The University of Georgia

Center for Agribusiness and Economic Development

College of Agricultural and Environmental Sciences

THE FEASIBILITY OF GENERATING ELECTRICITY FROM BIOMASS FUEL SOURCES IN GEORGIA

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I. INTRODUCTION

Premise of the Study

According to the Energy Information Administration, Georgia's electrical energy supply relies primarily on fossil fuel and nuclear power. In 1999, 64% of electrical power was generated by coal, 27% by nuclear, and 4% by natural gas and petroleum fuels. Hydroelectric sources generated 2.3% of Georgia's electrical supply. Other fuels, such as municipal solid waste and agricultural biomass, generated the remaining 2.6% of electricity.

Research suggests the generating potential from non-hydro renewables, particularly biomass, may be much greater than current use trends. In addition, the potential environmental and economic benefits may exceed traditional generation methods. Accordingly, the possibility of using Georgia's biomass resources as a potential fuel source has caught the interest of Georgia's farmers, the electric power industry, environmentalists, as well as the legislative community.

The main concern relies on whether biomass-fueled power generation can be economically feasible, given current generation technology. As a result, the Center for Agribusiness and Economic Development, at the University of Georgia College of Agriculture and Environmental Sciences, set out to determine the feasibility of electrical power generation from Georgia's farm produced biomass resources. This study was partially funded by an appropriation of the Georgia legislature. This study analyzes four generation technologies in use today: direct-fire, co-fire, gasification, and pyrolysis. To determine the economy of scale impact, each technology was evaluated for three facilities that increased in size, input, and output magnitude.

Objectives and Procedures

This research evaluates the economic implications for generating electrical power from Georgia's current available farm produced biomass resources. The objectives and the corresponding organization of this research are described in the following sections:

1. Evaluate Georgia's current available biomass supply by county,
2. Study the feasibility of four biomass generation technologies (direct-fire, co-fire, gasification, and pyrolysis),

3. Relate Georgia's available biomass supply with the feasibility analysis to determine which biomass sources are most feasible, in what regions, and with what type of generation technology, and
4. Evaluate any other options that may influence the feasibility of Georgia's biomass industry.

Biomass Feedstocks

The quantity, location, price, transportation cost, and heat content of Georgia's current available supply of biomass was determined through secondary production data sources, such as the 2000 Georgia Farm Gate Report, which lists the total amount of agricultural and forest products produced each year. To determine the amount of residuals left after harvest, various experts in the field were consulted. The field experts provided estimates for the residual quantity to production. Market prices were used for any marketable biomass feedstock. Cost of producing selected biomass feedstocks were calculated where market prices did not exist.

By starting with the annual yields produced, the total amount of agricultural by-products were evaluated by multiplying the total yield mass with the percent of residues left over after harvest. Quantities for closed-loop sources, which are those grown specifically for power generation, were determined by multiplying the annual yield per acre by the total acres in production. The following section describes Georgia's biomass feedstocks in greater detail.

Alternative Crops – Kenaf and Switchgrass were identified as alternative possibilities for increasing farm income and biomass. Neither crop has been planted in large acreage tracks in Georgia. Research indicates both crops produce around 6-10 tons per acre. The total cost per ton for ranges from $50-70. The switchgrass cost came from budget prepared by the Center for Agribusiness and Economic Development and the Crop and Soil Sciences Department at the University of Georgia. Inputs and yields for the production and harvesting of the Switchgrass came from university test plots. Switchgrass yields between 6 and 10 ten per acre depending on rainfall, soil type and maturity of the crop. Harvesting costs are very similar to most forage crops in the Southeast. The productive life of switchgrass starts in the third year and goes through the tenth year. Research suggests after the tenth year it is optimal to replant for yield sake. The Kenaf production costs were assembled by Ankal Inc and the Center for Agribusiness and Economic Development. Private firms and University personnel estimate a possible 13,000 acres of Kenaf may be planted in the near future for uses such as particle board, dash boards and various building materials. Currently, there are very few acres of kenaf available in Georgia. The Switchgrass acreage (1000 acres) estimate also came from University of Georgia's Crop and Soil Science Department and the Center for Agribusiness and Economic Development.

Bark - Foresters estimate that 322 cubic feet of bark is produced per acre. An estimated weight per cubic foot is 20 pounds. Foresters at the Warnell School of

Forestry and timber companies indicated that 85% of the bark produced in state is retained for fuel by the timber companies. Using the total number of harvested acres multiplied by the total bark per acre and 15% for the retained (85%) bark held by the timber companies, results in 229,908 tons of available bark. Researchers in the Warnell School of Forestry at the University of Georgia identified two main bark outlets, power and landscaping. Many lumber and pulp mills use the bark to heat and fuel the machinery, with higher quality bark sold to the landscaping industry. Bark ranges in price between $16 -19 depending on the quality and size of the final material. This is a market price where landscapers and large firms can purchase the bark from the timber companies. A survey of 6 large timber companies in Georgia provided the cost per ton of the bark and explained why the bark price varies.

Corn Stalks – Upon completion of harvesting the grain, corn stalks remain in the field, a little bent and broken but still a good source for biomass. A hay rake and baler will be used to harvest stalks. The UGA Crop and Soil Science Department estimates 1200 pounds of stalks per acre remain after grain is harvested. The Farmgate Report (2000) places corn acreage at 347,358, yielding an estimated 208,415 tons of corn stalks produced annually. The harvested cost ranges between $40-60 per ton as calculated by utilizing the machine cost calculator and various budgets created by the Extension Agriculture and Applied Economics Department.

Cotton Stalks – Many cotton producers cut and till cotton stalks back into the field. These stalks make a good biomass product. To estimate cotton stalk production, the total 2000 Farmgate acreage was multiplied by estimated pounds of stalks available per acre. In order to estimate cotton stalks per acre, researchers randomly cut cotton stalks of both irrigated and dry-land fields, weighed the stalks and converted it into an acreage figure. Irrigated cotton stalks yield 4,900 lbs per acre and dry-land yield 4,200 lbs per acre. The cost to harvest the cotton stalks using a forage harvester and nutrient replacement ranges from $27-49 depending on the machinery used and irrigated versus dry land. Georgia produced 3,363,000 tons of cotton stalks in 2000.

Excess Hay – In certain years hay production in Georgia is in excess of consumption. This may not be a consistent form of biomass but years with timely rainfalls will produce excess quantities of forage. Often farmers are willing to dispose of excess hay. The assumed cost per ton for excess hay is $30-40. The hay baled in large round bales weighs approximately 1,000 pounds. Excess hay was based off the top production years during the last 5 years and assumed 25% of the hay produced was in excess of the demand for the time period. This yielded approximately 78,000 tons of hay when using the Farmgate hay yield for 2000. This figure will change more frequently due to the excess idea, some years there may be a shortage and others overproduction.

Gin Trash – According to researchers at the University of Georgia, every bale of cotton ginned produces 200 pounds of gin trash. The Center for Agribusiness and Economic Development's Farmgate Report was used to calculate the number of tons produced by taking the total ginned bales produced in 2000 by 200 pounds of gin trash per bale. It is estimated that approximately 182,005 tons of gin trash is available in Georgia. The economic costs were more difficult to formulate. Gin trash is a light material, which would need to be placed into a module builder to be handled. An estimate of .5¢ per pound was given by various sources for a cost of packing the gin trash into a module. The cost per ton therefore ranges between $10-12. The only competition is cattle farmers who currently utilize gin trash as a supplemental feed source.

Peanut Hay – Each acre of peanuts produces 3-4 bales of peanut hay at 1,200 pounds per bale. Using the 2000 total Farmgate acres of peanuts, Georgia produces 948,587 tons of peanut hay. Baling the hay is a relatively inexpensive venture; however, there is a market for peanut hay, of around $15-20 a bale or $30-40 per ton. The market cost covers the harvest and baling cost of the hay plus a small return to the producer. Selling hay between farms is frown upon due to alpha toxins but still occurs. The hay prices were giving by the Peanut Economist in the Extension Agriculture and Applied Economics department and through a quick survey of county agents in major peanut production areas.

Peanut Hulls – The totals tons of peanut hulls available was estimated by taking 25% of the total production. Hulls comprise approximately 25% of the weight of the peanuts. Using the 2000 Farmgate production data, Georgia produced 702,785 tons of peanut hulls. Large peanut shellers in Georgia, Birdsong and Golden Nut, offered the hulls for free if picked up and transported off their facilities during peak times. Due to its light density, pelletizing was suggested as a means to create an efficient transportation system. Pelletized peanut hulls were assumed cost $20-30 per ton. This cost covers loading labor with a front end loader, pelletzing and unloading. These costs came from extension enterprise budgets, the Extension Peanut Specialist, and faculty in the Agricultural Engineering Department at The University of Georgia.

Pecan Hulls – To estimate the tons of pecan hulls available, the total production was multiplied by 33% (typical shelling rate) then multiplied by 51%, the average percentage between meat and hulls. The total estimated tons available in 2000 were 12,927. Shellers contacted stated they usually allow hulls to be loaded from their operation free of charge. The best way to load pecan hulls would be mechanically. The rental price of a front-end loader is $130 per day. It is estimated that 4-5 tons per hour can be handled by one person. $8 per hour for an employee, and the front-end loader on an hourly rate of $16.25, creates a total hourly figure of $26.25. The cost per ton of hulls ($6.60) was derived by dividing $26.25 by the tons handled per hour.

Pine Straw – Using the total acreage of all pines in the state as provided by the United States Department of Agriculture, Forestry Service, multiplied by 25 bales per acre and 20 pounds per bales produced 11,531,625 tons of pine straw. Pine straw prices range between $250 to $270 per ton, however most trading of pine straw occurs as bales with prices at $2.00 to $2.25. These are average wholesale sales prices in the landscaping industry.

Poultry Litter – To arrive at the total tons of poultry litter produced in the state, the number of head for both broilers and layers was used in respect to their annual pounds of litter per head, 10.8 and 15.4 pounds, respectively. Using the 2000 Farmgate production data the total tons of poultry litter available was estimated at 6,640,380 broilers and 160,283 for layers. Poultry production is concentrated in Northeast Georgia. Farmers use poultry litter as fertilizer but are experiencing criticism in urban areas and with compliance with the Environmental Protection Agency regulations. Overuse of poultry litter raises the phosphorus level in soil to unacceptable amounts. Spreading of poultry litter will continue to be popular in areas of high farm production because the crops reduce the phosphorus levels, although in Northeast Georgia limited acreage of crops exist and alternatives to spreading the litter are continuously being researched. The average cost per ton of litter was estimated at $5-15 based on current market conditions for litter as fertilizer. Litter prices vary by location, in south Georgia were row crop land is readily available the litter carries a slightly higher price than the north Georgia area which is having difficulty finding free land to spread the litter.

Sawdust – The sawdust residue on southern pines sawed in Georgia amounts to 1 to 1.2 tons per million board feet (MBF) (Utilization of Southern Pines, by Koch A.H.). 3,994.8 million board feet were harvested in 1997 yielding an estimated 4,794 tons of sawdust at 1.2 tons per MBF. Almost all of this sawdust is directed by the industry to produce power to run the lumber and pulp facilities. Dr. Larry Morris of the Warnell School of Forestry at the University of Georgia explained that 85% or more is kept for a direct power source to the paper industry. Looking at 15% of the original amount of sawdust leaves 719 tons remaining. The largest user of this component of sawdust is the poultry industry. Georgia is the number one grower of broilers in the country, so the researchers imagine sawdust is not likely a highly feasible option for biomass. A quoted price from a lumber facility ranged from $16-20 per ton depending on the mesh screen desired.

Soybean Hulls – According to the Report on the Feasibility of an Oilseed Processing Facility in Georgia, completed by the Center for Agribusiness and Economic Development at the University of Georgia, there are approximately 6,500 tons of soybeans hulls priced at $45 per ton available in Georgia.

Wheat and Rye Straw – Each of these commodities produce between 110-120 square bales per acre. Straw has a relatively strong market in the landscape sector. Straw price per 30-pound bale is $2. Using the 2000 Farmgate production data, if every acre of wheat and rye were baled, Georgia would produce 377,231 tons of wheat straw and 137,933 tons of rye straw. The cost per ton of straw based on the landscaping price is $120 or $2 per bale.

Wood chips – Koch (1976) wrote that 1.5 tons of wood chip residuals are produced per million board feet. Georgia's average harvest is 3994.8 million board feet per 476,000 acres. The total wood chips available would be 5,992 tons. The average acres harvested came from the Georgia Forestry Commission. Wood chips are priced at $16 to $19 per ton with uses ranging from a base in poultry houses to industrial applications for particle board. Timber companies were contacted and surveyed to see what they typically sell wood chips for per ton. This survey occurred prior to the large decline in timber prices.

Wood Residue – Wood residues are the remains (branches, bark, and needles) from harvested acreage. It is estimated that 15% of the tree remains after harvest. The average yield per acre is 2,254 cubic feet. Meaning approximately 338 cubic feet exist per acre. A cubic foot of residues is estimated to weigh 49.9 pounds. The state average for harvested acreage is 476,000 according to the Georgia Forestry Commission. Thus, approximately 4.5 million tons of wood residues are created annually. One problem related to using wood residue is transportation. Stacking branches on the bed of a trailer and/or truck is not efficient. These branches will have to be processed through a wood chipper for the most efficient means of transporting the waste material. This adds cost to an almost free product. Another cost is the nutrient replacement back into the acreage. Foresters estimate that 85% of the nitrogen in the soil comes from the remains left after harvest. To replace this amount of nitrogen, researchers at the Warnell School of Forestry estimate the cost to be between $75-$85 per acre. Adding all the costs per ton of wood residue results in approximately $15-25 per ton estimated residue cost (chipping and fertilizer opportunity cost).

Biomass Properties

The properties and characteristics of each potential biofuel have important implications to the feasibility of individual biomass sources. In order to optimize feasibility, feedstocks must provide generators with an abundant supply at the lowest cost of delivery possible. In addition, the heat content (BTU) of feedstocks varies depending upon the type of biomass, so a high energy fuel is critical. Biomass sources also differ in ash and moisture content. This affects the energy value of biofuels, since the chemical make-up of ash generally has no energy value and the amount of water in biofuel affects, in a decisive manner, the available energy within every biofuel.

Biomass sources also vary in weight and size. The altering weight, size, structure, and dimensions of varying biomass sources results in different processing and equipment use, which ultimately influences the transportation costs. Types of biomass that are most dense, or can be processed to use less space per ton, will have the lowest costs of transport and storage. A summary of Georgia's farm produced biomass resources is displayed in table 1, which shows the total tons of biomass produced, price per ton, average price per ton, delivered cost per ton, and the season of harvest.

Table 1: Biomass Supply and Delivered Prices

BioMass	Tons Avaliable	Price/Ton	Average Price/Ton	Cost Per Ton Delivered @ ($1.70)/Mile	Season
Pecan Hulls	12,927	$7-10	$ 8.5	14.00	fall
Poultry Litter	6,800,663	$5-15	$ 10.0	14.50	year round
Gin Trash	182,005	$10-12	$ 11.0	17.00	late sum -early fall
Wood Chips	5,992	$16-19	$ 17.5	23.00	year round
Bark	229,908	$16-19	$ 17.5	22.50	year round
Wood Residue	4,015,343	$15-25	$ 20.0	24.50	year round
Peanut Hulls	702,785	$20-30	$ 25.0	28.50	late sum -early fall
Cotton Stalks(Irrigated)	1,524,307	$27-42	$ 34.5	39.00	late sum -early fall
Hay	1,026,653	$30-40	$ 35.0	43.50	late sum -early fall
Cotton Stalks(Dry Land)	1,839,306	$31-49	$ 40.0	44.50	late sum -early fall
Corn Stalks	208,415	$40-60	$ 50.0	58.50	mid sum -ealry fall
Kenaf(13,000 acres)	90,750	$50	$ 50.0	58.50	fall
Switchgrass(1000 acres)	6,000	$60-70	$ 65.0	58.50	fall
Wheat Straw	377,231	$120-130	$ 125.0	136.00	late spr -early sum
Rye Straw	137,933	$120-130	$ 125.0	136.00	late spr -early sum

In Table 2, the Energy Information Administration provides data on Georgia's delivered fuel costs for coal, petroleum, and natural gas. Table 3 shows the biomass feedstock quality and delivered cost for some common agricultural biomass sources in Georgia. This research suggests the fuels with the least delivered cost per million BTU (MMBTU) will be the most likely fuel sources for a biomass power generation facility.

Table 2: Utility Delivered Fuel Costs and Quality for Coal, Petroleum, and Gas

Fuel	1990	1994	1999	Average Annual Rate of Change (Percent)
Coal (cents per million Btu) (1999 dollars)	216.5	184.6	154.6	-3.7%
Average heat value (Btu per pound)	11,893.0	11,774.0	11,740.0	-0.1%
Petroleum (cents per million Btu) (1999 dollars)	588.5	432.6	389.6	-4.5%
Average heat value (Btu per cubic foot)	139,814.0	138,484.0	138,495.0	-0.1%
Gas (cents per million Btu) (1999 dollars)	359.7	350.2	248.9	-4.0%
Average heat value (Btu per cubic foot)	1,024.0	1,025.0	1,032.0	0.1%

Source: Energy Information Administration, State Electricity Profiles, Georgia 2001.

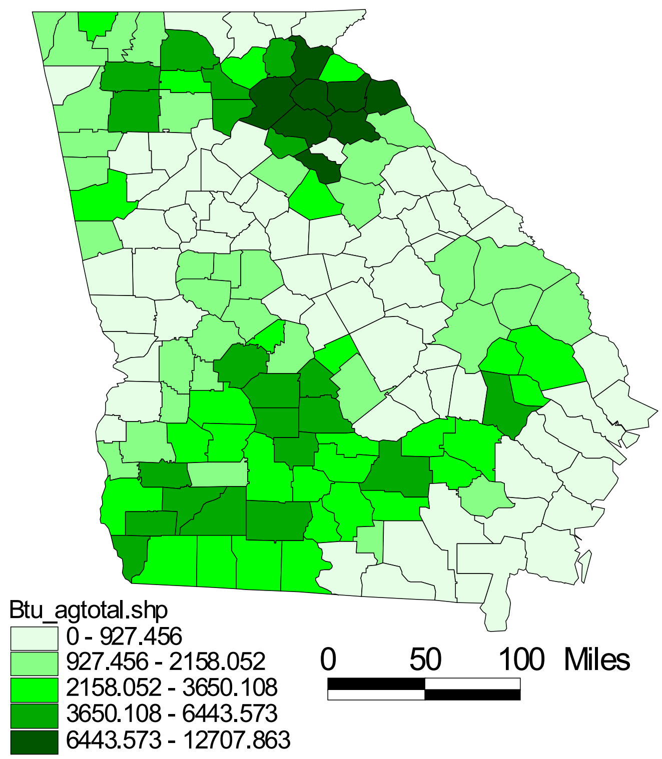
Table 3: Biomass Feedstock Quality & Delivered Cost

Biomass	Ash Content Dry Basis	mmBTU / ton	Price / Ton (low)	Price / Ton (high)	Average Price / Ton	Calculated Average $/mm BTU	Freight Cost per Ton mile	50 Mile Frt/Ton	50 Mile Frt/mm BTU	Delivered F/S $/mmBTU
Pecan Hulls	5.80%	16.35	$7.00	$10.00	$8.50	$0.52	$0.11	$5.50	$0.34	$0.86
Gin Trash	17.60%	13.10	$10.00	$12.00	$11.00	$0.84	$0.12	$6.00	$0.46	$1.30
Coal (1999 US$)	NA	NA	NA	NA	NA	NA	NA	NA	NA	**$1.55**
Bark, Pine	3.30%	14.08	$16.00	$19.00	$17.50	$1.24	$0.10	$5.00	$0.36	$1.60
Poultry Litter	26.68%	8.89	$5.00	$15.00	$10.00	$1.13	$0.09	$4.50	$0.51	$1.64
Peanut Hulls	5.90%	16.03	$20.00	$30.00	$25.00	$1.56	$0.07	$3.50	$0.22	$1.78
Natural Gas (1999 US$)	NA	NA	NA	NA	NA	NA	NA	NA	NA	**$2.49**
Wood Chips	1.30%	9.09	$16.00	$19.00	$17.50	$1.93	$0.11	$5.50	$0.61	$2.53
Wood Residue	3.20%	8.86	$15.00	$25.00	$20.00	$2.26	$0.09	$4.50	$0.51	$2.76
Hay	5.70%	14.00	$30.00	$40.00	$35.00	$2.50	$0.17	$8.50	$0.61	$3.11
Cotton Stalks	17.20%	12.37	$31.00	$49.00	$40.00	$3.23	$0.09	$4.50	$0.36	$3.60
Petroleum (1999 US$)	NA	NA	NA	NA	NA	NA	NA	NA	NA	**$3.90**
Kenaf	3.60%	14.78	$50.00	$50.00	$50.00	$3.38	$0.17	$8.50	$0.58	$3.96
Corn Stalks	6.40%	14.62	$40.00	$60.00	$50.00	$3.42	$0.17	$8.50	$0.58	$4.00
Switchgrass	5.40%	14.01	$60.00	$70.00	$65.00	$4.64	$0.17	$8.50	$0.61	$5.25
Wheat Straw	3.50%	14.57	$120.00	$130.00	$125.00	$8.58	$0.22	$11.00	$0.76	$9.34
Rye Straw	3.00%	12.70	$120.00	$130.00	$125.00	$9.84	$0.22	$11.00	$0.87	$10.71

Notes: (1) Biomass sources shaded dark green are cheaper than coal, followed by sources that are cheaper than natural gas, and the light green sources indicate those that are cheaper than petroleum on a delivered cost per mm BTU basis.

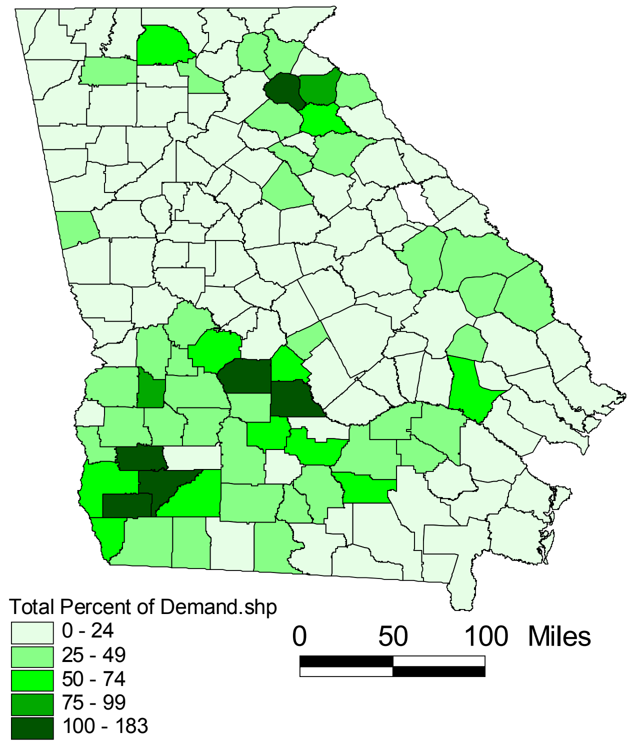
Based on the estimates, pecan hulls are the least expensive agricultural feedstock to purchase and transport, costing only 86¢ per million (MM) BTU. Rye straw is the most expensive, costing $10.71 per MM BTU. Comparing the delivered costs per MM BTU on these two charts, there are two biomass feedstocks that can be delivered cheaper than coal ($1.56/MMBTU), five that are cheaper than natural gas ($2.49/MMBTU), and nine that are cheaper than petroleum ($3.90/MMBTU). The total energy content for all applicable agricultural by-products is shown in Figure 1. Counties that are shaded in dark green possess the greatest amount of available energy for electricity production. This results from either a large quantity of biomass resources, biomass resources of high energy content, or a combination of the two within the given county.

Figure 1: Total Biomass BTU Content (MMBTU) per County



Assuming 25% of the total energy content of the input feedstock can be converted into usable electricity at the power plant, this research determines there is enough energy potential from Georgia's agricultural feedstocks to power nearly 12% of the State's total electrical demand, or over 31% of the State's residential consumers. Due to low electricity demand, large feedstock supply, or a combination of the two, some counties could generate over 100% of their electrical demand by utilizing agriculturally-based biomass fuels. Figure 2 displays the percent of electrical demand that could be supplied by the biomass resources produced in each county. Counties shaded dark green could produce enough power from their agricultural biomass sources to supply over 100% of their electrical demand. Many counties could supply over 50% of their electrical demand, if all agriculturally-based biomass resources were utilized within the county.

Figure 2: Agricultural Biomass Potential (Potential Electrical Supply per County)



Utilizing all biomass resources, Georgia's agriculturally based biomass resources could generate over a billion dollars per year in revenue. With the current average electricity rate of 6.24¢/kWh, revenue from the sale of electricity could amount to over $826 million per year for Georgia's electric utility industry. By multiplying the average price per ton by the total quantity produced each year, Georgia's biomass industry could generate over $422 million per year for the sale of agricultural by-products and forest residues.

