4.45
Employment (number of jobs)	908	261	586	1,756	1.93

[a]Type SAM multiplier is the ratio of total impact to direct impact.

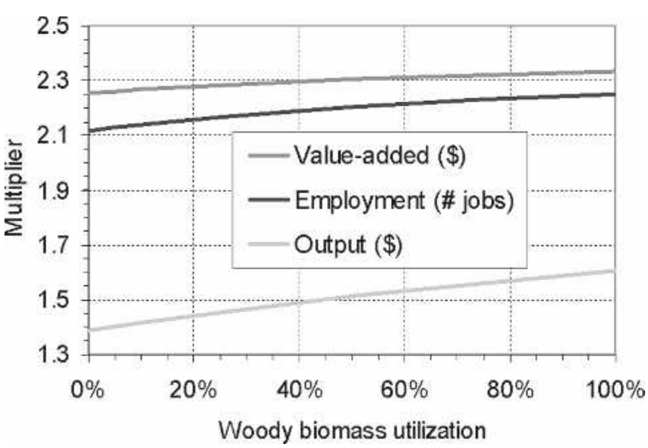

Figure 2. — Economic impacts of cofiring woody biomass and coal in Mississippi. The x-axis shows woody biomass rate. Coal is assumed to be the difference to complete 100 percent utilization. For example, 20 percent of woody biomass means 80 percent of coal use.

share. While the number of total jobs seems to be high, the employment multiplier of biofuels is the lowest of the three groups of bioenergy being analyzed. For every single job created in this industry, only 0.9 jobs will be created in other industries. The most affected sectors of biofuels were logging, manufacturing, and industrial buildings; domestic trade; business support services; other basic organic chemical manufacturing; maintenance and repair of nonresidential buildings; insurance carriers; building material and garden supply stores; and petroleum refineries. In total, these sectors accounted for 72 percent of total gross output.

Discussion

The economic impacts of recovery of logging residues for either biopower or biofuel conversion were examined in this study. The 4 million dry tons of woody biomass available each year in Mississippi can supply up to nine 100-MW power plants or five 52-million-gallon plants of ethanol production. The economic impacts of biofuels and biopower were modeled for a certain plant capacity to be used as a baseline reference because results can be extrapolated to more plants depending on the proportion of woody biomass utilization. For example, a 40 percent distribution of available biomass for biopower would be enough to supply three plants and generate $310 million of gross output. The remaining 60 percent would be enough to construct and operate three bioethanol plants, which would generate $728 million of output (**Fig. 3**). Either form of bioenergy is compatible with the objectives of reducing nonrenewable energy dependency and offsetting greenhouse gas emissions. Cellulosic ethanol is seen as a political, strategic, and economic source to control the price of corn and other agricultural feedstocks currently used for ethanol production (Solomon et al. 2007). However, ethanol development has been impeded by high construction costs, technological efficiencies, and financial constraints (Wyman 2003, Hamelinck et al. 2005, Solomon et al. 2007). Biopower has a slight advantage over biofuels due to existing plants that may use woody biomass and coal in cofiring systems. Electricity generated in cofiring systems requires no substantial investments in equipment and technology (Hughes 2000).

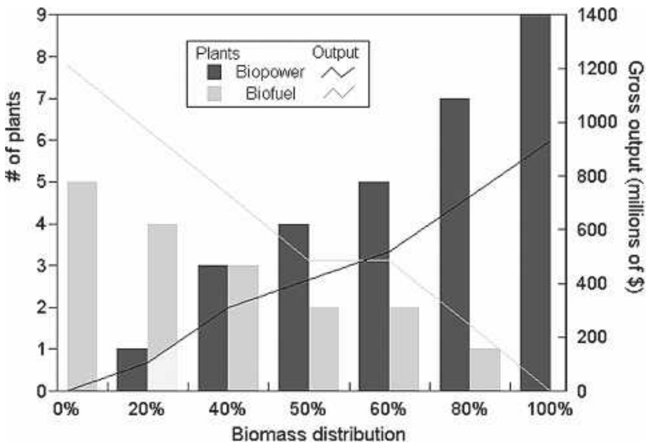

Figure 3. — Trade-offs between biopower and biofuels development in Mississippi. The left y-axis represents number of plants whereas the right y-axis stands for gross output. The x-axis is referenced for biopower.

