February 2004 • NREL/SR-510-35431

Subcontractor Report

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass to Ethanol Production Facility

Final Subcontract Report July 1998

American Coalition for Ethanol
Sioux Falls, South Dakota

L. Wu
Bloomington, Indiana

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Operated for the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
by Midwest Research Institute • Battelle

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Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

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Executive Summary

In 1994, there were over 1.8 million acres of CRP lands in South Dakota. This represented approximately 5 percent of the total U.S. cropland enrolled in the CRP. Nearly 200,000 acres of CRP lands were concentrated in three northeastern South Dakota counties: Brown, Marshall and Day. Most of the acreage was planted in Brohm Grass and Western Switchgrass.

Technology under development at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), and at other institutions, is directed towards the economical production of fuel-grade ethanol from these grasses.

The objective of this study is to identify and evaluate a site in northeastern South Dakota which would have the greatest potential for long-term operation of a financially attractive biomass-to-ethanol production facility. The effort shall focus on ethanol marketing issues which would provide for long-term viability of the facility, feedstock production and delivery systems (and possible alternatives), and preliminary engineering considerations for the facility, as well as developing financial pro-formas for a proposed biomass-to-ethanol production facility in northeastern South Dakota.

This Final Report summarizes what was learned in the tasks of this project, pulling out the most important aspects of each of the tasks done as part of this study. For greater detail on each area it is advised that the reader refer to the entire reports which are included as appendixes.

Financially, because such a plant has not been constructed before, it was hard to project some numbers with great certainty. In such cases, the most conservative numbers and approaches were uses. Hence, the Base Case Income Statement (see Appendix F) only shows a profit in the last year displayed in the projections (Year 12). The average annual after-tax income is -$1,072,419 over the first ten years of full operation, representing a -2.20% annual return on investment. Cumulative earnings reach a low at the end of Year 11 of -$12,693,924.

The Best Case Scenario incorporates the same assumptions as the Base Case with the following two exceptions: (1) a $0.20 per anhydrous gallon, state sponsored producer incentive is included, and (2) the cost of the feedstock grass was lowered to $22/ton (from $25/ton).

The state producers incentive and more favorable feedstock grass cost assumptions included in the Best Case Scenario have a dramatic effect on the cash flow and income projections. The average annual after-tax income for Years 3 through 12 is $364,344 representing an 0.82% return on investment. Income drops significantly after the state producers incentive is phased out after Year 11.

Though the return on investment would be small, it does, however, show that with existing technology a biomass-to-ethanol plant in northeastern South Dakota could be profitable. There is no doubt that continual advances in technology and process procedure, as well as revised or alternate process techniques could make such a venture even more attractive.

Though not addressed in this study, locating a biomass-to-ethanol processing facility at the site of an existing ethanol processing facility also has the potential to lower even further the capital costs of constructing such a facility. The National Renewable Energy Laboratory has been the leader in conducting and sponsoring research regarding the conversion of biomass materials to ethanol and the authors of this report would strongly suggest that NREL be contacted for more information along those lines.

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Introduction

The amount of fuel-grade ethanol produced from renewable sources has grown from practically zero in the mid-1970s to well over one-billion gallons of production annually two decades later. The USDA projected for 1995/96 that 563 million bushels of corn would be used to produce ethanol (Industrial Uses of Agricultural Materials, 1995). Roughly two-thirds of U.S. ethanol capacity is from wet-milling and one-third from dry-milling. Using the average conversion rate for the two processes as 2.525 gallons per bushel (Shapouri, and others, 1995), it can be estimated that over 1.4 billion gallons of fuel-grade ethanol will be produced in 1995/96.

While in the United States ethanol is principally produced from corn and other high-starch grains, it can be made from biomass materials such as wood, grasses, and waste paper. The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, Colorado, and other institutions, are actively improving the biomass-to-ethanol technology.

Biomass, such as grasses grown on CRP acreage, represent a potentially abundant and economical feedstock for ethanol production. Conversion of waste biomass materials and agricultural residues into ethanol could produce up to 3.8 quads (1 quad = 10^{15} Btu) of energy each year. It has been estimated that the U.S. production potential for biomass ethanol to be between 12.4 to 26.5 quads (Lynd, and others, 1991). By comparison, the estimated 1.4 billion gallons of fuel-grade ethanol produced in 1995/96 represents 0.11 quads of energy.

Project Objective

The objective of this study is to identify and evaluate a site in Brown, Marshall or Day Counties, South Dakota which would have the greatest potential for the long-term of a financially viable biomass-to-ethanol production facility. The effort shall focus on ethanol marketing issues which would provide for long-term viability of the facility, feedstock and delivery systems, and preliminary engineering considerations for the facility.

The CRP program, established in 1985, resulted in the enrollment of nearly 36 million acres of land that are prone to erosion and/or is highly environmentally sensitive. The first CRP contracts are due to expire in 1996. If the federal government is to continue the program a solution must involve keeping land out of production while reducing the existing CRP contract costs. One possible option would allow farmers to harvest grasses from CRP acres and sell it to a biomass-to-ethanol facility. This would help keep farmers in the CRP and land out of tillage.

If an acre of CRP land produces 2.5 tons of grass per year, it could produce the same ethanol yield as 100 bushels of corn from the same acre. Approximately 40,000 acres would be needed to produce enough feedstock for a 10 million gallon per year biomass-to-ethanol facility. In other terms, a biomass-to-ethanol facility processing 350 tons of grasses per day, yielding 100 gallons of ethanol per bone-dry ton (BDT) of grasses, in operation for 300 days would produce 10.5 million gallons of ethanol per year. At slightly lower yields, a facility processing 350 tons of grasses per day, yielding 80 gallons of ethanol per BDT of grasses, in operation for 330 days would produce 9.2 million gallons of ethanol per year (Wiselogel, 1996). This is the general scale of our projected biomass-to-ethanol facility.

