Final Report

Project Title: Biofuel Production Initiative at Claflin University
Award Number: DE-FG36-08-GO88072

Recipient: Claflin University
Project Location: Claflin University, Orangeburg, SC

Principal Investigator: Dr. Kamal Chowdhury

Date: July 21, 2011

Project Period: June 1, 2007 – September 30, 2010

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Executive Summary: For US transportation fuel independence or reduced dependence on foreign oil, the Federal Government has mandated that the country produce 36 billion gallons (bg) of renewable transportation fuel per year for its transportation fuel supply by 2022. This can be achieved only if development of efficient technology for second generation biofuel from ligno-cellulosic sources is feasible. To be successful in this area, development of a widely available, renewable, cost-effective ligno-cellulosic biomass feedstock that can be easily and efficiently converted biochemically by bacteria or other fast-growing organisms is required. Moreover, if the biofuel type is butanol, then the existing infrastructure to deliver fuel to the customer can be used without additional costs and retrofits. The Claflin Biofuel Initiative project is focused on helping the US meet the above-mentioned targets. With support from this grant, Claflin University (CU) scientists have created over 50 new strains of microorganisms that are producing butanol from complex carbohydrates and cellulosic compounds. Laboratory analysis shows that, out of the 50, 10 strains that are producing higher percentages of butanol than other methods currently in use. All of these recombinant bacterial strains are producing relatively high concentrations of acetone and numerous other byproducts as well. Therefore, we are carrying out intense mutations in the selected 10 strains to reduce undesirable byproducts and increase the desired butanol production to further maximize the yield of butanol. In addition, we have produced around 100 more recombinant strains that we are further analyzing. We have also acquired a 10 L bioreactor and we will be testing the proof of concept of producing pre-industrial large scale biobutanol production by utilizing this instrument and optimizing the production of the desired products and minimizing the undesirable by products. We are still in the process of hiring a bacterial geneticist to generate genetic profiles of the new bacteria that are producing bio-butanol. We are expecting the bacterial geneticist to join our group in August or Sept of 2011. Our sub-contractor on the project, Organic BioEnergy, has already developed an initial process flow diagram (PFD) and selected a site for a biobutanol pilot scale facility in Orangeburg, SC. With the recent success in engineering over 100 new strains of various biofuel producing bacteria at CU, it will soon be possible to provide bench test results to OBE to calculate material balances and provide other technical information for the development of process flow diagrams (PFD's) and piping and instrumentation diagrams (P&ID's). This information can be used for the equipment layout and general arrangement drawings for the proposed process and eventual plant. An efficient bio-butanol pilot plant to convert ligno-cellulosic biomass feedstock from bagasse and wood chips will create significant number of green jobs for the Orangeburg, SC community that will be environmentally-friendly and generate much-needed income for farmers in the area.

Introduction

Fossil fuel is a non-renewable resource that causes environmental hazards such as global warming and the release of toxic gases. Most importantly, while oil production reached its peak in 2005, the demand for oil worldwide will double in the next two decades due to the high demands of newly expanding economies such as China and India (with a total of 2.5 billion consumers). It is, therefore, essential to look for and develop alternative renewable sources of fuel.

Bio-fuels and biomass are renewable resources that are environmentally friendly, will reduce global warming and can help our nation become less energy dependent. Moreover, production of alternative bio-fuels will utilize abundant stocks of cellulosic biomass present in low-value agricultural commodities, leftover straw, solid garbage waste, waste paper, wood

chips and processing wastes, further reducing waste disposal and contributing to the more efficient use of such by-products.

Currently, the predominant bio-fuel is starch-based ethanol. Due to high demand for biofuels (36 billion gallons / year in the year 2022 as mandated by the USDA), it is essential to develop second generation biofuels from ligno-cellulosic biomass. Moreover, ethanol has a number of drawbacks when compared to butanol. Butanol is a four-carbon alcohol and thereby yields 25% more energy than ethanol as measured in Joules/gallon (or liter). This means that its energy output is closer to gasoline. Unlike ethanol, butanol does not need to be mixed with gasoline for use; therefore, it can be a 100% substitute for gasoline. Further, unlike ethanol, butanol can use the existing delivery infrastructure such as tanker trucks, pipelines and service stations. Butanol is less explosive, less evaporative (bp 117°C as compared to the ethanol bp of 78°C) and less corrosive than ethanol and, therefore, is safer to handle and distribute. Local/ Regional production capacity also means less dependence on long-distance fuel supplies; therefore, the systems would be less prone to bioterrorism and more favorable for homeland security.

To meet current gasoline needs with butanol, it will be necessary to utilize all our available biomass including stover (corn plant residue), bagasse (sugar cane residues), and other agricultural and forestry biomass to produce biofuels. It is therefore, important to develop a more efficient and cost-effective butanol production process.

Claflin University (CU) scientists with partner, Organic BioEnergy (OBE) are in the process of developing the technology for large-scale production of bio-butanol from cellulosic biomass. This involves genetic engineering of anaerobic bacteria that will convert cellulosic biomass into simple glucose followed by the conversion of glucose into butanol. CU is targeted to provide bench test results to OBE to generate material balance and other technical information for the development of process flow diagrams (PFDs) and piping and instrumentation diagrams (P&IDs). This information can be used for the equipment layout and general arrangement drawings for the proposed process and eventual processing plant. A pilot of an efficient bio-butanol plant to convert ligno-cellulosic biomass feedstock from bagasse and wood chips will create a significant number of green jobs for the Orangeburg, SC community that will be environment-friendly as well as a great source of income for the farmers in the area.

A. Material Balance Report

Summary of the activities:

Task#1: Genetic Engineering of Recombinant bacteria to produce biobutanol . Therefore, we have now produced over 100 strains of recombinant bacterial capable of producing biobutanol. We have analysed the data by HPLC to determine the butanol production. So far the production is in excess of 10 mM/L. We are further optimizing the biobutanol production whereas, minimizing the acetone production. In addition to HPLC we have initiated the NMR studies to validate and further analyze the results in collaboration with our Chemistry department faculty. We have provided equipment and supply support to Dr. Azezue Brozerdi, who is a NMR expert, to assist us in this task.

Task #2: Genetic Analyses of the recombinant strains: This work is on hold due to hiring difficulties of an expert. However, he hope to resolve this issue in coming months.

Task # 3: Bench-top research with sugarcane biomass as a source will provide data for energy mass balance calculations of yields of butanol from bagasse. Claflin's cost-

shared equipment time includes the use of an anaerobic chamber, an HPLC, a capillary DNA sequencer and thermocyclers that will be used to gather preliminary bench-top data. The equipment to be purchased by the sub-contractor includes fermentation vessels, separation equipment (a dedicated HPLC), piping, pumps and pressure regulation equipment that will need to be dedicated to the butanol production scale-up process. The university researchers will work with the sub-contractor to produce the life modeling of the processes via the greenhouse gases, regulated emissions and energy use in transportation (GREET) model developed for analysis of renewable fuels standards at the DOE's Argonne National Laboratory. The material balance report will serve as the deliverable for this task.

Actual Accomplishments: We have created over 50 new strains of bacteria that are producing butanol from complex carbohydrates and cellulosic compounds. Currently, our researcher is getting training in HPLC and GC Mass Spectroscopy to develop metabolic profiles of the chemical products generated from the new genetically engineered bacteria. The new anaerobic cultures are being evaluated and the experiments are in progress to carry out the genetic profile analyses of the microbes. We are in the process of hiring a bacterial geneticist to generate genetic profiles of the new bacteria that are producing bio-butanol.

B – Process Flow Diagrams (DL)

Task: Initial Process Flow diagrams (PFD) for the biobutanol pilot scale facility will be produced by the subcontractor. The PFDs will serve as the deliverable for this task. Information developed in the bench-top research phase will be used to develop PFDs to be considered in the initial design for the pilot plant in task #3.

Actual Accomplishments: This task is completed.

C. Site Feasibility Study (DL)

Task: A feasibility study will be undertaken to select a site for the pilot scale facility. This work will be undertaken by the sub-contractor. Evidence of site selection ability for certification will be provided as the deliverable for this task. In addition, an initial design plan for the facility will be produced as an additional deliverable.

Actual Accomplishments: This task is completed.

D. Final Technical Report (D-level project)

This technical report will be a deliverable for the project. The final technical report will be used for the go/no go decision point for proceeding with building the pilot plant.

