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The Economic Feasibility of Using Georgia Biomass for Electrical Energy Production

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This study investigates the potential for using biomass for the production of electricity in Georgia. The volume, important characteristics, and delivered costs per unit of energy are estimated for various locally produced biomass. Production of synthetic fuels using both pyrolysis and gasification technologies is investigated as potential means for converting biomass into electricity. Capital and operating costs for each of these two technologies are projected across three different scales of production. Estimated costs per unit of electricity generated are determined. It appears, under the conditions modeled, these technologies are not cost competitive with currently used technologies. Significant subsidies would be needed to induce the adoption of these technologies under current economic conditions.

Key Words: bio-electricity, bio-feedstocks, biomass, cost, electricity

This study evaluates the economic feasibility of current technology for pyrolysis and gasification for producing energy from Georgia's biomass resources. The basic process involves the use of pyrolysis and gasification to convert the biomass resources into "bio-gas" and "bio-oil" (or "syn-gas" and "syn-oil") that can be used as fuel to produce steam to generate electricity. The University of Georgia's Center for Agribusiness and Economic Development (CAED) contracted with Frazier, Barnes and Associates of Memphis, Tennessee, to provide research into the technologies of pyrolysis and gasification as methods for producing electricity. Their report forms the base upon which the feasibility of the two technologies is built. The CAED amassed data concerning the sources and costs of providing biomass for the process and evaluated the associated economic costs.

Biomass Feedstock Issues

Georgia has a large potential volume of biomass feedstocks for conversion into energy. There may be in excess of 18 million tons of material that could be converted each year. Different potential feedstocks have vastly different delivered

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costs per ton due to market prices of the product and relative cost of transportation per unit. In addition, some of the potential feedstocks are only available on a seasonal basis. Since generation of electricity is a minute-to-minute operation, assurance of a continuous supply of feedstocks is of critical importance.

Other factors to consider when evaluating potential feedstocks are the moisture and ash content. High moisture content implies high drying costs that can add to the total cost of electricity production, perhaps making a given feedstock less economically viable. High ash content feedstocks require added boiler design considerations, which would raise capital costs. Ash disposal costs are also an important factor.

The total amount of agricultural by-products was evaluated based on the annual production of total yield mass and the percentage of residues left over after harvest for each potential source. Quantities for closed-loop sources, those which are grown specifically for power generation, were calculated by multiplying the annual yield per acre by the total acres in production.

Biomass sources can be divided into three groups for discussion: (*a*) alternative crops such as kenaf and switchgrass, (*b*) traditional row crop residues, and (*c*) forestry products and co-products. The alternative crops are those with limited commercial production, and thus less is known concerning potential yields, costs of production, and likely potential volume. Research indicates each crop may yield between 6 and 10 tons of usable biomass per acre. Average estimated production cost is $65 per ton for kenaf and $80 per ton for switchgrass. It was estimated that 13,000 acres of kenaf and 1,000 acres of switchgrass may be planted in the near future to meet potential market demands. The expected yields were assumed to be 6.98 tons per acre for kenaf and 6 tons per acre for switchgrass.

Production of various row and forage crops is common in Georgia. Many of these crops have residues that could provide a source of biomass for the state. Production data from the "2005 Georgia Farmgate Value Report" (Boatright and McKissick, 2006) and expert opinions are used as the basis for tonnage estimates. Cost estimates were developed using Extension Service crop production budgets and machinery costs calculators. Transportation costs were obtained from quotes provided by trucking operators in south Georgia.

Current information for forest-related products was derived from communications and data supplied by the Georgia Forestry Commission. Analysis utilized the estimated annual harvest acreage for timber products in Georgia. The three primary sources of forest residue to be considered in this study are bark, wood chips, and wood (harvesting) residues.

For consistency, tonnage available was calculated utilizing similar assumptions as prior analysis. However, it is important to point out that given recent emphasis on renewable fuel sources and interest in biomass forest resources, the Georgia Forestry Commission is conducting extensive ongoing research examining forest biomass sources in much greater detail than covered in this report.

This analysis bases availability on the estimated annual harvested acreage in Georgia, which the Georgia Forestry Commission estimates to be about 500,000 acres. The total forestland in the state is estimated at 24.2 million acres with roughly 11 million being softwood (pine) forests.