The design for the biomass-to-ethanol facility was modeled after the process described in a 1994 report prepared for NREL entitled, "Biomass to Ethanol Process Evaluation," which was submitted by Chem Systems. For the studies prepared by Broin & Associates sizes and flows were altered to reflect the change in product output. (Changes or departures made from the Chem Systems model are discussed in Appendices D and E.) A detailed description of the plant design capacity can be found on page 1 of Appendix F.

Market Assessment (Appendix A)

Marketing Strategy

The marketing strategy for the biomass-to-ethanol plant proposed for this study should be viewed to maximize the revenues and conserve the working capital. The scale of the facility, although capital intensive, is small vis á vis the markets for the finished products. The revenue producing products are fuel ethanol, uncompressed carbon dioxide and co-generated electric power from burnable process residues.

The fuel ethanol produced from the biomass plant will flow into the North Central Region in competition with the established producers. The biomass plant can elect to establish its own sales force or contract for marketing service.

It appears contracts for sale for fuel ethanol will yield a higher net revenue to the project. This is due to the cost of entry for a new producer as the buyers pit the new supply against the established production. The cost of direct market entry is projected to cost from $0.02 to $0.04 per gallon during the first year of operation. At a capacity of 10 million gallons per year, the sale of fuel ethanol should be contracted with a distributor, whose territory covers the North Central Region, prior to the beginning of plant construction. Distributors with these capabilities are MILSOLV (Butler, Wisconsin), Koch Refining Company (Wichita, Kansas) or Heartland Fuels Division of Farmland Industries Cooperative.

Carbon dioxide may be sold across the fence to Koch Industries, Inc., Liquid Carbonic Industries Corporation, BOC Group, Inc., Liquid Air Corporation or CARDOX as uncompressed gas. This can be accomplished prior to the commencement of ethanol production. The range of price per ton is $9.00 to $12.00 per ton. Carbon dioxide may be sold directly to the bottler to distributor. The wholesale price of $44.00 to $59.00 per ton is attractive for a low cost new entry. Market penetration rate is projected at 3% per month of capacity. The break-even with the sale of uncompressed gas would occur during the mid-part of the second year of operation. Adequate working capital is required to sustain the sales effort. These costs may be capitalized and amortized.

The excess electric power may be sold to East River Power Cooperative or Otter Tail Power Company at established tariff rates in effect at the date of start up.

It is possible for all of the output of the biomass-to-ethanol plant to be committed prior to the commencement of production. The gross revenues, net of sales cost and freight is projected at $12,160,000 plus any state producer incentive payments, for the first full year of production.

Fuel Ethanol	$1.15/Gal.	11,500,000
CO_2	$9.00/Ton	260,000
Electric Power	$1,200.00/Day	400,000
Gross Revenue		$12,160,000

Summary

The evidence indicates ethanol produced from renewable sources is a practical component of reformulated motor fuel. The octane and oxygenate values have established a market value independent of price supporting subsidies. The market is growing. The projected demand for fuel ethanol in the year 2000 is 1.85 billion gallons and it could be has high as 2.28 billion gallons. This confirms that demand will be sufficient in the North Central Region to accommodate the 10 million gallon per year facility studied.

Western Switch Grass (WSG) yields greater than 2.5 tons per acre provide values per acre equivalent to oilseed and row crops in the region selected for the study. Price of $29 to $42 per ton, FOB, field edge are practical for the farmer.

The price of fuel ethanol appears to be market driven, based upon inherent values rather than subsidy payments. The producer payments available in some states are essential to the survival of the small ethanol producer using corn as a feedstock.

The products produced by the proposed study project can be contracted for sale prior to the beginning of production. The quantities are small in comparison to the markets involved. Fuel ethanol as a blending component is distributed in a parallel system to motor fuels because of its polar properties. Ethanol as ETBE may move in the historical fuel distribution network.

The availability of crop insurance for WSG is essential for the farmer to obtain adequate operating capital from lenders. The use of insurance as a risk management tool is a major factor in bank financing of operating capital for many farmers. The price of WSG would be higher if insurance is unavailable at reasonable prices, i.e., $3 to $7 per acre.

The raw feed stock cost, availability of markets, and the technology, combine to provide a reasonable opportunity for a successful biomass-to-ethanol plant in the study area.

Current Status of the Technology (Appendix B)

Hydrolysis

The differences from existing corn-derived ethanol production produce technical barriers to be overcome. A pretreatment of dilute acid is sufficient to break down hemicellulose into fermentable sugars. The conversion of cellulose to fermentable sugars is more difficult. The conversion (hydrolysis) of cellulose to sugars can be accomplished using dilute acids, concentrated acids or enzymes (cellulases).

Hydrolysis converts cellulose and hemicellulose to fermentable sugars. This can be accomplished using acids or cellulase enzymes. According to Lynd, and others (1991), while enzymatic processes are at a much earlier state of development, in the absence of unforeseen breakthroughs in acid hydrolysis, research is likely to result in enzyme-hydrolysis technologies that are significantly cheaper than acid-based ones.