Patents: None finalized. One pending

Publications / Presentations: None

Attachments: Organic Bio-Energy, Inc. Reports

- A. Task #1: Conduct Feasibility Study for Biomass Electricity Generation Facility to Determine Biomass Availability and Costs. Develop Purchase Power Agreements with Utilities and Memoranda of Understanding with Biomass Producers
- B. Task #2: Conduct Feasibility Study on Establishing Facility for Production of Biodiesel from DAF Treatment of Agricultural Waste Water and Reclaimed Corn Oil from Ethanol Production. Assess Local Area Feed Stocks for Project. If Project is Feasible, Develop License Agreement for Use of Technology and Memoranda of Understanding with Waste Producers.
- C. Task #3: Conduct Feasibility Study on Establishing Facility for Production of Synthetic Biodiesel from Biomass. Assess Biomass Availability for Project. If Project is Feasible, Develop License Agreement for Use of Technology and Memoranda of Understanding with Biomass Producers.

Prepared for

ORGANIC BIO-ENERGY, INC

Task # 1: Conduct Feasibility Study for Biomass Electricity Generation Facility to Determine Biomass Availability and Costs. Develop Purchase Power Agreements with Utilities and Memoranda of Understanding with Biomass Producers

To: Organic Bio-Energy, Inc
Attn: Dr. George E. Miller, III

Date: September 15, 2008

CONTACT INFORMATION:

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John Matthews Park Research Center and Biomass Plant

South Carolina has an exciting and strategic opportunity to create the Southeast's first Alternative Fuels & Energy Research & Development Center. This new R&D Center will consist of a series of pilot production plants utilizing a wide variety of new and emerging technologies to produce and utilize alternative fuels.

These pilot production facilities will produce jobs for researchers, scientists, engineers, and technicians, along with construction, maintenance and operations personnel. The ultimate goal, upon vetting the most promising and feasible technologies for producing alternative fuels & energy, will be to commercialize them and build a growing and sustainable alternative fuels industry in South Carolina.

In addition to the Alternative Fuels & Energy R&D Center, a new Wood Waste Biomass Power Generation Plant will be built on this site. This project will produce jobs in forestry, engineering, construction, maintenance and operations as well as protecting jobs in the logging industry threatened by the downturn in the housing and paper markets.

Our country desperately needs to lessen its dependence on foreign oil and other fossil fuels. Our future depends on the development of reliable and economically feasible sources of alternative energy and we here in the midlands of South Carolina are ready to meet this challenge with the shovel-ready projects at the John Matthews Park Alternative Fuels & Energy Research & Development Center.

John Matthews Park

Alternative Fuels & Energy R&D Center

And Biomass Plant

Figure 1: Google Earth Image of John Matthews Park boundaries with key tenants identified

Deliverable – Biomass Electricity Generation – feasibility study, purchase power agreement and memoranda of understanding with biomass producers

The goal of the Biomass Plant is to use wood waste and other waste biomass feedstock to generate “green” electricity. The project will produce 3 – 5 Megawatts (MW) of energy that will displace the need for current and new generation from nuclear, coal, natural gas, and other fossil fuel or nonrenewable resources.

Feedstock

The amount of renewable biomass resource needed for a biomass plant of 35 MW is proportional to the energy content (in BTU/lb) of the biomass to be combusted. In the southeast region of the United States, including Orangeburg, SC and the surrounding region, the wood resource will consist mainly of pulpwood, yellow pine, loblolly, and some hardwoods. Commercial thinning, clear-cut debris and mill residues will be utilized, as well as some clean construction debris and waste wood. A conservative estimate of the energy content of the wood is 4,500 BTU/lb wet. Wet or “green” wood is considered to have a moisture content of 45-55%. A small percentage of the wood to be received is believed to have a much lower moisture content of closer to 30%, and this wood, therefore, will have higher energy content than the greener, wetter wood. (See Attachment 2 – Price Companies document of confirmation for “Fiber Procurement for Wood Energy Plants”.)

To feed a plant of 35 MW production capacity, approximately 438,000 tons/year of mostly green wood will be needed. This equates to 1200 tons/day or 50 tons/hour, with an energy content of 4,500 BTU/lb to produce 350,000 lbs/hour of steam. (Dry wood is commonly considered to have a moisture content of around 8%, which gives an energy content of approximately 8,500 BTU/lb.)

The resulting equation is:

$$478 \text{ MMBTU/hr heat input} \times 88\% \text{ Boiler Efficiency} \times 28\% \text{ Turbine Efficiency} \times 0.29 \text{ MW/MMBTU/hr} = \sim 35 \text{ MW}$$

The biomass plant will receive wood from a radius of approximately 50 miles.

It has been stated that simply through proper forestry practices of thinning, pruning, and crop management, up to five (5) tons of waste wood per acre per year can be obtained for use at a biomass facility in this area. This equates to over 25 million tons of available biomass in a 50 mile radius of such a facility. This alone would run this facility for more than 55 years. This facility will only use around 438,000 tons/year and has a design life of 30 years. In addition, whole logs and pulp wood can be utilized to supplement the wood waste products as necessary. There appears to be adequate biomass feedstock in the area without disrupting or interrupting the balance of current wood stock supply for other processes such as mills, paper companies, and OSB plants in the state. Local, state, and regional surveys have shown that most of the counties in South Carolina are growing 20% more trees than are being harvested today.

Within a 50-mile radius of the Orangeburg County site is an adequate supply of the roughly 438,000 tons of biomass fuel that will be consumed annually. Biomass fuel will include whole tree chips from land clearing, road side tree trimming, power line maintenance, ground stumps, and pallets. Significant volumes of biomass waste are generated in this region each year, and are subject to high disposal costs for landowners. As a first step in executing its commitment, Green Energy Partners has negotiated with potential fuel suppliers for approximately 450,000 tons/year starting in 2011. The availability of wood and wood waste from thinning operations alone meets the plant's demands. Approximately 5 tons of wood per acre per year are available just from thinning and normal forestry practices which alone would feed the capacity of this plant easily.

Wood Cost

The anticipated wood cost for this project is \$30/ton, based on the assumption that the range of waste wood chips can be delivered to the site at a cost of \$30-\$38/ton. The anticipated cost for whole logs plus 8- 12% waste wood will range from \$25-\$30/ton delivered. Currently, market wood prices are below these ranges, but historically the wood market has only fluctuated up or down by roughly \$5-\$8/ton quarterly. This data is supported by the University of Georgia's TimberMart South (<http://www.tmart-south.com/tmart/>) wood study reports, SC Renewables Study performed by La Cappa & Associates for Central Utilities of SC & local area wood surveys.

Production Requirements

Wood will be delivered to the site 330 days a year, which represents approximately a 90% wood delivery time per year. Wood delivered is a direct function of expected days per year of power generation (i.e., power will also be generated 90% of days annually). Wood will be delivered as needed, with a backup storage capacity of 3-4 weeks worth of wood for rainy seasons and unexpected delays in wood supply. In addition, the hopper at the boiler will have a 24 hour storage capacity to ensure continuous operations.

Feedstock Conclusion

By locating the biomass plant in Orangeburg County, the biomass fuel supply and price benefits are maximized. "South Carolina enjoys an abundance of pine forests and the biomass that is produced from timbering operations is formidable," according to the study "*Biomass Availability in South Carolina*" produced for the South Carolina Electric Cooperatives in 2007. Also according to this report, there are only six to eight areas in the state with an optimal supply of biomass to support a 25-35 megawatt biomass power plant. Orangeburg County is one of the sites specifically identified in the report.

Wood Suppliers

Completion of the fuel supply task involved obtaining letters of interest from potential local wood fuel suppliers. Green Energy Partners is currently negotiating with several of the larger timber management companies in the gulf coast & southeast for a long-term feedstock arrangement.

- **Price Companies** www.thepricecompanies.com,
www.pricebiostock.com
- **Plum Creek Timber, Inc.** www.plumcreek.com

GEP is confident that the projects will have a more than adequate supply to meet the plant's feedstock requirements. As a contingency, the plant can also receive other opportunity fuels such as construction and demolition waste, tire-derived fuels and torrefied wood. The plant is only being permitted for wood use at this time.

The Price Companies, Inc

Overview of Relationship with Green Energy Partners

The Price Companies are a group of wood procurement/processing companies that have been contracted (still pending) to provide all feedstock services to the Orangeburg County Biomass (OCB) project. These services will include all wood procurement, gathering, hauling, and processing, as well as the feed/conveyor system to the boiler. The contract is to provide 438,000 green tons per year of wood and wood waste, including thinning and logging residue when available. The feed system will be designed to supply 51 tons/hour to the boiler.

The current contract with Price Companies is waiting to be finalized.