II. BIOMASS GENERATION TECHNOLOGY

Introduction

Data used in this section was acquired from two primary sources. Georgia's agricultural production data was obtained from the 2000 Georgia Farm Gate Report. The University of Georgia (UGA) retained the consulting services of Frazier, Barnes & Associates (FBA) for the engineering information on the four, biomass generation technologies; direct fire, co-fire, gasification, and pyrolysis. This study uses the engineering assessment performed by FBA to evaluate the economic feasibility of the generation technologies for generating electrical power from Georgia's agriculturally-based biomass resources. This research analyzes data on biomass feedstocks and electrical generation technologies in order to determine the following objectives:

1. Capital, operating costs, and overall feasibility of four currently commercialized or emerging technologies for biomass generation (Direct Fire, Co-fire, Gasification, and Pyrolysis)

2. Economy of scale impact by evaluating three different size facilities for each technology

3. Feedstock price sensitivity analysis

4. Capital cost sensitivity analysis

The following sections will specifically describe the procedures and results of the aforementioned study. In addition, this research will conclude with an economic analysis of external factors, which may impact the feasibility of these four biomass technologies.

Feedstock Assumptions

The biomass generation facilities considered in this research has the capability to utilize a variety of feedstocks. The practicality of any particular feedstock is limited by season, quantity, price, and various costs associated with the transportation, handling, and storage of the feedstock. Determining the effects of individual biomass sources in each technology would create hundreds of outcomes with similar results. Though specific types of biomass are an important variable when considering energy output per ton of fuel, some assumptions are made in order to reduce the complexity and focus more on the specific feasibility of biomass technologies. The assumptions taken in this study are listed below:

1. The biomass will be a combination of various types, therefore calculations will assume an average ash content of 8%, an average moisture content of 25%, and an average heat content of 13 million BTU/ton (6500 BTU/lb). After consulting with numerous biomass generation facilities, FBA found each generation facility utilizes some blend of biomass. These figures are consistent with typical biomass feedstocks.

2. Since the receiving system must be capable of handling the biomass mix and processing/blending them to a uniform heat content, a five-day supply of feedstock is assumed to be sufficient to sustain the reliability of supply and the blending process to a uniform heat content.

3. The generation plant is assumed to shut-down for maintenance approximately 5.5% of the operation time, therefore the plant will operate 345 days/year 24hours/day. In order to provide a consistent flow of power to clients, the sale of electricity is assumed to stay on a 365 day/year cycle. As a result, power must be purchased from the grid 20 days/year. The purchased power is assumed to cost the typical industrial rate of 5¢/kWh.

4. Feedstock quantity will vary by technology. The feedstock blend assumes 25% moisture content. The moisture content is consistent with typical feesdstock blends after harvest, transport, and storage. Since the original biomass input is not dried, the daily input feedstock quantity is designated in wet tons per day (WTPD). Georgia produces over 22 million tons of biomass each year, therefore, a particular feedstock or feedstock blend is assumed to be available for the entire operational period, 345 days/year.

5. Each facility requires electrical power in order to operate; therefore, some of the power generated from the facility must be used internally. This power is deducted from the total amount generated to yield the net electrical output, measured in kilo-Watts per hour (kWh). The net electrical output is the total amount of saleable power produced and is subsequently used in all economic calculations at the end of this section.

Conversion Technologies

The relative efficiency of some technologies may be influenced by the size of the facility itself, referred to as the economy of scale impact. To determine how size would influence overall feasibility, this study evaluates three scenarios for each technology. Each scenario, designated as case 1, case 2, and case 3, require a similar amount of wet biomass input (WTPD) with respect to each generation technology. Case 1 represents the smallest facility studied and requires the least amount of biomass input. Case 3 represents the largest facility studied, therefore requires the greatest input of biomass. Case 2 is the middle scenario.

The preliminary assessment of the four generation technologies, along with their respective cases, was performed by FBA. Based on the original FBA engineering assessments, all economic calculations were reevaluated for the purposes of this study. The original basis for assessment, paraphrased from the FBA Biomass Cogeneration Final Report, is described below in greater detail.

Direct Fire- Direct fire combustion involves the burning of biomass with excess air, producing hot flue gases, which then produce steam in the heat exchange section of a boiler. The steam is then passed through a steam turbine generator to produce electric power. The direct fire technology was evaluated for 120, 200, and 400 WTPD of biomass input for Case 1, 2, and 3, respectively. Appendix I, page 48 shows the specific plant generational process.

Co-fire- Co-firing refers to the practice of introducing biomass as a supplementary energy source in high efficiency boilers. The flue gases are then used to produce steam and/or electric power as in a direct fire technology. Co-fire is used when either the moisture content of the biomass is high or when the supply of biomass is intermittent. In each of the co-fire cases the biomass fuel supply deficit was supplemented with enough natural gas, measured in thousand cubic feet (MCF), to generate the same amount of power as in the direct fire cases. The corresponding levels of fuel are 60, 100, and 200

WTPD of biomass and 523, 872, and 1744 MCF of natural gas for Case 1, 2, and 3, respectively. Appendix I, page 49 shows the specific plant generational process

Gasification- Gasification for power production involves the chemical conversion of biomass in an atmosphere of steam or air to produce a medium or low calorific gas. This "biogas" is then used as a fuel in a power generation plant that includes a gas turbine generator for power production and a waste heat boiler for steam production. The steam can then be used to generate power. For this study the only heat available for power generation is assumed to be the heat content of the bio-gas. All other heat generated by the gasification process is used to dry the feedstock. The gasification technology was evaluated for 160, 267, and 533 WTPD of biomass input for Case 1, 2, and 3, respectively. Appendix I, page 51 shows the specific plant generational process

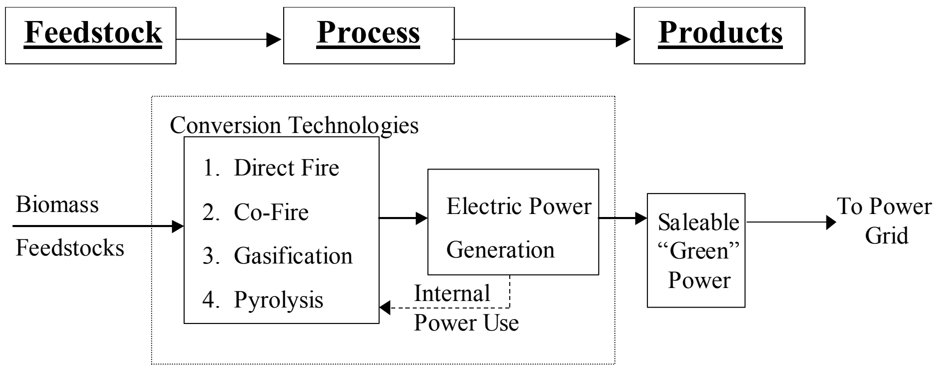
Pyrolysis- Pyrolysis is a process by which biomass is heated in the absence of oxygen. For this study the feedstock is assumed to be dried via heat generated by the pyrolysis process. As a result the biomass decomposes to generate mostly vapors, aerosols, and some charcoal. After cooling and condensation, a transportable dark brown liquid oil is formed which has approximately one half the heat content of conventional fuel oil. Bio-oil, is approximately 20% heavier than water and is both transportable and storable. The bio-oil can be fed directly to a turbine and combusted. Both power and steam can be generated from this process.

Energy from all bio-oil produced is saleable. Commercialization of the pyrolysis process is in its initial stages, although technology suppliers typically have small scale pilot plants and are working to build full size facilities. The pyrolysis process assumes biomass inputs at 160, 320, and 480 WTPD for case 1, 2, and 3, respectively. The pyrolysis technology used in this study is being commercialized by Renewable Oil International, LLC. This model envisions smaller plants located close to the source of the biomass. For this reason, pyrolysis assumes some geographic dependency, which is reflected in the biomass transportation costs. Case 1 scenario assumes the pyrolysis facility and the generation plant are co-located at the feedstock source and therefore bare no transportation fees. Case 2 assumes the same basis as the case 1 scenario plus an additional pyrolysis facility located 50-miles away from the generation plant. The bio-oil from the first facility still bears zero costs of transportation, while the bio-oil produced at the second, off-site feedstock location is charged 50-mile truck-load transportation fees. Case 3 assumes the same basis as the case 2 scenario plus an additional pyrolysis facility located 50-miles away from the generation plant. The two off-site facilities are charged 50-mile freight fees, while the on-site facility bears no charge. Appendix I, page 52 shows the specific plant generational process.

Base Model

The base case model is generally non-site specific and utilizes a blend of biomass feedstocks with a conversion technology that produces electrical power. Figure 3 demonstrates a general depiction of this process.

Figure 3: Base Case Model



Appendix 1 contains case and technology specific figures adapted from the FBA Biomass Cogeneration Final Report. These figures show the process of biomass inputs, generation technology and requirements, and the resulting output for each size and type of technology. The output power displayed in Appendix 1 represents the total amount of electricity produced. Table 4 displays the net electrical output, or the total quantity of saleable power for each scenario. Table 5 displays the daily quantity of feedstock required. Table 6 calculates the total kilo-Watts produced per hour for each ton of biomass input.

Table 4: Electrical Output (kWh)

Technology	Direct Fire		Co-Fire		Gasification		Pyrolysis	
Capacity (kWh)	Total	Net	Total	Net	Total	Net	Total	Net
Case #1	1666	1386	1666	1526	6666	6294	5073	4752
Case #2	2777	2309	2777	2543	10699	10061	10147	9570
Case #3	5555	4623	5555	5095	21396	20227	15220	14370

Table 5: Quantity of Feedstock Required (Wet Tons per Day)

Plant Size	Direct Fire	Co-Fire	Gasification	Pyrolysis
Case #1	120	60	160	160
Case #2	200	100	267	320
Case #3	400	200	533	480

Table 6: Electricity Produced (kWh) per Feedstock Ton

Plant Size	Direct Fire	Co-Fire	Gasification	Pyrolysis
Case #1	277	610	944	713
Case #2	277	610	904	718
Case #3	277	611	911	719

The Costs of Capital

Both operating and capital costs of production increase with each technology case due to additional requirements on infrastructure, administration, and operational procedures necessary for additional biomass inputs. The capital costs for each technology are divided into three main categories, feedstock receiving and processing, land and infrastructure, and operational equipment. Tables 7 through 10 lists the capital costs for each technology. A more detailed description for each section of the capital costs follows Table 10.

Table 7: Capital Costs for Direct Fire Technology

Direct-Fire Capital Costs				
	Plant Component	Case #1 120 WTPD 1666 kWh	Case #2 200 WTPD 2777 kWh	Case #3 400 WTPD 5555 kWh
Feedstock Receiving & Processing				
1	Feedstock Truck Dump	$ 100,000	$ 100,000	$ 100,000
2	Front End Loader	$ 120,000	$ 120,000	$ 120,000
3	Fuel Processing Building	$ 700,000	$ 1,155,000	$ 1,990,000
4	Metal Removal Equipment	$ 15,000	$ 15,000	$ 15,000
5	Grinding/Sizing Equipment	$ 165,000	$ 185,000	$ 225,000
6	Blending Equipment	$ 75,000	$ 100,000	$ 125,000
7	Fuel Storage Bins	$ 100,000	$ 200,000	$ 400,000
8	Conveyors	$ 125,000	$ 125,000	$ 125,000
Operational Equipment				
1	Power Generation Equipment	$ 1,640,000	$ 2,120,000	$ 3,700,000
2	Demineralizer System	$ 115,000	$ 170,000	$ 260,000
3	Boiler	$ 290,000	$ 388,000	$ 900,000
4	Instrumentation & Controls	$ 150,000	$ 225,000	$ 300,000
Land and Infrastructure				
1	Land/ Site Preparation	$ 100,000	$ 150,000	$ 200,000
2	Buildings	$ 388,000	$ 512,000	$ 600,000
3	Eng/Permitting	$ 247,000	$ 425,000	$ 585,000
Sub-Total		$ 4,330,000	$ 5,990,000	$ 9,645,000
Contingency (20%)		$ 866,000	$ 1,198,000	$ 1,929,000
Total Capital		**$ 5,196,000**	**$ 7,188,000**	**$ 11,574,000**

Table 8: Capital Costs for Co-Fire Technology

Co-Fire Capital Costs				
Plant Component		Case #1 60 WTPD 523 MCF/Day 1666 kWh	Case #2 100 WTPD 872 MCF/Day 2777 kWh	Case #3 200 WTPD 1744 MCF/Day 5555 kWh
Feedstock Receiving & Processing				
1	Feedstock Truck Dump	$ 100,000	$ 100,000	$ 100,000
2	Front End Loader	$ 120,000	$ 120,000	$ 120,000
3	Fuel Processing Building	$ 350,000	$ 577,500	$ 995,000
4	Metal Removal Equipment	$ 15,000	$ 15,000	$ 15,000
5	Grinding/Sizing Equipment	$ 145,000	$ 160,000	$ 185,000
6	Blending Equipment	$ 60,000	$ 70,000	$ 100,000
7	Fuel Storage Bins	$ 60,000	$ 100,000	$ 200,000
8	Conveyors	$ 125,000	$ 125,000	$ 125,000
Operational Equipment				
1	Power Generation Equipment	$ 1,640,000	$ 2,120,000	$ 3,730,000
2	Demineralizer System	$ 115,000	$ 170,000	$ 260,000
3	Boiler	$ 264,500	$ 364,500	$ 743,000
4	Instrumentation & Controls	$ 150,000	$ 225,000	$ 300,000
Land and Infrastructure				
1	Land/ Site Preparation	$ 100,000	$ 150,000	$ 200,000
2	Buildings	$ 331,000	$ 406,000	$ 468,000
3	Eng/Permitting	$ 247,000	$ 425,000	$ 585,000
Sub-Total		$ 3,822,500	$ 5,128,000	$ 8,126,000
Contingency (20%)		$ 764,500	$ 1,025,600	$ 1,625,200
Total Capital		**$ 4,587,000**	**$ 6,153,600**	**$ 9,751,200**

Table 9: Capital Costs for Gasification Technology

Gasification Capital Costs				
Plant Component		Case #1 160 WTPD 6294 kWh	Case #2 267 WTPD 10061 kWh	Case #3 533 WTPD 20227 kWh
Feedstock Receiving & Processing				
1	Feedstock Truck Dump	$ 100,000	$ 100,000	$ 100,000
2	Front End Loader	$ 120,000	$ 120,000	$ 120,000
3	Fuel Processing Building	$ 700,000	$ 1,155,000	$ 1,990,000
4	Metal Removal Equipment	$ 15,000	$ 15,000	$ 15,000
5	Grinding/Sizing Equipment	$ 165,000	$ 185,000	$ 225,000
6	Blending Equipment	$ 75,000	$ 100,000	$ 125,000
7	Fuel Storage Bins	$ 100,000	$ 200,000	$ 400,000
8	Conveyors	$ 125,000	$ 125,000	$ 125,000
Operational Equipment				
1	Power Generation Equipment	$ 5,243,000	$ 7,388,000	$ 13,090,000
2	Gasification Process	$ 4,900,000	$ 7,500,000	$ 11,300,000
3	Interconnections	$ 900,000	$ 1,300,000	$ 2,000,000
4	Waste Heat Boiler	$ 2,125,000	$ 2,780,000	$ 5,500,000
5	Heat Recovery	$ 500,000	$ 1,700,000	$ 1,300,000
Land and Infrastructure				
1	Land/ Site Preparation	$ 110,000	$ 150,000	$ 200,000
2	Buildings	$ 510,000	$ 612,000	$ 810,000
3	Eng/Permitting	$ 247,000	$ 425,000	$ 585,000
Sub-Total		$ 15,935,000	$ 23,855,000	$ 37,885,000
Contingency (20%)		$ 3,187,000	$ 4,771,000	$ 7,577,000
Total Capital		**$ 19,122,000**	**$ 28,626,000**	**$ 45,462,000**

Table 10: Capital Costs for Pyrolysis Technology

Pyrolysis Capital Costs				
Plant Component		Case #1 160 WTPD 4752 kWh	Case #2 320 WTPD 9570 kWh	Case #3 480 WTPD 14370 kWh
Feedstock Receiving & Processing				
1	Feedstock Truck Dump	$ 100,000	$ 200,000	$ 300,000
2	Front End Loader	$ 120,000	$ 240,000	$ 360,000
3	Fuel Processing Building	$ 700,000	$ 1,155,000	$ 1,990,000
4	Metal Removal Equipment	$ 15,000	$ 30,000	$ 45,000
5	Grinding/Sizing Equipment	$ 165,000	$ 330,000	$ 495,000
6	Blending Equipment	$ 75,000	$ 150,000	$ 225,000
7	Fuel Storage Bins	$ 100,000	$ 200,000	$ 300,000
8	Conveyors	$ 125,000	$ 250,000	$ 375,000
Operational Equipment				
1	Power Generation Equipment	$ 5,890,000	$ 8,900,000	$ 11,390,000
2	Pyrolysis Process	$ 1,300,000	$ 2,600,000	$ 3,900,000
3	Waste Heat Boiler	$ 2,000,000	$ 3,130,000	$ 4,080,000
4	Demineralizer System	$ 125,000	$ 250,000	$ 375,000
Land and Infrastructure				
1	Land/ Site Preparation	$ 100,000	$ 200,000	$ 300,000
2	Buildings	$ 510,000	$ 1,020,000	$ 1,530,000
3	Eng/Permitting	$ 300,000	$ 529,000	$ 800,000
Sub-Total		$ 11,625,000	$ 19,184,000	$ 26,465,000
Contingency (20%)		$ 2,325,000	$ 3,836,800	$ 5,293,000
Total Capital		**$ 13,950,000**	**$ 23,020,800**	**$ 31,758,000**

The feedstock receiving and processing costs were determined by six criteria: feedstock truck dump, front-end loader, metal removal equipment, grinding/sizing equipment, blending equipment, and conveyors. These criteria were assessed by FBA and vary proportionally to the set quantity of feedstock inputs.

The land and infrastructure cost section consists of the land value and site preparation, engineering and permitting, and the construction costs for all buildings. With the exception of pyrolysis, land requirements were assumed to increase 2.5 acres for every increase in case scenario. The acreage requirements are: 5, 7.5, and 10 acres for scenarios 1, 2, and 3, and each are assessed at $20,000/acre. Pyrolysis is assumed to require an additional 2.5 acres of land for each off-site pyrolysis facility, resulting in 5, 10, and 15 acres for scenarios 1, 2, and 3, each assessed at $20,000/acre.

The engineering and permitting cost section was assessed by FBA and is the same for each technology, with the exception of pyrolysis. Since pyrolysis is a more complex and emerging technology, the engineering costs exceed direct-fire, co-fire, and gasification by approximately 20%.

The building line item includes the costs of buildings to house boiler, turbines, maintenance area, offices, and other required facilities. This item was assessed by FBA and is directly correlated to the technology level of each generation method. For this reason, direct-fire and co-fire technologies are significantly less expensive than gasification and pyrolysis technologies.

The operational equipment assessment is based upon technology specific criteria. These costs become significantly higher as the level of technology increases. The power generation equipment is consistently the largest capital cost for each technology, ranging from nearly $4 million in case 3 of the direct-fire and co-fire technologies to over $11 million in case 3 of the gasification and pyrolysis technologies. The boilers used in direct-fire and co-fire cost under $1 million, while the waste heat boilers for pyrolysis and gasification cost over $4 million. The instrumentation and demineralizer systems used in case 3 direct and co-fire technologies cost approximately $1 million, while the system for the pyrolysis process costs nearly $4 million and over $11 million for the gasification system.

In conclusion, the capital costs ranged from approximately $4 million to $38 million. The lowest total capital cost technology is co-fire, followed by direct-fire, then pyrolysis, and lastly gasification. A contingency factor, calculated at 20% of total capital, was added to the final costs of each technology in order to account for any unforeseen expenses. Table 11 summarizes the final capital costs for each technology.

Table 11: Capital Cost Summary

Summary of Capital Costs				
Technology		**Case #1**	**Case #2**	**Case #3**
Direct - Fire	**Sub-Total**	$ 4,330,000	$ 5,990,000	$ 9,645,000
	Contingency (20%)	$ 866,000	$ 1,198,000	$ 1,929,000
	Total Capital	**$ 5,196,000**	**$ 7,188,000**	**$ 11,574,000**
	Capital per WT Biomass	43300	$ 35,940	$ 28,935
	Capital per kWh Capacity	$ 3,749	$ 3,113	$ 2,504
Co - Fire	**Sub-Total**	$ 3,822,500	$ 5,128,000	$ 8,126,000
	Contingency (20%)	$ 764,500	$ 1,025,600	$ 1,625,200
	Total Capital	**$ 4,587,000**	**$ 6,153,600**	**$ 9,751,200**
	Capital per WT Biomass	76450	$ 61,536	$ 48,756
	Capital per kWh Capacity	$ 3,006	$ 2,420	$ 1,914
Gasification	**Sub-Total**	$ 15,935,000	$ 23,855,000	$ 37,885,000
	Contingency (20%)	$ 3,187,000	$ 4,771,000	$ 7,577,000
	Total Capital	**$ 19,122,000**	**$ 28,626,000**	**$ 45,462,000**
	Capital per WT Biomass	119512.5	$ 107,213	$ 85,295
	Capital per kWh Capacity	$ 3,038	$ 2,845	$ 2,248
Pyrolysis	**Sub-Total**	$ 11,625,000	$ 19,184,000	$ 26,465,000
	Contingency (20%)	$ 2,325,000	$ 3,836,800	$ 5,293,000
	Total Capital	**$ 13,950,000**	**$ 23,020,800**	**$ 31,758,000**
	Capital per WT Biomass	87187.5	$ 71,940	$ 66,163
	Capital per kWh Capacity	$ 2,936	$ 2,406	$ 2,210

Total Operating Cost

The operating costs increase from case 1 to case 3 for each technology due to the additional requirements necessary for operation of the larger facilities. These costs were calculated based upon three primary criteria: overhead and administration fees, variable costs of operation, and the yearly expenditures on capital. Tables 12 through 15 summarize the operating costs for each technology. A more detailed description of the operating costs and revenue analysis follows Table 13. Appendix II displays the accounting spreadsheets used in all calculations for the capital, operating, and marginal costs of production (refer to the Appendix II spreadsheets to view all calculations in greater detail). The percent share for each operating cost is displayed in the Appendix III graphs. Since case 3 is consistently the most efficient scenario, the Appendix III graphs display each technology for case 3 for low, medium, and high fuel cost.