Fermentation Using *Zymomonas mobilis*

Zymomonas mobilis has demonstrated ethanol yields of up to 97 percent of theoretical yield and ethanol concentrations of up to 12 percent w/v in glucose fermentation. In addition to the bacterium's high ethanol yield and tolerance, it shows high fermentation selectivity and specific productivity, the ability to ferment sugars at low pH, and considerable tolerance to the inhibitors found in lignocellulosic hydrolysates. Additionally, the distillers dried grain (DDG) from a *Zymomonas* fermentation is generally recognized as safe (GRAS) for use as an animal feed (Zhang, and others, 1995). With-respect-to biomass-to-ethanol conversions, the major drawback of *Zymomonas mobilis* is its inability to ferment xylose (a five-carbon sugar commonly found in hemicellulose).

Genetic engineering techniques inserted xylose metabolic pathways into a strain of *Zymomonas mobilis*. Zhang, and others (13 January 1995), reported after the introduction of four key genes, the new bacterium fermented a mixture of glucose and xylose at 95 percent of theoretical yield within 30 hours. Their continuing work seeks to optimize strain performance in commercial feedstocks.

Grasses

For elephantgrass and energycane grown in Florida, it has been reported that the highest annual yields were produced when stands were harvested one time at the end of the warm-growing season, compared to multiple cuttings. For the four bunchgrasses studied by Woodard and Prine (1993), annual dry matter yields ranged from 37 to 53 Mg ha^{-1}. In full season, for elephantgrass, 80 percent of the total plant dry biomass was in above-ground components while 20 percent was in rhizomes and roots.

Woodard, and others (1993), reported for the same aforementioned grasses that dry matter accumulation consistently showed a linear relationship with incoming total solar radiation. The higher dry matter yields from a single harvest was attributed to the ability of the bunchgrasses to maintain high levels of light interception and radiation-use efficiency over an extended period.

Additional Areas of Concern

1. Climate. The influence of degree days (Sanderson and Wolf, 1995) and should not be overlooked when evaluating the biomass yield potential of a given site. Similarly, precipitation is another key factor affecting yield. From data gathered over a 90-year period of the Park Grass Experiment in England (Silvertown, and others, 1994), rainfall in the growing period before the first hay cut (early-June to mid-July) increased the biomass and the proportion of grass in that cut on some of their plots not receiving nitrogen, but had less effect on biomass and favored other species on some of the nitrogen-fertilized plots.

2. Feedstock. According to Wright (1995) the technological barriers to the sustainable commercial production switchgrass for energy are minimal but improvements to assure the availability of low-cost supplies are still needed. Demand for switchgrass seed for CRP plantings indicate that seed availability could be a problem during a period of rapid scale-up. Establishment of a new crop in a way that leads to optimal production in the first and second years requires attention for risk reduction. Also needed is development, testing and demonstration of optimal harvesting, and handling strategies for switchgrass crops that exceed the yields normally found with forage crops.

3. Milling. Before hydrolysis, biomass must be reduced in size to decrease heat- and mass-transfer limitations. In work performed by Schell and Harwood (1994), they determined the power requirements to reduce baled waste paper and switchgrass to particles approximately 3 centimeters long. For the switchgrass, the first pass produced material 10 to 20 centimeters long. The second pass reduced the grass length to approximately 2.5 to 6 centimeters. No significant reduction is size was achieved on the third pass. The initial moisture content was 10 percent.

4. Storage. Work by Sanderson, and others (1995) investigated, (a) the loss of biomass during baling and transport of switchgrass, (b) the dry matter losses during storage of large round bales of switchgrass, and (c) determined the potential rainfall runoff from switchgrass bales to become a surface water pollutant. For eight bales, the average biomass loss during baling was 3.38 percent. Bale weight changes and biomass loss during handling and transport over 11 miles were only 0.4 percent of the bale weight.

5. Burning. In a study of *Symphoricarpos occidentalis*, a common prairie shrub of the Northern Great Plains, Romo, and others (1993), observed its growth density increased two- to three-fold over preburn densities in the first two growing seasons following a burn.

Opportunities for Improvement

Wyman (1994) discussed a number of areas where substantial opportunities exist to reduce the cost of producing ethanol from biomass. They include, (1) reduction of the milling power by 25 percent through optimized approaches to size reduction, (2) improving the yield of sugars from hemicellulose hydrolysis from about 80 percent to over 90 percent, (3) innovative pretreatment designs or alternative approaches to increase the digestibility of the cellulose, minimize the degradation of hemicellulosic sugars during pretreatment, and reduce energy requirements for pretreatment, (4) improve yields of ethanol from xylose from about 70 percent to over 90 percent through better fermentative organisms, (5) reduce conversion times from two days to only one day or less, (6) eliminate the requirement for inoculum preparation to seed hemicellulose conversion vessels, (7) use xylose converting organisms which can tolerate higher ethanol concentrations and can tolerate various byproducts created during pretreatment steps, (8) improve the pretreatment step to make cellulose more accessible to enzymes, as well as through the enzymatic hydrolysis step by increasing enzyme activity, (9) reduce the cost of cellulase by higher productivities and titers, (10) improve cellulase specific activity by reducing the amount of enzyme required to achieve a given sugar, (11) extending the lifetime of enzymes by cost-effective enzyme recovery, (12) cellulose conversion would benefit by insuring propagation of fermentative organisms in the ethanol production vessel, thereby eliminating the need for seed fermentation vessels for inoculum preparation, (13) improving the ethanol concentrations from the current levels of 4 to 5 percent to 8 to 12 percent, (14) reduce power requirements in areas such as air compressors, vessel mixing and size reduction, (15) integrate the entire ethanol process from front to back, and (16) continue to improve the feedstock production and collection activity. Feedstock costs under $2/million Btu could be achieved though enhanced biomass productivity.

Wyman (1994) concludes that process engineering studies have shown that a combination of improvements as he discussed could reduce the projected selling price of ethanol from the current level of $1.22 per gallon to about $0.67 per gallon. Such a price would be competitive with gasoline derived from oil at about $25 per barrel without tax incentives for the ethanol.