Biomass Properties

The properties and characteristics of each biomass have important implications for its feasibility as a potential source. To optimize feasibility, feedstocks must provide electricity generators an abundant supply at low delivered cost. In addition, the heat content (BTU) of feedstocks varies depending upon the type of biomass, so an energy-dense fuel is critical. Biomass sources also differ in ash and moisture content. These ingredients affect the energy value—i.e., the ash has no energy value, and the amount of water in biomass affects the available energy per unit.

Biomass sources also vary in weight, particle size, and bulk density. The weight, size, structure, and dimensions of varying biomass sources result in different processing and equipment and transportation costs. The biomass sources that are the densest, or can be processed to use less space per ton, will have the lowest cost of transport and storage.

A summary of Georgia's farm-produced biomass resources is shown in table 1, reporting the total tons of biomass produced, price per ton, average price per ton, delivered cost per ton, and the season of harvest. Delivered costs per ton vary widely across various biomasses, ranging from a low of just under $18 per ton to nearly $165 per ton.

In order for an alternative fuel source to find widespread acceptance in the market place, it must be price competitive with the current market favorite. The most critical measure of competitiveness is the cost per delivered energy per delivered ton. Table 2 presents the biomass feedstock quality and delivered cost for some common agricultural biomass sources in Georgia. Research suggests the fuels with the least delivered cost per million BTU (mmBTU) would be the most likely fuel sources for a biomass power generation facility.

Table 3 shows a summary of historical energy data for Georgia from the Energy Information Agency (2010). The delivered fuel costs and quantities for electricity generation for coal, petroleum, and natural gas for 1999 through September 2006 are summarized.

Georgia Electrical Power Rates

The bench used in evaluating the feasibility of electrical power generation using biomass feedstocks is the current rates charged for electricity produced by other means. In order to compete in the market place, the cost of biomass-fueled power generation must be competitive with existing technologies.

Table 1. Biomass Supply and Delivered Prices

Biomass	Tons Available	Price/Ton (Avg. Price/Ton) ($)	Freight Cost/Ton (50 miles) ($)	Cost/Ton Delivered (@ $2.25/mi.)	Harvest Season
Pecan Hulls	7,976	9.50–11.50 (10.50)	7.28	17.78	Fall
Poultry Litter	9,133,815	12.00–25.00 (18.50)	5.96	24.46	Year-Round
Gin Trash	205,226	10.00–14.00 (12.00)	7.94	19.94	Late Summer/ Early Fall
Wood Chips	6,294	18.00–22.00 (20.00)	7.28	27.28	Year-Round
Bark (pine)	241,500	16.00–20.00 (18.00)	6.62	24.62	Year-Round
Wood Residue	4,217,798	18.00–23.00 (20.50)	5.96	26.46	Year-Round
Peanut Hulls	289,000	15.00–65.00 (40.00)	4.63	44.63	Late Summer/ Early Fall
Cotton Stalks	2,717,505	35.00–55.00 (45.00)	5.96	50.96	Late Summer/ Early Fall
Hay	674,811	40.00–60.00 (50.00)	11.25	61.25	Late Summer/ Early Fall
Corn Stalks	164,570	36.00–60.00 (48.00)	11.25	59.25	Mid-Summer/ Early Fall
Kenaf	90,750	57.50–72.50 (65.00)	11.25	76.25	Fall
Switchgrass	6,000	70.00–90.00 (80.00)	11.25	91.25	Fall
Wheat Straw	366,834	133.00–167.00 (150.00)	14.56	164.56	Late Spring/ Early Summer
Rye Straw	139,993	133.00–167.00 (150.00)	14.56	164.56	Late Spring/ Early Summer

Table 4 reports the average Georgia retail prices for electricity for various sectors and how the price has changed since 1990. The benchmark for competitiveness would appear to be the ability to produce electricity from biomass sources at an average cost of about 7.43 cents per kilowatt hour.

Gasification and Pyrolysis Technologies

Gasification and pyrolysis are similar technologies for converting carbon-laden products into component products that can be used as fuel. There are three main products produced from the processes: (*a*) hydrocarbon gas (“syn-gas”); (*b*) hydrocarbon oils (“syn-oils”) that can be further processed; and (*c*) char, the solids residual. The gasification system will produce a greater volume of syn-gas, while the pyrolysis system will produce a greater volume of the oil product.