The Price Companies is based in Monticello, Arkansas and is one of the largest and most experienced wood processing companies in the U.S. The Price Companies operate as a contract wood chipper with experience in consulting, wood procurement, systems design/engineering and facilities management. Today, The Price Companies has 19 facilities under contract for many respected manufacturing companies in the United States with a majority in the gulf coast and southeast regions. The local office, located in Lizella, Georgia, will be handling the Orangeburg project needs.

Power Production

Power will be produced by the facility 330 days a year, which represents 90% run time for the facility. This represents a conservative schedule, as it is expected that the boiler and other critical equipment packages for this plant are expected to run at 95% run time. This is assuming a two-week planned maintenance shutdown each year for boiler and facility maintenance. Other similar operating plants and vendor information reflect that 95% run time is expected.

The objective of the power sale options task was to obtain expressions of interest from prospective power purchasers, principally municipal electric companies. The response was positive – Central Electric Power Cooperative, Inc. represents 15 of the 20 electric cooperatives in South Carolina. Tri-County Electric Cooperative is the local off-take partner in Orangeburg County.

Santee Cooper/
Central Electric Power Cooperative, Inc./
Tri-County Electric Cooperative

Power Purchase Agreement Overview

Santee Cooper is South Carolina's state-owned electric and water utility, generating the power distributed by the state's 20 electric cooperatives. Central Electric Power Cooperative provides total wholesale electric service to 15 of the 20 electric cooperatives in the state. Central has no direct generation capacity; the cooperative designs and builds transmission lines between Santee's generating systems and the delivery points. Tri-County Electric is the specific electric cooperative that serves rural areas of Richland, Calhoun and Orangeburg Counties. Green Energy Partners is currently in negotiations concerning with Central Utilities regarding the Power Purchase Agreement (PPA) for the take-offs from the Orangeburg County Biomass (OCB) project.

Technology

Three boiler technologies were evaluated during this feasibility study; Fluidized bed boilers (circulating fluidized bed (CFB) and bubbling fluidized bed (BFB) and Stoker Grate boilers. A fluidized bed has been selected due to many state regulations that exclude stoker-fired boilers from their Renewable Portfolio Standard (RPS) qualifications, emissions profile, thermal combustion efficiency, ash quality and content, along with other technical and economic determinations.

The Orangeburg Biomass Plant will consist of a Bubbling Fluidized Bed boiler generating steam for a steam turbine/ generator, wood fuel handling system, automated process control system, air pollution control system consisting of state-of-the-art particulate filtration systems and other emission control technologies including a bag house, sorbent lime injection system, regenerative selective catalytic reduction (RSCR).

Technology research of boiler companies consisted of the following:

- AE&E-Von Roll www.aee-vonroll.com
- The Babcock Wilcox Company (B&W) www.babcock.com
- Energy Products of Idaho (EPI) www.energyproducts.com & others

AUSTRIAN ENERGY
& ENVIRONMENT

Austrian Energy & Environment – Von Roll

Technology Overview

Austrian Energy & Environment (AE&E), through its American subsidiary AE&E-Von Roll, is providing Green Energy Partners with the bubbling fluidized bed (BFB) boiler for the Orangeburg County Biomass (OCB) project. This technology for biomass combustion utilizes a bed of sand that is fluidized using high-velocity combustion air from nozzles in the orifice plate. The sand and combustion chamber are heated to a uniform 850°C by the air, which causes complete combustion of the fuel to occur. For this project, the fuel will consist of wood and wood waste from the surrounding area. The combustion process will heat water to produce steam that will

be used in a steam-condensing turbine to produce electricity. The AE&E technology produces fewer emissions than traditional forms of combustion, making it a more environmentally friendly option for energy generation.

Technology Conclusion

The AE&E Group is an international provider of systems for thermal power generation and environmental technologies for producing clean energy. AE&E-Von Roll is their American subsidiary based in Norcross, Georgia. AE&E-Von Roll has more than 60 boiler systems operating worldwide.

Environmental Permitting

No technical or permitting “fatal flaws” have been identified for a plant size up to 35 MW.

The proposed Bubbling Fluidized Bed boiler for the project will be equipped with inherent combustion technologies and various add-on emission control technologies to reduce emissions of NO_x, SO₂, CO, PM/PM-10 (filterable and condensable) and HCl in accordance with pollution control requirements. Measures for air emissions control include; Flue Gas Recirculation, Flue Gas Sorbent Injection, Particulate Control with a Bag House

Waste Water/Storm water permit required : National Pollutant Discharge Elimination System (NPDES)-General Permit of Solid Waste discharge will be applied for when appropriate.

No permits are anticipated for solids leaving the plant at this time. It has been determined that with sorbent lime injection the ash produced from the facility will have a value as a soil additive for farmers or agricultural operations.

The biomass plant will use approximately 1.25 million gallons of water per day. The project is co-locating next to the new Orangeburg County Tertiary Waste Water Treatment Plant. The effluent from the plant is expected to be 1.5 million gallons of water per day. The effluent will be treated with a GE ZENON membrane filtration system which uses very little or no treatment chemicals. It is expected that the biomass plant will be able to utilize the treated water directly from the adjacent treatment facility.

Environmental Impact

The biomass plant produces 35 MW of power, equal to the generation of 946,075 million BTU (MMBTU) per year of energy and powering 25,000 homes. Compared to coal plants, biomass plants will have superior emission controls with state of the art technology systems. Biomass combustion produces no mercury or sulfur emissions, which is a problem with fossil fuel coal combustion. This biomass power facility will directly offset 20 tons/hour of coal, which will result in 158,400 tons of coal displaced during each year of operation by a renewable resource that is carbon-neutral and sustainable.

Overall Summary

The potential biomass supply in the region appears sufficient to support a plant of this size. By locating the plant at the John Matthews Industrial Park adjacent to the new Orangeburg County Wastewater Treatment Facility, the plant can use a large percentage of the effluent water for the cooling tower, blow down and other plant usage. Therefore, it will save freshwater and eliminate extra treatment and land application costs for the county. These positive environmental impacts will also save money and reduce transportation costs for the county. By having a large wood supplier handle procurement, gathering, delivery and processing the plant is able to sustain business for the life of the plant. Also by using a bubbling fluidized bed boiler emission limits are lower, combustion is more efficient which means less feedstock is required. In addition, to a more complete combustion system the best and most effective emission control equipment will be utilized to make this facility as environmentally friendly as possible. For this state biomass plants' utilizing the abundant wood resources within this state exist as one of the top renewable options for South Carolina.

ATTACHMENTS

- **Attachment 1: Historical Fuel Price Comparison for Electricity Production (on a per MW basis)**
- **Attachment 2: Historical Fuel Price Comparison for Electricity Production (on a per MMBTU basis)**
- **Attachment 3: Fiber Procurement for Wood Energy Plants**
- **Attachment 4: Price Companies Report on Biomass Availability in North and South Carolina**

Attachment 1: Historical Fuel Price Comparison for Electricity Production (on a per MW basis)

Attachment 2: Historical Fuel Price Comparison for Electricity Production (on a per MMBTU basis)

Attachment 3: Fiber Procurement for Wood Energy Plants

The Price Companies is committed to the procurement of woody fiber that incorporates material not fully utilized by today's conventional methods. The present technology in growing and harvesting forest products will be used until the energy plants have demonstrated the need for different systems. Our forest and their byproducts are sustainable even with increased consumption, but improvement can be obtained with better harvesting methods and enhanced growth in the forest.

Our procurement plan will offer as many different options as there are sources of woody fiber. Flexibility will be our focus in order to insure supply and utilization of lower valued products. Major points of our system will be:

- As pulpwood roundwood is the mainstay of the forest industry at present, it will be the bedrock of our procurement in the beginning. A chipping operation will be installed for this purpose. However, we will be able to handle the roundwood with the limbs and tops still on the stem to a large extent. This will add 20% volume previously unused or unmarketable.

This method will also allow smaller trees (mostly pines) to be cut. What is now considered pre-commercial may be utilized, allowing early thinning of plantation. These trees must be removed from planted and high density natural stands in order to maintain the health of the stand and allow faster growth for the remaining trees. Pulpwood of this nature is a byproduct of growing sawtimber. The process of thinning earlier, along with the additional volume with the tops and limbs, should allow increased profits for the landowner.

Much of the pulpwood we will purchase will be the residue of sawtimber harvesting. The portion of the tree stem that is too small or has defects preventing it from being processed into lumber will be utilized by our procurement program. Again, this pulpwood is a byproduct of sawtimber.