Feedstock Production and Delivery System (Appendix C)

Based on the 190,635 acres currently enrolled in the CRP in the study area and an estimated average biomass yield of 2.5 tons per acre, 476,588 tons of forage would be available for biomass-to-ethanol processing. By utilizing a higher proportion of warm season grasses, such as switchgrass, and applying simple management techniques, average yields could most likely raise to at least 4 tons per acre, making the maximum potential supply from the CRP shed about 762,540 tons.

Politically and environmentally, it would be unfeasible to utilize (harvest) all the CRP acres in a given area. Environmental and wildlife organizations support the CRP because it provides important habitat for a variety of wildlife. The cutting and harvesting of all of those acres would mitigate those benefits, potentially costing the support of the program, and its government payments, by those wildlife organizations. However, given the option of seeing those acres put back into annual crop production or kept out of tillage and used to produce biomass for conversion to energy, the wildlife and environmental organizations would no doubt support the biomass option. A more feasible approach would be only to harvest ¼ to ½ of the CRP acres in any given area in any given year. Given a large enough number of available acres and effective management, this would provide the best solution for all interested parties, and should the CRP be modified by the government to allow for harvesting for energy production, a limit like this would most certainly be implemented.

Cutting only a percentage would still mean that the land would remain out of tillage, preserving environmental benefits as well as supporting acceptable habitat for wildlife. By effective management, such as fertilization, the effective number of acres used to produce the necessary amount of biomass feedstock could be lowered, further reducing any concerns of environmental and wildlife organizations.

The cutting of the feedstock would most likely be done in August and September. This would be after the nesting season of resident ducks, geese and pheasants, thereby ensuring support from the wildlife community. From a more practical standpoint, the August and September time frame is generally open for area farmers being it is after the wheat harvest ends and before the harvesting of corn and soybeans begins.

Yields would be dependent on the types of grasses planted as well as the management of the field. It has been proven that warm season grasses, such as switchgrass, will generally produce greater yields than cool season grasses, while having a fairly low nutrient requirement. The use of nitrogen to boost yields could further increase production.

Based on current estimates of using 350 tons of biomass per day for 330 days to produce ethanol in the study area, about 115,500 tons of biomass would be needed. At the current estimated yield of 2.5 tons per acre, only about 24% of the current CRP-based biomass 476,588 tons available in the study area would be needed. This would be a reasonable amount to begin with. Efficiencies would be expected to increase in future years as farmers became more knowledgeable of practices used to increase the yield of biomass crops.

Summary

After review of the information regarding the availability of potential feedstocks for a biomass-to-ethanol facility, we conclude that there is more than enough procurable biomass materials available to adequately supply a moderate-sized biomass-to-ethanol production facility in the study area. Furthermore, because of the large amount of current unutilized biomass feedstock materials it is doubtful that the location of such a processing facility in the study area would raise the cost of the feedstock in any significant way, which would have a negative impact on the processing facility, as well as potentially on local livestock producers.

The price to obtain an adequate supply of biomass feedstock for such a processing plant would most likely be between $28.93 and $38.27 per ton, although it could be as low as $20.52 per ton, given the right circumstances, namely cooperation by the federal government in supporting the use of biomass grown on CRP acres for energy production.

Screening Study Report (Appendix D)

Establish Processing Facility for Site Selection Requirement

Feedstock Supply Quantities and Quality Mix

From discussion with bale handlers and movers in the study area, the switchgrass is expected to be delivered on trucks each carrying 18 to 20 tons (32 to 38 round bales). Delivery costs were given as $3.00 per loaded mile. Bales should be bound with sisal twine, which can pass directly through the milling operation and the process. The bales are estimated to weigh an average of 1100 pounds apiece. This is equivalent to a raw material feed rate of about 740 bales per day, or about 30.8 bales per hour.

The round bale handlers have also advised that each Spring, weight restrictions are imposed on area roads because of frost. This prohibits the use of the heavy truck loads during the "frost months." This obstacle will be overcome by using either partially loaded trucks, or smaller trucks during the Spring. Also, the contracts with area farmers should be arranged so that Winter and Spring deliveries are from areas closer to the plant than Summer and Fall deliveries.

It is understood that any feedstock moisture content about 14% will result in a marked increase in energy consumption for the milling process. In practice, the facility should be capable of processing a wide moisture range feedstock because controlling the actual moisture content will be difficult. To some degree, the milling operation can blend high moisture feedstock with low moisture feedstock, resulting in material feed to the process that meets specifications. Rejection of feedstocks for slightly high moisture content would only serve to increase the acreage required to provide the feedstock, alienate producers, and increase delivery distances and associated costs.

Ethanol and Byproduct Production Rates

The composition of the switchgrass feedstock, which is classified as a Herbaceous Energy Crop, is 45% cellulose, 30% hemicellulose, 15% lignin, and 10% other components (Wyman, 1994). If all of the cellulose and hemicellulose were converted into their respective hexose and pentose sugars, there would remain 25% lignin and other components, or 500 pounds per ton of feedstock.

The biomass-to-ethanol production plant is sized to produce 10 million gallons of 200 proof ethanol per year. The plant would operate 330 days per year, 24 hours per day, requiring an ethanol production rate of about 30,303 gallons per day. At the previously stated feedstock supply rate of 350 tons per day (bone dry basis), and ethanol weighing 6.62 pounds per gallon, this translates to an ethanol production rate of about 86.58 gallons per ton of feedstock. In other terms, the 200 proof ethanol flow rate will be about 21 gallons per minute.