This advantage represents a considerable savings in bioenergy development compared to facility building for biofuel production.

To differentiate economic impacts of biopower and biofuels on a per-unit basis, a standard energy unit called British thermal unit measured as millions of Btu (MMBtu) was used. In this case, one MWh is equivalent to 3.41 MMBtu (Gan and Smith 2006) whereas 1 gallon of ethanol is approximately 0.08 MMBtu. Per unit indicators of output and value-added were measured as dollars per MMBtu and employment as MMBtu per person. Accordingly, output, value-added, and employment indicators were greater for biofuels than biopower. Biofuel impacts were estimated at \$55.3/MMBtu for output, \$19.7/MMBtu for value-added, and 2,499 MMBtu/person for employment. Biopower impacts were estimated at \$37.8/MMBtu for output, \$12.8/MMBtu for value-added, and 4,328 MMBtu/person for employment. These results indicated that biofuels is more resource efficient that biopower. Biofuel yields more revenues and requires fewer jobs to produce one energy unit.

Replacing coal in power plants resulted in slightly more economic impacts for wood. Coal, Mississippi's leading energy source, has a higher energy content, is more efficient and, therefore, a lower tonnage is required to produce the same amount of electricity than wood (Hughes 2000). However, the majority of coal has to be imported from other areas, as far away as Colorado and Wyoming (EIA 2007), increasing its delivery price. Coal is estimated at \$43/ton (EIA 2007) whereas wood has been estimated at \$41/dry ton (Grebner et al. In press). In contrast, woody biomass is locally produced and all production inputs (i.e., labor, capital, equipment) are found in the area. Acquiring resources in the area make both impact multipliers and expenditure retention to be slightly higher than coal. Another major impact of woody biomass utilization for electricity generation stems from the amount of carbon dioxide (CO_2) that can be displaced if coal were the primary energy source. The 430,000 tons of woody biomass required to power a 100-MW plant would displace 340,000 tons of CO_2 emitted from a coal-fired plant (see Gan and Smith 2007 for conversion procedures). This is equivalent to 1.3 percent of the total CO_2 emissions generated in 2007 by all electric power industries in Mississippi. At the current price of CO_2 traded at the Chicago Climate Exchange (\$4.08/ton CO_2, March 3, 2008), the value of carbon displaced is \$1.4 million.

The economic impacts of each group of bioenergy to its respective aggregated sector were analyzed following IMPLAN production functions. The idea was to evaluate the role of each bioenergy group in Mississippi's economic sectors. The sectoring developed for IMPLAN was based on the former Standard Industrial Classification (SIC), now called North American Industry Classification System (NAICS), and the Bureau of Economic Analysis classification (IMPLAN 2004). Accordingly, impacts of recovery of logging residues were compared to the *logging* sector and biopower to the aggregated *power generation and supply* sector (see IMPLAN 2004, Appendix A, for details). Due to the nature of feedstocks and technology involved, no apparent sectors were identified for a biofuels analysis and comparison. The closest sector was *pulp and paper* industry, but differences in technology, type of feedstock, and efficiency made comparisons difficult. To establish a reference point, results were compared to this sector considering that the future vision of integrated biorefineries is to process all products for chemical feedstocks and energy as a by-product of the pulping process (Coleman and Stanturf 2006). With 2006 data adjusted to the year 2008, total gross output of the logging sector was estimated at \$1.6 billion, value-added at \$409 million, and the number of full- and part-time jobs were estimated at 6,427. Comparing these numbers to our results (**Table 4**), recovery of logging residues represents 17 percent of gross output, 24 percent of value-added, and 27 percent of employment of the aggregated sector. The logging sector is largely dominated by roundwood for pulpwood production[2], but pulpwood's low cost contributed little to this sector's economy.

The economic impacts of biopower to the aggregated electricity sector represent only 4 percent, 2 percent, and 11 percent of gross output, value-added, and employment, respectively. Note that impacts of biopower and biofuels were estimated at a certain plant production capacity. These numbers could be higher if more plants were operated or capacity was increased. In contrast, biofuels seemed to narrow differences with the pulp and paper sector. The proportion of economic impacts of biofuels to the aggregated pulp and paper sector represents 25 percent, 11 percent, and 35 percent of gross output, value-added, and employment, respectively. This narrowing may be attributed to the construction factor that attracts considerable investments, expenditures, and employment (**Fig. 4**).