- Field chippers will be used as they prove valuable in the sustainability of the forest. They can be used in early thinning of planted pines and in natural stands to remove the underbrush and low quality or unmerchantable stems. They can produce fiber that has been

previously left behind requiring expensive site preparation for the next stand. Depending on the tract and the purpose of the cut, their production can be 20-50% of previously unused material.

- Residues from other wood using plants will be used to a large extent. Bark, residue chips, fines, sawdust, shavings, etc. from sawmills will be purchased as practical. Again, a byproduct.
- Material sources such as construction waste, tree stumps, trees from small land clearings, road construction and powerline waste, discarded wood pallets, etc. offer a significant challenge. Creating a method to economically gather this material is an important part of our plan. Every effort will be made to establish this material as a continuing source of fiber.

Claude Yearwood
COO
The Price Companies

Attachment 4: Price Companies Report on Biomass Availability in North and South Carolina

THE PRICE COMPANIES, INC.

Project: Resource Evaluations and site recommendations for North and South Carolina.

Date: March 24, 2008

Study conducted by: Ward Consulting Services, Inc.

INTRODUCTION

The Price Companies, Inc. are entertaining a request to evaluate several potential plant site locations in North and South Carolina for the express purpose of recommending sites to locate wood using facilities for the generation of power. Estimated consumption by each plant site is expected to be 300 to 400M tons of wood based feedstock. It is anticipated that growth in plant consumption is a real possibility. All sources of fiber are to be considered in the evaluation. The final recommendations should include the locations of 3 to 4 plant sites.

The following pages will contain:

- The methodology employed to reach conclusions and recommendations
- A summary of the wood resources for each area studied
- Analysis of current and future known competition
- Estimates of current cost structures
- Final recommendations for proposed sites.

METHODOLOGY:

I have approached this plant site evaluation from a perspective that identifies "No specific" potential plant location in a particular city or county but rather from a broader overview of both North and South Carolina that divides the two states into distinct areas of opportunity. These areas have been selected based on the following criteria:

- Inclusion of a particular city or county identified by the client.
- My experience guiding me toward particular areas of each State that fit the desired outcome.

Three broad areas have been identified in South Carolina with one being further subdivided into two smaller units. Two major areas of geography have been selected in North Carolina with one further being subdivided into two smaller study units. This provides us 7 distinct units of geography to evaluate. These areas are shown on Maps 1 and 2 on the accompanying page.

MAP 1

MAP 2

A summary of the Areas is as follows:

1. SC Area 1 – is located in the midlands of the State and includes the areas of interest identified by the client (Fairfield, Lancaster and Richland counties as well as Great Falls, SC.
2. SC Area 2 – is located in the upstate of SC and is further subdivided into 2a and 2b which includes Newberry, as identified by the Client.
3. SC Area 3 – is located in the lowlands and includes Orangeburg County, as identified by the Client.
4. NC Area 4 – includes south central and coastal NC and is further divided into 4a which encompasses both Clinton and Kinston. NC 4b includes Hoke County and the area west toward Charlotte, while also including 3 SC counties. Clinton, Kinston and Hoke County were identified by the Client.
5. NC Area 5 – is in the Halifax County (Roanoke Rapids) area and includes 3 Virginia Counties. Halifax County was also identified by the Client.

A forced ranking system will be employed to arrive at final site recommendations. The forced ranking will combine 5 resource attributes, a competitive environment analysis and wood cost estimates.

FINDINGS:

Step 1 in evaluating these areas involves a summary and analysis of the wood resource for each using FIA data from the US Forest Service. The most current survey years for the 4 States involved are shown below and indicate that the data is very current and should provide the most comprehensive look we can find of the areas in question.

<u>State</u>	<u>Survey Year</u>
Georgia	2004
North Carolina	2005
South Carolina	2005
Virginia	2005

The information gleaned from the FIA database includes the following:

- Acreage Summaries of timberland ownership
- Acreage Summaries of timberland type
- Pine and Hardwood pulpwood (5.0 – 8.9” dbh) volumes in tons.
- Growth/Drain Ratios for softwood.
- Summaries of plantation acreages in each Area.

Each of these attributes of data is shown below in Tables 1 through 5.

TABLE 1

TIMBERLAND OWNERSHIP				Total Timberland Acres
<u>Area</u>	<u>Federal</u>	<u>State/Co.</u>	<u>Private</u>	
SC1	166,660	114,910	2,536,385	2,797,955
SC2a	229,971	52,010	1,474,132	1,756,113
SC2b	144,410	20,007	1,427,475	1,591,892
SC3	229,246	0	1,718,790	1,948,036
NC4a	213,600	207,617	2,688,609	3,109,826
NC4b	207,109	79,656	2,684,569	2,971,334
NC5	62,816	38,773	2,812,714	2,914,303

TABLE 2

TIMBERLAND TYPE					Total Timberland Acres
<u>Area</u>	<u>Pine</u>	<u>Pine/Hdwd.</u>	<u>Hdwd.</u>	<u>Other</u>	
SC1	1,332,924	286,884	1,098,164	79,983	2,797,955
SC2a	902,819	242,581	587,784	22,929	1,756,113
SC2b	616,742	133,071	815,264	26,815	1,591,892
SC3	971,247	240,081	736,708	0	1,948,036
NC4a	1,633,609	410,940	1,065,277	0	3,109,826
NC4b	1,151,173	422,698	1,364,505	32,958	2,971,334
NC5	1,267,286	341,504	1,303,505	2,008	2,914,303

TABLE 3

PULPWOOD VOLUME (TONS)			Pine Pulpwood Tons Per Timberland Ac.
<u>Area</u>	<u>Pine</u>	<u>Hardwood</u>	<u>Ac.</u>
SC1	21,721,918	12,580,492	7.8
SC2a	14,418,139	8,677,608	8.2
SC2b	10,713,294	6,568,411	6.7
SC3	18,970,214	8,079,456	9.7
NC4a	20,876,354	14,079,653	6.7
NC4b	20,674,648	15,159,543	7
NC5	25,492,306	17,417,329	8.7

TABLE 4

SOFTWOOD GROWTH/REMOVALS (CUBIC FEET)			
<u>Area</u>	<u>Growth</u>	<u>Removals</u>	<u>G/D Ratio</u>
SC1	155,209,166	91,036,366	1.7
SC2a	92,267,157	67,304,081	1.37
SC2b	81,281,839	80,627,872	1.01
SC3	142,694,567	114,129,605	1.25
NC4a	177,866,343	119,243,531	1.49
NC4b	147,577,983	129,134,098	1.14
NC5	206,170,211	223,843,495	0.92

TABLE 5

PLANTATION SUMMARY			
<u>Area</u>	<u>Plantation Acres</u>	<u>Plantation Acs. % of Tmbld. Acs.</u>	<u>Plantation Acs. % of PineTmbld. Acs.</u>
SC1	740,897	26.5%	55.6%
SC2a	431,119	24.5%	47.8%
SC2b	378,776	23.8%	61.4%
SC3	643,802	33.0%	66.3%
NC4a	862,848	27.7%	52.8%
NC4b	692,846	23.3%	60.2%
NC5	1,002,334	34.4%	79.1%

After compiling the data shown in the tables above I employed a forced ranking system based on the following to identify the areas most desirable based on resource alone.

Forced ranking System:

Each area was ranked from best to worst in each of the 5 resource attributes with the best receiving a 7 and the worst a 1. I then forced an overall ranking by assigning a level of importance to each attribute as follows:

- Pine pulpwood volume per timberland acre accounted for 35% of the total score.
- Growth/Drain ratios accounted for 30% of the overall score.
- Plantation acres as a percent of timberland accounted for 20%.
- Land type accounted for 10%.
- And ownership class accounted for 5% with the areas ranked based on % of private lands.

The results are shown in Table 6 below.

TABLE 6

Importance Area	FORCED RANK MATRIX						Area Rank
	Land Ownership 5%	Land Type 10%	Pulpwood Volume 35%	G/D Ratio 30%	Plantation Acreages 20%	Prorated Score	
SC1	6	4	4	7	4	5	2
SC2a	1	6	5	5	3	4.5	3
SC2b	4	1	2	2	2	2	7
SC3	3	5	7	4	6	5.5	1
NC4a	2	7	1	6	5	3.95	5
NC4b	5	2	3	3	1	2.6	6
5	7	3	6	1	7	4.45	4

Recent additions of two new OSB plants tend to support these findings as Grant Forest Products has located a new facility in Fairfax, SC (SC3 – my No. 1 ranked area) and a second facility is 90% complete in Alcolu, SC which is on the fringe of SC3 and SC1 (my number 2 ranked area).