The facility will produce a considerable amount of carbon dioxide. The ratio of carbon dioxide formation to ethanol formation is calculated to be about 0.961 (Singh and Kumar, 1991). Therefore, this plant will produce about 550.8 pounds of carbon dioxide per ton of switchgrass feedstock. Provisions will be made to strip the organic compounds from the carbon dioxide stream with process scrubber units, and the scrubbed carbon dioxide will then be further purified at a carbon dioxide processing plant adjacent to the ethanol facility.

Of the remaining 500 pounds per ton of feedstock, theoretically 300 pounds per ton would be lignin. The lignin is expected to be around 40% solids concentration after separation. This would be about 750 pounds of lignin/water boiler fuel per ton of feedstock, which would be sent to a recycle fuel burner nearby. The actual weight will be higher than this theoretical figure, due to the addition of sludge from the wastewater treatment operations.

Environmental Emission Characteristics

Emissions from a facility of this type are expected to be low. The 200 proof ethanol, the fuel ethanol, and the gasoline denaturant storage and custody transfer systems will be designed to reduce the potential for any fugitive emissions. Using low pressure storage tanks, floating roofs, and/or storage tank carbon dioxide blanketing will accomplish this. An Air Quality Permit would be required for process vent and boiler stack emissions.

All solids generated by this biomass-to-ethanol facility are, for the initial design without cogeneration, shipped off-site as fuel for burning in a nearby coal-fired power plant. Any solids, including sludges from the wastewater treatment operations, will be blended with the lignin residue to constitute a fuel coproduct.

Wastewater will be recovered and recycled to the greatest feasible extent. The BOD and COD of any effluent discharged will be reduced with an anaerobic digester, an aerobic biotreater, and associated equipment, to levels below acceptable limits as defined by Water Quality Standards. This would require a Surface Water Discharge Permit, or a Pretreatment Industrial Users Permit if the discharge goes to a municipal treatment facility.

Area Requirements

The desired acreage of the biomass-to-ethanol plant site is a minimum of 40 acres and a maximum of 80 acres, and the selected site should be entirely on one side of any road to reduce any possibility of conflict with traffic. The site should be on the same side of a road as the railroad, and must be of sufficient elevation to reduce the possibility of seasonal flooding.

Utility and Chemical Requirements

Water requirements were estimated to average 175 gallons per minute (252,000 gallons per day), with potential short periods of use up to 240 gallons per minute (345,600 gallons per day). In addition, plans are to provide for additional capacity, up to a total of 360 gallons per minute (518,400 gallons per day), to accommodate any future expansion.

Steam will be produced using a process boiler fired by natural gas, supplemented with biogas generated from wastewater treatment operations. Steam requirements of the biomass-to-ethanol plant are estimated to total about 40,000 pounds per hour of high pressure steam. The boiler will carry a rating of 250 psig, and will be sized to provide the necessary volume. Note that this process uses high pressure steam only, since there will be no cogeneration facility that provides excess quantities of low pressure steam.

Initial electrical power requirements were estimated to be 3000 kW, with the plant requiring transformers for 4160 V three phase, 480 V three phase, and 120/240 V single phase services. The load factor is estimated at 80%. It appears that procuring electrical power will not be a problem because most of the electrical transmissions lines follow corridors in which the preliminary potential plant sites are also found.

Screen Available Sites for Match with Facility Requirements

Factors Limiting Site Suitability

Day County statistically has the largest share of CRP acres, followed by Brown County and then Marshall County. The density of CRP acreage is also highest in Day County (an area of 1013 square miles), with about 81 CRP acres per square mile. Marshall County (an area of 888 square miles) has a CRP density of about 47 acres per square mile, and Brown County (an area of 1683 square miles) has a CRP density of about 40 acres per square mile. For purposed of site selection concerning current and future availability of nearby feedstocks, southeast Day County can be considered the best. Feedstock availability will generally decrease as one goes to northwest Brown County.

It would be difficult to obtain the required quantities of water for this facility no matter the location within the study area. The plant will probably be supplied with well water, which is possible to obtain in most of the study area. The preferred site should not be near existing wells unless it is certain that there is not a reduction in their water production, as this may violate existing water rights.

Exclusion of Unacceptable Sites

The most important limiting factor is the requirement for this facility to have access to a railroad. Only a core railroad can be considered safe in terms of its long-term viability. Two core railroads are in the study area - one going east-west through Aberdeen (Brown County) and through Day County, and another one which goes south from Aberdeen. The only potential sites will be found along these corridors. This effectively rules out the vast majority of the study area, including Britton and all of Marshall County.

Initial Outcome of Selection Process

After applying the most critical factors as described in Appendix D, three of the four originally selected areas have been removed from consideration. These are the areas in and around the towns of Aberdeen, Britton, and Webster. The city of Groton remains as a possibility, while a region of possible plant sites can be further defined as being on the railroad side of U.S. Highway 12, between the city of Groton and State Highway 27 in western Day County (three miles east of Andover).

Identification of Potential Sites

The study area was visited to locate suitable sites with the previously defined qualifications. There are a total of eight sites which have been identified which meet the minimum requirements for site selection for a biomass-to-ethanol plant. The ranking of these sites is discussed on page 15 of Appendix D.

Develop Budgetary Capital and Operating Costs Based on Process Considerations

Process Design and Equipment Requirements by Area

Switchgrass Handling and Milling

Diesel powered forklifts will be used to set 1000 to 1200 pound round bales of switchgrass feedstock on a chain drag conveyor that runs the length of a large storage building. The drag conveyor transports the bales to one end of the building, where hydraulic rams roll each bale off the conveyor and into the hopper of one of four identical shredding/milling lines. Vibrating screens in each of the four lines separate feedstock particles over one-quarter inch size, and send them back to the impact mill.