Table 12: Direct Fire Annual Operating Costs

Direct Fire				
		Case # 1	**Case # 2**	**Case # 3**
	Biomass Input (Wet Tons per Day)	120	200	400
	Net Generation (kilo-Watts per hour)	1,386	2,309	4,623
Overhead and Administration				
1	General Manger	$ 108,800	$ 128,000	$ 140,800
2	Accounting Support	$ 64,000	$ 89,600	$ 115,200
3	Clerical Support	$ 25,600	$ 56,320	$ 96,000
	Total	**$ 198,400**	**$ 273,920**	**$ 352,000**
Variable Cost of Operation				
1	Purchasing Cost for Downtime Electricity per Year	$ 33,264	$ 55,416	$ 110,952
2.1	Fuel Costs per Year (Low at $10/ton)	$ 414,000	$ 690,000	$ 1,380,000
2.2	Fuel Costs per Year (Medium at $20/ton)	$ 828,000	$ 1,380,000	$ 2,760,000
2.3	Fuel Costs per Year (High at $35/ton)	$ 1,449,000	$ 2,415,000	$ 4,830,000
3	Ash Disposal Cost per Year	$ 66,240	$ 110,400	$ 220,800
4	Water and Water Treatment	$ 22,000	$ 57,000	$ 159,000
5	Labor	$ 240,000	$ 240,000	$ 240,000
6	Workers' Compensation	$ 16,800	$ 16,800	$ 16,800
7	Miscellaneous	$ 39,000	$ 39,000	$ 39,000
10.1	Interest on Working Capital ($10/ton feedstock)	$ 16,886	$ 24,337	$ 42,861
10.2	Interest on Working Capital ($20/ton feedstock)	$ 23,786	$ 35,837	$ 65,861
10.3	Interest on Working Capital ($35/ton feedstock)	$ 34,136	$ 53,087	$ 100,361
	Total (Low Fuel Cost - $10/ton)	**$ 848,190**	**$ 1,232,953**	**$ 2,209,413**
	Total (Medium Fuel Cost - $20/ton)	**$ 1,269,090**	**$ 1,934,453**	**$ 3,612,413**
	Total (High Fuel Cost - $35/ton)	**$ 1,900,440**	**$ 2,986,703**	**$ 5,716,913**
Yearly Expenditures on Capital				
8	Yearly Taxes and Insurance Costs	$ 77,940	$ 107,820	$ 173,610
9	Yearly Maintenance Costs	$ 103,920	$ 143,760	$ 231,480
1	Depriciation - Buildings	$ 59,400	$ 93,350	$ 149,500
2	Depreciation - Equipment	$ 250,500	$ 316,000	$ 497,000
3	Interest on Investment - Buildings	$ 29,700	$ 46,675	$ 74,750
4	Interest on Investment - Equipment	$ 69,875	$ 88,700	$ 146,750
	Total	**$ 591,335**	**$ 796,305**	**$ 1,273,090**
Total Operational Costs				
Operational Costs/yr (Low at $10/ton)		$ 1,637,925	$ 2,303,178	$ 3,834,503
Operational Costs/yr (Medium at $20/ton)		$ 2,058,825	$ 3,004,678	$ 5,237,503
Operational Costs/yr (High at $35/ton)		$ 2,690,175	$ 4,056,928	$ 7,342,003
Generation Analysis				
Total kilo-Watts Sold per Year		12,141,360	20,226,840	40,497,480
Average Cost/yr (Low at $10/ton)		**$ 0.13490**	**$ 0.11387**	**$ 0.09468**
Average Cost/yr (Medium at $20/ton)		**$ 0.16957**	**$ 0.14855**	**$ 0.12933**
Average Cost/yr (High at $35/ton)		**$ 0.22157**	**$ 0.20057**	**$ 0.18130**

Table 13: Co-Fire Annual Operating Costs

Co-Fire				
		Case # 1	Case # 2	Case # 3
	Biomass Input (Wet Tons per Day)	60	100	200
	Net Generation (kilo-Watts per hour)	1,526	2,543	5,095
Overhead and Administration				
1	General Manger	$ 108,800	$ 128,000	$ 140,800
2	Accounting Support	$ 64,000	$ 89,600	$ 115,200
3	Clerical Support	$ 25,600	$ 56,320	$ 96,000
	Total	**$ 198,400**	**$ 273,920**	**$ 352,000**
Variable Cost of Operation				
1	Purchasing Cost for Downtime Electricity per Year	$ 36,624	$ 61,032	$ 122,280
2.1	Biomass Costs per Year (Low at $10/ton)	$ 207,000	$ 345,000	$ 690,000
2.2	Biomass Costs per Year (Medium at $20/ton)	$ 414,000	$ 690,000	$ 1,380,000
2.3	Biomass Costs per Year (High at $35/ton)	$ 724,500	$ 1,207,500	$ 2,415,000
3	Naturla Gas Costs per Year	$ 249,000	$ 415,159	$ 830,318
4	Ash Disposal Cost per Year	$ 33,120	$ 55,200	$ 110,400
5	Water and Water Treatment	$ 22,000	$ 57,000	$ 159,000
6	Labor	$ 240,000	$ 240,000	$ 240,000
7	Workers' Compensation	$ 16,800	$ 16,800	$ 16,800
8	Miscellaneous	$ 39,000	$ 39,000	$ 39,000
11.1	Interest on Working Capital ($10/ton feedstock)	$ 16,735	$ 24,076	$ 42,485
11.2	Interest on Working Capital ($20/ton feedstock)	$ 20,185	$ 29,826	$ 53,985
11.3	Interest on Working Capital ($35/ton feedstock)	$ 25,360	$ 38,451	$ 71,235
	Total (Low Fuel Cost - $10/ton)	**$ 860,279**	**$ 1,253,267**	**$ 2,250,283**
	Total (Medium Fuel Cost - $20/ton)	**$ 1,070,729**	**$ 1,604,017**	**$ 2,951,783**
	Total (High Fuel Cost - $35/ton)	**$ 1,386,404**	**$ 2,130,142**	**$ 4,004,033**
Yearly Expenditures on Capital				
9	Yearly Taxes and Insurance Costs	$ 68,805	$ 92,304	$ 146,268
10	Yearly Maintenance Costs	$ 91,740	$ 123,072	$ 195,024
1	Depriciation - Buildings	$ 37,050	$ 54,175	$ 83,150
2	Depreciation - Equipment	$ 247,000	$ 310,500	$ 493,500
3	Interest on Investment - Buildings	$ 18,525	$ 27,088	$ 41,575
4	Interest on Investment - Equipment	$ 68,363	$ 86,738	$ 141,950
	Total	**$ 531,483**	**$ 693,876**	**$ 1,101,467**
Total Operational Costs				
Operational Costs/yr (Low at $10/ton)		$ 1,590,162	$ 2,221,063	$ 3,703,750
Operational Costs/yr (Medium at $20/ton)		$ 1,800,612	$ 2,571,813	$ 4,405,250
Operational Costs/yr (High at $35/ton)		$ 2,116,287	$ 3,097,938	$ 5,457,500
Generation Analysis				
Total kilo-Watts Sold per Year		13,367,760	22,276,680	44,632,200
Average Cost/yr (Low at $10/ton)		**$ 0.11895**	**$ 0.09970**	**$ 0.08298**
Average Cost/yr (Medium at $20/ton)		**$ 0.13470**	**$ 0.11545**	**$ 0.09870**
Average Cost/yr (High at $35/ton)		**$ 0.15831**	**$ 0.13907**	**$ 0.12228**

Table 14: Gasification Annual Operating Costs

Gasification				
		Case # 1	**Case # 2**	**Case # 3**
	Biomass Input (Wet Tons per Day)	160	267	533
	Net Generation (kilo-Watts per hour)	6,294	10,061	20,227
Overhead and Administration				
1	General Manger	$ 108,800	$ 128,000	$ 140,800
2	Accounting Support	$ 64,000	$ 89,600	$ 115,200
3	Clerical Support	$ 25,600	$ 56,320	$ 96,000
	Total	**$ 198,400**	**$ 273,920**	**$ 352,000**
Variable Cost of Operation				
1	Purchasing Cost for Downtime Electricity per Year	$ 151,056	$ 241,464	$ 485,448
2.1	Fuel Costs per Year (Low at $10/ton)	$ 552,000	$ 921,150	$ 1,838,850
2.2	Fuel Costs per Year (Medium at $20/ton)	$ 1,104,000	$ 1,842,300	$ 3,677,700
2.3	Fuel Costs per Year (High at $35/ton)	$ 1,932,000	$ 3,224,025	$ 6,435,975
3	Ash Disposal Cost per Year	$ 13,000	$ 27,000	$ 54,000
4	Water and Water Treatment	$ 22,000	$ 57,000	$ 159,000
5	Labor	$ 540,000	$ 540,000	$ 600,000
6	Workers' Compensation	$ 37,800	$ 37,800	$ 42,000
7	Miscellaneous	$ 39,000	$ 39,000	$ 39,000
8	Inert Gas	$ 10,000	$ 10,000	$ 10,000
11.1	Interest on Working Capital ($10/ton feedstock)	$ 33,902	$ 46,732	$ 79,414
11.2	Interest on Working Capital ($20/ton feedstock)	$ 43,102	$ 62,085	$ 110,062
11.3	Interest on Working Capital ($35/ton feedstock)	$ 56,902	$ 85,113	$ 156,033
	Total (Low Fuel Cost - $10/ton)	**$ 1,398,758**	**$ 1,920,146**	**$ 3,307,712**
	Total (Medium Fuel Cost - $20/ton)	**$ 1,959,958**	**$ 2,856,649**	**$ 5,177,210**
	Total (High Fuel Cost - $35/ton)	**$ 2,801,758**	**$ 4,261,402**	**$ 7,981,456**
Yearly Expenditures on Capital				
9	Yearly Taxes and Insurance Costs	$ 286,830	$ 398,790	$ 658,530
10	Yearly Maintenance Costs	$ 382,440	$ 531,720	$ 878,040
1	Depriciation - Buildings	$ 65,500	$ 98,350	$ 160,000
2	Depreciation - Equipment	$ 1,286,800	$ 1,831,300	$ 3,060,000
3	Interest on Investment - Buildings	$ 32,750	$ 49,175	$ 80,000
4	Interest on Investment - Equipment	$ 356,700	$ 490,325	$ 815,000
	Total	**$ 2,411,020**	**$ 3,399,660**	**$ 5,651,570**
Total Operational Costs				
Operational Costs/yr (Low at $10/ton)		$ 4,008,178	$ 5,593,726	$ 9,311,282
Operational Costs/yr (Medium at $20/ton)		$ 4,569,378	$ 6,530,229	$ 11,180,780
Operational Costs/yr (High at $35/ton)		$ 5,411,178	$ 7,934,982	$ 13,985,026
Generation Analysis				
Total kilo-Watts Sold per Year		55,135,440	88,134,360	177,188,520
Average Cost/yr (Low at $10/ton)		**$ 0.07270**	**$ 0.06347**	**$ 0.05255**
Average Cost/yr (Medium at $20/ton)		**$ 0.08288**	**$ 0.07409**	**$ 0.06310**
Average Cost/yr (High at $35/ton)		**$ 0.09814**	**$ 0.09003**	**$ 0.07893**

Table 15: Pyrolysis Annual Operating Costs

Pyrolysis				
		Case # 1	**Case # 2**	**Case # 3**
	Biomass Input (Wet Tons per Day)	120	200	400
	Net Generation (kilo-Watts per hour)	4,752	9,570	14,370
Overhead and Administration				
1	General Manger	$ 108,800	$ 128,000	$ 140,800
2	Accounting Support	$ 64,000	$ 89,600	$ 115,200
3	Clerical Support	$ 25,600	$ 56,320	$ 96,000
	Total	**$ 198,400**	**$ 273,920**	**$ 352,000**
Variable Cost of Operation				
1	Purchasing Cost for Downtime Electricity per Year	$ 114,048	$ 229,680	$ 344,880
2.1	Fuel Costs per Year (Low at $10/ton)	$ 552,000	$ 1,104,000	$ 1,656,000
2.2	Fuel Costs per Year (Medium at $20/ton)	$ 1,104,000	$ 2,208,000	$ 3,312,000
2.3	Fuel Costs per Year (High at $35/ton)	$ 1,932,000	$ 3,864,000	$ 5,796,000
3	Ash Disposal Cost per Year	$ 17,500	$ 35,000	$ 52,000
4	Water and Water Treatment	$ 22,000	$ 57,000	$ 159,000
5	Labor	$ 510,000	$ 1,020,000	$ 1,530,000
6	Workers' Compensation	$ 35,700	$ 71,400	$ 107,100
7	Miscellaneous	$ 39,000	$ 39,000	$ 39,000
10.1	Interest on Working Capital ($10/ton feedstock)	$ 29,215	$ 55,226	$ 82,114
10.2	Interest on Working Capital ($20/ton feedstock)	$ 38,415	$ 73,626	$ 109,714
10.3	Interest on Working Capital ($35/ton feedstock)	$ 52,215	$ 101,226	$ 151,114
	Total (Low Fuel Cost - $10/ton)	**$ 1,319,463**	**$ 2,611,306**	**$ 3,970,094**
	Total (Medium Fuel Cost - $20/ton)	**$ 1,880,663**	**$ 3,733,706**	**$ 5,653,694**
	Total (High Fuel Cost - $35/ton)	**$ 2,722,463**	**$ 5,417,306**	**$ 8,179,094**
Yearly Expenditures on Capital				
8	Yearly Taxes and Insurance Costs	$ 198,270	$ 324,630	$ 445,230
9	Yearly Maintenance Costs	$ 264,360	$ 432,840	$ 593,640
1	Depriciation - Buildings	$ 45,000	$ 77,750	$ 129,500
2	Depreciation - Equipment	$ 991,500	$ 1,608,000	$ 2,154,500
3	Interest on Investment - Buildings	$ 22,500	$ 38,875	$ 64,750
4	Interest on Investment - Equipment	$ 247,875	$ 402,000	$ 538,625
	Total	**$ 1,769,505**	**$ 2,884,095**	**$ 3,926,245**
Total Operational Costs				
Operational Costs/yr (Low at $10/ton)		$ 3,287,368	$ 5,769,321	$ 8,248,339
Operational Costs/yr (Medium at $20/ton)		$ 3,848,568	$ 6,891,721	$ 9,931,939
Operational Costs/yr (High at $35/ton)		$ 4,690,368	$ 8,575,321	$ 12,457,339
Generation Analysis				
Total kilo-Watts Sold per Year		41,627,520	83,833,200	125,881,200
Average Cost/yr (Low at $10/ton)		**$ 0.07897**	**$ 0.06882**	**$ 0.06552**
Average Cost/yr (Medium at $20/ton)		**$ 0.09245**	**$ 0.08221**	**$ 0.07890**
Average Cost/yr (High at $35/ton)		**$ 0.11267**	**$ 0.10229**	**$ 0.09896**

Overhead and Administration

The overhead and administration section deals primarily with the annual salary of the general manager, accounting support, and clerical services. Each technology was assumed to require an equal amount of services from a general manager, accounting department, and clerical support; therefore, these services for direct-fire case 1 will incur the same amount as all other case 1 technologies. Case 2 and case 3 are respectively equal for each technology.

Company benefits are assessed within the salary for the general manager, accounting, and clerical support services. These benefits are intended to include typical employee benefits, such as health insurance, dental, vacation time, and 401K. Benefits are assessed at a flat rate of 28% of the yearly employee salary.

Variable Costs of Operation

The variable costs of operation are dependent upon the costs of fuel, operating labor, purchased power for plant downtime, worker's compensation benefits, water and water treatment, ash disposal, interest on working capital, and miscellaneous variable costs. The following sections describe the variable costs of operation in greater detail.

Fuel Cost - Areas that are most dense in biomass potential may be able to purchase a variety of biomass at low costs. Areas that are less dense may not be able to purchase low-cost biomass fuels. The field price of Georgia's five cheapest biomass sources is \$14/ton on average. Georgia's ten cheapest biomass sources cost \$23.5/ton. For these reason's the costs of biomass fuels were assessed in low (\$10/ton), medium (\$20/ton), and high cost scenarios (\$35/ton). For co-fire technology, the natural gas fuel charge is assessed at \$1.38 per thousand cubic feet, which is consistent with long-term regional averages. Fuel costs, even at the lowest price of \$10/ton, is generally the single largest operational cost for any given technology.

Operating Labor - The operating laborer's section relates to the manpower necessary for the operation of each facility. Some technologies will require more manpower than others. In order to operate the direct-fire and co-fire technologies, eight laborers will be required for case 1 and 2, and ten for case 3. Gasification technology requires 18, 18, and 20 for case 1, 2, and 3, respectively. Pyrolysis requires 17, 34, and 51 laborers for case 1, 2, and 3, respectively. Laborers for each technology are assumed to earn an average of \$30,000 per year. Generally, the operating labor cost is the second largest variable cost of operation, next to the fuel costs.

Worker's Compensation – To account for any injury that may occur during operation, worker's compensation benefits are assessed for all laborers. These benefits are intended to cover plant workers, such as loader operators, plant technicians, and mechanics. Worker's compensation is assessed at the typical rate of 7% of the laborer's total yearly salary.

Interest on Working Capital – Working capital was assessed to cover two months of the variable costs of operation. Since there are three fuel cost scenarios, the interest on working capital was assessed for each. The total variable costs of operation for two months time period was assessed for the short-term rate of 10%. This cost is intended to cover any lag-time between the start of operation and the incoming revenue stream.

Ash Disposal - This study assumes an 8% ash content per biomass input for direct-fire and co-fire technologies. Natural Gas fuel assumes a 0% ash content. Since gasification and pyrolysis convert the biomass feedstock into a more condensed biofuel, less ash is generated per original biomass input. As a result, gasification and pyrolysis generate ash at approximately 1.4 and 1.6% of the original biomass input, respectively. Multiplying the yearly tons of biomass input, by the percent ash content for each respective technology, and then by the ash disposal rate of $20/ton determines the yearly ash disposal fees.

Water Fees - The amount of boiler feed water used is dependent upon the generating capacity. Increased generation will require more steam to turn the turbine and also require more water for cooling. Direct-fire and co-fire models use the same multi-stage turbine generator with equal water requirements. The gasification model utilizes the waste heat from the turbine generator to produce steam in a boiler for an additional multi-stage turbine generator. The water requirement for gasification is not significantly different from the direct-fire and co-fire models. Therefore, the water costs for the direct fire, co-fire, and gasification models are equal. The pyrolysis technology also utilizes the waste heat from the turbine generator to produce steam in a boiler for an additional multi-stage turbine generator. Since the pyrolysis model requires less energy input, there is less waste heat generated from the gas turbine. This reduces the amount of steam that can be produced within the boiler. As a result, the pyrolysis model requires the least amount of water requirements.

In order to feed the boiler, direct-fire, co-fire, and gasification take in the same 4.5, 7.4, and 14.8 million gallons of water per year for case 1, 2, and 3, respectively. Pyrolysis generation requires inputs of 3.6, 7.2, and 10.8 million gallons per year for case 1, 2, and 3, respectively. Sewer water loads are determined as a function of the boiler feed water. About $1/3_{rd}$ of the boiler feed water evaporates through the cooling towers. Therefore, $2/3_{rds}$ of the boiler feed water load equals the total sewer load. Water and water treatment rates increase as the water requirements increase for each case study. Cumulatively, water and water treatment amount to approximately .49¢, .77¢, and 1.1¢ per gallon of water input for case 1, 2, and 3, respectively.

Taxes and Insurance – Taxes and insurance are assessed a flat rate of 1.5% of capital for each technology.

Maintenance - Maintenance is assessed at 2% of capital for direct-fire and co-fire technologies and 3% of capital for the more technical gasification and pyrolysis systems.

Inert Gas – In the gasification process, combustible gases are created by heating dried biomass within a reactor vessel. In this model, the heat is introduced by a heat exchange medium that uses sand, char, steam, and inert gas. The inert gas needed for the gasification process is assessed at $10,000 per year for each case scenario.

Miscellaneous – Various expenditures for items, parts, and services will be required to keep the facility in regular operation. The miscellaneous section is intended to capture these expenditures, which may include: contractual administrative support, office supplies, maintenance supplies, safety gear, or any other required expense.

Yearly Capital Expenditures

The third primary category that influences the yearly operational costs is the yearly expenditures on capital. These costs include both depreciation and interest for buildings and equipment. This research assumes the plant will remain in operation as long as it is economically and mechanically practical; therefore, zero salvage value was assessed for the plant buildings and equipment. Depreciation on buildings is assessed at a 20-year lifetime, while depreciation on equipment is assessed at a 10-year lifetime. The interest on investment is calculated at an interest rate of 5% for the total capital costs of land, buildings, and equipment for each respective technology.

Maintenance Downtimes and Average Cost

The average cost analysis ($/kWh) for each technology is located on the lower half of tables 12, 13, 14, and 15. The plant is assumed to operate 345 days per year and shut-down for maintenance during the remaining time. In order to provide a constant flow of power to the generator's contractors, the generator must purchase the power it usually produces from the electrical power grid. This power is used to supply power consumers during the maintenance shut-down periods. The total yearly quantity of power produced is derived from the net generating capacity multiplied by 345 days/year. The total amount of power sold is derived from multiplying the net generating capacity by 365 days/year. The average cost of electricity, or the cost per kWh, is derived from the total amount of power sold divided by the annual operating costs.

The total amount of power sold is used to determine the price per kWh, because in order to supply contracted customers, the generator must sell power continuously for the entire year. During maintenance periods, the plant is shut down, and the generator is assumed to act as a sub-contractor, by purchasing power at the typical industrial rate of 5¢/kWh. The generator then sells the purchased power back to the consumer at the generator's usual fee. The generator does not alter the set contract price when the facility undergoes maintenance. In addition, the generator must account for the purchased power as an annual cost, while accounting for the revenue it receives from the resold power. If the final cost per kWh is calculated using the total amount of power produced during a 345-day period, this would defer the revenue gained from the resold power the additional 20 days per year.

Biomass Production Cost and Electricity Rate Comparison

In Georgia, the retail sale of electricity is separated into three primary markets, commercial, industrial, and residential. Although these sectors use roughly the same amount of electricity, the electrical power rate is determined by the individual consumer's demand for power. Since industrial facilities buy electricity in bulk loads, power generators will offer consumers in the industrial sector the least expensive rate for electricity. Industrial rates are typically fixed for wholesale electricity markets. Commercial consumers pay around 2¢-3¢ more per kWh than the industrial sector. The commercial sector consumes virtually the same amount of electricity as the industrial sector; however, these facilities pay higher rates because they require less power on a site-by-site basis. The residential sector requires the least amount of electricity on a site-by-site basis, but consumes the greatest total quantity. As a result, the residential sector is charged the highest rate for electricity, typically 1-2¢ more than the commercial rate.

According to the Tennessee Valley Authority 1999 Investor Relations Research, Cost and Price Comparison, the 1999 Southeastern rates averaged 7.86¢/kWh for the residential sector, 6.56¢/kWh for the commercial sector, and 4.3¢/kWh for the industrial sector. Georgia's 1999 utility retail sales and revenue data, provided by the Energy Information Administration, is shown in Table 16. As shown in the table, Georgia sold 112,656 Megawatt-hours of electricity in 1999 at the average rate of 6.24¢/kWh.

Table 16: 1999 Georgia Utility Sales, Revenue, and Average Revenue per kWh

Item	Investor-Owned	Public	Federal	Cooperative	Total
Number of Utilities	2	53	0	43	98
Number of Retail Customers	1,982,155	320,723	0	1,429,267	3,732,145
Retail Sales (thousand megawatthours)	74,685	10,871	0	27,100	112,656
Percentage of Retail Sales	66.3	9.7	0	24.1	100
Revenue from Retail Sales (million 1999 dollars)	4,368	682	0	1,975	7,025
Percentage of Revenue	62.2	9.7	0	28.1	100
Average Revenue per Kilowatthour (cents/kWh)	5.85	6.27	0	7.29	6.24

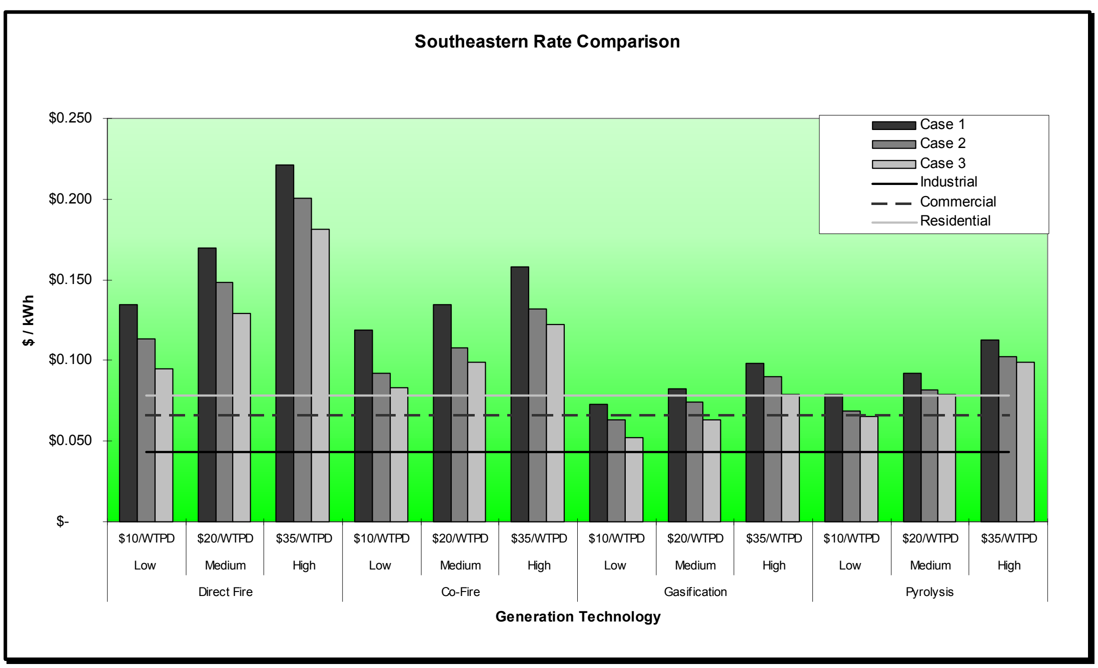
Source: Energy Information Administration.
http://www.eia.doe.gov/cneaf/electricity/st_profiles/georgia/ga.html#t9

Table 17 summarizes the cost of generating power ($/kWh) for each technology. We can employ a direct comparison among the operating costs of each technology and the average annual rates for commercial, industrial, and residential consumers. Figure 4 compares each technology with the rate averages for the southeastern region, since electricity generation in the southeastern United States is slightly cheaper than the national average. It is important to note that transmission and distribution costs, which are reflected in the Southeastern rates for electricity, are not accounted for in the marginal costs of the biomass generation technologies.