At this point in the potential site evaluation process; however, no consideration has been given to levels of competition or wood costs, which can be a direct result of competition. An overview of the competition found in each area is discussed in the following pages.

COMPETITION:

An examination of the level or degree of competitiveness within each Area includes identification of the roundwood pulpwood, residual and in-woods chip consumers, as well as assigning a designation to each area that reflects the level of competition already present in the area. I have attempted to reflect this level of competitiveness by using the designations Low, Medium and High.

First, the accompanying multi-state map identifies the consumers that have an impact on the 7 Areas under review.

A further breakdown of competitors will be identified on individual Area maps with discussion on the potential impact each will have on any particular Area.

COMPETITORS

◇ Integrated and Non-Integrated Pulp Mills

△ OSB Plants

As is obvious when reviewing the map of competitor mills, the major concentration of consumers is along the I-95 corridor and the Atlantic coast. These mills are all major consumers of both pine and hardwood pulpwood with each impacting all or portions of the identified Areas of interest in both North and South Carolina. More detailed maps of both states are added below to clarify the locations and impacts to the Areas under consideration.

Although these maps appear to be somewhat "Busy" they serve to identify the competition that exists or very soon will be active in the Areas of interest. Only Weyerhaeuser in North Carolina has a fee land base and internal residual chip sources (2 sawmills) to supplement their procurement operations. Others; however, like IP have existing long term agreements to purchase or market chips and receive wood from previous fee land holdings and Wood Products mills. The OSB plants within the broader two State areas are all dependent on marketwood sources for their supply and consume primarily pine with a very small component of hardwood.

I have included a Table (7) following the maps that estimates the annual consumption of the identified competitors.

North Carolina

South Carolina

TABLE 7
Estimated Consumption
(M Tons)

<u>Competitor</u>	<u>Mill Type</u>	<u>Softwood</u>			<u>Hardwood</u>		
		<u>R'wood</u>	<u>Chips</u>	<u>Total</u>	<u>R'wood</u>	<u>Chips</u>	<u>Total</u>
Abitibi - Augusta	P&P	650	0	650	0	0	0
Bowater - Catawba	P&P	1,900	950	2,850	0	0	0
Capstone - Roanoke Rapids	P&P	1,050	850	1,900	0	0	0
Domtar - Bennettsville	P&P	700	0	700	1,300	0	1,300
IP - Augusta	P&P	150	0	150	2,250	350	2,600
IP - Eastover	P&P	1,100	100	1,200	1,500	350	1,850
IP - Georgetown	P&P	1,600	900	2,500	650	175	825
IP - Riegelwood	P&P	1,450	420	1,870	1,950	430	2,380
IP - Savannah	P&P	1,880	500	2,380	550	0	550
MeadWVaco - Charleston	P&P	1,835	530	2,365	1,050	160	1,210
Sonoco - Hartsville	P&P	Min.	Min.	Min.	Min.	Min.	Min.
Stone - Florence	P&P	1,235	875	2,110	0	0	0
Weyco - New Bern	P&P	1,800	0	1,800	0	175	175
Weyco - Plymouth	P&P	1,250	350	1,600	0	250	250
Weyco - Pt. Wentworth	P&P	1,300	200	1,500	0	0	0
Nexfor - JoAnna	OSB	800	0	800	0	0	0
GP - Dudley	OSB	185	0	185	0	0	0
Grant - Fairfax	OSB	1,500	0	1,500	100	0	100
Grant - Alcolu*	OSB	1,500	0	1,500	100	0	100
IP - Silverstreet**	Chipmill	350	0	350	0	0	0

* Grant @ Alcolu is estimated to be 90% complete and is currently on hold.

** Longterm supply agreement with Blue Ridge Paper in Canton, NC.

It is very easy to see that some Areas stand out when reviewing the competitive environment present in both North and South Carolina. For example, Area SC1 is undoubtedly the most highly competitive area in either State. The presence of Bowater @ Catawba, IP @ Eastover, Domtar @ Bennettsville and Stone @ Florence all point to a highly competitive circumstance. Couple this with the fact that this area also contains the Midland's sand ridges that are excellent winter habitat for hungry paper mills and the resulting \$26.50/ton delivered wood cost is an obvious result. This represents current cost during a relatively extended period of dry ground conditions and abundant wood. This area will also be impacted by Grant's new OSB mill in Alcolu. It currently stands at an estimated 90% complete with further work slowed or halted. They have also very recently released their procurement forester who was to manage wood supply for Alcolu. No known timetable for mill startup is public knowledge at this time.

SC3 has been designated as an area of Medium competitiveness but that assessment results from a combination of High intensity in the eastern and southern portions of the area and a relatively moderate level of competitiveness in its western and northern sections. I must also point out that Grant's other OSB mill in Fairfax has been slow to move up the startup curve and much downward pressure has been exerted on wood cost as a result. The area has also been under a relatively extended dry period with lower wood cost and restricted deliveries the result. The upper and western portions of the area offer opportunities to site a plant based on competition, level of resource and opportunity to access areas that are not heavily impacted by pine pulpwood usage.

I also think it best to not to locate directly under the "smokestacks" of a major paper mill consumer for obvious reasons. This will result in identifying sites that are located in areas that fall between this type of consumer and in areas with adequate resource and infrastructure. Such an example would be NC4 and NC5. Locating a plant in an area between the two in the I-95 corridor and well away from competing paper mills would present a promising opportunity.

The area between Greenwood – McCormick – and Newberry, SC (SC2a & b) should prove to be a good opportunity and I believe could provide the best sites to locate a facility. There are only two major sources of competition for pine pulpwood, Nexfor @ JoAnna and the IP chipmill @ Silverstreet. The entire upstate of SC is virtually cut-off from the eastern half of the State by the traffic jam that is Columbia. There also exists excellent wood resource and very few markets across the state line into Georgia, above Augusta. This is an area that could provide a wealth of material to a future facility.

As indicated earlier, in assessing the competitive environment in the areas in question, I have used a High, Medium and Low attribute to be assigned to each of the 7 areas. These assessments are shown in Table 8. Delivered pine roundwood and pine pulpwood stumpage prices in Table 9 also help to reflect the level of competition that is present and support the competitive assessments shown in Table 8.

TABLE 8

<u>Area</u>	<u>Area Competitiveness</u>
SC1	Medium
SC2a	Low
SC2b	Low
SC3	High
NC4a	Medium
NC4b	High
NC5	Medium

TABLE 9

<u>Area</u>	<u>Pine Stumpage</u>	<u>Pine Delivered</u>
SC1	\$8 - \$10	\$25.50 - \$26.50
SC2a	\$5 - \$8	\$21.00 - \$23.00
SC2b	\$6 - \$8.50	\$23.00 - \$24.00
SC3	\$8 - \$10	\$22.50 - \$26.00
NC4a	\$6 - \$8	\$22.00 - \$25.00
NC4b	\$8 - \$10	\$26.50
NC5	\$6 - \$7	\$25.00

In summarizing my findings and prorating the 7 Areas based on best potential locations for locating new facilities, I have combined the 5 resource attributes and

the attributes of Competitive Environment and Delivered Wood Costs to come to a final recommendation. Those are shown in Table 10.

TABLE 10

<u>Area</u>	<u>Resource Rank</u>	<u>Competitive Environment</u>	<u>Wood Costs</u>
SC1	2	Medium	\$23.00 - \$26.00
SC2a	3	Low	\$21.00 - \$23.00
SC2b	7	Low	\$23.00 - \$24.00
SC3	1	High	\$25.50 - \$26.50
NC4a	5	Medium	\$22.00 - \$25.00
NC4b	6	High	\$26.50
NC5	4	Medium	\$25.00

FEEDSTOCK SOURCING:

To this point determination of potential plant sites has been guided by evaluations of pine and hardwood pulpwood resource, growth/drain ratios of softwood, competitive environment and delivered pine pulpwood costs.

The opportunity will exist to furnish a future plant with a mix of sourcing that reflects the drain area in and around the site. All areas under consideration present a variety sourcing opportunities at some volume level and cost. Residual chips and wood waste residues (both sawmill and plymill) and both pine and hardwood are available in all areas, in – woods chipping operations are functioning in all areas and a sufficient level of roundwood production is available to be utilized.