Prehydrolysis

A pug mill mixer mixes the metered milled grass with dilute sulfuric acid at 30% solids concentration. The sulfuric acid concentration will be adjusted to maintain an acid concentration of approximately 0.85% of the total water present during prehydrolysis. The mixture discharged from the pug mill mixer then goes into the first of two plug screw feeders, arranged in series, which are part of a Sunds Defibrator prehydrolysis system. Steam is added to raise the temperature to 360°F.

Batch Fermentation of Xylose and Cellulose SSF

Chem Systems' process design has been modified, for the purposes of this task, to provide batch fermentation of both the pentose and hexose sugars plus saccharification of the cellulose with cellulase while the mash resides in a single vessel. This can be accomplished simultaneously by inoculating the mash with a microorganism that can ferment both types of sugar, or by inoculating the mash with two different microorganisms simultaneously, or at different times. In either case, the cellulase enzyme and accompanying broth from cellulase production will be added to the fermenter as well. Eight 600,000 gallon stainless steel fermenters will provide up to seven and one-half days of total fermentation time.

Cellulase Production

Cellulase production is carried out in batch fermenters and a fungus such as *Trichoderma reesei* is grown in batch seed fermenters.

Distillation, Dehydration, and Centrifugation

Distillation is carried out in a continuous atmospheric binary distillation column. Because of the low concentration of ethanol in the beer, the stripper section is larger in diameter than the rectifying section of the column. The 4 to 6% by-weight ethanol beer is first preheated in a precondenser on the column overheads, then heated in an interchanger with the column bottoms to 200°F. Heat to drive the column comes from three reboilers, one that condenses 200 proof ethanol, one that condenses the flash vapors from prehydrolysis, and one that condenses boiler steam. The required reflux ratio to achieve 190 proof ethanol will be approximately 5.2 to one.

Tank Farm

A shift tank with one day's worth of 200 proof ethanol capacity is connected by piping to the distillation area. Each day, the ethanol is transferred to one of two large storage tanks. Following each transfer, gasoline from the denaturant tank is added to the ethanol storage tanks to reach a 5% denaturant concentration. Piping also connects a low proof ethanol storage tank, with enough capacity for two days, to the distillation area to compensate for different operational rates of the molecular sieve and distillation column.

Wastewater Treatment

Wastewater treatment design is similar to the design used by Chem Systems. Anaerobic treatment is the first step and generates biogas containing methane for combustion in the boiler. The effluent from the anaerobic digester will be further treated in an activated sludge aerobic treatment system. Approximately 50% of the effluent from the aerobic treatment system will be recycled back to the plant. The remaining 50% will be discharged to surface waters.

Utilities

A gas-fired, 250 psig water-tube boiler will burn a blend of biogas and natural gas to provide steam for the process, and for building heat. Cooling towers and a mechanical chiller will provide cooling. Rotary screw air compressors with refrigerated dryers and various filters will provide air for instrumentation and fermentations.

Preliminary Capital Cost Estimate

The preliminary cost estimate for the island of process equipment for the biomass-to-ethanol production facility is $27.7 million. Included in this estimate are costs for the following: buildings, concrete, and structures; process and inventory equipment; electrical; instrumentation; mechanical equipment and piping; and other construction related costs.

This cost estimate does not include site and site improvement costs such as surveying, soil boring, site engineering, site work contracts, water storage and supply, natural gas supply system, rail spurs, site security fences, road improvements, and related site improvement costs. It also does not include other project-related equipment and costs, such as maintenance equipment, radio equipment, spare parts inventory, laboratory equipment, office equipment and furnishings, or engineering fees. A contingency and other soft costs have not been included.

Facility Operating Requirements

The annual facility operating costs, less utility costs, have also been estimated, and they total more than $6 million. Over $3.3 million of the operating costs would be for the switchgrass feedstock. Remaining contributing costs are for chemicals, maintenance, supplies, services, and payroll.

Evaluate Site-Specific Issues Relative to Permitting and Community Interests

Environmental Permits

South Dakota has three types of wastewater permits for the National Pollution Discharge Elimination System (NPDES) Permit Program. The first type is a Surface Water Discharge Permit, which would be required for the biomass-to-ethanol plant.

The second type of permit is the Pretreatment Industrial Users Permit, which is issued to industries that discharge process wastewater to a sanitary sewer. This permit would not be required for the ethanol production facility unless the selected site exercises any option to discharge effluents into a municipal wastewater treatment facility. The third type of permit is the Storm Water Permit, which would be required for the facility. (Additional permit requirements and environmental regulations are discussed in Appendix D.)

Environmental & Community Impact Issues

Issues discussed in Appendix D include: wetlands, wildlife/threatened and endangered species, known site competing uses, site zoning restrictions, residential density, and sensitive nearby receptors.

Evaluate and Rank Final Sites

Eight potential sites for a biomass-to-ethanol plant were identified in Subtask 3.2. For the purposes of further site evaluation, these eight sites will be more accurately described, and given a corresponding letter. Sites identified a s "A" and "B" are near Groton in Brown County, and sites identified as "C" through "H" are near Andover in Day County. (See Appendix D for the site descriptions and a discussion of their relative merits.)

Final Ranking of Sites

Broin & Associates' has determined that the most preferred site for a biomass-to-ethanol facility within the study area of Brown, Day, and Marshall Counties in northeast South Dakota is the site identified as "Site DE." The remaining sites ranked in decreasing preference: "Site FGH," "Site B," "Site A," and "Site C." For any these other sites, however, much work would have to be done to ensure that the facility's water requirements would be met.