Previous works have demonstrated the multiplicative impacts of bioenergy in other regions of the U.S. (Hjerpe 2006, REMI 2006, Gan and Smith 2007). Gan and Smith estimated Type SAM multipliers for recovery of logging residues of 2.0, 1.7, and 2.1 in terms of value-added, gross output, and employment, respectively. They estimated multipliers for electricity generation of 1.3, 1.3, and 5.2 for the same components as well. Though results of impact multipliers are difficult to compare across regions, because they depend on regionalized socioeconomic structures, what is important to note is that bioenergy can help diversify and improve regional economies in many rural areas of the country (Hjerpe 2006, Gan and Smith 2007). In particular for Mississippi, by looking at

[2] In 2006, roundwood for pulpwood production accounted for 80% of total timber production in Mississippi (MAFES 2007).

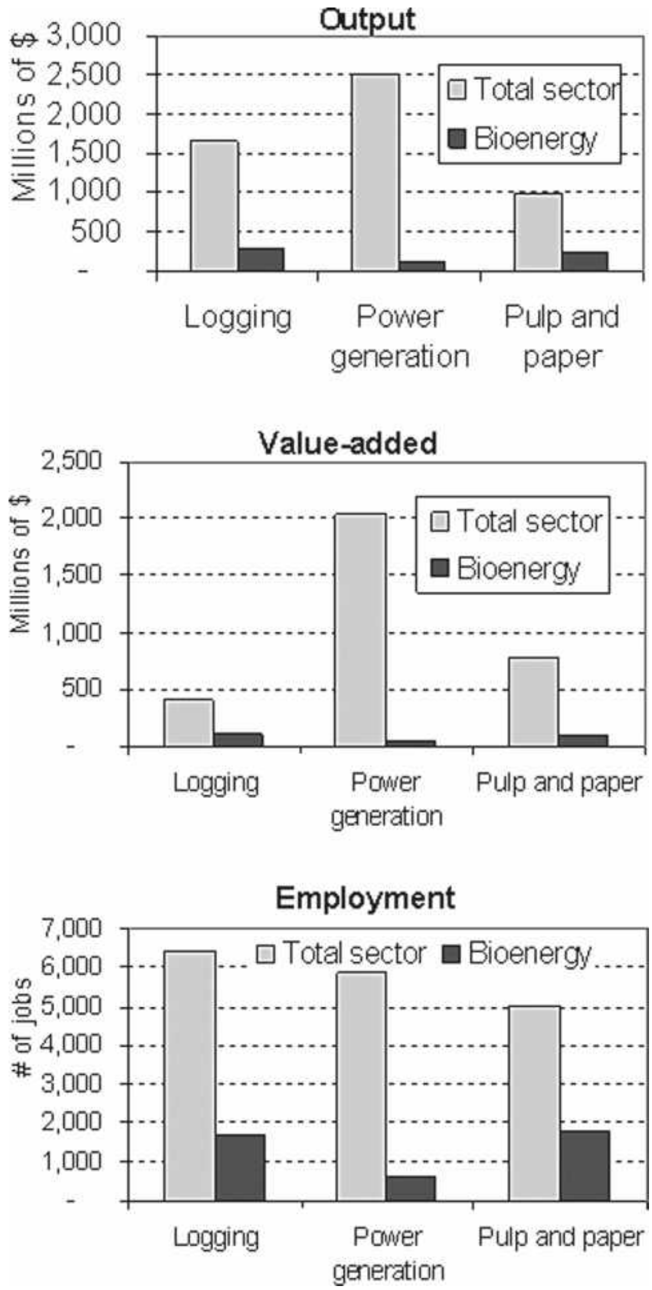

Figure 4. — Comparison of three groups of bioenergy to aggregated sectors in Mississippi. The aggregated sectors were logging, power generation, and pulp and paper (see Tilley and Munn 2007 for details on pulp and paper's aggregation).

the contribution of each group to the aggregated sectors, employment generation represents the greatest impact of bioenergy development. It is expected that as technology, equipment, and human capital are gradually attracted to the area, the multiplicative impact and expenditure retention should also increase.