However; I would identify the following sources as points of concern:

1. Residual chips
2. Wood waste (bark, sawdust & shavings)
3. Hardwood pulpwood

Alternate “high dollar” markets make these sources problematic at best and the “closed” systems that are present in residual material sales will make it difficult to break into these markets. Some long-term contracts are in place for chip and waste sales while other companies engage in reciprocal sales of sawtimber for chips and

waste. It is also quite possible that some will view this new enterprise as short – term in nature or as a threat to their supply and will be difficult to manage and would not want to alienate their long- term customers. Hardwood pulpwood is the more costly – higher demand product in many areas. The mills involved in hardwood will be extremely difficult to compete with on a roundwood basis.

The opportunity to purchase non-debarked in-woods chips and under story residue will present a significant positive influence on a power plant's source mix.

CONCLUSIONS:

In summarizing this report I would offer the following:

1. Successful identification of plant sites can be accomplished following the previously outlined assessments.
2. At least 4 and possibly more sites can be found and I believe adequately and cost effectively sourced in the areas discussed.
3. Primary plant sourcing will be pine roundwood pulpwood supplemented with in-woods chipping of 1st thinnings, fuel type under story material, logging slash and poorly stocked mixed pine and hardwood stands. The purchase of residual chips and wood waste will be possible but will play a minor role in overall plant sourcing.
4. More detailed work is needed; particularly in the North Carolina areas, to finalize site recommendations and determine accurate pricing for sources other than pine roundwood pulpwood.
5. In compiling this review I have found that significant interest is ongoing in power plant establishment in some of the areas reviewed in North Carolina and southern Virginia.
6. Should Price wish to pursue this opportunity further I have a comprehensive xl file containing the numerous sold wood plants with consumption figures and residual production estimates residing in both North and South Carolina as well as the neighboring states of Virginia and Georgia that would serve as an important resource in developing more detailed cost and sourcing estimates.

Therefore, based on all of my research and understanding of the dynamics of the areas in question I would propose that the following maps represent potential sites for establishment of the power generating plants in question.

North Carolina

SUGGESTED SITES ○

CLIENT INQUIRIES ★

1. Clinton
2. Halifax County
3. Hoke County
4. Kinston

SUGGESTED SITES ○

CLIENT INQUIRIES ★

1. Fairfield County
2. Great Falls
3. Lancaster County
4. Orangeburg County

South Carolina

To address the sites suggested by your client I offer the following:

TABLE 11

<u>Client Site</u>	<u>Area Location</u>	<u>Recommended Y or N</u>	<u>Reason for N</u>
Fairfield Co, SC	SC1	N	Competition & Cost
Lancaster Co., SC	SC1	N	Competition & Cost
Great Falls, SC	SC1	N	Competition & Cost
Orangeburg Co., SC	SC3	Y - but further west	
Newberry, SC	SC2b	Y - toward Greenwood	
Kinston, NC	NC4a	Y - in general	
Clinton, NC	NC4a	Y - in general	
Hoke Co., NC	NC4b	Y - but to the East	
Halifax Co., NC	NC5	N	Competition & Cost

Finally, if the preliminary inquiries by your client truly represent a real interest in pursuing power generation using wood sources then I believe a positive opportunity exists for Price to become involved in this initiative.

MAPS & TABLES

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Attachment B
GO88072 Final Report

Prepared for

ORGANIC BIO-ENERGY, INC.

**Task # 2 Conduct Feasibility Study on Establishing Facility for
Production of Biodiesel from DAF Treatment of Agricultural
Waste Water and Reclaimed Corn Oil from Ethanol Production.
Assess Local Area Feed Stocks for Project. If Project is
Feasible, Develop License Agreement for Use of Technology and
Memoranda of Understanding with Waste Producers.**

To: George E. Miller, III
President

Date: November 13, 2008

CONTACT INFORMATION:

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Deliverable - Biodiesel from DAF treatment of agricultural water and reclaimed corn oil from ethanol production – feasibility study, license agreement for use of technology, and memoranda of understanding with waste producers.

November 13, 2008

Biodiesel Technical Report and Feasibility Study

Summary

Green Energy Partners, LLC (GEP) was hired by Organic Bio-Energy, Inc. (OBE) to investigate the production of Biodiesel and the technologies associated with its production.

Biodiesel production technologies were researched along with feedstock requirements to yield oils that could be used for conversion to Biodiesel. Representatives from GEP traveled to several Midwestern states to determine the feasibility of various systems by evaluating currently operating Biodiesel plants. Several types of agricultural products were investigated as possible feedstocks, including Corn Ethanol Dried Distiller Grains, Algae, and other South Carolina native agricultural products. The technology chosen as most applicable was the Green Shift Biodiesel conversion technology, which can utilize a range of feedstock oils to produce biodiesel. Technical information on the Green Shift biodiesel system was collected and evaluated.

The following report gives an overview of Biodiesel and its production methods, as well as technical information on Green Shift and other emerging technologies as well as feedstock information.

Technical Overview of Biodiesel and its Production

Biodiesel, as defined in ASTM D6751, is “a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the requirements of ASTM D6751”. Biodiesel is usually produced by a reaction of vegetable oil or animal fat with an alcohol (typically methanol or ethanol) in the presence of a catalyst to yield mono-alkyl esters and glycerin. The glycerin is removed and Biodiesel is left as the end product. The production can be achieved by three basic processes:

- Base catalyzed transesterification of the oil.
- Direct acid catalyzed transesterification of the oil.
- Conversion of the oil to its fatty acids and then to Biodiesel.

The vast majority of Biodiesel production done today is achieved by the base catalyzed reaction. This method uses low temperatures and pressures and achieves conversion percentages as high as 98% with minimal side reactions and reaction time. The chemical reaction associated with Biodiesel produced from a based catalyzed reaction is shown below.

The oil or fat is combined with the alcohol in the presence of a catalyst to yield Glycerin and Biodiesel.

Benefits of Biodiesel

The use of Biodiesel as fuel offers many benefits when compared to traditional petroleum-based diesel fuel. Biodiesel does not contain any sulfur or aromatics and the combustion of Biodiesel in traditional diesel engines produces significantly lower amounts of unburned hydrocarbons, carbon monoxide and particulate emissions. The US Department of Energy conducted a study that monitored the carbon dioxide emissions during the production and use of Biodiesel. The study found that the production and use of Biodiesel reduces carbon dioxide emissions by 78.5% when compared to petroleum diesel.

The use of Biodiesel also leads to increased energy independence and security, compared to using imported fossil fuels. Biodiesel can be produced from commodity crops and waste products that are found within the US, greatly increasing our nation's independence and security.

One of the largest benefits of Biodiesel over other alternative fuels is its compatibility with existing infrastructure and engines. This means that production and consumption can happen rapidly to help reduce America's dependence on foreign oil. There are Federal and several State mandates requiring the use of alternative fuels or the reduction of consumption of foreign oil. In many cases, the most cost effective way to meet these mandates is the use of Biodiesel.

In addition to the above benefits, producing Biodiesel domestically would create jobs. Production facilities would be needed to process a range of feedstocks. Quite possibly, the largest increase would be seen by farmers of oil seed crops such as soybeans. The oil seed crop production would need to increase as the demand for Biodiesel increases.

Identified Technologies

GEP identified and investigated several available technologies to process Biodiesel. Green Shift's technology can process a wide range of feedstocks, including all known waste fats, oils and greases.

One of Green Shift's emerging technologies is the process of corn oil extraction at ethanol plants. One of the byproducts of the ethanol production process is dried distiller's grains (DDGs). The spent grains left over from the production process must be dried before being sold to animal farms as feed. This drying process can be very costly and can vary greatly based on the cost of natural gas. However the DDGs still have a significant amount of energy remaining in them. Green Shift has developed a method to extract corn oil from the spent grains before they are dried. The corn oil extracted is then processed to produce Biodiesel. The processed grains can then be dried and still sold to animal farmers as feed. The Green Shift technology can be retrofitted to existing ethanol plants providing another revenue stream for the owners. The Corn Oil Extraction process decreases the overall mass of grain that has to be dried or shipped, reducing the owner's fossil fuel consumption, utility costs and carbon footprint. Also, the protein content of the DDGs is increased due to the removal of fat/oil used for the Biodiesel production.

Another technology offered by Green Shift is the process of Animal Fat Extraction. This process is targeted to remove the fats and oils from the co-products and wastes from agri-product facilities. Meat processing facilities are

required by the USDA to use large volumes of water to continually rinse the meats as they are processed and packaged. The result is a large volume of waste water with a high concentration of fats and proteins. The waste water treatment process removes these, yielding a clean stream of water and a sludge known as Dissolved Air Flotation (DAF) Sludge. This sludge is typically transported and land applied. Green Shift's process removes the fat from the DAF sludge, reducing the amount of DAF sludge to be disposed of by up to 80%. The removed fat can be used in Biodiesel production, offering another revenue stream to meat processors and reducing their waste disposal costs.