Refine Budgetary Capital and Operating Cost for Preferred Site (Appendix E)

Process Description and Equipment Requirements by Area

Switchgrass Handling and Milling

Each hopper is mounted above Mac Corporation Saturn Model 62-40HT primary shredders, which shred the bales into pieces 10-20 cm long and discharge shredded switchgrass, twine, and foreign matter to conveyors (one for each line). Shredded switchgrass then passes through a secondary set of Mac Corporation Model 44-28HT Saturn shredders, which reduce the switchgrass to 2.5-6 cm long pieces. The shredded switchgrass is then sent through ABB Raymond #63 air impact hammer mills. These mills would reduce the switchgrass to 1.2 mm particle size.

Prehydrolysis

An on-line microwave moisture analyzer continuously measures the moisture content of the milled switchgrass. This will allow a controlled value of bone dry equivalent feedstock to be delivered to the process. In a pug mill mixer, water and sulfuric acid are mixed with milled switchgrass.

Residence time is carefully controlled to an estimated four minutes. The Sunds Defibrator system was originally quoted for us with a 15 minute retention time and the wetted materials were of 316 stainless steel. Reducing the retention time reduces the size of the equipment as well as the cost of the system. However, since Sunds Defibrator declined to revise their budget estimate for the new parameters, we are using the original prehydrolyzer estimate for the purposes of this study. This estimate may not be excessive for a smaller system, since the more realistic construction of carbon steel with zirconium 705 cladding would likely offset savings which might come from smaller equipment.

Under the stated process conditions, constructing this equipment from 316 stainless steel is not prudent, because it is subject to severe corrosion in the presence of sulfuric acid. The service life of 316 stainless steel is estimated to be less than one year, and possibly as little as six months (Plantz, personal communications with Broin & Associates, 1996).

Batch Fermentation of Xylose and Cellulose SSF

The yearly 200 proof ethanol production level of 10 million gallons was based on an overall conversion efficiency of holocellulose to ethanol of 85.5%. Most process equipment and piping in this area would be constructed of stainless steel; however, the fermenters themselves will be constructed of carbon steel, which is adequate since the pH level should never fall below 5.0.

Broin & Associates' experience in the design, engineering, construction, and operation of fuel ethanol plants brings us to the conclusion that the benefits of batch fermentation outweigh any benefits of a continuous fermentation process. Continuous fermentation process are susceptible to significant losses if the fermenters become contaminated. This is particularly important as the scale of the facility is increased, or if the fermentation rate is slow, as the case is here. In a batch operation, potential losses would be limited only to each fermenter which becomes contaminated.

Cellulase Production

Most process equipment and piping in this area would be constructed of stainless steel. The Process Flow Diagram (see page 12, Appendix E) and the associated text generally describe the cellulase production area and its operation, which is essentially the same as Chem Systems' model.

Distillation, Dehydration, and Centrifugation

The lignin cake produced will be blended with sludge from wastewater treatment, then loaded onto a truck or rail car for transport to a nearby recycle fuel burner. The total weight of the lignin fuel coproduct has been refined from Task 3 (see Appendix D), to an estimated 238 tons per day. The yearly fuel coproduct production would be about 78,540 tons per year, or approximately 3.9% of Big Stone Power Plant's annual coal burn. The total estimated dry weight of the combined solids fractions would be 544 pounds per ton of feedstock, or 190,400 pounds per day. The fuel (dry basis) contains 11,800 BTU per pound (see page 2, Appendix A), and will be sold to a recycle fuel burner until a future cogeneration plant is build on the site.

Tank Farm

Most process equipment and piping in this area would be constructed of carbon steel.

Wastewater Treatment

The wastewater generated by this biomass-to-ethanol facility is expected to be highly treatable. Lignin is a natural aromatic organic polymer which cannot be easily processed by wastewater treatment. While it is not very treatable, most of the lignin will be removed by centrifugation in Area 600. Much of the remaining wastes are of polysaccharide origin, resulting in high biodegradability.

Most process equipment and piping in this area would be constructed of carbon steel, with the treatment basins being of concrete construction.

Mechanical Equipment and CIP

Steam for the process and for building heat will be provided by a gas-fired, 250 psig water-tube boiler. Fuel for the boiler will come from three sources, the main source being biogas which is generated by the anaerobic reactor in Area 800. The methane portion of the biogas could supply 41.45 million BTU per hour to the boiler, or about 86.4% of the total projected fuel requirement of 48 million BTU per hour. Natural gas will be used when there is not enough biogas to meet the demand. Economics dictate that a backup propane system be installed to provide fuel when the gas utility interrupts the natural gas service.

Recommendations for Additional Investigations

Milling Methods

The milling process is energy intensive, and overall process economics would improve significantly if the milling requirements could be reduced. Future investigations and advancements in processing methods may warrant reevaluation of the milling requirements before this plant is built.

Prehydrolysis Equipment and Processes

Broin & Associates feel that alternatives to the Sunds Defibrator horizontal hydrolyzer system should continue to be evaluated. Simplifying the internals would greatly reduce the system cost. However, any such equipment must provide adequate agitation to allow saturated steam to penetrate the entire cross-section of the plug material flow to ensure a uniform cook. Alternatives to sulfuric acid, such as nitric acid, should also be investigated.

Neutralization Methods

We strongly suggest that alternatives to the use of calcium oxide or calcium hydroxide be evaluated. The formation of the practically insoluble salt calcium sulfate from the neutralization process will cause many problems including solids buildup in the fermenters, fouling of heat exchange surfaces, and handling and disposal concerns. For example, the use of anhydrous ammonia for neutralization would result in the formation of ammonium sulfates, which are quite soluble in water. The use of sodium hydroxide would yield sodium sulfate salts, which are also much more soluble than calcium sulfate.