Table 17: Summary of Operating Costs in $/kWh

Summary of Operating Costs $/kWh				
Technology	**Scenario**	**Case #1**	**Case #2**	**Case #3**
Direct - Fire	Low Fuel Cost Scenario	$ 0.135	$ 0.114	$ 0.095
	Medium Fuel Cost Scenario	$ 0.170	$ 0.149	$ 0.129
	High Fuel Cost Scenario	$ 0.222	$ 0.201	$ 0.181
Co - Fire	Low Fuel Cost Scenario	$ 0.119	$ 0.100	$ 0.083
	Medium Fuel Cost Scenario	$ 0.135	$ 0.115	$ 0.099
	High Fuel Cost Scenario	$ 0.158	$ 0.139	$ 0.122
Gasification	Low Fuel Cost Scenario	$ 0.073	$ 0.063	$ 0.053
	Medium Fuel Cost Scenario	$ 0.083	$ 0.074	$ 0.063
	High Fuel Cost Scenario	$ 0.098	$ 0.090	$ 0.079
Pyrolysis	Low Fuel Cost Scenario	$ 0.079	$ 0.069	$ 0.066
	Medium Fuel Cost Scenario	$ 0.092	$ 0.082	$ 0.079
	High Fuel Cost Scenario	$ 0.113	$ 0.102	$ 0.099
Southeastern Rate Average (1999)	Residential	$ 0.079		
	Comercial	$ 0.066		
	Industrial	$ 0.043		
Georgia Rate Average (1999)	Residential	$ 0.076		
	Comercial	$ 0.067		
	Industrial	$ 0.042		

Figure 4: Southeastern Rate Comparison

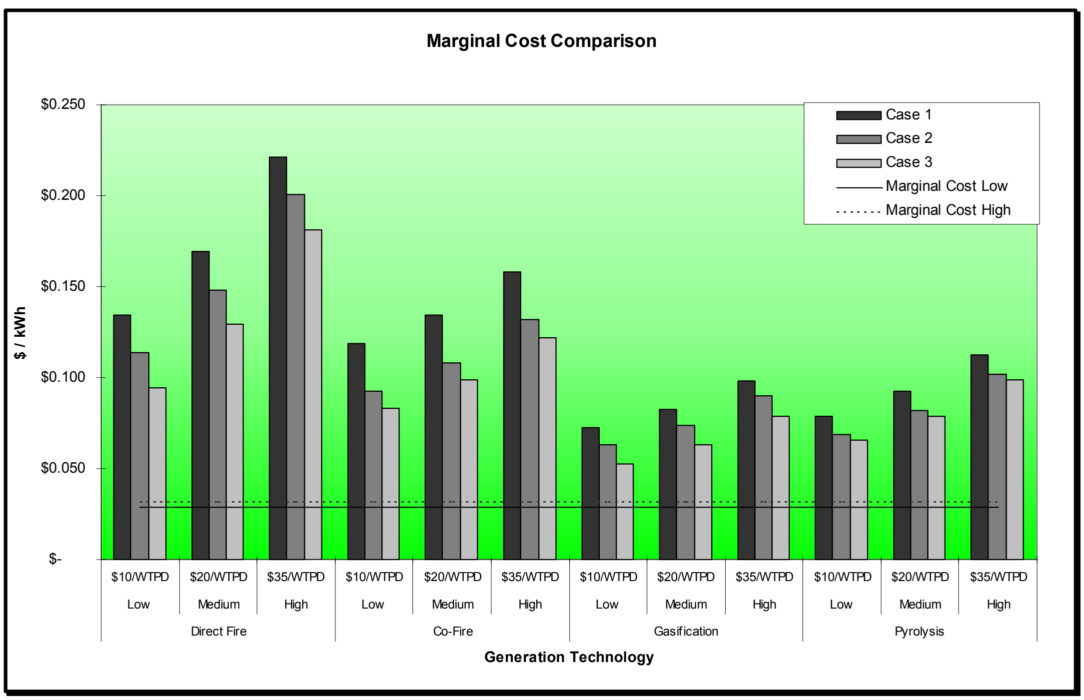


Marginal Cost Comparison

Data provided from *Customer Choice, Consumer Value: An Analysis of Retail Competition in America's Electric Utility Industry* indicate that the marginal cost of production from existing steam facilities is 1.7¢/kWh. The full costs, including capital, were assessed at approximately 3¢/kWh. The 1998 Annual Energy Outlook reports similar figures for the capital and fuel costs, at approximately 3.2 and 2.9¢ per kWh for coal-fired and natural gas combined cycle generation, respectively. These costs represent only the generation cost of producing electricity per kWh; therefore, they are 1 to 4¢ less than the actual selling price of electricity. Costs that are incorporated in the selling price of electricity, such as transmission, distribution, and transaction costs, are not used in the marginal cost of production figures. In the following sections, this research will use the low-end (2.9¢) and high-end (3.2¢/kWh) marginal cost of production figures as a basis for comparison. Since transmission, distribution, and transaction costs are not incorporated in the biofuel generation assessments, the actual feasibility of biomass generation technology will be represented with this direct comparison with the current marginal costs of production (2.9 and 3.2¢ per kWh).

Figure 5 indicates the average cost comparison of the biomass generation technologies with the marginal cost of generation for existing facilities. As displayed in the following graph, there is a direct relationship with the larger biomass facilities and lowered electricity costs. Therefore, case 3 proves to be the best-case scenario for each technology. For simplicity, further discussion on feasibility will focus on case 3 for each technology, unless otherwise noted.

Figure 5: Marginal Cost Comparison



Of the four technologies studied, none are shown to be competitive with current marginal costs of production. The low-fuel cost gasification case 3 scenario can generate electricity at 5.2¢ per kWh, which is above the highest marginal cost by 2¢ per kWh.

Sensitivity Analysis of Production Costs to Varying Fuel and Capital Costs

The most significant cost variables, fuel cost and capital costs, were altered to determine the overall affect on the average cost of production. The capital costs were adjusted by 10%, higher and lower, than the original assessment. Fuel costs were assessed from \$0 to \$50 per wet ton. Figures 6 through 13 display the results of the sensitivity analysis.

Figure 6: Direct Fire Fuel Cost Sensitivity

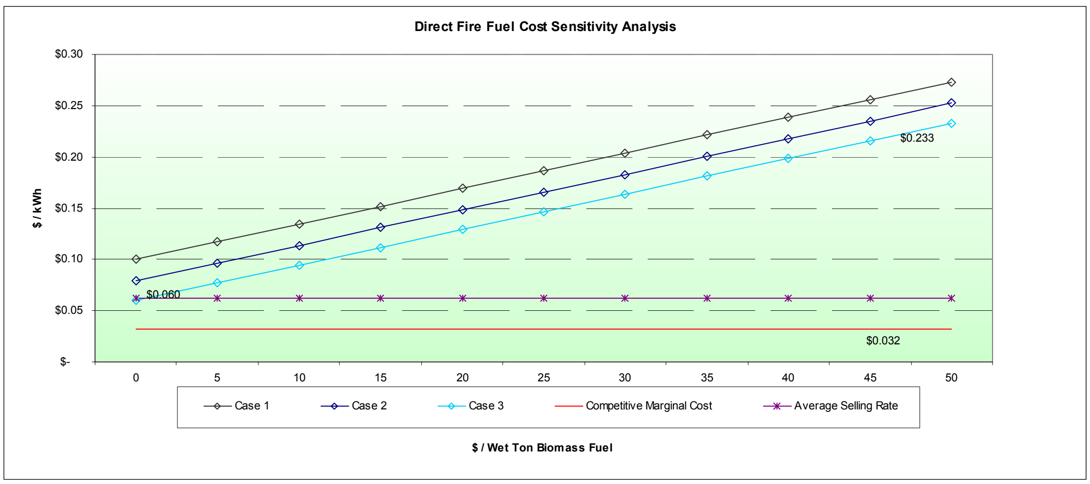


Figure 7: Co-Fire Fuel Cost Sensitivity

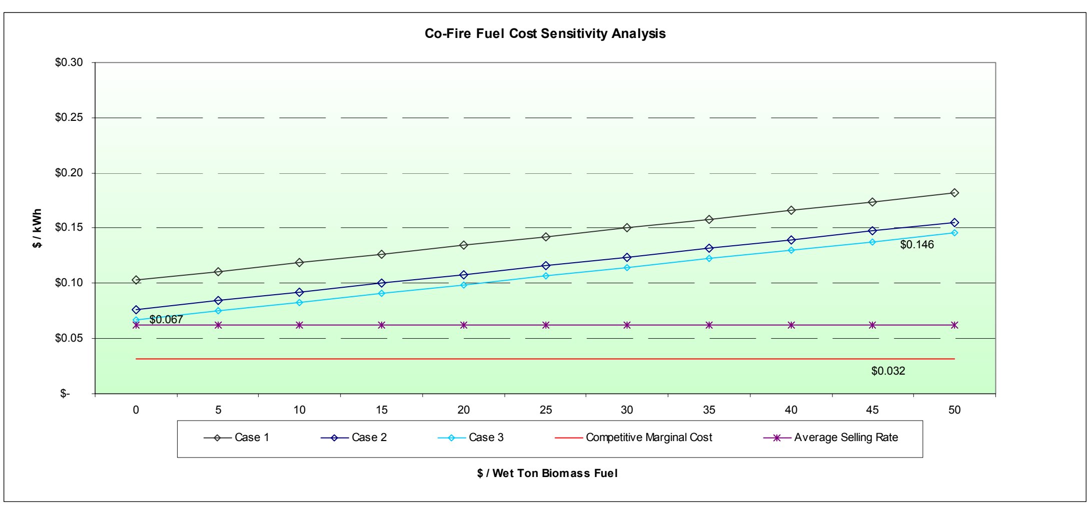


Figure 8: Gasification Fuel Cost Sensitivity

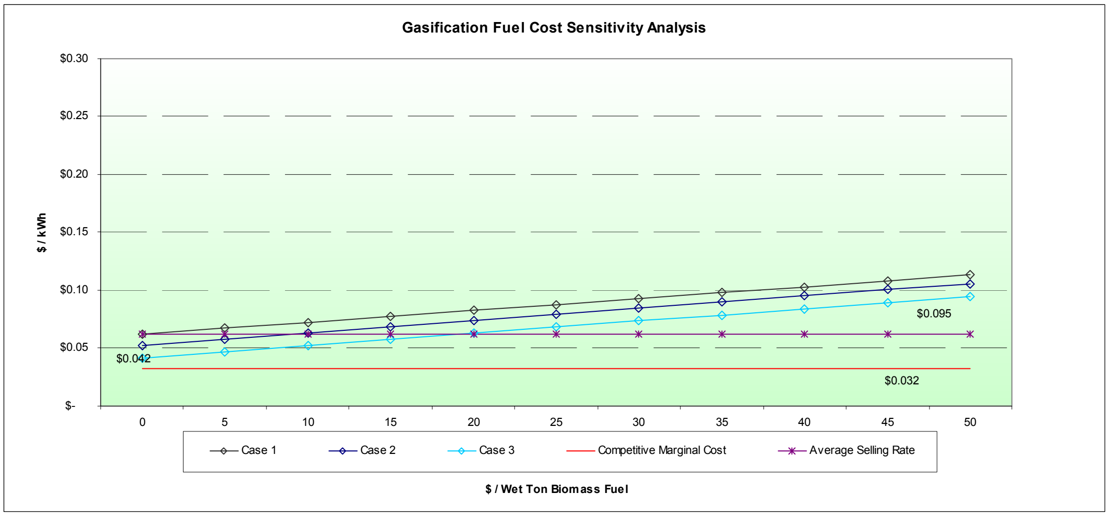
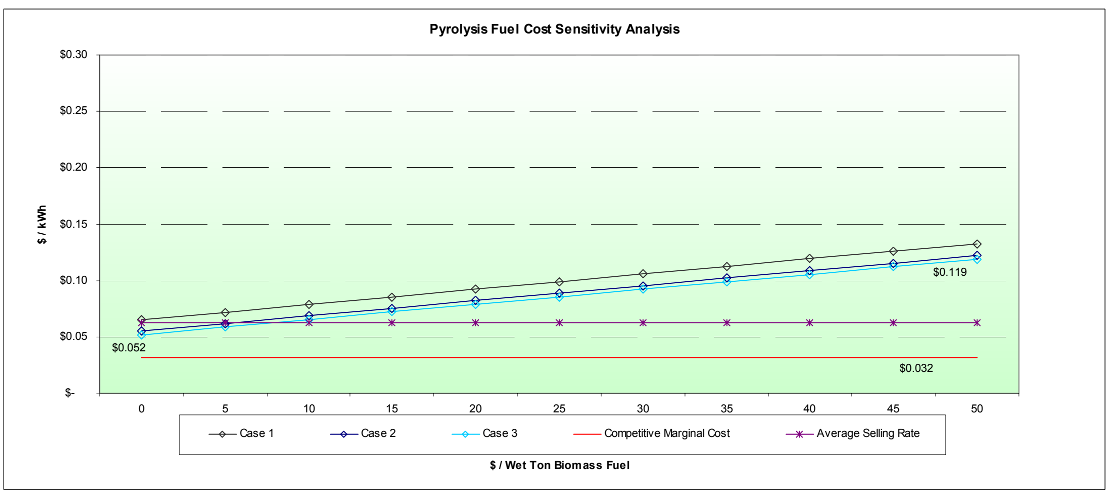


Figure 9: Pyrolysis Fuel Cost Sensitivity



Fuel Cost Sensitivity – As shown in the preceding figures, direct-fire is the most sensitive technology, with respect to changes in fuel costs. Co-fire, pyrolysis, and gasification display respectively decreasing sensitivity to changes in fuel cost. Fuel cost sensitivity is dependant upon the feedstock input to operational cost ratio. Technologies that utilize the greatest amount of biomass input per dollar of total operational cost, will be the most sensitive to feedstock price changes.

Two technologies, gasification and pyrolysis, can produce electricity below Georgia's 1999 average selling rate of 6.24¢ per kWh. With feedstock prices at or below $20/ton, Gasification can produce electricity below the average selling rate, and with feedstock prices at or below $7.50/ton, pyrolysis can produce electricity below the average selling rate. None of the four technologies studied were shown to produce electricity below current generation rates. This analysis concludes that no technology is competitive with traditional generation methods, even at zero fuel cost.

Figure 10: Direct Fire Capital Cost Sensitivity

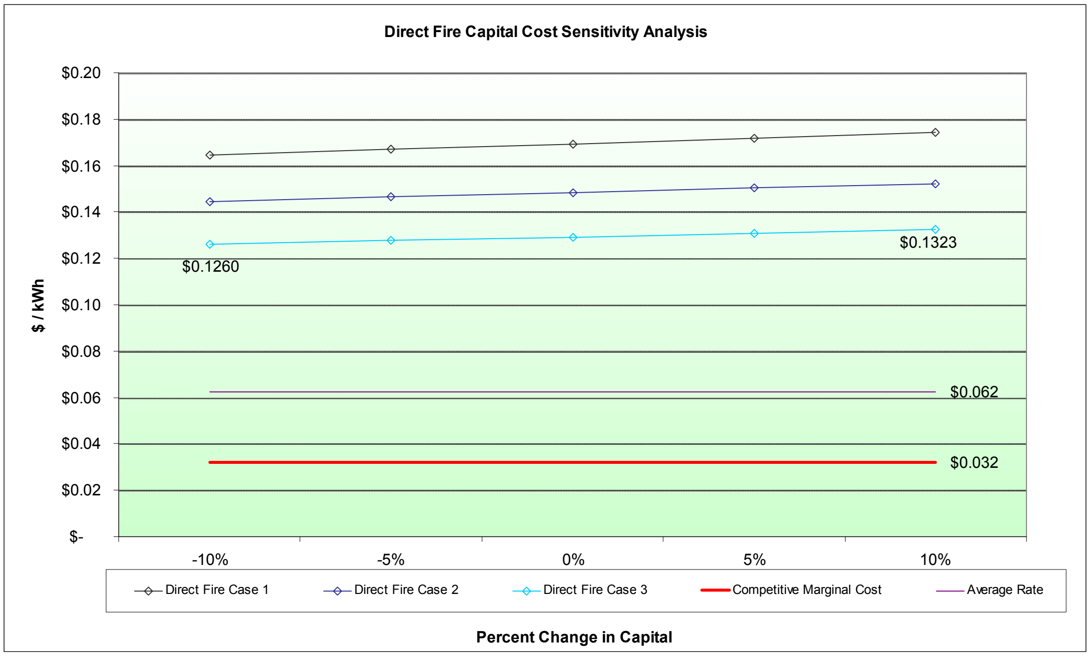


Figure 11: Co-Fire Capital Cost Sensitivity

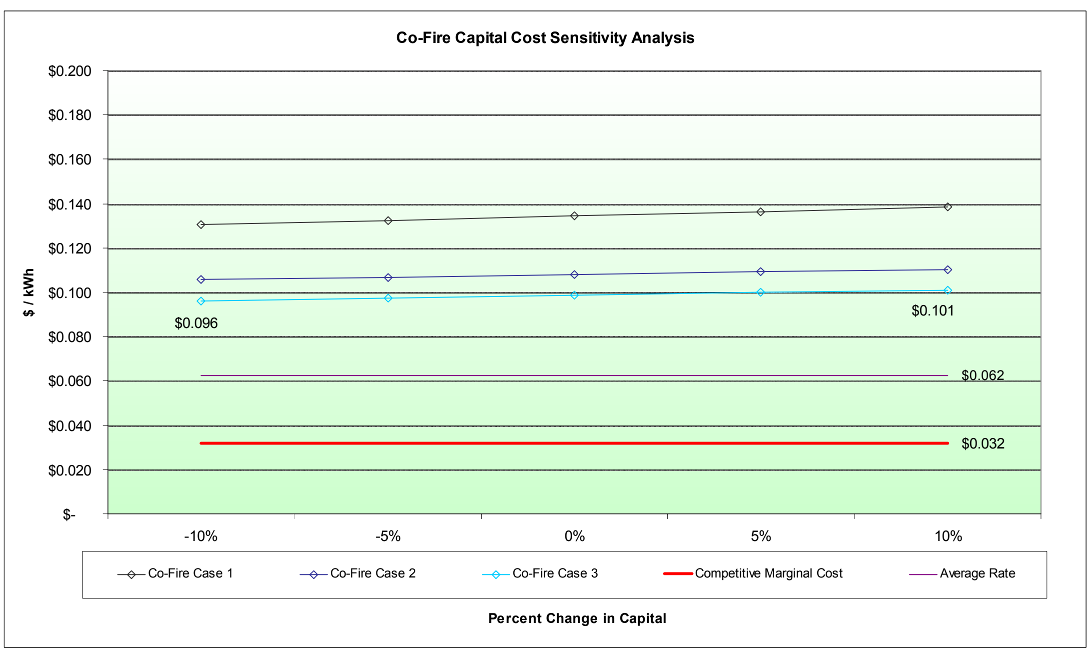


Figure 12: Gasification Capital Cost Sensitivity

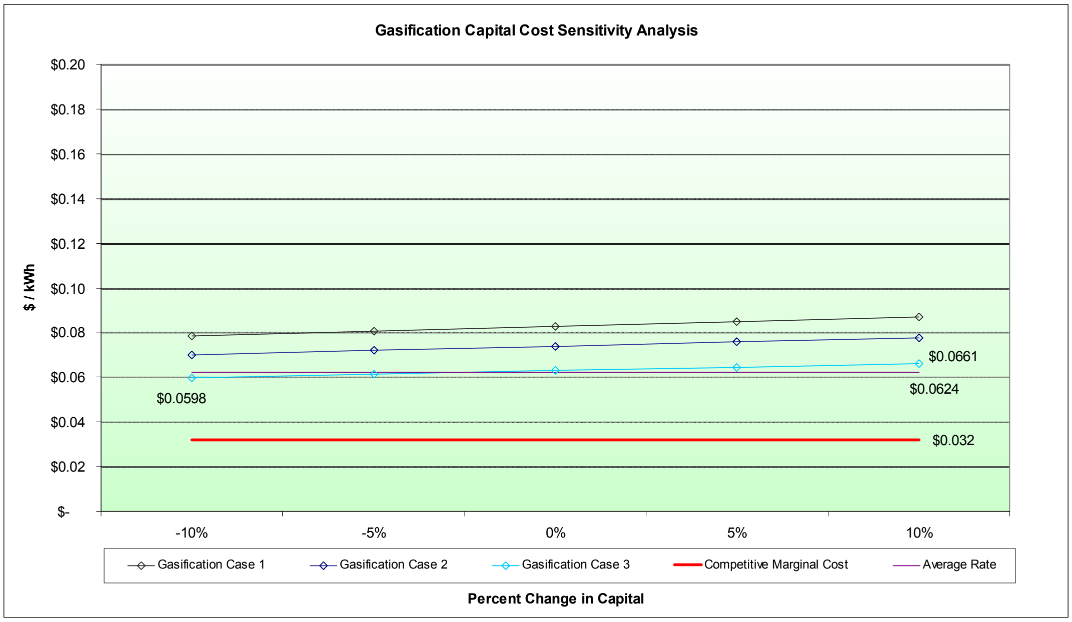
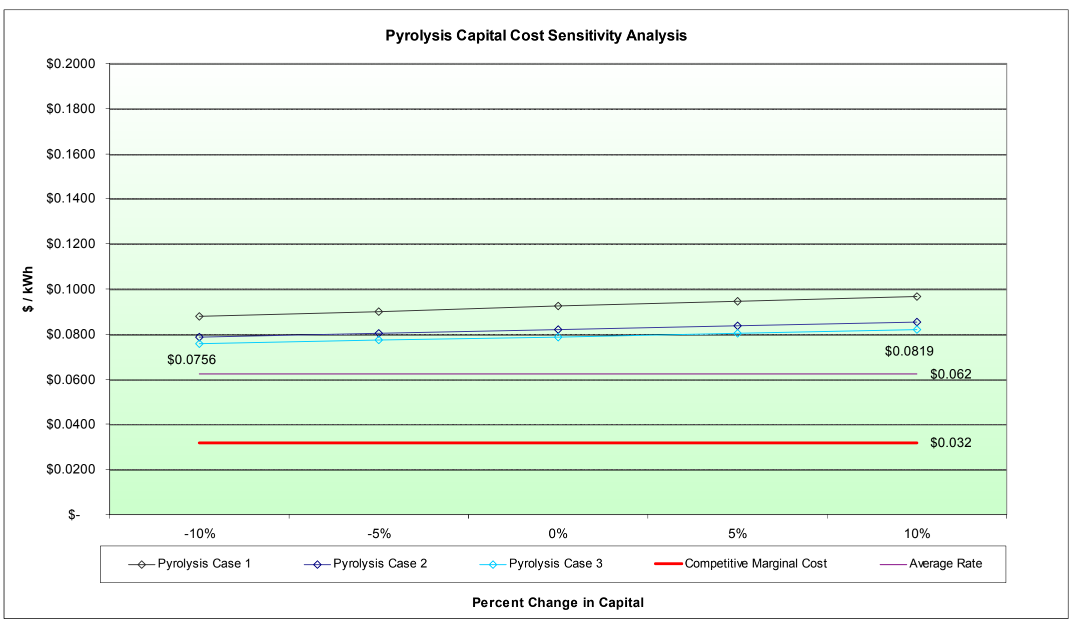


Figure 13: Pyrolysis Capital Cost Sensitivity

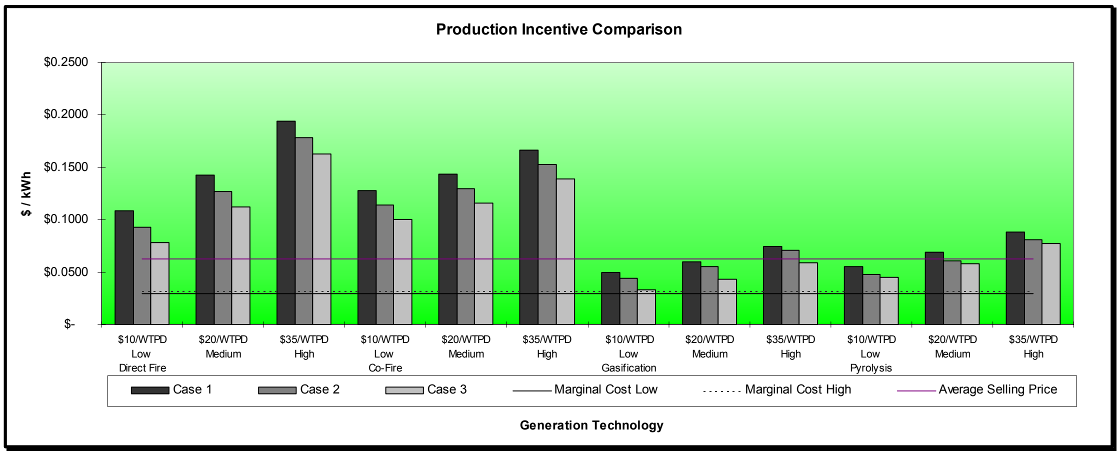


Capital Cost Sensitivity – As displayed in figures 10 through 13, none of the four generation technologies are significantly sensitive to changes in capital cost. Co-fire is the least sensitive, with a total price change of .51¢ between the positive and negative 10% change in capital cost. Direct fire, gasification, and pyrolysis all exhibit a total price change of .63¢ between the ranges of capital cost. None are shown to be competitive with traditional generation technologies.

Renewable Energy Production Incentive

Due to its many potential benefits, renewable energy resources, such as biomass generation technologies, can sometimes qualify for certain incentives to help encourage entry into the competitive electric utility industry. The most substantial government-based incentive is the renewable energy production incentive. This incentive can be obtained for closed-loop biomass and poultry litter feedstocks. The incentive is adjusted annually for inflation and is currently set at 1.8¢ per kWh. The inclusion of this incentive would shift the low fuel cost gasification case 3 scenario to be near competitive cost levels. Assuming proper biomass feedstocks, all technologies could qualify for the production incentive, except co-fire. Since co-firing mixes fossil fuels with biomass, it does not qualify for the production incentive. Figure 14 includes the production incentive and reevaluates the marginal cost comparison between the four biomass generation technologies and traditional technologies.

Figure 14: Production Incentive Comparison



Green Power Markets

Each technology, with the exception of co-fire, are authentic green power sources. Therefore the electricity generated can be sold in separate green power markets. Green power markets, such as Georgia's newly established Green Power EMC, sells green power in 150 kWh blocks to consumers who wish to purchase some of their energy from renewable sources. Georgia's green power generators are currently fueled from landfill gas. Any new green power facility can take advantage of Georgia's green power market.

The green power premium will be set at the average rate for all green power generation. For example, Georgia's green power market may eventually consist of 25% landfill gas, 25% hydro, 25% direct-fire, and 25% gasification. The break-even rate of electricity will vary with each technology. Example rates could be 8¢, 11¢, 15¢, and 6¢ per kWh, respectively. In Georgia, the green power premium would be set from average of the green power generation rates, which would be 10¢ per kWh in this example.

Subtracting the regional residential average rate of 7.8¢ from 10¢ would yield a set premium at 2.2¢ per kWh. The consumers will withdraw the power they use from the grid, and the green power contractor will bill the consumer at the premium rate for the amount of green power bought, currently sold in monthly 150kWh blocks. A premium of 2.2¢ per kWh for a monthly 150 kWh block of green power would raise the price to the consumer by $3.30 per month, which is consistent with the current Green Power EMC premium.

This research compares studies on consumer's willingness-to-pay for green power premiums performed by the National Renewable Energy Laboratory (NREL). A review and synthesis of 14 surveys conducted in 12 utility service territories (1995-1997) found that majority (52 to 95%) of residential customers said they were willing to pay more on their electric bills for power from renewable sources (NREL 2001). The NREL studies indicate that a fewer percentage of respondents are willing to pay for green power as the premium increases. Relating the NREL results to the current Green EMC premium, this research shows most respondents are willing to pay for this type of premium. The more competitive rates for gasification and pyrolysis would aid in lowering the market premium, thereby increasing the feasibility for all green power sources allocated through the green power market.