Summary and conclusions

This study examined woody biomass utilization economic impacts for bioenergy conversion in Mississippi. Results showed that the single activity of recovery of logging and thinning residues would create a significant number of jobs and stimulate rural economies with more economic resources coming to local industries and households. Economic impacts of biopower, based on cofiring systems, showed some differences between wood and coal use. Wood registered slightly more economic impacts than coal due to higher regional expenditure retention and lower energy content, which requires more feedstock supplies and higher feedstock costs. About 240,000 tons of coal, compared to 430,000 tons of woody biomass, are required to generate 800,000 MWh of electricity per year. Production costs of wood were 41 percent greater than coal. This study suggested that wood brings more economic impacts, but it is not as efficient as coal. Other differences stem from environmental impacts such as carbon dioxide offset, as well as reduction of sulfur dioxide, nitrogen oxides, and other emissions. Wood has the unique advantage to offset emissions generated by the otherwise use of coal.

It was determined that employment generation is the greatest impact of bioenergy development in Mississippi. Due to construction and operation costs, the economic impacts of biofuels were higher than biopower. Despite that total value-added was higher and more jobs would be created in biofuels, the value-added and employment multipliers were lower than biopower. This difference can be due in part to equipment and material manufactured or produced in other areas generating leakages in Mississippi's economy. Gan and Smith (2007) and REMI (2006) found employment multipliers of 5.2 and 5.7 for biopower and biofuels, respectively. In these cases, it may be possible that most of the equipment and material were acquired within the study area. Mississippi has low regional purchase coefficients due to the lack of specialized industry and incipient market for bioenergy. However, it is expected that this change could be reversed because of the State's forest potential that could attract more investments into the region.

More research is necessary to assess the combined effect of biopower and biofuels in one industry (i.e., integrated biorefineries). Evaluation of the effects of land use changes as a result of increasing demand for biofuels or biopower is also necessary. Finally, more research is necessary to address social and ecological issues of biomass utilization to provide a more comprehensive analysis of bioenergy development.

Literature cited

Axelsson, H., S. Harvey, A. Asblad, and T. Berntsson. 2003. Potential for greenhouse gas reduction in industry through increased heat recovery and/or integration of combined heat and power. Appl. Therm. Eng. 23:65–87.

Bartuska, A. 2006. Why biomass is important—The role of the USDA Forest Serv. in managing and using biomass for energy and other uses. Speech given at 25x25 Summit II, Washington, D.C. Available at www.fs.fed.us/research/pdf/biomass_importance.pdf. Accessed April 3, 2008.

Beér, J.M. 2007. High efficiency electric power generation: The environmental role. Progress in Energy and Combustion Sci. 33(2): 107–134.

Caputo, A.C., M. Palumbo, P.M. Pelagagge, and F. Scacchia. 2005. Economics of biomass energy utilization in combustion and gasification plants: Effects of logistic variables. Biomass Bioenergy 28(1):35–51.

Caywood, R.E. 1972. Electric utility rate economics. McGraw-Hill Book Company, Inc., New York. 278 pp.

California Energy Commission (CEC). 2001. Costs and benefits of a biomass-to-ethanol production industry in California. Rept. P500-01-002. Available at www.energy.ca.gov/reports/2001-04-03_500-01-002+002A.PDF. Accessed April 3, 2008.

Coleman, M.D. and J.A. Stanturf. 2006. Biomass feedstock production systems: Economic and environmental benefits. Biomass Bioenergy 30(8-9):693–695.

Cook, J. and J. Beyea. 2000. Bioenergy in the United States: Progress and possibilities. Biomass Bioenergy 18(6):441–455.

Demirba, A. 2003. Sustainable cofiring of biomass with coal. Energy Convers. Manage. 44(9):1465–1479.

Energy Information Administration (EIA). 2006. Annual energy outlook 2006. National Energy Information Center. Rept. DOE/EIA-0353(2005), Washington, D.C.

__________. 2007. State energy profiles. http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=MS. Accessed Jan. 23, 2008.

Gan, J. and C.T. Smith. 2006. Availability of logging residues and potential for electricity production and carbon displacement in the USA. Biomass Bioenergy 30(12):1011–1020.

__________ and __________. 2007. Co-benefits of utilizing logging residues for bioenergy production: The case for East Texas, USA. Biomass Bioenergy 31(9):623–630.