In addition to Green Shift several other technologies were identified and investigated. The most promising are detailed below;

Greenline Industries (<http://www.greenlineindustries.com>) – Greenline has developed a waterless wash system for the production of Biodiesel. This system has been honored by the EPA for a clean, green technology. This sets them apart from other Biodiesel production skids. Other solutions require that every gallon of Biodiesel produced be “washed” with water near the end of the process. The water wash process is expensive and can pose some difficulties in the permitting process due to the waste water contaminants. Greenline's technology eliminates this need in turn reducing initial capital costs and ongoing costs associated with waste water treatment. The Greenline process is also capable of utilizing multiple feedstocks; this lends itself well to smaller facilities that have varying streams of feedstocks. The Greenline process has been used in five German Biodiesel production facilities.

Orbitek Inc. (<http://www.orbitekinc.com>) – Orbitek offers a multiple feedstock system to process Biodiesel that meet ASTM specifications. The main offering is a closed loop skid mounted system capable of producing four million gallons of Biodiesel per year. Orbitek in partnership with Cornell University's Graduate School of Chemical Engineering developed a patented process technology that is the heart of their CFT™ rapid reaction Biodiesel production system. Orbitek currently has a system installed in Tulsa, Oklahoma as an R&D project to test new feedstocks, catalysts, fuel additives and preprocessing methods. The Tulsa project is projected to lead to a commercially ready system for mass production utilizing Orbitek's patented process technology.

McNeff Research Consultants (<http://www.mcneffresearchconsultants.com>) – McNeff has developed a patented process known as the Mcgyan process. The Mcgyan process uses a fixed bed flow-through reactor. This combined with the patented process dramatically reduces the reaction time needed for Biodiesel production. This process has the potential to revolutionize the production methods of Biodiesel.

There are dozens of companies that offer Biodiesel production equipment, however the organizations outlined above have made significant innovations in streamlining the process; making the production of Biodiesel more economical on the small scale while having the flexibility to process multiple feedstocks.

Feedstock Information

South Carolina, including the Orangeburg area, has a wide range of feedstocks available for Biodiesel production. Using the innovative technologies identified above, small scale plants can prove to be economically feasible and help to decrease the state's dependence on foreign oil.

It has been found that only a few select feedstocks are gaining momentum as being economically viable for conversion and processing into biodiesel. One of those has been cooking oils such as vegetable oil, corn oil, peanut oil, sunflower oil, and canola oil. Many companies collect used cooking oil, filter the oil and provide a productive product for conversion into biodiesel. Several companies are gaining ground with a process that can receive FOG (fats, oils, grease) and, by dehydrating the product, turn it into a coal-like granule that can be co-fired and combusted as a renewable fuel, offsetting coal. One company that utilizes a proprietary process for this conversion is Eco Plus www.ecoplusinc.com. Many municipalities receive FOG and must treat it at the waste water treatment plant, which becomes very expensive, or landfill the product, which causes an unstable base as the products are high in moisture. A much better solution could be to take the "O" out of FOG by separating out the usable oils. Under this scenario, a usable feedstock could be used for biodiesel production and the remaining waste products can still be converted into a renewable co-fired product for combustion.

During the process of producing oil seed crops for biodiesel production, the "food versus fuel" argument must be considered. If farmlands that were utilized for crops for human consumption are replaced by crops for fuel production, then it becomes a no-win situation. In many cases, however, farmers across the country (with South Carolina as no exception) have found themselves unable to economically grow any cash crop for human consumption. In those situations, putting the land to use growing crops for fuel is not affecting the food infrastructure. When candidate lands for oil seed production are evaluated, consideration must be made for growing fuel crops on land that is unusable due to environmental regulations, spills, landfills, or lands that require environmental remediation. For instance, a soybean crop could be grown on a capped landfill, or otherwise unsuitable property, where food for human consumption is not allowed to be grown.

Barriers to Success

The driving factor in the success of any alternative fuel is the economic feasibility of its production and use. Biodiesel is no exception to this rule. Biodiesel can offset a significant amount of foreign oil if there is a clear policy enacted to encourage the use of biodiesel and other biomass fuels. This policy will need to utilize tools such as purchasing incentives and tax credits in addition to further state and federal mandates on the use of alternative fuels. Also, incentives need to be put in place for the growing of oil seed crops for fuel production. With a struggling agricultural economy in South Carolina, nationwide federal credits and state level credits have to be strategically put in place to jump start the biodiesel markets into a viable large scale renewable fuel for South Carolina.

As well as defining the proper regulatory incentives, a project must consider decentralizing production to smaller regional areas. The high costs associated with processing feedstocks and transporting them to site lead to a significant advantage for small, decentralized sites that draw feedstock crops from a smaller area, thus reducing transportation costs. Large plants that require large feedstock volumes, and especially plants that require feedstocks grown outside of its regional area, usually are not sustainable or economical. When at all feasible, plants should be strategically located so as to not increase feedstock competition which better yields a competitive and sustainable fuel infrastructure for biodiesel. Each state has the resources, infrastructure, and climate to grow certain oil seed crops or perhaps only waste oil products. For example, it has been proven that soybean is one of the oil seed crops that yield the most oil per acre in South Carolina. Certain regional alternative fuels are based directly on the available feedstocks that can be grown in a particular region for its climate conditions. Most all areas will have a supply of waste products from other processes such as cooking but only select areas will have the availability of corn oil from the DDG's of an ethanol plant or climate to grow oil seed crops. Certain regions of the state will have the ability for producing larger amounts of biodiesel, while other parts of the state will have a larger abundance of waste products from cooking. In some regions, biodiesel may not be feasible at all and other alternative fuels are more economical, such as compressed natural gas created from purified landfill gas.

Conclusions

Biodiesel is and will continue to be a leader in the alternative fuels market. The production will continue to increase as demand grows and new technologies make production even more economical. Through market research and travel to existing sites, Green Shift has been identified as an industry leader in the

extraction of fat/oils and the production of biodiesel. Green Shift and others are on the forefront of stream lining the production of alternative fuels. The technologies identified in this report make the small scale localized production of biodiesel economical in South Carolina.

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Prepared for

ORGANIC BIO-ENERGY, INC.

Task # 3 Conduct Feasibility Study on Establishing Facility for Production of Synthetic Biodiesel from Biomass. Assess Biomass Availability for Project. If Project is Feasible, Develop License Agreement for Use of Technology and Memoranda of Understanding with Biomass Producers.

To: George E. Miller, III
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Deliverable – Synthetic Biodiesel from Biomass- feasibility study, license agreement for use of technology, and memoranda of understanding with waste producers.

Feasibility Study on Renewable Diesel Production from Biomass

I. What is Renewable Diesel?

a. Definition

Renewable diesel, also known as *synthetic (syn-) diesel* or *Fischer-Tropsch (FT-) diesel*, is an alternative fuel derived from wood or other biomass (carbon-containing) feedstocks. This fuel can be substituted directly for traditional petroleum-based diesel (“petro-diesel”) without any engine modifications, or can be blended with petro-diesel in any percentage, as required.

Renewable diesel is not technically considered “biodiesel” by the formal (legislative) definition (“a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats and meeting the requirements of ASTM D6751”), since it is not made from oil or fat. This means that renewable diesel is not governed by ASTM D6751, but instead must follow the testing methods and standards of ASTM D975, the general “Diesel Fuel Specification”.

This feasibility study is only concerned with so-called “Biomass-to-Liquids”, or BTL, technologies to produce diesel fuel. These methods are discussed in Part II below.

b. Properties

Renewable diesel is very similar to petro-diesel in most of its properties. It has a comparable energy content, or heat of combustion, to petro-diesel (renewable diesel: 45-48 MJ/kg, or 126,000-134,000 BTU/US gallon; petro-diesel: 43-48 MJ/kg, or 130,000-146,000 BTU/gal), which means a similar fuel economy. It also has a higher cetane number (the diesel equivalent of octane), contains virtually no sulfur or aromatics, and produces fewer hydrocarbon and particulate emissions than petro-diesel. In addition, renewable diesel has lower tailpipe emissions of oxides of nitrogen (NO_x) and other greenhouse gases (although the additional processing required to produce the fuel makes the overall emissions profiles of these compounds equal to or higher than petro-diesel).