The economic potential for Georgia's green power premiums could be highly significant. Table 18 shows Georgia's power sales and corresponding price rate for Georgia's electricity sectors. Green power rates were calculated by setting premiums at 5%, 10%, and 15%. The inclusion of a premium would raise the initial cost per kWh by approximately 4 mills (tenths of a cent) for each 5% increase in the premium.

Table 18: Impact on Electricity Rates for Green Power Premiums

	Utility Retail Sales (GWh)	Revenue (million 1999 dollars)	Average Revenue per kWh	Av Cost per kWh with the 5% premium	Av Cost per kWh with the 10% premium	Av Cost per kWh with the 15% premium
Residential	41,767	$ 3,159	$ 0.0756	$ 0.07942	$ 0.08320	$ 0.08698
Commercial	34,093	$ 2,272	$ 0.0666	$ 0.06997	$ 0.07331	$ 0.07664
Industrial	35,255	$ 1,463	$ 0.0415	$ 0.04357	$ 0.04565	$ 0.04772
Other	1,541	$ 130	$ 0.0844	$ 0.08858	$ 0.09280	$ 0.09701
Total	112,656	$ 7,024	$ 0.0623	$ 0.06547	$ 0.06858	$ 0.07170

For Georgia's residential consumers, the 5% premium would raise the cost of electricity approximately $6 month. Research has shown that most consumers are willing to pay for this type of premium. If 40% of Georgia's residential consumers purchased the 5% green power premium, 470 thousand 150kWh power blocks would be demanded each month in the residential sector alone. If 10% of Georgia's residential, industrial, and commercial consumers contributed a 5% premium towards their power bills, over six million green power blocks could be sold each month. One case 3 gasification plant (533 WTPD) could generate approximately 91,700 green power blocks, monthly. Therefore, if 10% of Georgia's consumers purchased green power at a 5% premium, this would support approximately 65 case 3 gasification plants. Currently, the 16 Green EMC cooperatives serve only 900,000 Georgia homes, businesses, factories, and farms, however as new renewable generation comes online; Green EMC will be able to expand the green power option to more of Georgia's consumers.

III. CONCLUDING REMARKS

Currently, biomass accounts for 2.5% of Georgia's electrical supply. From the agricultural sources studied, this research determines there is enough energy from these sources to power nearly 12% of the State’s total electrical demand, or over 31% of the State’s residential consumers at 25% conversion efficiency, which is consistent with the most efficient technologies, gasification (26%) and pyrolysis (20%). However, economic analysis revealed direct-fire; co-fire, gasification, and pyrolysis are not competitive with existing generation facilities. With the inclusion of the renewable energy production incentive (1.8¢/kWh), the gasification generation technology (reduces from 5.2¢ to 3.4¢/kWh) was shown to be .2¢ above the competitive marginal cost rate (3.2¢/kWh), but well below Georgia's 1999 average selling price (6.24¢/kWh).

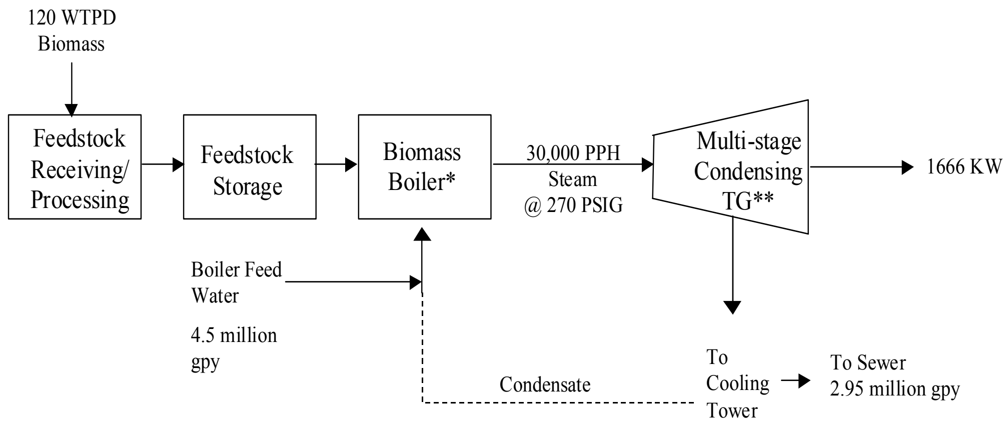
Out of the four technologies studied, gasification and pyrolysis proved to be the most feasible for electricity generation from biomass fuel sources. These technologies can become economically feasible, only with the aid of green power programs. The renewable energy production incentive will further enhance the feasibility of these two technologies, but specific feedstock criteria must be met in order to qualify for this credit. Green technologies that can produce electricity near competitive rates, such as gasification and pyrolysis, could aid in reducing the green power premium for all green power sources.

Further Study

As each technology increased in size and input quantity, the average cost of producing power decreased. At $20/ton of biomass feedstock, Gasification could produce electricity at 6.1¢/kWh, Pyrolysis at 7.6¢/kWh, Co-Fire at 9.9¢/kWh, and Direct-Fire at 12.9¢/kWh. Since the largest facility in each technology produced the least expensive power, further study could determine if even larger facilities could further reduce the cost of electricity from biofuel generation technologies.

APPENDIX I

Figure A-1: Direct Fire Process Flow Diagram, Case # 1 (120 WTPD)



** gpy = gallons per year
KW = kiloWatts
PPH = pounds per hour
PSIG = pounds per square inch gauge
TG = turbine generator
WTPD = wet tons per day

Note: (1) Boiler system design pressure for steam is assumed to be 300 pounds per square inch gauge (psig) with 270 psig turbine inlet pressure in all cases. Higher design pressures would increase capital and maintenance costs but also increase slightly the electric power generated. Note that boiler feed water requirements are to replace that lost to boiler blow down (5%), cooling tower blow down (5%) and evaporation losses in the cooling tower (5%). Sewer water load consists of boiler and cooling tower blow down.

Figure A-2: Direct Fire Process Flow Diagram, Case # 2 (200 WTPD)

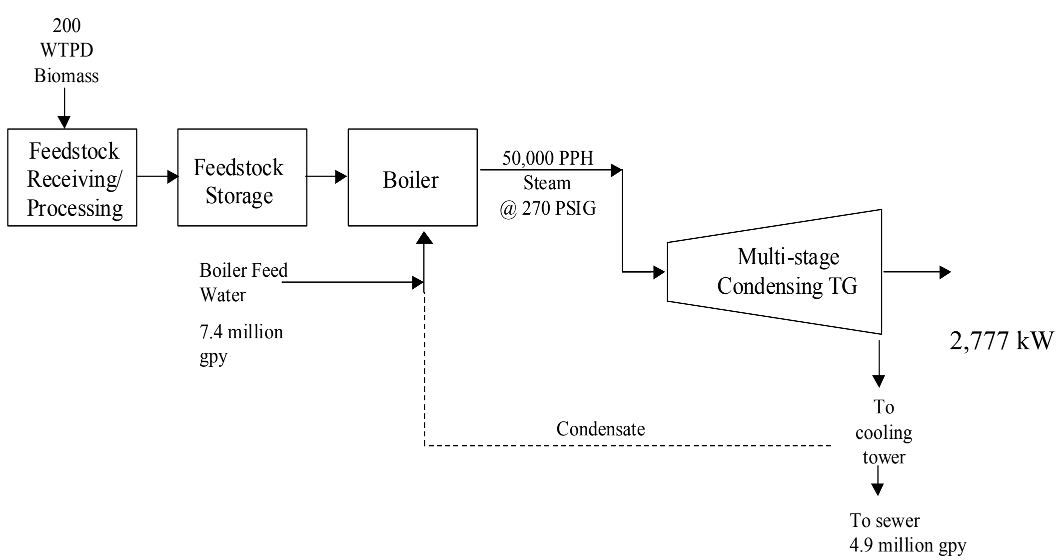


Figure A-3: Direct Fire Process Flow Diagram, Case # 3 (400 WTPD)

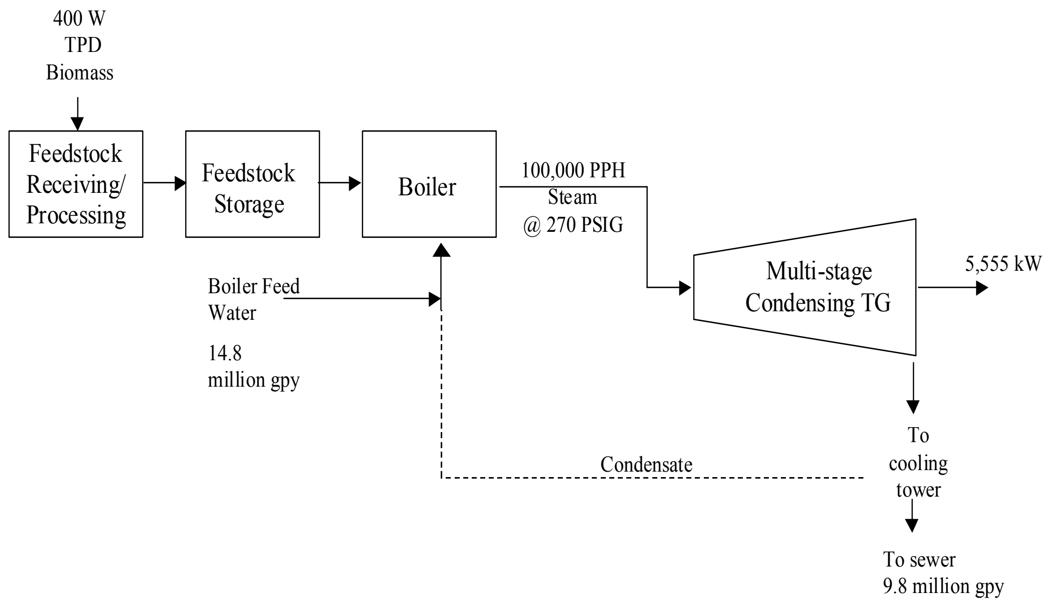


Figure A-4: Co-Fire Process Flow Diagram, Case # 1 (60 WTPD)

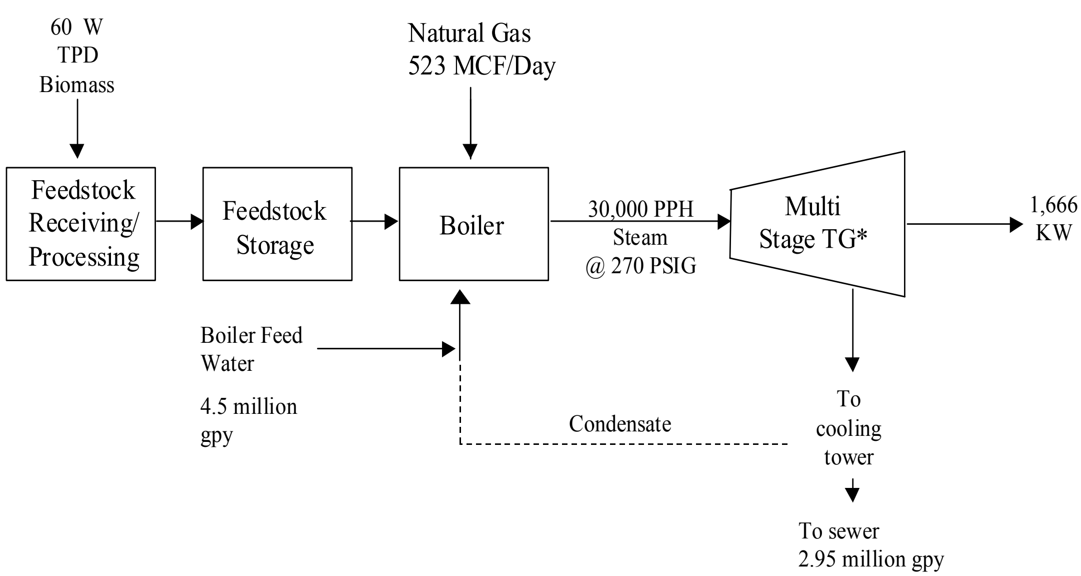


Figure A-5: Co-Fire Process Flow Diagram, Case # 2 (100 WTPD)

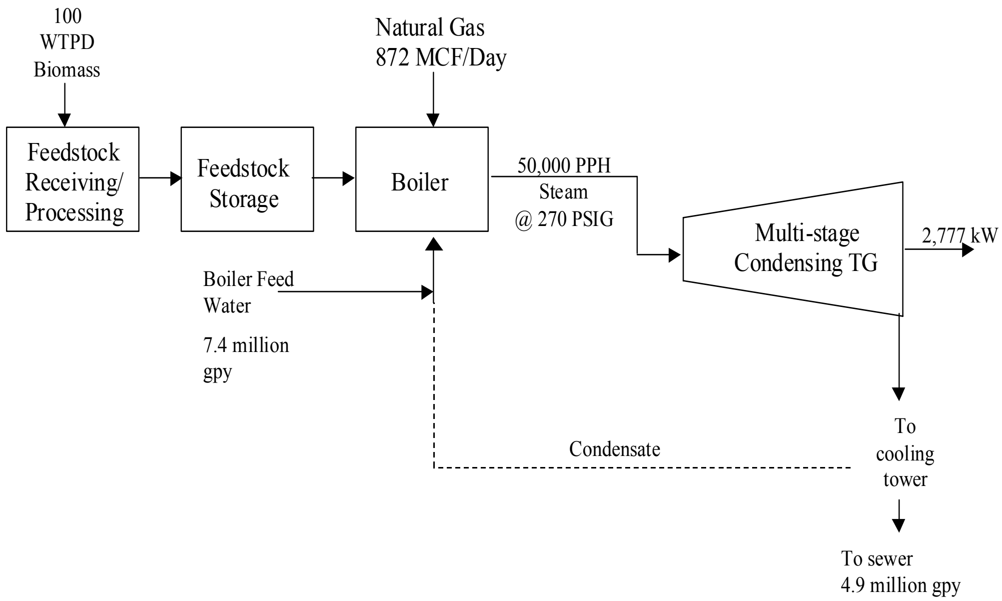


Figure A-6: Co-Fire Process Flow Diagram, Case # 3 (200 WTPD)

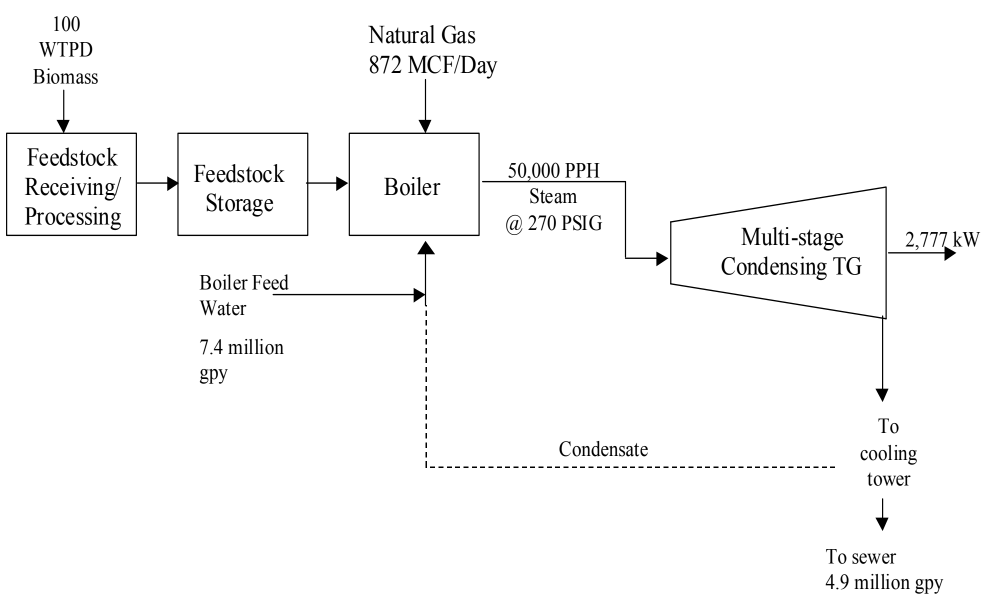
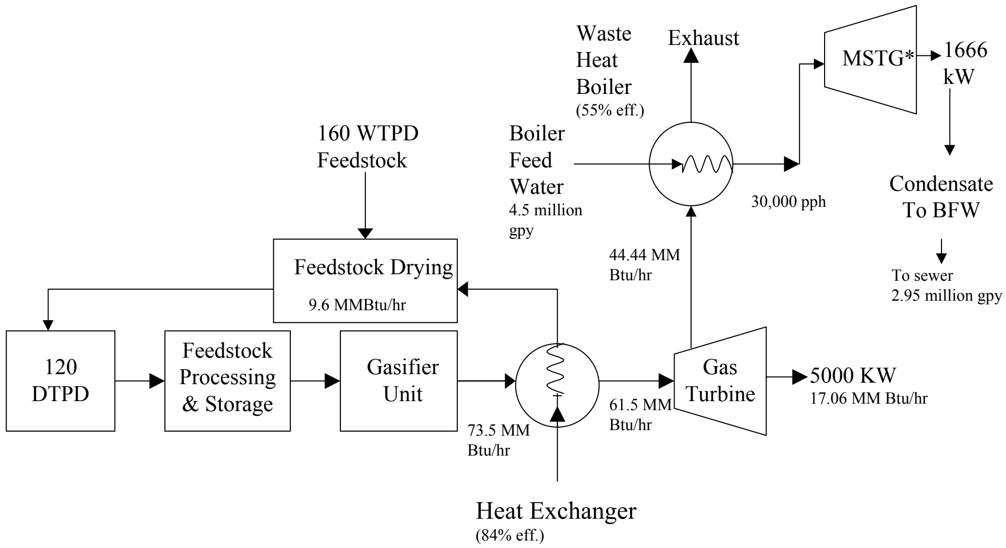


Figure A-7: Gasifier Flow Diagram, Case # 1 (160 WTPD)



* MSTG = Multi-Stage Turbine Generator

Figure A-8: Gasifier Flow Diagram, Case # 2 (267 WTPD)

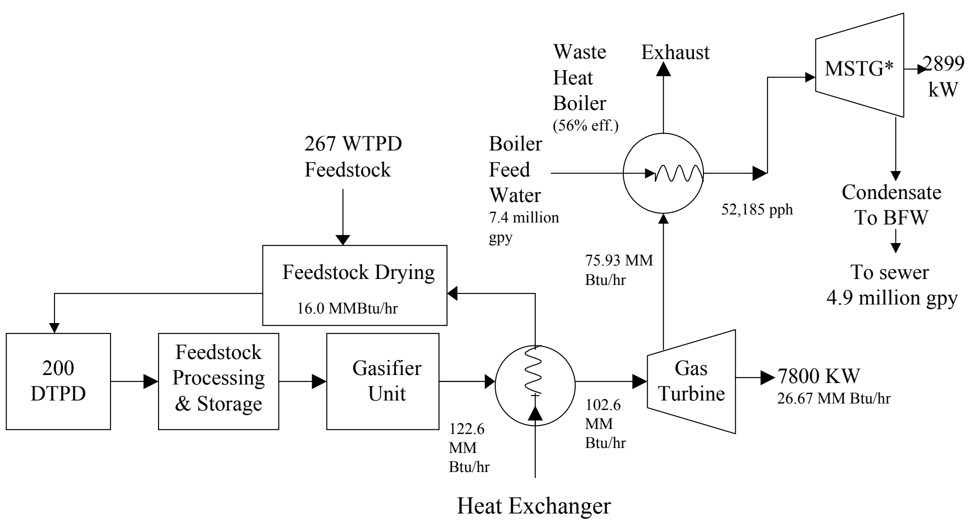


Figure A-9: Gasifier Flow Diagram, Case # 3 (533 WTPD)

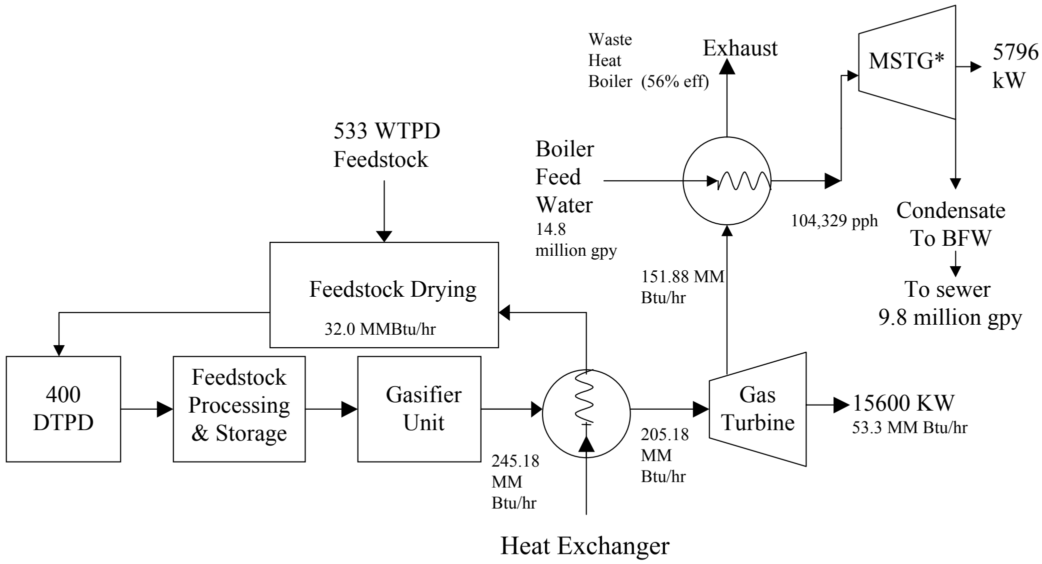
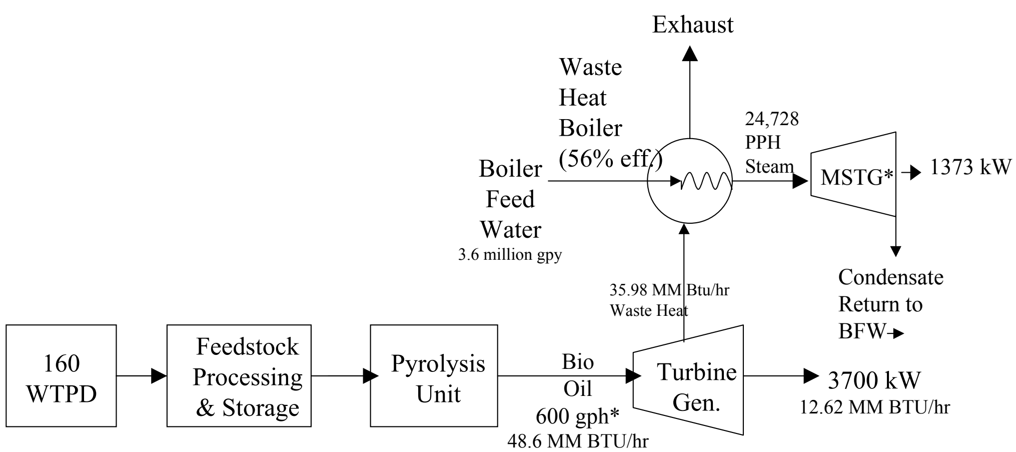


Figure A-10: Pyrolysis Process Flow Diagram, Case # 1 (160 WTPD)



* MSTG = Multi-Stage Turbine Generator
gph = Gallons per Hour

Figure A-11: Pyrolysis Process Flow Diagram, Case # 2 (320 WTPD)

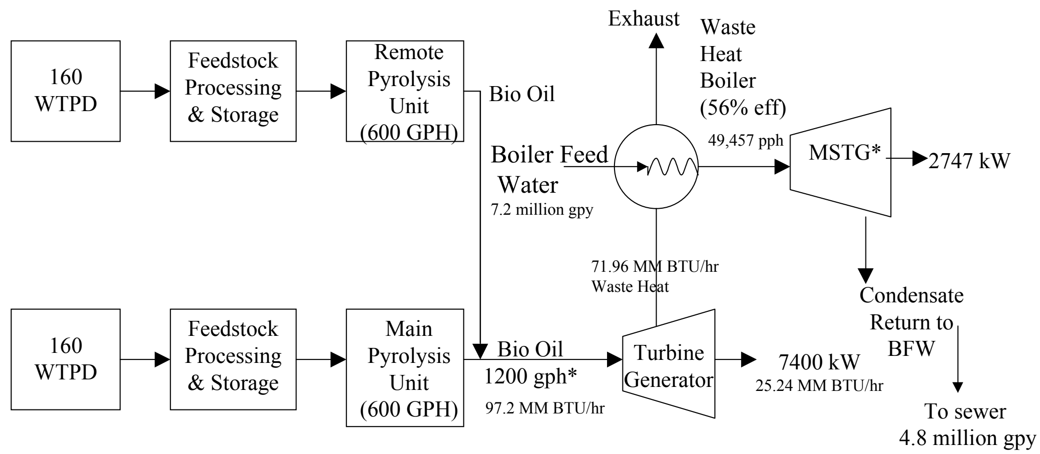
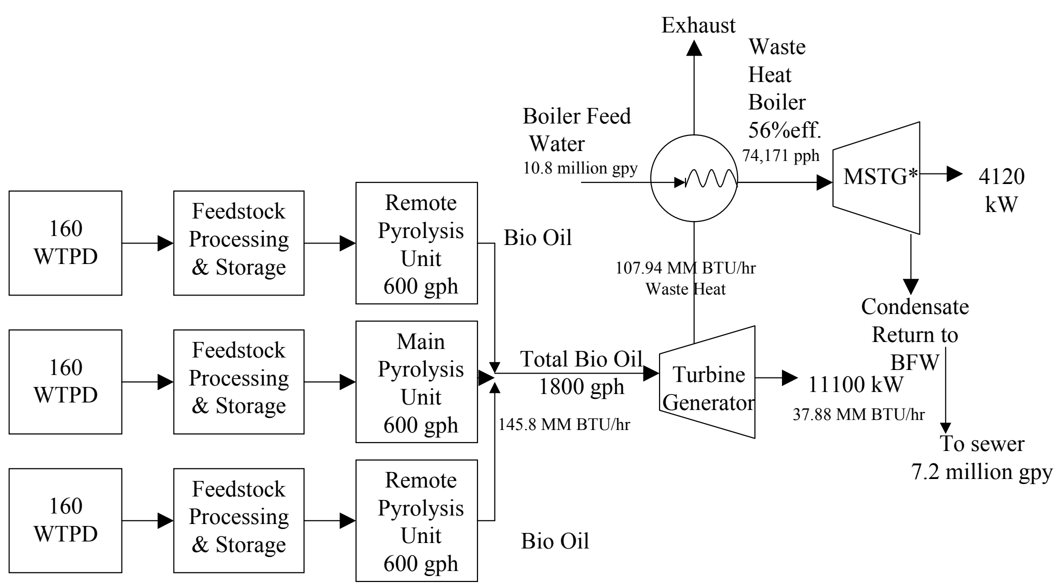