These processes involve the chemical conversion of the biomass in a heated atmosphere of pressurized steam or air. The gasification process is conducted in an atmosphere of limited oxygen, and in pyrolysis, oxygen is excluded to avoid any combustion. The processes drive the volatile compounds from the biomass to produce a low-to-medium calorific gas termed "syn-gas" or "bio-gas." The syn-gas can be combusted immediately to produce power or it can be cooled, filtered, and cleaned for use in combustion engines, gas turbines, and fuel cells. The syn-gas contains 70%–80% of the energy originally present in the feedstock. Syn-oil is the cooled and condensed form of the volatiles from the feedstock. It is a stable, transportable oil having about one-half the heat content of conventional fuel oil. The syn-gas and syn-oil can be refined and used as a fuel to power a generator to produce electricity. The power plant could be a syn-gas or oil-powered turbine combined with a steam-powered turbine driven by waste heat that is converted into steam. Since the refining process is costly, a more practical approach is to fire the syn-fuels directly in a boiler and produce steam that can then be used to generate electricity.

The syn-gas produced from the gasification process is cleaned of most impurities and then burned in a boiler to create steam. The steam powers a turbine generator that produces electricity. To date, the direct-gas-fired turbine design has not proven to be practical due to impurities inherent in the bio-gas for smaller than 50 megawatt (MW) gasification plants. However, it may be practical for large-size plants.

Scope of Financial Analysis

This study evaluates both gasification and pyrolysis technologies for production of electricity using various feedstocks. The following assumptions are made:

- The feedstock will be dried using heat generated through the gasification and pyrolysis processes.
- Electricity will be produced from the bio-fuels.
- The energy from the bio-fuels can be sold locally at competitive prices.
- The plant should be limited in size to less than 10 MW to keep feedstock transportation cost at a minimum.

The study also evaluates potential scale economies by analyzing three different plant sizes based on wet tons of feedstock. For the gasification technology, the three plant sizes are 160 wet tons per day, which would produce about 3,370 kilowatts (kW); 267 wet tons per day, producing about 5,627 kW; and 533 wet tons per day, producing about 11,232 kW. The three plant sizes for the pyrolysis

Table 2. Characteristics of Potential Biomass Feedstocks and Delivered Costs

Georgia Biomass	Ash Content Dry Basis (%)	mmBTU/ Ton	Price per Ton Low / High ($)	Average Price/Ton ($)	Calculated Average $/mmBTU
Pecan Hulls	5.80	16.35	9.50 / 11.50	10.50	0.64
Gin Trash	17.60	13.10	10.00 / 14.00	12.00	0.92
Bark (pine)	3.30	14.08	16.00 / 20.00	18.00	1.28
Coal [a]	NA	NA	NA	NA	NA
Poultry Litter	26.68	8.89	12.00 / 25.00	18.50	2.08
Peanut Hulls	5.90	16.03	15.00 / 65.00	40.00	2.50
Wood Residue	3.20	8.86	18.00 / 23.00	20.50	2.31
Wood Chips	1.30	9.09	18.00 / 22.00	20.00	2.20
Corn Stalks	6.40	14.62	36.00 / 60.00	48.00	3.28
Cotton Stalks	17.20	12.37	35.00 / 55.00	45.00	3.64
Hay	5.70	14.00	40.00 / 60.00	50.00	3.57
Kenaf	3.60	14.78	57.50 / 72.50	65.00	4.40
Switchgrass	5.40	14.01	70.00 / 90.00	80.00	5.71
Natural Gas [a]	NA	NA	NA	NA	NA
Wheat Straw	3.50	14.57	133.33 / 166.67	150.00	10.30
Petroleum [a]	NA	NA	NA	NA	NA
Rye Straw	3.00	12.70	133.33 / 166.67	150.00	11.81

[a] Coal, natural gas, and petroleum: 2006 US$.