The only drawbacks to renewable diesel, like biodiesel, are its poor lubricity and poor cold-flow properties, so in cold climates, a blend of renewable diesel and petro-diesel may be appropriate.

c. Benefits

The higher cetane number for renewable diesel means better engine performance, better cold starting capabilities, and less white smoke emissions. The environmental impact of renewable diesel is the same as that of petro-diesel, however renewable diesel has lower air emissions and a greater energy security due to a decrease in the dependence on foreign oil. Another benefit of this alternative fuel as opposed to many others than are currently being considered today, is that the existing diesel infrastructure can be used. This means the fuel can be transported in existing diesel pipelines, distributed through existing diesel fueling stations, and used in existing diesel vehicle engines, without any modifications being required.

d. Tax Credits

Since renewable diesel is not included under the definition of biodiesel, it is not eligible for any biodiesel tax credits. Similarly, renewable diesel derived specifically from BTL processes has not yet been recognized as an alternative fuel under the Energy Policy Act (according to a 2007 report). Each manufacturer of renewable diesel must have its product registered by the Environmental Protection Agency (EPA) before it can be sold to the public (according to 40 CFR Part 79). Once BTL fuels are officially recognized under the Energy Policy Act, this fuel may be eligible for any renewable diesel tax credits, but none are available at this time (the renewable diesel tax credit expired at the end of 2008).

II. Production Methods

a. Overview

Renewable diesel can be produced in a number of different ways from a variety of feedstocks. Technically, “syn-diesel” or “FT-diesel” can be produced from coal or fossil fuel natural gas as well as biomass, but to be considered renewable diesel, it must come from a renewable source. For the purposes of this feasibility study, only the classification of technologies known as “Biomass-to-Liquids”, or BTL, will be considered.

The production of diesel from any of these sources entails two discrete steps. The first step is to produce the intermediate gas, either natural gas (methane, CH_4) or “syngas” (a combination of carbon monoxide, CO , and hydrogen, H_2). In the case of renewable diesel, non-fossil fuel natural gas is produced by the decomposition of organic waste in an oxygen-free (anaerobic) environment. The gas can be collected from a landfill or produced as biogas in an anaerobic digester (see section “c” below). Syngas can be produced from wood or other biomass in any of several types of gasification units (see section “d” below). Following gasification, the gas stream must be purified and then passed through a “water-gas shift reactor” to obtain the proper composition of syngas for the next step.

The second step in the production process is to convert the intermediate gas into the liquid diesel fuel using a process called Fischer-Tropsch Synthesis (see section “b” below).

Figure 1 shows a general flow diagram of the production process for renewable diesel from biomass. Each step will be discussed individually in the following sections.

Figure 1: Various options for making renewable diesel fuel from biomass.

b. Fischer-Tropsch Synthesis

The Fischer-Tropsch (FT) process was originally developed in the 1920s by German researchers Franz Fischer and Hans Tropsch. Since then, many refinements and adjustments have been made to the basic process to increase efficiency and applicability. FT Synthesis is a process by which a chemical catalyst is used to convert natural gas or syngas into a liquid hydrocarbon (including alcohols, waxes, gasoline, diesel, etc.) that can be used as synthetic fuels or lubricants.

The chemical reactions taking place during FT Synthesis are complex, but can be simplified as:

where 'n' is a positive integer. The catalyst and process conditions are chosen in order to maximize production of the desired product (i.e., the ideal 'n'). A low value of 'n', such as n=1, would mean methane production, which is undesirable in most applications. Very high values of 'n' denote waxes, which are solid at room temperature, and these are also avoided. Diesel fuel is typically a mixture of hydrocarbon chains of varying lengths, where 'n' is between 9 and 25.

The specific type of catalyst to be used depends on the type of gas (natural gas or syngas) to be converted and the desired product. Some common catalysts used in the reaction are iron and cobalt, although other metals are used for certain applications. Iron catalysts are generally preferred for syngas conversion, while cobalt is more often used when the feedstock is natural gas.

Temperature and pressure are also adjusted to maximize production of the desired product. The temperature for this reaction is generally 150-300°C (302-572°F), but since higher temperature favors methane production, the lower to middle part of this range is usually preferred. Increasing the pressure will also help to produce longer chained molecules, such as those found in gasoline and diesel fuel.

Prior to FT Synthesis, a water-gas shift reaction must be undertaken to ensure the proper ratio of H₂:CO in the syngas. This reaction is shown as:

The ideal ratio for most applications is around two (i.e., twice as much H₂ as CO), although the exact ratio varies depending on the application and the catalyst being used.

There are very few commercial companies currently using the Fischer-Tropsch process at large scale. Shell in Malaysia and Sasol in South Africa are the two larger users of this process, but both of these companies are using fossil fuels (coal and natural gas) as their feedstocks. Other small companies that are starting to use the FT process are Rentech, in the United States, and Choren Industries, in Germany. In the United States, several coal-producing states such as Pennsylvania and Montana are

making plans to use coal as a feedstock in the FT process to produce fuel, and the U.S. Air Force is also investigating the possibilities of this technology.

c. Production of Natural Gas for Renewable Diesel

The decomposition of non-woody organic waste (food scraps, grass clippings, animal manure, sewage sludge, etc.) by microbes in the absence of oxygen produces a methane-rich gas. This process takes place naturally in landfills, where the waste is buried, thus creating an anaerobic (oxygen-free) environment. Since methane is a very strong greenhouse gas (21 times stronger than carbon dioxide), it is very hazardous to allow this gas to escape into the atmosphere. Its release is also undesirable from an economic standpoint, since methane is a valuable fuel source for a variety of alternative fuels. The strategic placement of “wells” into the landfill can facilitate the collection of the gas, in this case referred to as landfill gas, or LFG. The LFG that is collected in this way generally has a methane content of 50-60% (the remainder being carbon dioxide and other trace contaminants). This gas stream can be purified using any number of gas separation technologies to produce a nearly pure stream of methane, or non-fossil fuel natural gas, which can then be converted in an FT reactor to produce renewable diesel fuel.

Alternately, this non-woody organic waste can be processed before even being put into the landfill, by using an Anaerobic Digestion (AD) System. This reactor performs the same role as the landfill in producing a similar methane-rich gas, in this case referred to as “biogas”, but still containing 50-60% methane. However, by using an AD system, 100% of the methane can be captured, altogether eliminating any release into the atmosphere, which can occur at landfills. Also, processing this waste before it goes into the landfill will help to extend the life of the landfill and help with local waste management issues.

d. Production of Syngas for Renewable Diesel

The primary gasification process that was investigated in this feasibility study is *ultra-high temperature gasification* (by a company called Pyromex™). Traditional gasification processes operate at a lower temperature (500-1200°C) and use oxygen or air for combustion of the feedstock, which is less efficient and yields lower conversion rates and more leftover ash residue.

The Pyromex™ process uses ultra-high temperature (1250°C) thermal degradation of wood or other carbon-containing feedstocks to produce syngas. In this process, steam is used instead of the air or oxygen stream that is used in other forms of gasification. The higher temperature and lack of oxygen increase the combustion (technically “oxidation”) of the feedstock and thus the efficiency of the system. This type of gasification has no harmful emissions, since the extreme temperatures sanitize the waste and destroy any toxins that may have been present in the feedstock. The bottom ash, or residue, from the gasification process will contain any inorganic

materials, metals, or other heavy compounds that were not consumed by the process. Many of these compounds could be recovered as saleable byproducts.

Following the gasifier itself, the gas stream requires purification to remove any excess hydrocarbons or other materials to yield a clean syngas stream containing only CO, CO₂ and H₂, in some ratio. Figure 2 below shows a basic flow diagram of the Pyromex™ process to convert biomass to syngas for renewable diesel production.

Figure 2: Conversion of biomass to syngas using the Pyromex™ gasification process.

III. Feasibility at Organic Bio-Energy Park in Orangeburg County, South Carolina

For the purposes of the Organic Bio-Energy (OBE) facility, the most viable feedstock for producing renewable diesel fuel is wood. Green Energy Partners is currently in the process of building a 35 megawatt (MW) biomass plant at the John Matthews Park, adjacent to the OBE Research Facility. This biomass facility will be using primarily wood and wood waste products as its feedstock, so it will have a complete wood yard installed and operating daily. By co-locating the OBE renewable diesel production plant near this biomass plant, the wood yard could be shared by both facilities.

The Price Companies was contracted by Green Energy Partners to perform a feedstock assessment for the original 35 MW biomass plant in Orangeburg County. This report shows that there is more than enough wood available within a 50-mile radius of John Matthews Park for accommodate both a biomass plant and a renewable diesel plant using wood as the feedstock. The Price Companies report is included as an attachment to the Task 1 Feasibility Study for this project.

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