Figure A-12: Pyrolysis Process Flow Diagram, Case # 3 (480 WTPD)



APPENDIX II

Direct Fire Generation - Full Capacity					
	Case # 1				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	1,666			
	Internal Power Used (kWh)	280			
	Net Generating Capacity (kWh)	1,386			
	Total Quantity of Electricity Sold (kWh per Year)	12,141,360			
	Total Quantity of Electricity Produced per Year	11,476,080			
	Biomass Input (WTPD)	120			
	Biomass Input (WT per Year)	41,400			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	277			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 85,000	28%	$ 108,800	$ 0.008961
2	Accounting Support	$ 50,000	28%	$ 64,000	$ 0.005271
3	Clerical Support	$ 20,000	28%	$ 25,600	$ 0.002108
	Total	$ 155,000	28%	$ 198,400	$ 0.016341
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	665,280	$ 0.0500	$ 33,264	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	41,400	$ 10	$ 414,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	41,400	$ 20	$ 828,000	$ 0.068197
2.3	Fuel Costs per Year (High at $35/ton)	41,400	$ 35	$ 1,449,000	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	3312	$ 20.00	$ 66,240	$ 0.005456
4	Water and Water Treatment			$ 22,000	$ 0.001812
		Employees	Averaage Salary		
5	Labor	8	$ 30,000	$ 240,000	$ 0.019767
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 240,000	7%	$ 16,800	$ 0.001384
7	Miscellaneous			$ 39,000	$ 0.003212
		Total Capital	Percent of Capital		
8	Yearly Taxes and Insurance Costs	$ 5,196,000	1.50%	$ 77,940	$ 0.006419
9	Yearly Maintenance Costs	$ 5,196,000	2.00%	$ 103,920	$ 0.008559
	Sub-total (Low Fuel Cost $10/ton)			$ 1,013,164	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 1,427,164	$ 0.117546
	Sub-total (High Fuel Cost $35/ton)			$ 2,048,164	NA
		Rate	2 Months Working Capital	Total $	
10.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 168,860.67	$ 16,886	NA
10.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 237,860.67	$ 23,786	$ 0.001959
10.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 341,360.67	$ 34,136	NA
	Total (Low Fuel Cost $10/ton)			$ 1,030,050	NA
	Total (Medium Fuel Cost $20/ton)			$ 1,450,950	$ 0.119505
	Total (High Fuel Cost $35/ton)			$ 2,082,300	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 59,400	$ 0.004892
2	Depreciation - Equipment	0	10	$ 250,500	$ 0.020632
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 1,188,000	5%	$ 29,700	$ 0.002446
4	Interest on Investment - Equipment	$ 2,795,000	5%	$ 69,875	$ 0.005755
	Total			$ 409,475	$ 0.033726
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 1,637,925	$ 0.134905
	Medium Fuel Cost $20/ton			$ 2,058,825	$ 0.169571
	High Fuel Cost $35/ton			$ 2,690,175	$ 0.221571

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 165,000
5	Blending Equipment				$ 75,000
6	Conveyors				$ 125,000
	Total				$ 600,000
Operational Equipment					
1	Power Generation Equipment				$ 1,640,000
2	Demineralizer System				$ 115,000
3	Boiler				$ 290,000
4	Instrumentation & Controls				$ 150,000
	Total				$ 2,195,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 100,000
2	Plant Buildings				$ 388,000
3	Eng/Permitting				$ 247,000
4	Fuel Processing Building				$ 700,000
5	Fuel Storage Bins				$ 100,000
	Total				$ 1,535,000
	Sub-Total				$ 4,330,000
	Contingency (20%)				$ 866,000
	Total Capital				$ 5,196,000

Direct Fire Generation - Full Capacity					
	Case # 2				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	2,777			
	Internal Power Used (kWh)	468			
	Net Generating Capacity (kWh)	2,309			
	Total Quantity of Electricity Sold (kWh per Year)	20,226,840			
	Total Quantity of Electricity Produced per Year	19,118,520			
	Biomass Input (WTPD)	200			
	Biomass Input (WT per Year)	69,000			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	277			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 100,000	28%	$ 128,000	$ 0.006328
2	Accounting Support	$ 70,000	28%	$ 89,600	$ 0.004430
3	Clerical Support	$ 44,000	28%	$ 56,320	$ 0.002784
	Total	$ 214,000	28%	$ 273,920	$ 0.013542
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	1,108,320	$ 0.0500	$ 55,416	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	69,000	$ 10	$ 690,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	69,000	$ 20	$ 1,380,000	$ 0.068226
2.3	Fuel Costs per Year (High at $35/ton)	69,000	$ 35	$ 2,415,000	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	5520	$ 20.00	$ 110,400	$ 0.005458
4	Water and Water Treatment			$ 57,000	$ 0.002818
		Employees	Averaage Salary		
5	Labor	8	$ 30,000	$ 240,000	$ 0.011865
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 240,000	7%	$ 16,800	$ 0.000831
7	Miscellaneous			$ 39,000	$ 0.001928
		Total Capital	Percent of Capital		
8	Yearly Taxes and Insurance Costs	$ 7,188,000	1.50%	$ 107,820	$ 0.005331
9	Yearly Maintenance Costs	$ 7,188,000	2.00%	$ 143,760	$ 0.007107
	Sub-total (Low Fuel Cost $10/ton)			$ 1,460,196	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 2,150,196	$ 0.106304
	Sub-total (High Fuel Cost $35/ton)			$ 3,185,196	NA
		Rate	2 Months Working Capital	Total $	
10.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 243,366.00	$ 24,337	NA
10.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 358,366.00	$ 35,837	$ 0.001772
10.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 530,866.00	$ 53,087	NA
	Total (Low Fuel Cost $10/ton)			$ 1,484,533	NA
	Total (Medium Fuel Cost $20/ton)			$ 2,186,033	$ 0.108076
	Total (High Fuel Cost $35/ton)			$ 3,238,283	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 93,350	$ 0.004615
2	Depreciation - Equipment	0	10	$ 316,000	$ 0.015623
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 1,867,000	5%	$ 46,675	$ 0.002308
4	Interest on Investment - Equipment	$ 3,548,000	5%	$ 88,700	$ 0.004385
	Total			$ 544,725	$ 0.026931
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 2,303,178	$ 0.113867
	Medium Fuel Cost $20/ton			$ 3,004,678	$ 0.148549
	High Fuel Cost $35/ton			$ 4,056,928	$ 0.200571

Feedstock Receiving and Processing						
1	Feedstock Truck Dump				$	100,000
2	Front End Loader				$	120,000
3	Metal Removal Equipment				$	15,000
4	Grinding/Sizing Equipment				$	185,000
5	Blending Equipment				$	100,000
6	**Conveyors**				$	125,000
	Total				$	645,000
Operational Equipment						
1	Power Generation Equipment				$	2,120,000
2	Demineralizer System				$	170,000
3	Boiler				$	388,000
4	Instrumentation & Controls				$	225,000
	Total				$	2,903,000
Land and Infrastructure						
1	Land/ Site Preparation				$	150,000
2	Plant Buildings				$	512,000
3	Eng/Permitting				$	425,000
4	Fuel Processing Building				$	1,155,000
5	Fuel Storage Bins				$	200,000
	Total				$	2,442,000
	Sub-Total				$	5,990,000
	Contingency (20%)				$	1,198,000
	Total Capital				$	7,188,000

Direct Fire Generation - Full Capacity					
	Case # 3				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	5,555			
	Internal Power Used (kWh)	932			
	Net Generating Capacity (kWh)	4,623			
	Total Quantity of Electricity Sold (kWh per Year)	40,497,480			
	Total Quantity of Electricity Produced per Year	38,278,440			
	Biomass Input (WTPD)	400			
	Biomass Input (WT per Year)	138,000			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	277			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 110,000	28%	$ 140,800	$ 0.003477
2	Accounting Support	$ 90,000	28%	$ 115,200	$ 0.002845
3	Clerical Support	$ 75,000	28%	$ 96,000	$ 0.002371
	Total	$ 275,000	28%	$ 352,000	$ 0.008692
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	2,219,040	$ 0.0500	$ 110,952	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	138,000	$ 10	$ 1,380,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	138,000	$ 20	$ 2,760,000	$ 0.068152
2.3	Fuel Costs per Year (High at $35/ton)	138,000	$ 35	$ 4,830,000	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	11040	$ 20.00	$ 220,800	$ 0.005452
4	Water and Water Treatment			$ 159,000	$ 0.003926
		Employees	Averaage Salary		
5	Labor	8	$ 30,000	$ 240,000	$ 0.005926
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 240,000	7%	$ 16,800	$ 0.000415
7	Miscellaneous			$ 39,000	$ 0.000963
		Total Capital	Percent of Capital		
8	Yearly Taxes and Insurance Costs	$ 11,574,000	1.50%	$ 173,610	$ 0.004287
9	Yearly Maintenance Costs	$ 11,574,000	2.00%	$ 231,480	$ 0.005716
	Sub-total (Low Fuel Cost $10/ton)			$ 2,571,642	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 3,951,642	$ 0.097577
	Sub-total (High Fuel Cost $35/ton)			$ 6,021,642	NA
		Rate	2 Months Working Capital	Total $	
10.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 428,607.00	$ 42,861	NA
10.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 658,607.00	$ 65,861	$ 0.001626
10.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 1,003,607.00	$ 100,361	NA
	Total (Low Fuel Cost $10/ton)			$ 2,614,503	NA
	Total (Medium Fuel Cost $20/ton)			$ 4,017,503	$ 0.099204
	Total (High Fuel Cost $35/ton)			$ 6,122,003	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 149,500	$ 0.003692
2	Depreciation - Equipment	0	10	$ 497,000	$ 0.012272
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 2,990,000	5%	$ 74,750	$ 0.001846
4	Interest on Investment - Equipment	$ 5,870,000	5%	$ 146,750	$ 0.003624
	Total			$ 868,000	$ 0.021433
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 3,834,503	$ 0.094685
	Medium Fuel Cost $20/ton			$ 5,237,503	$ 0.129329
	High Fuel Cost $35/ton			$ 7,342,003	$ 0.181295

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 225,000
5	Blending Equipment				$ 125,000
6	**Conveyors**				$ 125,000
	Total				$ 710,000
Operational Equipment					
1	Power Generation Equipment				$ 3,700,000
2	Demineralizer System				$ 260,000
3	Boiler				$ 900,000
4	Instrumentation & Controls				$ 300,000
	Total				$ 5,160,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 200,000
2	Plant Buildings				$ 600,000
3	Eng/Permitting				$ 585,000
4	Fuel Processing Building				$ 1,990,000
5	Fuel Storage Bins				$ 400,000
	Total				$ 3,775,000
	Sub-Total				$ 9,645,000
	Contingency (20%)				$ 1,929,000
	Total Capital				$ 11,574,000

Co-Fire Generation - Full Capacity					
	Case # 1				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	1,666			
	Internal Power Used (kWh)	140			
	Net Generating Capacity (kWh)	1,526			
	Total Quantity of Electricity Sold (kWh per Year)	13,367,760			
	Total Quantity of Electricity Produced per Year	12,635,280			
	Biomass Input (WTPD)	60			
	Biomass Input (WT per Year)	20,700			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	610			
Operating Cost					
				Total $	**$ / kWh ($20/Wet ton)**
Overhead and Administration		Salary	Benefits		
1	General Manger	$ 85,000	28%	$ 108,800	$ 0.008139
2	Accounting Support	$ 50,000	28%	$ 64,000	$ 0.004788
3	Clerical Support	$ 20,000	28%	$ 25,600	$ 0.001915
	Total	$ 155,000	28%	$ 198,400	$ 0.014842
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	732,480	$ 0.0500	$ 36,624	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Biomass Costs per Year (Low at $10/ton)	20,700	$ 10	$ 207,000	NA
2.2	Biomass Costs per Year (Medium at $20/ton)	20,700	$ 20	$ 414,000	$ 0.030970
2.3	Biomass Costs per Year (High at $35/ton)	20,700	$ 35	$ 724,500	NA
		Quantity (MCF/day)	Gas Costs ($/MCF)		
3	Naturla Gas Costs per Year	523	$ 1.38	$ 249,000	$ 0.018627
		Ash (Tons per Yr)	Disposal $/ton		
4	Ash Disposal Cost per Year	1656	$ 20.00	$ 33,120	$ 0.002478
5	Water and Water Treatment			$ 22,000	$ 0.001646
		Employees	Averaage Salary		
6	Labor	8	$ 30,000	$ 240,000	$ 0.017954
		Total Salary	Workers Comp.		
7	Workers' Compensation	$ 240,000	7%	$ 16,800	$ 0.001257
8	Miscellaneous			$ 39,000	$ 0.002917
		Total Capital	Percent of Capital		
9	Yearly Taxes and Insurance Costs	$ 4,587,000	1.50%	$ 68,805	$ 0.005147
10	Yearly Maintenance Costs	$ 4,587,000	2.00%	$ 91,740	$ 0.006863
	Sub-total (Low Fuel Cost $10/ton)			$ 1,004,089	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 1,211,089	$ 0.090598
	Sub-total (High Fuel Cost $35/ton)			$ 1,521,589	NA
		Rate	2 Months Working Capital	Total $	
11.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 167,348.22	$ 16,735	NA
11.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 201,848.22	$ 20,185	$ 0.001510
11.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 253,598.22	$ 25,360	NA
	Total (Low Fuel Cost $10/ton)			$ 1,020,824	NA
	Total (Medium Fuel Cost $20/ton)			$ 1,231,274	$ 0.092108
	Total (High Fuel Cost $35/ton)			$ 1,546,949	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 37,050	$ 0.002772
2	Depreciation - Equipment	0	10	$ 247,000	$ 0.018477
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 741,000	5%	$ 18,525	$ 0.001386
4	Interest on Investment - Equipment	$ 2,734,500	5%	$ 68,363	$ 0.005114
	Total			$ 370,938	$ 0.027749
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 1,590,162	$ 0.118955
	Medium Fuel Cost $20/ton			$ 1,800,612	$ 0.134698
	High Fuel Cost $35/ton			$ 2,116,287	$ 0.158313

Feedstock Receiving and Processing		
1	Feedstock Truck Dump	$ 100,000
2	Front End Loader	$ 120,000
3	Metal Removal Equipment	$ 15,000
4	Grinding/Sizing Equipment	$ 145,000
5	Blending Equipment	$ 60,000
6	Conveyors	$ 125,000
	Total	$ 565,000
Operational Equipment		
1	Power Generation Equipment	$ 1,640,000
2	Demineralizer System	$ 115,000
3	Boiler	$ 264,500
4	Instrumentation & Controls	$ 150,000
	Total	$ 2,169,500
Land and Infrastructure		
1	Land/ Site Preparation	$ 100,000
2	Plant Buildings	$ 331,000
3	Eng/Permitting	$ 247,000
4	Fuel Processing Building	$ 350,000
5	Fuel Storage Bins	$ 60,000
	Total	$ 1,088,000
	Sub-Total	$ 3,822,500
	Contingency (20%)	$ 764,500
	Total Capital	$ 4,587,000

Co-Fire Generation - Full Capacity					
	Case # 2				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	2,777			
	Internal Power Used (kWh)	234			
	Net Generating Capacity (kWh)	2,543			
	Total Quantity of Electricity Sold (kWh per Year)	22,276,680			
	Total Quantity of Electricity Produced per Year	21,056,040			
	Biomass Input (WTPD)	100			
	Biomass Input (WT per Year)	34,500			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	610			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 100,000	28%	$ 128,000	$ 0.005746
2	Accounting Support	$ 70,000	28%	$ 89,600	$ 0.004022
3	Clerical Support	$ 44,000	28%	$ 56,320	$ 0.002528
	Total	$ 214,000	28%	$ 273,920	$ 0.012296
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	1,220,640	$ 0.0500	$ 61,032	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	34,500	$ 10	$ 345,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	34,500	$ 20	$ 690,000	$ 0.030974
2.3	Fuel Costs per Year (High at $35/ton)	34,500	$ 35	$ 1,207,500	NA
		Quantity (MCF/day)	Gas Costs ($/MCF)		
3	Naturla Gas Costs per Year	872	$ 1.38	$ 415,159	$ 0.018636
		Ash (Tons per Yr)	Disposal $/ton		
4	Ash Disposal Cost per Year	2760	$ 20.00	$ 55,200	$ 0.002478
5	Water and Water Treatment			$ 57,000	$ 0.002559
		Employees	Averaage Salary		
6	Labor	8	$ 30,000	$ 240,000	$ 0.010774
		Total Salary	Workers Comp.		
7	Workers' Compensation	$ 240,000	7%	$ 16,800	$ 0.000754
8	Miscellaneous			$ 39,000	$ 0.001751
		Total Capital	Percent of Capital		
9	Yearly Taxes and Insurance Costs	$ 6,153,600	1.50%	$ 92,304	$ 0.004144
10	Yearly Maintenance Costs	$ 6,153,600	2.00%	$ 123,072	$ 0.005525
	Sub-total (Low Fuel Cost $10/ton)			$ 1,444,567	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 1,789,567	$ 0.080334
	Sub-total (High Fuel Cost $35/ton)			$ 2,307,067	NA
		Rate	2 Months Working Capital	Total $	
11.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 240,761.20	$ 24,076	NA
11.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 298,261.20	$ 29,826	$ 0.001339
11.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 384,511.20	$ 38,451	NA
	Total (Low Fuel Cost $10/ton)			$ 1,468,643	NA
	Total (Medium Fuel Cost $20/ton)			$ 1,819,393	$ 0.081673
	Total (High Fuel Cost $35/ton)			$ 2,345,518	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 54,175	$ 0.002432
2	Depreciation - Equipment	0	10	$ 310,500	$ 0.013938
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 1,083,500	5%	$ 27,088	$ 0.001216
4	Interest on Investment - Equipment	$ 3,469,500	5%	$ 86,738	$ 0.003894
	Total			$ 478,500	$ 0.021480
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 2,221,063	$ 0.099704
	Medium Fuel Cost $20/ton			$ 2,571,813	$ 0.115449
	High Fuel Cost $35/ton			$ 3,097,938	$ 0.139066

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 160,000
5	Blending Equipment				$ 70,000
6	Conveyors				$ 125,000
	Total				$ 590,000
Operational Equipment					
1	Power Generation Equipment				$ 2,120,000
2	Demineralizer System				$ 170,000
3	Boiler				$ 364,500
4	Instrumentation & Controls				$ 225,000
	Total				$ 2,879,500
Land and Infrastructure					
1	Land/ Site Preparation				$ 150,000
2	Plant Buildings				$ 406,000
3	Eng/Permitting				$ 425,000
4	Fuel Processing Building				$ 577,500
5	Fuel Storage Bins				$ 100,000
	Total				$ 1,658,500
	Sub-Total				$ 5,128,000
	Contingency (20%)				$ 1,025,600
	Total Capital				$ 6,153,600

Co-Fire Generation - Full Capacity					
	Case # 3				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	5,555			
	Internal Power Used (kWh)	460			
	Net Generating Capacity (kWh)	5,095			
	Total Quantity of Electricity Sold (kWh per Year)	44,632,200			
	Total Quantity of Electricity Produced per Year	42,186,600			
	Biomass Input (WTPD)	200			
	Biomass Input (WT per Year)	69,000			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	611			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 110,000	28%	$ 140,800	$ 0.003155
2	Accounting Support	$ 90,000	28%	$ 115,200	$ 0.002581
3	Clerical Support	$ 75,000	28%	$ 96,000	$ 0.002151
	Total	$ 275,000	28%	$ 352,000	$ 0.007887
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	2,445,600	$ 0.0500	$ 122,280	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	69,000	$ 10	$ 690,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	69,000	$ 20	$ 1,380,000	$ 0.030919
2.3	Fuel Costs per Year (High at $35/ton)	69,000	$ 35	$ 2,415,000	NA
		Quantity (MCF/day)	Gas Costs ($/MCF)		
3	Naturla Gas Costs per Year	1744	$ 1.38	$ 830,318	$ 0.018604
		Ash (Tons per Yr)	Disposal $/ton		
4	Ash Disposal Cost per Year	5520	$ 20.00	$ 110,400	$ 0.002474
5	Water and Water Treatment			$ 159,000	$ 0.003562
		Employees	Averaage Salary		
6	Labor	8	$ 30,000	$ 240,000	$ 0.005377
		Total Salary	Workers Comp.		
7	Workers' Compensation	$ 240,000	7%	$ 16,800	$ 0.000376
8	Miscellaneous			$ 39,000	$ 0.000874
		Total Capital	Percent of Capital		
9	Yearly Taxes and Insurance Costs	$ 9,751,200	1.50%	$ 146,268	$ 0.003277
10	Yearly Maintenance Costs	$ 9,751,200	2.00%	$ 195,024	$ 0.004370
	Sub-total (Low Fuel Cost $10/ton)			$ 2,549,090	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 3,239,090	$ 0.072573
	Sub-total (High Fuel Cost $35/ton)			$ 4,274,090	NA
		Rate	2 Months Working Capital	Total $	
11.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 424,848.40	$ 42,485	NA
11.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 539,848.40	$ 53,985	$ 0.001210
11.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 712,348.40	$ 71,235	NA
	Total (Low Fuel Cost $10/ton)			$ 2,591,575	NA
	Total (Medium Fuel Cost $20/ton)			$ 3,293,075	$ 0.073782
	Total (High Fuel Cost $35/ton)			$ 4,345,325	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 83,150	$ 0.001863
2	Depreciation - Equipment	0	10	$ 493,500	$ 0.011057
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 1,663,000	5%	$ 41,575	$ 0.000932
4	Interest on Investment - Equipment	$ 5,678,000	5%	$ 141,950	$ 0.003180
	Total			$ 760,175	$ 0.017032
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 3,703,750	$ 0.082984
	Medium Fuel Cost $20/ton			$ 4,405,250	$ 0.098701
	High Fuel Cost $35/ton			$ 5,457,500	$ 0.122277

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 185,000
5	Blending Equipment				$ 100,000
6	**Conveyors**				$ 125,000
	Total				$ 645,000
Operational Equipment					
1	Power Generation Equipment				$ 3,730,000
2	Demineralizer System				$ 260,000
3	Boiler				$ 743,000
4	Instrumentation & Controls				$ 300,000
	Total				$ 5,033,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 200,000
2	Plant Buildings				$ 468,000
3	Eng/Permitting				$ 585,000
4	Fuel Processing Building				$ 995,000
5	Fuel Storage Bins				$ 200,000
	Total				$ 2,448,000
	Sub-Total				$ 8,126,000
	Contingency (20%)				$ 1,625,200
	Total Capital				$ 9,751,200

Gasification Generation - Full Capacity					
	Case # 1				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	6,666			
	Internal Power Used (kWh)	372			
	Net Generating Capacity (kWh)	6,294			
	Total Quantity of Electricity Sold (kWh per Year)	55,135,440			
	Total Quantity of Electricity Produced per Year	52,114,320			
	Biomass Input (WTPD)	160			
	Biomass Input (WT per Year)	55,200			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	944			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 85,000	28%	$ 108,800	$ 0.001973
2	Accounting Support	$ 50,000	28%	$ 64,000	$ 0.001161
3	Clerical Support	$ 20,000	28%	$ 25,600	$ 0.000464
	Total	$ 155,000	28%	$ 198,400	$ 0.003598
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	3,021,120	$ 0.0500	$ 151,056	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	55,200	$ 10	$ 552,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	55,200	$ 20	$ 1,104,000	$ 0.020023
2.3	Fuel Costs per Year (High at $35/ton)	55,200	$ 35	$ 1,932,000	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	650	$ 20.00	$ 13,000	$ 0.000236
4	Water and Water Treatment			$ 22,000	$ 0.000399
		Employees	Averaage Salary		
5	Labor	18	$ 30,000	$ 540,000	$ 0.009794
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 540,000	7%	$ 37,800	$ 0.000686
7	Miscellaneous			$ 39,000	$ 0.000707
8	Inert Gas			$ 10,000	$ 0.000181
		Total Capital	Percent of Capital		
9	Yearly Taxes and Insurance Costs	$ 19,122,000	1.50%	$ 286,830	$ 0.005202
10	Yearly Maintenance Costs	$ 19,122,000	2.00%	$ 382,440	$ 0.006936
	Sub-total (Low Fuel Cost $10/ton)			$ 2,034,126	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 2,586,126	$ 0.046905
	Sub-total (High Fuel Cost $35/ton)			$ 3,414,126	NA
		Rate	2 Months Working Capital	Total $	
11.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 339,021.00	$ 33,902	NA
11.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 431,021.00	$ 43,102	$ 0.000782
11.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 569,021.00	$ 56,902	NA
	Total (Low Fuel Cost $10/ton)			$ 2,068,028	NA
	Total (Medium Fuel Cost $20/ton)			$ 2,629,228	$ 0.047687
	Total (High Fuel Cost $35/ton)			$ 3,471,028	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 65,500	$ 0.001188
2	Depreciation - Equipment	0	10	$ 1,286,800	$ 0.023339
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 1,310,000	5%	$ 32,750	$ 0.000594
4	Interest on Investment - Equipment	$ 14,268,000	5%	$ 356,700	$ 0.006470
	Total			$ 1,741,750	$ 0.031590
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 4,008,178	$ 0.072697
	Medium Fuel Cost $20/ton			$ 4,569,378	$ 0.082876
	High Fuel Cost $35/ton			$ 5,411,178	$ 0.098143