(extended . . . →)

Table 3. Delivered Fuel Costs and BTU Yield for Coal, Petroleum, and Natural Gas

Fuel	2006	2005	2004	2003	2002	2001	2000	1999
Coal ($/mmBTU)	$2.39	$2.14	$1.79	$1.72	$1.68	$1.66	$1.54	$1.55
Avg. Heat Value (BTU/lb.)	9,994	9,994	9,990	10,041	10,119	10,169	10,256	10,245
Petroleum ($/mmBTU)	$12.05	$9.48	$7.60	$6.37	$5.10	$5.95	$5.89	$3.48
Avg. Heat Value (BTU/gal.)	147,357	147,357	147,429	147,190	146,976	147,595	147,357	147,738
Natural Gas ($/mmBTU)	$7.14	$9.77	$6.38	$5.73	$3.65	$3.28	$4.18	$2.49
Avg. Heat Value (BTU/cubic ft.)	1,028	1,028	1,027	1,025	1,020	1,026	1,021	1,022

Source: Energy Information Agency (2010).

Table 2. Extended

Georgia Biomass	Conversion Factor	Freight Cost per Ton Mile ($)	50-Mile Freight/Ton ($)	50-Mile Freight/mmBTU ($)	Delivered F/S $/mmBTU
Pecan Hulls	129.4	0.15	7.28	0.45	1.09
Gin Trash	141.2	0.16	7.94	0.61	1.52
Bark (pine)	117.6	0.13	6.62	0.47	1.75
Coal [a]	NA	NA	NA	NA	2.39
Poultry Litter	105.9	0.12	5.96	0.67	2.75
Peanut Hulls	82.4	0.09	4.63	0.29	2.78
Wood Residue	105.9	0.12	5.96	0.67	2.99
Wood Chips	129.4	0.15	7.28	0.80	3.00
Corn Stalks	200.0	0.23	11.25	0.77	4.05
Cotton Stalks	105.9	0.12	5.96	0.48	4.12
Hay	200.0	0.23	11.25	0.80	4.38
Kenaf	200.0	0.23	11.25	0.76	5.16
Switchgrass	200.0	0.23	11.25	0.80	6.51
Natural Gas [a]	NA	NA	NA	NA	7.14
Wheat Straw	258.8	0.29	14.56	1.00	11.29
Petroleum [a]	NA	NA	NA	NA	12.05
Rye Straw	258.8	0.29	14.56	1.15	12.96

Table 4. Georgia Average Retail Prices (2005 ¢/kWh) by Sector

Sector	1990	1995	2000	2005
Residential	9.90	9.22	8.23	8.64
Commercial	9.73	8.60	7.03	7.67
Industrial	6.41	5.31	4.44	5.28
Other	10.76	10.10	9.22	6.90
All Sectors	8.70	7.77	6.72	7.43

Source: Energy Information Agency (2010).

technology are based on a 160 wet tons per day plant that would produce 2,266 kW scaled up by replicating the same plant two and three times.

Capital Costs for Gasification and Pyrolysis Facilities

Tables 5 and 6 itemize the capital cost estimates for different sized facilities that will produce electricity using biomass feedstocks. The range of capacity for the pyrolysis systems is from 2,266 kW to 6,801 kW with a capital cost range from $11.2 to $31.6 million (table 6). Likewise, the range of the gasification systems is from 3,370 to 11,232 kW with a capital cost range from $19.6 to $43.8 million (table 5).

Table 5. Gasification Capital Costs ($)

	Plant Size / (Kilowatts of Electricity Capacity)		
Description	160 WTPD (3,370 kW)	267 WTPD (5,627 kW)	533 WTPD (11,232 kW)
Buildings	596,700	716,040	947,700
Feedstock Receiving & Processing	1,638,750	2,338,750	3,637,750
Dump Truck	117,000	117,000	117,000
Front-End Loader	140,000	140,000	140,000
Fuel Processing Building	820,000	1,350,000	2,339,000
Metal Removal Equipment	18,000	18,000	18,000
Grinding/Sizing Equipment	193,000	216,500	263,250
Blending Equipment	87,500	117,000	146,250
Fuel Storage Bins	117,000	234,000	468,000
Conveyors	146,250	146,250	146,250
Gasification Process Equipment	6,880,000	10,000,000	15,560,000
Interconnections	1,053,000	1,521,000	2,340,000
Waste Heat Boiler	3,500,000	6,000,000	8,000,000
Power Generation Equipment	1,500,000	2,000,000	3,300,000
Heat Recovery System	600,000	1,040,000	1,560,000
Engineering/Permitting	296,400	510,000	702,000
Land/Site Preparation	238,700	325,000	434,000
Subtotal	16,303,550	24,450,790	36,481,450
Contingency (20%)	3,260,710	4,890,158	7,296,290
Total Estimated Cost	**19,564,260**	**29,340,948**	**43,777,740**

Source: Frazier, Barnes and Associates, Memphis, TN.
Note: WTPD = wet tons per day of feedstock.