Giampietro, M., S. Ulgiati, and D. Pimentel. 1997. Feasibility of large-scale biofuel production. Bioscience 47(9):587–600.

Graf, A. and T. Koehler. 2000. Oregon cellulose-ethanol study. An evaluation of the potential for ethanol production in Oregon using cellulose-based feedstocks. Rept. prepared by the Oregon Office of Energy. Available at www.oregon.gov/ENERGY/RENEW/Biomass/docs/OCES/OCES.PDF. Accessed April 8, 2008.

Grebner, D.L., G. Perez-Verdin, C. Sun, I.A. Munn, E.B. Schultz, and T.G. Matney. In press. Woody biomass feedstocks: A case study on availability, production costs, and implications for bioenergy conversion in Mississippi. *In*: Renewable Energy From Forest Resources in the United States, B. Solomon and V. Luzadis, Eds. Taylor and Francis. pp. 261–280.

Hamelinck, C.N., G. van Hooijdonk, and A.P. Faaij. 2005. Ethanol from lignocellulosic biomass: Techno-economic performance in short, middle, and long term. Biomass Bioenergy 28(4):384–410.

Hjerpe, E.E. 2006. Economics of forest restoration and fuels reduction programs in the Southwest. Diss. Northern Arizona Univ., School of Forestry, Flagstaff, Arizona.

Howell, M., T.G. Johnson, and J.W. Bentley. 2005. Mississippi's timber industry—An assessment of timber product output and use, 2002. RB-SRS-102. USDA Forest Serv., Southern Res. Sta. Asheville, North Carolina.

Hughes, E. 2000. Biomass cofiring: Economics, policy and opportunities. Biomass Bioenergy 19(6):457–465.

Impact Analysis for Planning (IMPLAN). 2004. IMPLAN Pro. User's Guide, Analysis Guide, and Data Guide. MIG, Inc., Stillwater, Minnesota.

Mississippi Agri. and Forestry Expt. Sta. (MAFES). 2007. Economics: Harvest of forest products report. http://msucares.com/forestry/economics/reports/index.html. Accessed April 14, 2008.

Miller, R.E. and P.D. Blair. 1985. Input-Output Analysis, Foundations and Extensions. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Munn, I.A. and B.K. Tilley. 2005. Forestry in Mississippi. The impact of the forest products industry on the Mississippi economy: An input-output analysis. Rept. FO301. Forest and Wildlife Res. Center, Mississippi State Univ.

National Renewable Energy Lab. (NREL). 2007. Renewable Electric Plant Information System. www.nrel.gov/analysis/repis/. Accessed Jan. 30, 2008.

Perlack, R.D., L.L. Wright, A.F. Turhollow, and R.L. Graham. 2005. Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply. Rept. DOE/GO-102005-2135. U.S. Dept. of Energy, Oak Ridge, Tennessee.

Regional Economic Models, Inc. (REMI). 2006. An assessment of the economic and demographic impacts of developing, operating, and maintaining a lignocellulosic ethanol plant in the Great Lakes region. Rept. prepared for Michigan Technological Univ. by REMI, Amherst, Massachusetts.

Rickman, D.S. and R.K. Schwer. 1995. A comparison of the multipliers of IMPLAN, REMI, and RIMS II: Benchmarking ready-made models for comparison. Ann. Reg. Sci. 29(4):363–374.

Schaffer, W.A. 1999. Regional impact models. Regional Res. Inst., West Virginia Univ. 81 pp.

Solomon, B.D., J.R. Barnes, and K.E. Halvorsen. 2007. Grain and cellulosic ethanol: History, economies, and energy policy. Biomass Bioenergy 31(6):416–425.

Tilley, B. and I.A. Munn. 2007. 2001 Economic impacts of the forest products industry in the South. Southern J. of Applied Forestry 31(4): 181–186.

U.S. Dept. of Energy (USDE). 2006. Breaking the biological barriers to cellulosic ethanol: A joint research agenda. Rept. DOE/SC-0095. Office of Sci. and Office of Energy Efficiency and Renewable Energy, Rockville, Maryland.

Wyman, C.E. 2003. Potential synergies and challenges in refining cellulosic biomass to fuels, chemicals, and power. Biotechnol. Prog. 19(2): 254–262.