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 165,000
5	Blending Equipment				$ 75,000
6	Conveyors				$ 125,000
	Total				$ 600,000
Operational Equipment					
1	Power Generation Equipment				$ 5,243,000
2	Gasification Process				$ 4,900,000
3	Interconnections				$ 900,000
4	Waste Heat Boiler				$ 2,125,000
5	Heat Recovery				$ 500,000
	Total				$ 13,668,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 110,000
2	Plant Buildings				$ 510,000
3	Eng/Permitting				$ 247,000
4	Fuel Processing Building				$ 700,000
5	Fuel Storage Bins				$ 100,000
	Total				$ 1,667,000
	Sub-Total				$ 15,935,000
	Contingency (20%)				$ 3,187,000
	Total Capital				$ 19,122,000

Gasification Generation - Full Capacity					
	Case # 2				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	10,699			
	Internal Power Used (kWh)	638			
	Net Generating Capacity (kWh)	10,061			
	Total Quantity of Electricity Sold (kWh per Year)	88,134,360			
	Total Quantity of Electricity Produced per Year	83,305,080			
	Biomass Input (WTPD)	267			
	Biomass Input (WT per Year)	92,115			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	904			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 100,000	28%	$ 128,000	$ 0.001452
2	Accounting Support	$ 70,000	28%	$ 89,600	$ 0.001017
3	Clerical Support	$ 44,000	28%	$ 56,320	$ 0.000639
	Total	$ 214,000	28%	$ 273,920	$ 0.003108
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	4,829,280	$ 0.0500	$ 241,464	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	92,115	$ 10	$ 921,150	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	92,115	$ 20	$ 1,842,300	$ 0.020903
2.3	Fuel Costs per Year (High at $35/ton)	92,115	$ 35	$ 3,224,025	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	1350	$ 20.00	$ 27,000	$ 0.000306
4	Water and Water Treatment			$ 57,000	$ 0.000647
		Employees	Averaage Salary		
5	Labor	18	$ 30,000	$ 540,000	$ 0.006127
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 540,000	7%	$ 37,800	$ 0.000429
7	Miscellaneous			$ 39,000	$ 0.000443
8	Inert Gas			$ 10,000	$ 0.000113
		Total Capital	Percent of Capital		
9	Yearly Taxes and Insurance Costs	$ 26,586,000	1.50%	$ 398,790	$ 0.004525
10	Yearly Maintenance Costs	$ 26,586,000	2.00%	$ 531,720	$ 0.006033
	Sub-total (Low Fuel Cost $10/ton)			$ 2,803,924	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 3,725,074	$ 0.042266
	Sub-total (High Fuel Cost $35/ton)			$ 5,106,799	NA
		Rate	2 Months Working Capital	Total $	
11.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 467,320.67	$ 46,732	NA
11.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 620,845.67	$ 62,085	$ 0.000704
11.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 851,133.17	$ 85,113	NA
	Total (Low Fuel Cost $10/ton)			$ 2,850,656	NA
	Total (Medium Fuel Cost $20/ton)			$ 3,787,159	$ 0.042970
	Total (High Fuel Cost $35/ton)			$ 5,191,912	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 98,350	$ 0.001116
2	Depreciation - Equipment	0	10	$ 1,831,300	$ 0.020779
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 1,967,000	5%	$ 49,175	$ 0.000558
4	Interest on Investment - Equipment	$ 19,613,000	5%	$ 490,325	$ 0.005563
	Total			$ 2,469,150	$ 0.028016
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 5,593,726	$ 0.063468
	Medium Fuel Cost $20/ton			$ 6,530,229	$ 0.074094
	High Fuel Cost $35/ton			$ 7,934,982	$ 0.090033

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 185,000
5	Blending Equipment				$ 100,000
6	Conveyors				$ 125,000
	Total				$ 645,000
Operational Equipment					
1	Power Generation Equipment				$ 7,388,000
2	Gasification Process				$ 7,500,000
3	Interconnections				$ 1,300,000
4	Waste Heat Boiler				$ 2,780,000
5	Heat Recovery				$ 1,700,000
	Total				$ 18,968,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 150,000
2	Plant Buildings				$ 612,000
3	Eng/Permitting				$ 425,000
4	Fuel Processing Building				$ 1,155,000
5	Fuel Storage Bins				$ 200,000
	Total				$ 2,542,000
	Sub-Total				$ 22,155,000
	Contingency (20%)				$ 4,431,000
	Total Capital				$ 26,586,000

Gasification Generation - Full Capacity					
	Case # 3				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	21,396			
	Internal Power Used (kWh)	1,169			
	Net Generating Capacity (kWh)	20,227			
	Total Quantity of Electricity Sold (kWh per Year)	177,188,520			
	Total Quantity of Electricity Produced per Year	167,479,560			
	Biomass Input (WTPD)	533			
	Biomass Input (WT per Year)	183,885			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	911			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 110,000	28%	$ 140,800	$ 0.000795
2	Accounting Support	$ 90,000	28%	$ 115,200	$ 0.000650
3	Clerical Support	$ 75,000	28%	$ 96,000	$ 0.000542
	Total	$ 275,000	28%	$ 352,000	$ 0.001987
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	9,708,960	$ 0.0500	$ 485,448	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	183,885	$ 10	$ 1,838,850	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	183,885	$ 20	$ 3,677,700	$ 0.020756
2.3	Fuel Costs per Year (High at $35/ton)	183,885	$ 35	$ 6,435,975	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	2700	$ 20.00	$ 54,000	$ 0.000305
4	Water and Water Treatment			$ 159,000	$ 0.000897
		Employees	Averaage Salary		
5	Labor	20	$ 30,000	$ 600,000	$ 0.003386
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 600,000	7%	$ 42,000	$ 0.000237
7	Miscellaneous			$ 39,000	$ 0.000220
8	Inert Gas			$ 10,000	$ 0.000056
		Total Capital	Percent of Capital		
9	Yearly Taxes and Insurance Costs	$ 43,902,000	1.50%	$ 658,530	$ 0.003717
10	Yearly Maintenance Costs	$ 43,902,000	2.00%	$ 878,040	$ 0.004955
	Sub-total (Low Fuel Cost $10/ton)			$ 4,764,868	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 6,603,718	$ 0.037269
	Sub-total (High Fuel Cost $35/ton)			$ 9,361,993	NA
		Rate	2 Months Working Capital	Total $	
11.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 794,144.67	$ 79,414	NA
11.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 1,100,619.67	$ 110,062	$ 0.000621
11.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 1,560,332.17	$ 156,033	NA
	Total (Low Fuel Cost $10/ton)			$ 4,844,282	NA
	Total (Medium Fuel Cost $20/ton)			$ 6,713,780	$ 0.037891
	Total (High Fuel Cost $35/ton)			$ 9,518,026	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 160,000	$ 0.000903
2	Depreciation - Equipment	0	10	$ 3,060,000	$ 0.017270
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 3,200,000	5%	$ 80,000	$ 0.000451
4	Interest on Investment - Equipment	$ 32,600,000	5%	$ 815,000	$ 0.004600
	Total			$ 4,115,000	$ 0.023224
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 9,311,282	$ 0.052550
	Medium Fuel Cost $20/ton			$ 11,180,780	$ 0.063101
	High Fuel Cost $35/ton			$ 13,985,026	$ 0.078927

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 225,000
5	Blending Equipment				$ 125,000
6	Conveyors				$ 125,000
	Total				$ 710,000
Operational Equipment					
1	Power Generation Equipment				$ 13,090,000
2	Gasification Process				$ 11,300,000
3	Interconnections				$ 2,000,000
4	Waste Heat Boiler				$ 5,500,000
5	Heat Recovery				$ 1,300,000
	Total				$ 31,890,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 200,000
2	Plant Buildings				$ 810,000
3	Eng/Permitting				$ 585,000
4	Fuel Processing Building				$ 1,990,000
5	Fuel Storage Bins				$ 400,000
	Total				$ 3,985,000
	Sub-Total				$ 36,585,000
	Contingency (20%)				$ 7,317,000
	Total Capital				$ 43,902,000

Pyrolysis Generation - Full Capacity					
	Case # 1				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	5,073			
	Internal Power Used (kWh)	321			
	Net Generating Capacity (kWh)	4,752			
	Total Quantity of Electricity Sold (kWh per Year)	41,627,520			
	Total Quantity of Electricity Produced per Year	39,346,560			
	Biomass Input (WTPD)	160			
	Biomass Input (WT per Year)	55,200			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	713			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 85,000	28%	$ 108,800	$ 0.002614
2	Accounting Support	$ 50,000	28%	$ 64,000	$ 0.001537
3	Clerical Support	$ 20,000	28%	$ 25,600	$ 0.000615
	Total	$ 155,000	28%	$ 198,400	$ 0.004766
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	2,280,960	$ 0.0500	$ 114,048	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	55,200	$ 10	$ 552,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	55,200	$ 20	$ 1,104,000	$ 0.026521
2.3	Fuel Costs per Year (High at $35/ton)	55,200	$ 35	$ 1,932,000	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	875	$ 20.00	$ 17,500	$ 0.000420
4	Water and Water Treatment			$ 22,000	$ 0.000528
		Employees	Averaage Salary		
5	Labor	17	$ 30,000	$ 510,000	$ 0.012252
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 510,000	7%	$ 35,700	$ 0.000858
7	Miscellaneous			$ 39,000	$ 0.000937
		Total Capital	Percent of Capital		
8	Yearly Taxes and Insurance Costs	$ 13,218,000	1.50%	$ 198,270	$ 0.004763
9	Yearly Maintenance Costs	$ 13,218,000	2.00%	$ 264,360	$ 0.006351
	Sub-total (Low Fuel Cost $10/ton)			$ 1,752,878	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 2,304,878	$ 0.055369
	Sub-total (High Fuel Cost $35/ton)			$ 3,132,878	NA
		Rate	2 Months Working Capital	Total $	
10.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 292,146.33	$ 29,215	NA
10.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 384,146.33	$ 38,415	$ 0.000923
10.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 522,146.33	$ 52,215	NA
	Total (Low Fuel Cost $10/ton)			$ 1,782,093	NA
	Total (Medium Fuel Cost $20/ton)			$ 2,343,293	$ 0.056292
	Total (High Fuel Cost $35/ton)			$ 3,185,093	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 45,000	$ 0.001081
2	Depreciation - Equipment	0	10	$ 991,500	$ 0.023818
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 900,000	5%	$ 22,500	$ 0.000541
4	Interest on Investment - Equipment	$ 9,915,000	5%	$ 247,875	$ 0.005955
	Total			$ 1,306,875	$ 0.031394
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 3,287,368	$ 0.078971
	Medium Fuel Cost $20/ton			$ 3,848,568	$ 0.092452
	High Fuel Cost $35/ton			$ 4,690,368	$ 0.112675

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 100,000
2	Front End Loader				$ 120,000
3	Metal Removal Equipment				$ 15,000
4	Grinding/Sizing Equipment				$ 165,000
5	Blending Equipment				$ 75,000
6	Conveyors				$ 125,000
	Total				$ 600,000
Operational Equipment					
1	Power Generation Equipment				$ 5,890,000
2	Demineralizer System				$ 1,300,000
3	Boiler				$ 2,000,000
4	Instrumentation & Controls				$ 125,000
	Total				$ 9,315,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 100,000
2	Plant Buildings				$ 100,000
3	Eng/Permitting				$ 100,000
4	Fuel Processing Building				$ 700,000
5	Fuel Storage Bins				$ 100,000
	Total				$ 1,100,000
	Sub-Total				$ 11,015,000
	Contingency (20%)				$ 2,203,000
	Total Capital				$ 13,218,000

Pyrolysis Generation - Full Capacity					
	Case # 2				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	10,147			
	Internal Power Used (kWh)	577			
	Net Generating Capacity (kWh)	9,570			
	Total Quantity of Electricity Sold (kWh per Year)	83,833,200			
	Total Quantity of Electricity Produced per Year	79,239,600			
	Biomass Input (WTPD)	320			
	Biomass Input (WT per Year)	110,400			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	718			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 100,000	28%	$ 128,000	$ 0.001527
2	Accounting Support	$ 70,000	28%	$ 89,600	$ 0.001069
3	Clerical Support	$ 44,000	28%	$ 56,320	$ 0.000672
	Total	$ 214,000	28%	$ 273,920	$ 0.003267
Variable Cost of Operation		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	4,593,600	$ 0.0500	$ 229,680	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	110,400	$ 10	$ 1,104,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	110,400	$ 20	$ 2,208,000	$ 0.026338
2.3	Fuel Costs per Year (High at $35/ton)	110,400	$ 35	$ 3,864,000	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	1750	$ 20.00	$ 35,000	$ 0.000417
4	Water and Water Treatment			$ 57,000	$ 0.000680
		Employees	Average Salary	Total $	
5	Labor	34	$ 30,000	$ 1,020,000	$ 0.012167
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 1,020,000	7%	$ 71,400	$ 0.000852
7	Miscellaneous			$ 39,000	$ 0.000465
		Total Capital	Percent of Capital		
8	Yearly Taxes and Insurance Costs	$ 21,642,000	1.50%	$ 324,630	$ 0.003872
9	Yearly Maintenance Costs	$ 21,642,000	2.00%	$ 432,840	$ 0.005163
	Sub-total (Low Fuel Cost $10/ton)			$ 3,313,550	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 4,417,550	$ 0.052695
	Sub-total (High Fuel Cost $35/ton)			$ 6,073,550	NA
		Rate	2 Months Working Capital	Total $	
10.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 552,258.33	$ 55,226	NA
10.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 736,258.33	$ 73,626	$ 0.000878
10.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 1,012,258.33	$ 101,226	NA
	Total (Low Fuel Cost $10/ton)			$ 3,368,776	NA
	Total (Medium Fuel Cost $20/ton)			$ 4,491,176	$ 0.053573
	Total (High Fuel Cost $35/ton)			$ 6,174,776	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 77,750	$ 0.000927
2	Depreciation - Equipment	0	10	$ 1,608,000	$ 0.019181
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 1,555,000	5%	$ 38,875	$ 0.000464
4	Interest on Investment - Equipment	$ 16,080,000	5%	$ 402,000	$ 0.004795
	Total			$ 2,126,625	$ 0.025367
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 5,769,321	$ 0.068819
	Medium Fuel Cost $20/ton			$ 6,891,721	$ 0.082208
	High Fuel Cost $35/ton			$ 8,575,321	$ 0.102290

Feedstock Receiving and Processing						
1	Feedstock Truck Dump				$	200,000
2	Front End Loader				$	240,000
3	Metal Removal Equipment				$	30,000
4	Grinding/Sizing Equipment				$	330,000
5	Blending Equipment				$	150,000
6	Conveyors				$	250,000
	Total				$	1,200,000
Operational Equipment						
1	Power Generation Equipment				$	8,900,000
2	Pyrolysis Process				$	2,600,000
3	Waste Heat Boiler				$	3,130,000
4	Demineralizer System				$	250,000
	Total				$	14,880,000
Land and Infrastructure						
1	Land/ Site Preparation				$	200,000
2	Plant Buildings				$	200,000
3	Eng/Permitting				$	200,000
4	Fuel Processing Building				$	1,155,000
5	Fuel Storage Bins				$	200,000
	Total				$	1,955,000
	Sub-Total				$	18,035,000
	Contingency (20%)				$	3,607,000
	Total Capital				$	21,642,000

Pyrolysis Generation - Full Capacity					
	Case # 3				
	Days Per Year	365			
	Hours Per Year	8,760			
	Days of Maintenance Downtime per Year	20			
	Hours of Maintenance Downtime per Year	480			
	Operational Hours per year	8,280			
	Plant Capacity (kWh)	15,220			
	Internal Power Used (kWh)	850			
	Net Generating Capacity (kWh)	14,370			
	Total Quantity of Electricity Sold (kWh per Year)	125,881,200			
	Total Quantity of Electricity Produced per Year	118,983,600			
	Biomass Input (WTPD)	480			
	Biomass Input (WT per Year)	165,600			
	Biomass Efficiency (kWh per Wet Ton of Biomass)	719			
Operating Cost					
Overhead and Administration		Salary	Benefits	**Total $**	**$ / kWh ($20/Wet ton)**
1	General Manger	$ 110,000	28%	$ 140,800	$ 0.001119
2	Accounting Support	$ 90,000	28%	$ 115,200	$ 0.000915
3	Clerical Support	$ 75,000	28%	$ 96,000	$ 0.000763
	Total	$ 275,000	28%	$ 352,000	$ 0.002796
Variable Cost of Operation					
		Maintenance Downtime (kW/yr)	Industrial $/kWh		
1	Purchasing Cost for Downtime Electricity per Year	6,897,600	$ 0.0500	$ 344,880	$ 0.002740
		Wet Tons per Year	Price / ton		
2.1	Fuel Costs per Year (Low at $10/ton)	165,600	$ 10	$ 1,656,000	NA
2.2	Fuel Costs per Year (Medium at $20/ton)	165,600	$ 20	$ 3,312,000	$ 0.026311
2.3	Fuel Costs per Year (High at $35/ton)	165,600	$ 35	$ 5,796,000	NA
		Ash (Tons per Yr)	Disposal $/ton		
3	Ash Disposal Cost per Year	2600	$ 20.00	$ 52,000	$ 0.000413
4	Water and Water Treatment			$ 159,000	$ 0.001263
		Employees	Average Salary		
5	Labor	51	$ 30,000	$ 1,530,000	$ 0.012154
		Total Salary per Year	Workers Comp.		
6	Workers' Compensation	$ 1,530,000	7%	$ 107,100	$ 0.000851
7	Miscellaneous			$ 39,000	$ 0.000310
		Total Capital	Percent of Capital		
8	Yearly Taxes and Insurance Costs	$ 29,682,000	1.50%	$ 445,230	$ 0.003537
9	Yearly Maintenance Costs	$ 29,682,000	2.00%	$ 593,640	$ 0.004716
	Sub-total (Low Fuel Cost $10/ton)			$ 4,926,850	NA
	Sub-total (Medium Fuel Cost $20/ton)			$ 6,582,850	$ 0.052294
	Sub-total (High Fuel Cost $35/ton)			$ 9,066,850	NA
		Rate	2 Months Working Capital	Total $	
10.1	Interest on Working Capital ($10/ton feedstock)	10%	$ 821,141.67	$ 82,114	NA
10.2	Interest on Working Capital ($20/ton feedstock)	10%	$ 1,097,141.67	$ 109,714	$ 0.000872
10.3	Interest on Working Capital ($35/ton feedstock)	10%	$ 1,511,141.67	$ 151,114	NA
	Total (Low Fuel Cost $10/ton)			$ 5,008,964	NA
	Total (Medium Fuel Cost $20/ton)			$ 6,692,564	$ 0.053166
	Total (High Fuel Cost $35/ton)			$ 9,217,964	NA
Yearly Expenditures on Capital					
		Salvage	Lifetime (Years)		
1	Depriciation - Buildings	0	20	$ 129,500	$ 0.001029
2	Depreciation - Equipment	0	10	$ 2,154,500	$ 0.017115
		Capital	Interest Rate		
3	Interest on Investment - Buildings	$ 2,590,000	5%	$ 64,750	$ 0.000514
4	Interest on Investment - Equipment	$ 21,545,000	5%	$ 538,625	$ 0.004279
	Total			$ 2,887,375	$ 0.022937
Total Operational Costs per Year				**Total $**	**Average Cost ($/kWh)**
	Low Fuel Cost $10/ton			$ 8,248,339	$ 0.065525
	Medium Fuel Cost $20/ton			$ 9,931,939	$ 0.078899
	High Fuel Cost $35/ton			$ 12,457,339	$ 0.098961

Feedstock Receiving and Processing					
1	Feedstock Truck Dump				$ 300,000
2	Front End Loader				$ 360,000
3	Metal Removal Equipment				$ 45,000
4	Grinding/Sizing Equipment				$ 495,000
5	Blending Equipment				$ 225,000
6	Conveyors				$ 375,000
	Total				$ 1,800,000
Operational Equipment					
1	Power Generation Equipment				$ 11,390,000
2	Demineralizer System				$ 3,900,000
3	Boiler				$ 4,080,000
4	Instrumentation & Controls				$ 375,000
	Total				$ 19,745,000
Land and Infrastructure					
1	Land/ Site Preparation				$ 300,000
2	Plant Buildings				$ 300,000
3	Eng/Permitting				$ 300,000
4	Fuel Processing Building				$ 1,990,000
5	Fuel Storage Bins				$ 300,000
	Total				$ 3,190,000
	Sub-Total				$ 24,735,000
	Contingency (20%)				$ 4,947,000
	Total Capital				$ 29,682,000

APPENDIX III

Figure A-25: Direct Fire Operational Cost Breakdown ($10/ton)

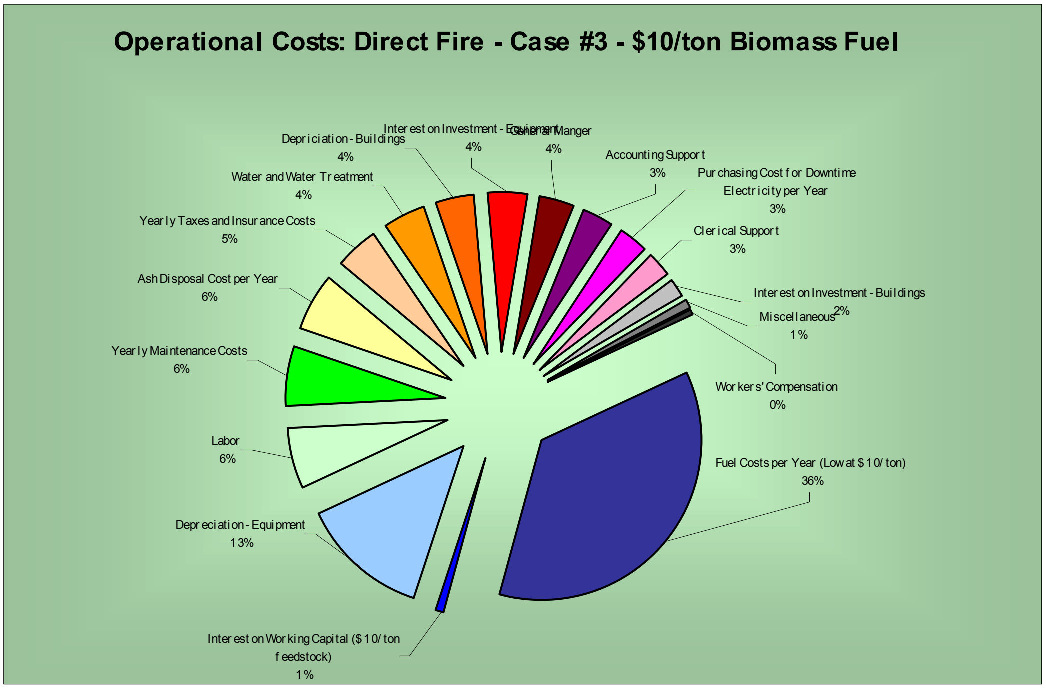


Figure A-26: Direct Fire Operational Cost Breakdown ($20/ton)

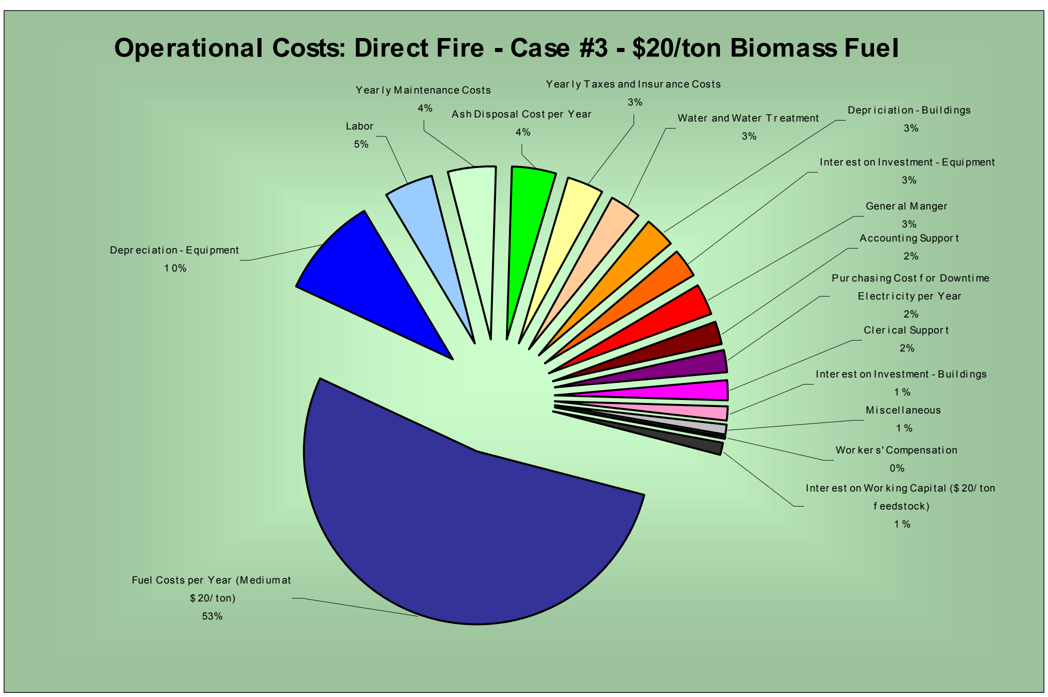


Figure A-27: Direct Fire Operational Cost Breakdown ($35/ton)