Operating Costs

Tables 7 and 8 summarize the operating costs of three different sized plants for both the gasification and pyrolysis technologies. Basic assumptions include operating 24 hours per day for 350 days per year, annual average delivered feedstock costs of $25 per ton, and other details identified in the left-hand column of the respective tables. The range of estimated electricity production cost for the pyrolysis systems (table 8) was $0.217 for the smallest system to $0.198 for the largest model. The corresponding cost range for the gasification systems (table 7) was $0.193 to $0.140.

The costs of producing electricity with both the gasification and pyrolysis systems modeled in this study are well above the current rates for electricity sold in Georgia. It appears that neither the gasification nor the pyrolysis technology, similar to those modeled here, are viable sources of electricity at the present time.

Table 6. Pyrolysis Capital Costs ($)

	Plant Size / (Kilowatts of Electricity Capacity)		
Description	160 WTPD (2,266 kW)	320 WTPD (4,534 kW)	480 WTPD (6,801 kW)
Buildings	596,700	1,193,400	1,790,100
Feedstock Receiving & Processing	1,638,750	2,338,750	3,637,750
Dump Truck	117,000	117,000	117,000
Front-End Loader	140,000	140,000	140,000
Fuel Processing Building	820,000	1,350,000	2,339,000
Metal Removal Equipment	18,000	18,000	18,000
Grinding/Sizing Equipment	193,000	216,500	263,250
Blending Equipment	87,500	117,000	146,250
Fuel Storage Bins	117,000	234,000	468,000
Conveyors	146,250	146,250	146,250
Pyrolysis Process Equipment	1,300,000	2,600,000	3,900,000
Interconnections	600,000	1,200,000	1,800,000
600 PSIG Steam Boiler	3,000,000	6,000,000	9,000,000
Demineralizer System	175,000	350,000	525,000
Power Generation Equipment	875,000	1,750,000	2,250,000
Heat Recovery System	702,000	1,404,000	2,106,000
Engineering/Permitting	351,000	620,000	940,000
Land/Site Preparation	120,000	240,000	360,000
Subtotal	9,358,450	17,696,150	26,308,850
Contingency (20%)	1,871,690	3,539,230	5,261,770
Total Estimated Cost	**11,230,140**	**21,235,380**	**31,570,620**

Source: Frazier, Barnes and Associates, Memphis, TN.
Note: WTPD = wet tons per day of feedstock.

The reasons for the relative high cost of electricity production with these technologies are many, but a few include the high capital cost of the technology relative to electrical power generated. The high capital cost raises the fixed costs of operation and places a large financial burden on the venture.

Another observation on the relative efficiency of the two processes may offer insight into the potential for using these technologies to produce electricity or other energy. The term "efficiency" in the biomass energy conversion vernacular should be viewed with a great deal of caution. It can be influenced by the type of feedstock, the variables that affect the boiler operation, and above all, the feedstock moisture and percentage ash that will remain after conversion. We have assumed that the moisture content will not exceed 25% and that ash will be in the 4%–8% range. The boiler should be designed for dual firing (both solid fuel and natural gas) and with sufficient excess air to minimize emissions.