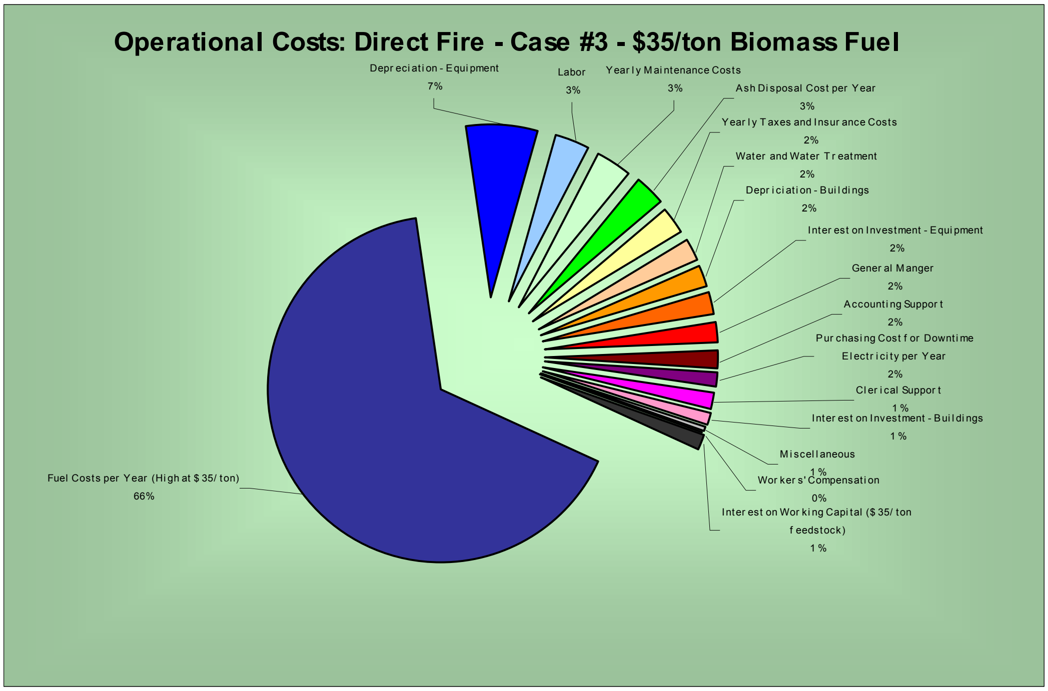


Figure A-28: Co-Fire Operational Cost Breakdown ($10/ton)

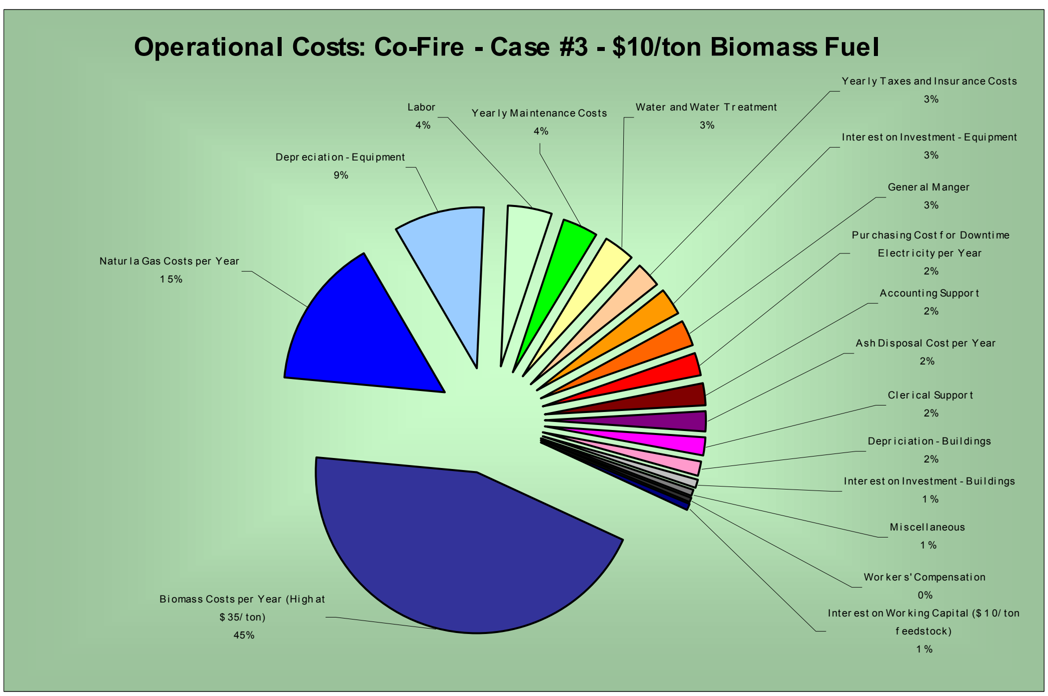


Figure A-29: Co-Fire Operational Cost Breakdown ($20/ton)

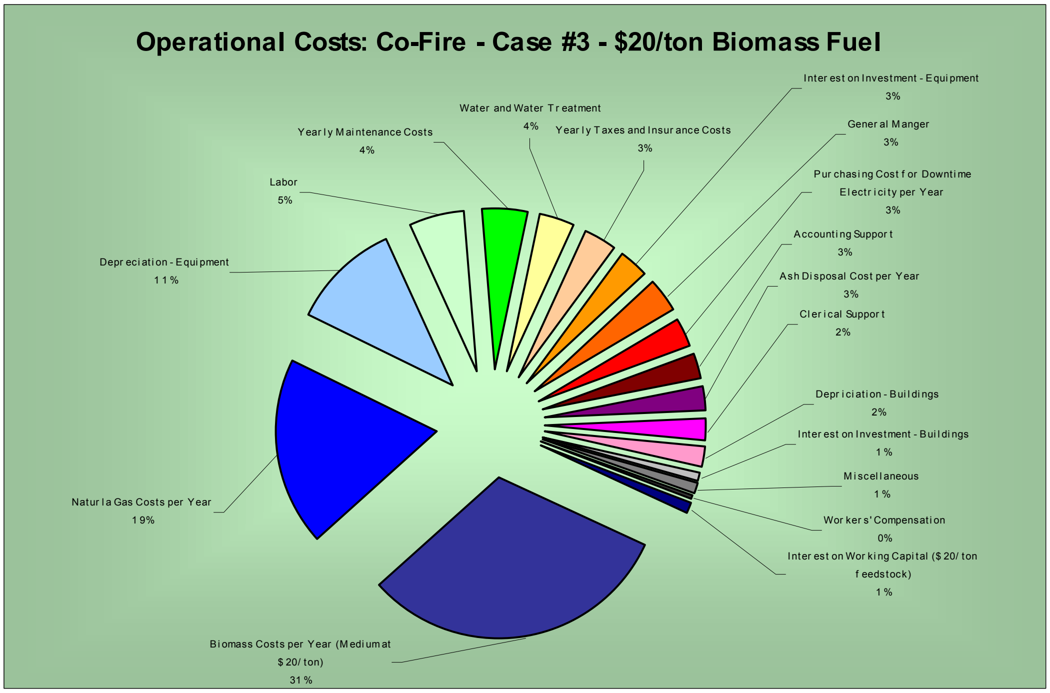


Figure A-30: Co-Fire Operational Cost Breakdown ($35/ton)

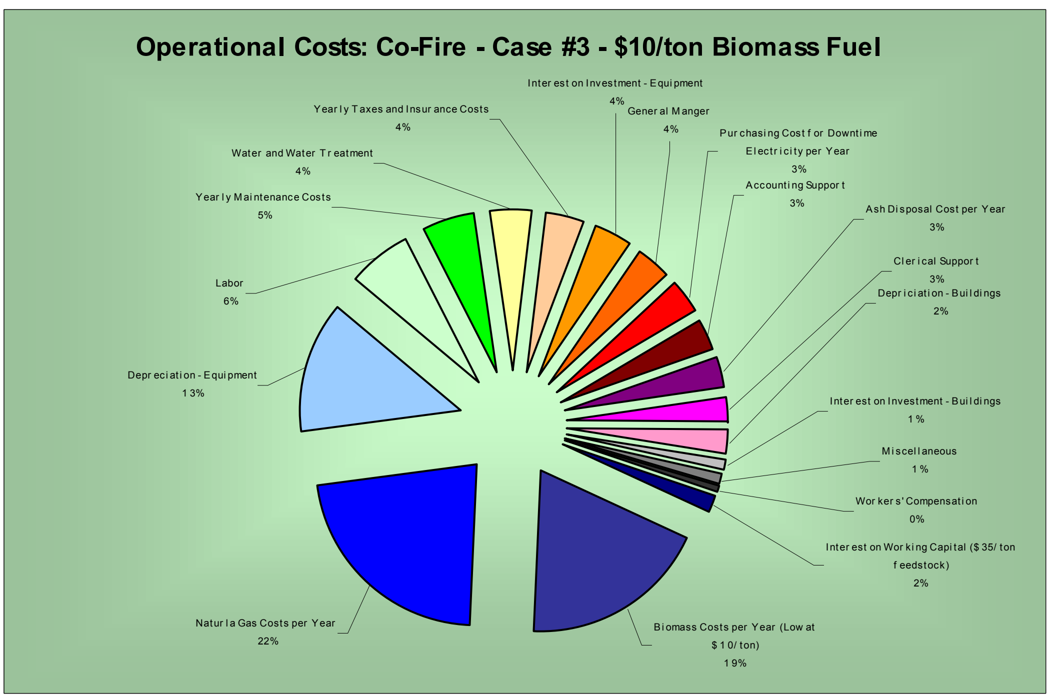


Figure A-31: Gasicfication Operational Cost Breakdown ($10/ton)

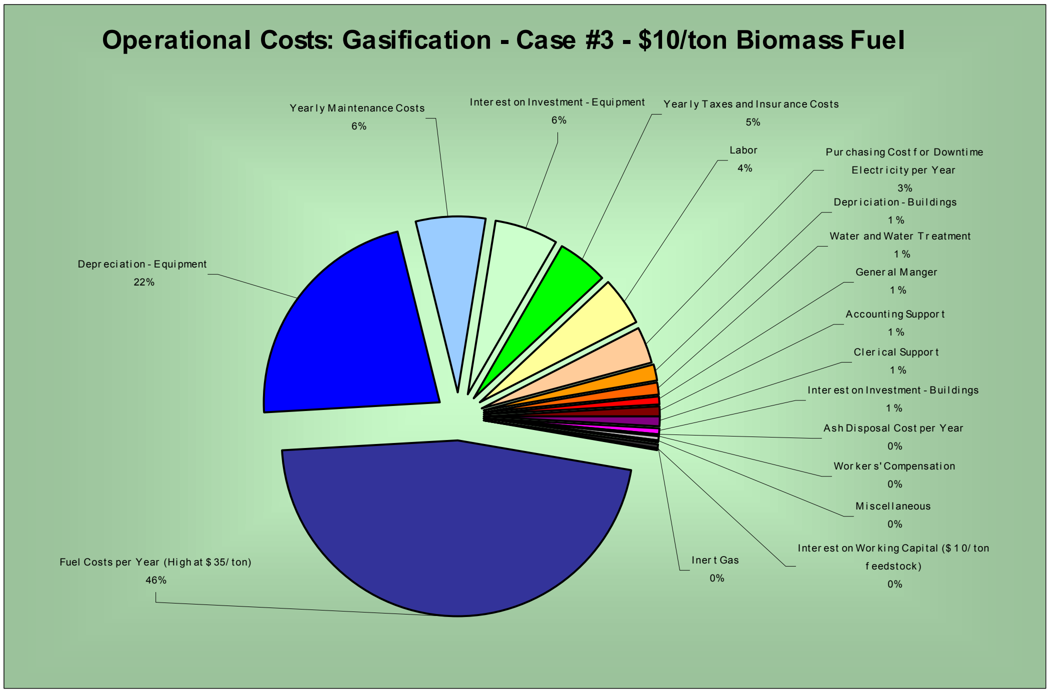


Figure A-25: Gasification Operational Cost Breakdown ($20/ton)

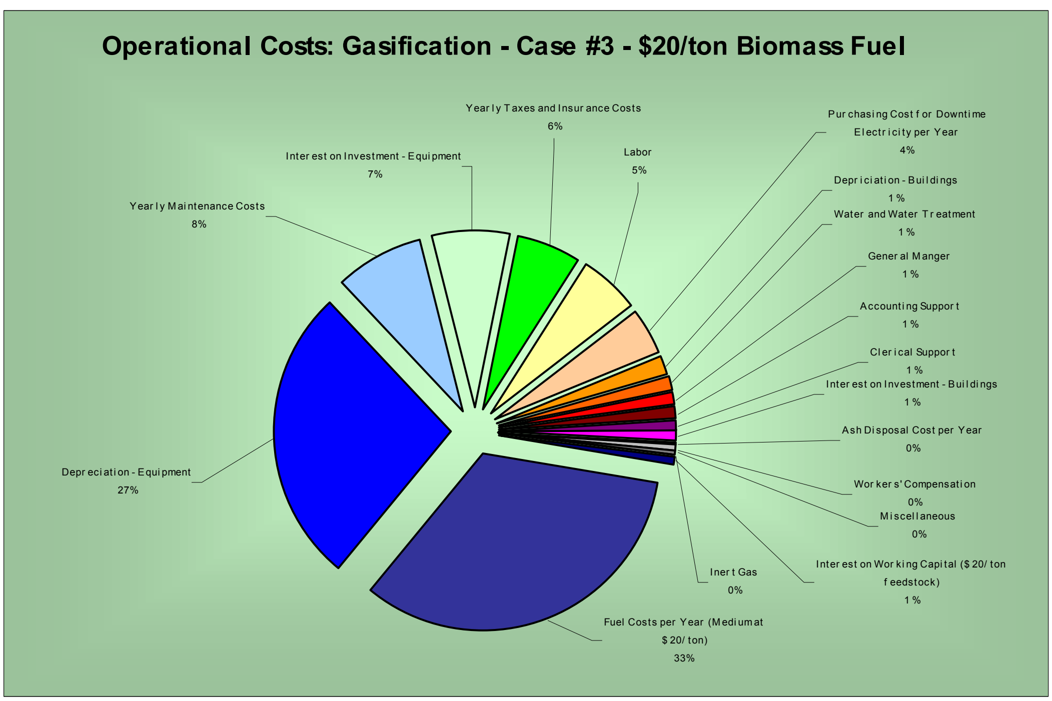


Figure A-31: Gasification Operational Cost Breakdown ($35/ton)

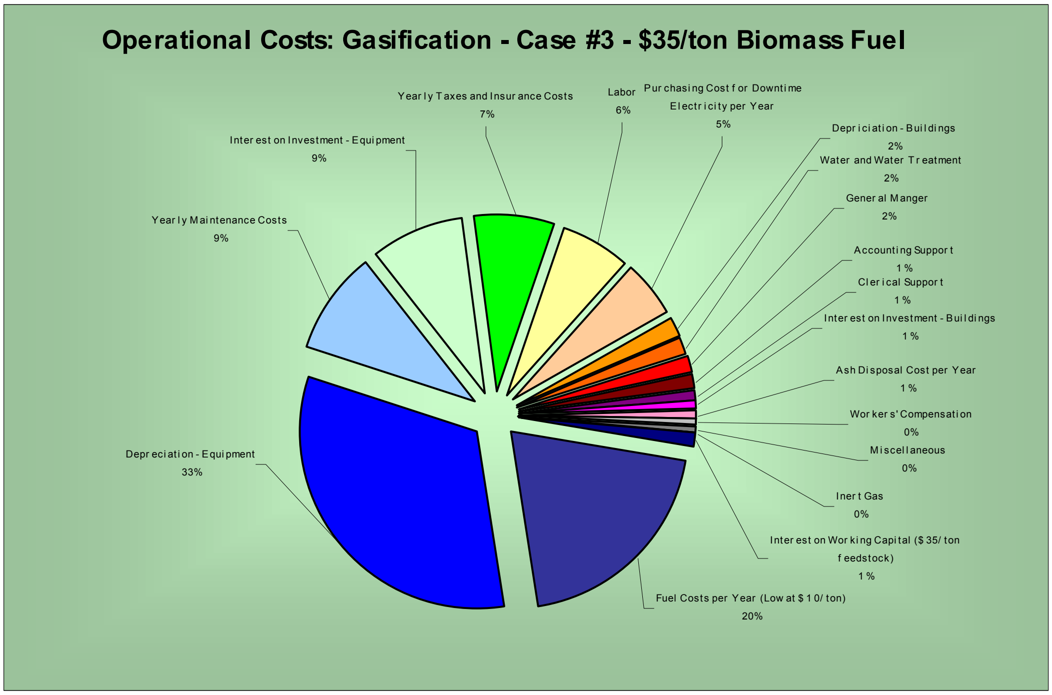


Figure A-33: Pyrolysis Operational Cost Breakdown ($10/ton)

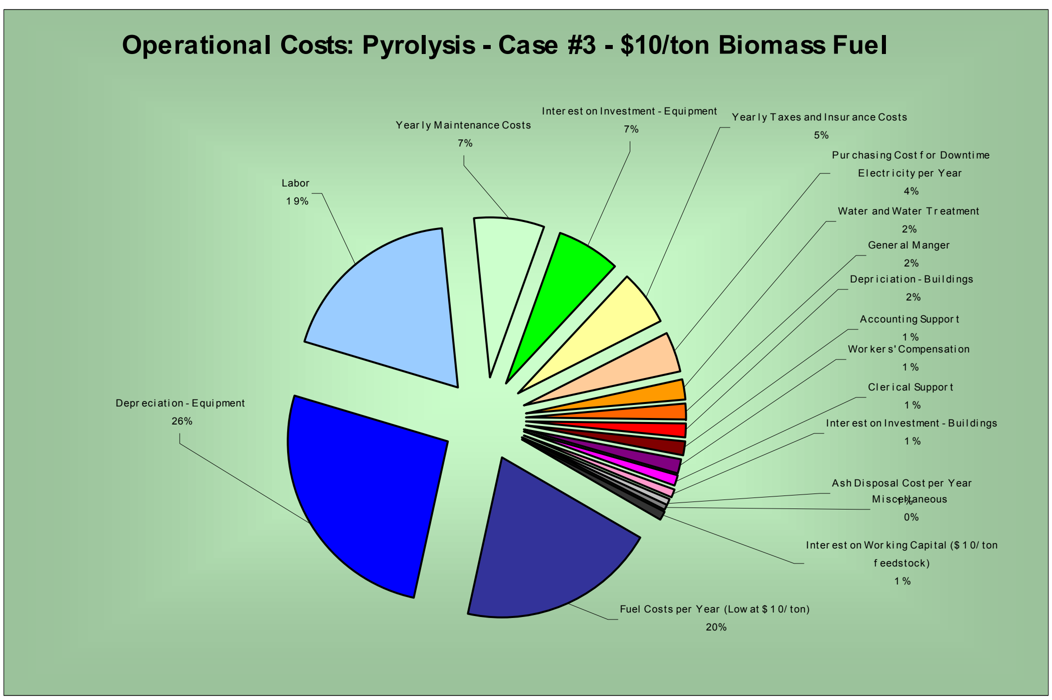


Figure A-34: Pyrolysis Operational Cost Breakdown ($20/ton)

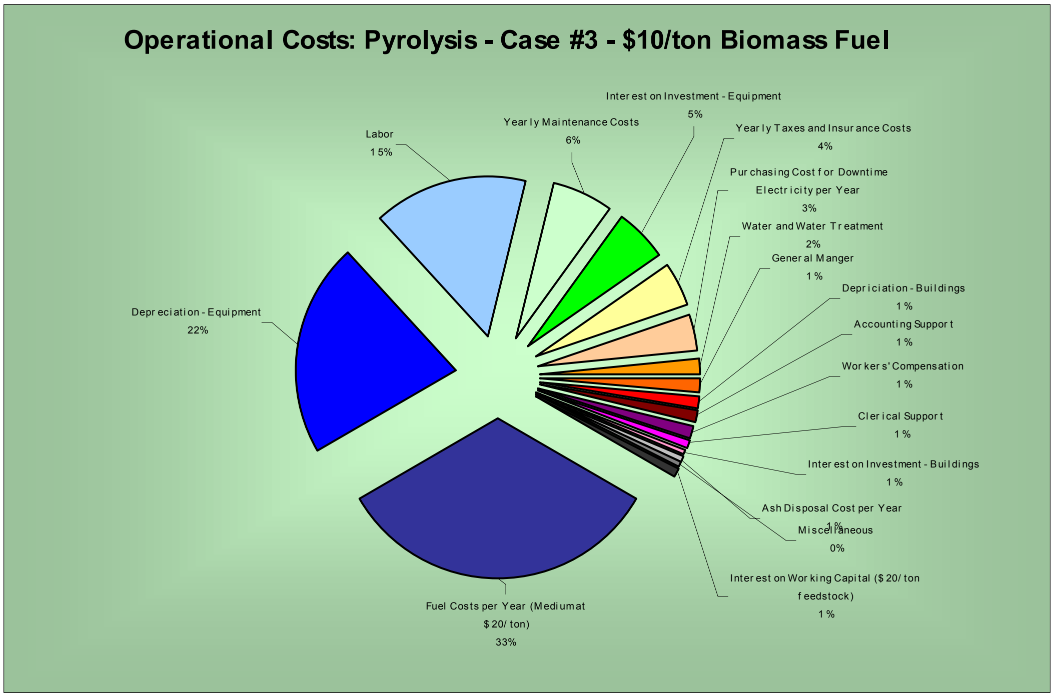
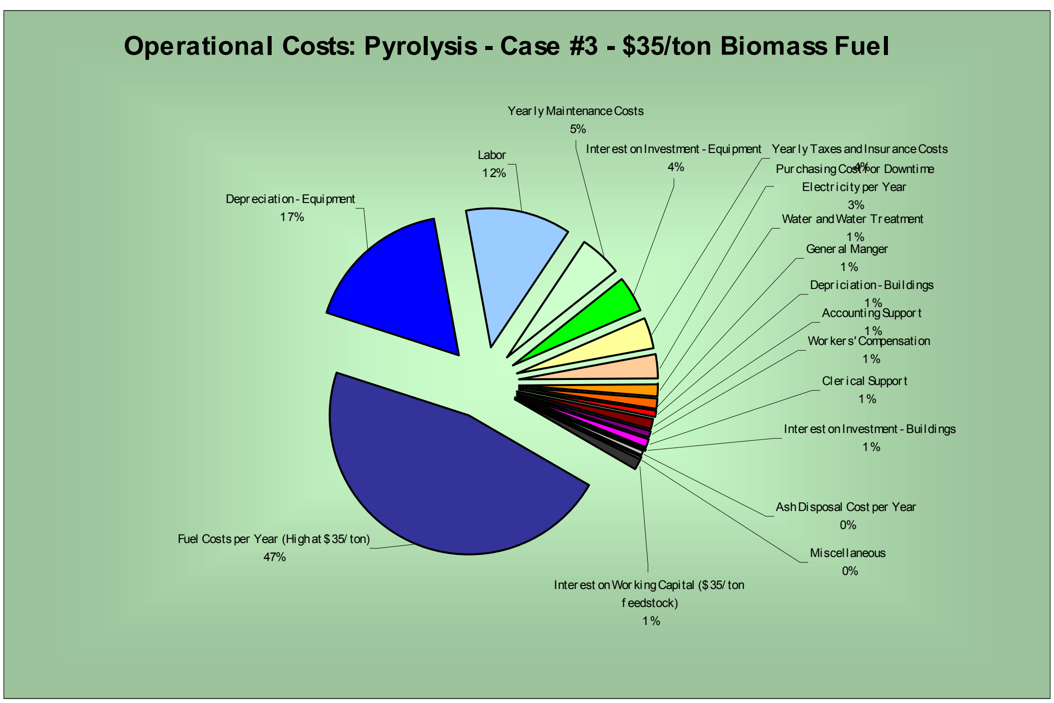


Figure A-35: Pyrolysis Operational Cost Breakdown ($35/ton)



The Center for Agribusiness & Economic Development

The Center for Agribusiness and Economic Development is a unit of the College of Agricultural and Environmental Sciences of the University of Georgia, combining the missions of research and extension. The Center has among its objectives:

> To provide feasibility and other short term studies for current or potential Georgia agribusiness firms and/or emerging food and fiber industries.
>
> To provide agricultural, natural resource, and demographic data for private and public decision makers.

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J. Scott Angle, Dean and Director