Table 7. Gasification Operating Costs ($)

	Plant Size		
Description	160 WTPD	267 WTPD	533 WTPD
Electricity Produced (kW):	3,370	5,627	11,232
Annual Production (kWh)	28,308,000	47,266,800	94,348,800
Sales Price = $0.0743/kWh	0.074	0.074	0.074
Daily Sales ($)	6,009	10,034	20,029
Annual Sales ($)	2,103,284	3,511,923	7,010,116
Variable Costs ($):			
Feedstock @ $25/ton	1,400,000	2,336,250	4,663,750
Electricity @ $0.055/kWh	169,000	290,400	532,400
Water & Water Treatment	25,740	66,690	186,000
Ash Disposal @ $20/ton	13,650	27,300	54,600
Inert Gas	12,000	20,025	39,975
Labor	720,000	720,000	800,000
Total Variable Costs	2,340,390	3,460,665	6,276,725
Fixed Costs ($):			
Maintenance (3% of investment)	586,928	880,228	1,313,332
Taxes & Insurance (1.5% of investment)	293,464	440,114	656,666
Interest on Capital (8% of avg. investment)	782,570	1,173,638	1,751,110
Depreciation (SL 13.5 years)	1,449,204	2,173,404	3,242,796
Total Fixed Costs	3,112,167	4,667,384	6,963,903
Total Costs	**5,452,557**	**8,128,049**	**13,240,628**
Net Revenues	**−3,349,272**	**−4,616,126**	**−6,230,513**
Cost of Generation per kWh	**0.193**	**0.172**	**0.140**

Table 9 reports the percentage of total feedstock energy that is ultimately available in the form of electricity. These system losses represent a considerable inefficiency. To improve the likelihood of adoption for electricity production, these systems must demonstrate greatly improved energy efficiency to capture a much higher percentage of the available energy from biomass feedstocks.

Summary of Gasification and Pyrolysis

In summary, it does not appear that it is feasible to produce electricity from biomass using pyrolysis and gasification technologies under the current economic environment. The operating costs of producing electricity using these technologies range from 2.4 to nearly 5 times the current cost of electricity produced using atomic, coal, and gas-fired plants. Improvements in system efficiency and reductions in capital costs will be needed before these technologies can be competitive.

Table 8. Pyrolysis Operating Costs ($)

	Plant Size		
Description	160 WTPD	320 WTPD	480 WTPD
Electricity Produced (kW):	2,266	4,534	6,801
Annual Production (kWh)	19,034,400	38,085,600	57,128,400
Sales Price = $0.0743/kWh	0.074	0.074	0.074
Daily Sales ($)	4,041	8,085	12,128
Annual Sales ($)	1,414,256	2,829,760	4,244,640
Variable Costs ($):			
Feedstock @ $25/ton	1,400,000	2,336,250	4,663,750
Electricity @ $0.055/kWh	169,000	290,400	532,400
Water & Water Treatment	25,740	66,690	186,000
Ash Disposal @ $20/ton	13,650	27,300	54,600
Inert Gas	12,000	20,025	39,975
Labor	720,000	720,000	800,000
Total Variable Costs	2,340,390	3,460,665	6,276,725
Fixed Costs ($):			
Maintenance (3% of investment)	336,904	637,061	947,119
Taxes & Insurance (1.5% of investment)	168,452	318,531	473,559
Interest on Capital (8% of avg. investment)	449,206	849,415	1,262,825
Depreciation (SL 13.5 years)	831,862	1,572,991	2,338,564
Total Fixed Costs	1,786,424	3,377,998	5,022,067
Total Costs	**4,126,814**	**6,838,663**	**11,298,792**
Net Revenues	**−2,712,558**	**−4,008,903**	**−7,054,152**
Cost of Generation per kWh	**0.217**	**0.180**	**0.198**

Table 9. Biomass Cogeneration Energy Efficiency Summary

Technology	Biomass Conversion Efficiency (%)	Energy Conversion System Efficiency (%)			Total System Energy Efficiency (%)		
		Case #1	Case #2	Case #3	Case #1	Case #2	Case #3
Gasification [a]	80	20	20	20	16	16	16
Pyrolysis [b]	56	20	20	20	11	11	11

Source: Frazier, Barnes and Associates, Memphis, TN.

[a] Gasification efficiency courtesy of PRIMENERGY, Inc.

[b] Pyrolysis efficiency courtesy of ROI, Inc.

If public policy mandates the use of biomass for electricity production, significant subsidies would be required to induce electricity producers to utilize gasification and/or pyrolysis technologies as modeled in this study. The subsidies would be more than double the cost of producing electricity through current technologies using traditional feedstocks. Significant technological improvements are needed for these techniques to be widely adopted.

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