Other Uses for Lignin

There are some alternatives to the use of lignin as fuel which may be evaluated, including its use as a raw material for the production of other chemicals.

Capital Cost Estimate

Our capital cost estimate for major process equipment for the biomass-to-ethanol production facility is \$14,781,000, with an accuracy of ±30%. (See Table 1, page 17, Appendix E.) The estimates for each item listed are from vendor budget quotations and/or our own current and previous experience in the design, engineering, construction, operation, and maintenance of fuel ethanol plants with capacities ranging up to 15 million gallons per year.

The total cost estimate, with an accuracy of ±30%, for the fuel ethanol facility is \$40,496,160. (See Table 2, page 19, Appendix E.) This estimate is inclusive of all costs for the facility, including all direct costs and indirect costs requested for Task 4. The only exceptions, which are not included, are for "soft" costs such as business development costs, business operation costs during construction, financing costs, interest during construction, etc.

Operating Cost Estimate

The fuel ethanol facility operating costs for the first year of operation, including utility costs, have also been estimated, with an accuracy of ±30%. Fixed costs have been estimated at $1,013,000, and the variable costs have been estimated at $7,622,793 for a total of $8,635,793 for the first year. Over $3.3 million of the operating costs would be for the switchgrass feedstocks. (See Table 3, page 23, Appendix E.)

The actual operating costs will very likely be less than reflected by the estimates. This is because the facility will, due to its size, be able to negotiate better prices for the utilities needed. Since the outcome of such future negotiations is uncertain, current prices had to be used for this estimate, resulting in a high estimate.

Facility Utilities

To avoid being classified as a public water system, it makes more economic sense to use the available domestic water from WEB Water Development. This water already meets all applicable standards. By using WEB water, the facility would not need to perform routine testing for bacteriological and chemical quality standards for the relatively small projected domestic water use.

A well will be developed for process water supply, drawing from the Dakota Aquifer. By far most of the Dakota wells are located in the James Basin region of Day County with very few found on the Coteau des Prairies because the wells on the highlands have to be pumped with a required water lift of 500 feet in places (Leap, 1988). The well depth is estimated at 1400 feet, and will be sized to pump 250 gallons per minute.. The bore hole would be 14-¾ inches in diameter, the casing would be 10 inches in diameter, and the 60 HP pump would deliver water through a four-inch drawpipe. The pump setting will be at an estimated 600 feet; the well development costs include the drilling of a five-inch test well to measure the drawdown and recovery rates (Osberg, personal communications with Broin & Associates, 1996).

(Additional utility issues are included on pages 24 to 26, Appendix E.)

Site Description and Layout

In Task 3 of this study, "Site DE" was identified as the best location within the study area for the proposed biomass-to-ethanol processing plant. This site is in Sections 1 and 12 of Andover Township, Day County, South Dakota (see Map 1, page 27, Appendix E.)

Map 2 (page 28, Appendix E) is an example of a process plant site layout. For most of the buildings and features shown, the layout example is at a scale of 200' per inch for a 10 million per year biomass-to-ethanol plant.

Financial Evaluation of the Preferred Site (Appendix F)

A financial analysis was prepared for the construction and long-term operation of a nominal 10 million gallon per year, biomass-to-ethanol facility in northeast South Dakota. This site was selected in Task 3 (see Appendix D) as the most preferred location within the study area. The evaluation incorporates site specific capital and operating costs, as well as feedstock cost and market value of the ethanol and other byproducts determined in Task 4 (see Appendix E).

A "Base Case," based on capital costs, operating costs, feedstock costs, and final products market value provided in Task 4, as well as a "Best Case Scenario," incorporating a more favorable feedstock cost and a state producers incentive, is provided. Each analysis consist of the following:

Sources and Application of Funds (Year 1)
Sources and Application of Funds (Year 2)
Balance Sheet (Years 1 through 12)
Income Statement (Years 1 through 12)
Cash Flow Statement (Years 1 through 12)
Price Sensitivity Matrix - Average Annual Pre-tax Income (Years 3 through 12)
Price Sensitivity Matrix - Average Annual Cash Flow (Years 3 through 12)

Plant Design Capacity

The annual design production capacity of the plant is as follows:

Fuel Grade Ethanol	10,526,316 gallons
Carbon Dioxide	31,812 tons
Lignin Fuel	31,416 tons

Grass consumption is estimated at 134,310 tons annually, based on an incoming moisture content of 14%.

Project Cost and Financing

It was estimated in Task 4 (see Appendix E) that the total installed plant cost will equal $40,496,160. Working capital and other reserves will bring the total project cost to approximately $44,500,000.

Total project financing is assumed at $31,500,000 with equity participation making up the remaining necessary capital. This represents a 2.4 to 1 debt-to-equity ratio.

Construction Period

The facility will be constructed over a 12 month period. After construction is complete, the plant will be started in Month 13, when it is expected to achieve an overall production rate of 30% of rated capacity. It is assumed that production in Month 14 will be 70% of rated capacity with full rated capacity anticipated for Month 15.

Financing Terms

It is assumed that the project will be financed with a $31,500,000 loan bearing a fixed interest rate of 10% over a 15 year term and structured so that interest only is paid on the note balance during Years 1 and 2. In Year 3, full amortization begins with a total annual debt service of $4,141,424, including both principal and interest.

Depreciation and Amortization

The projections anticipate that the term loan will be fully amortized over a 15 year period.

Interest paid during construction on the draw down of the available credit line is capitalized and added to the cost of the plant. The project will incur fees to the lenders. It is anticipated that these fees will equal 2% of the financing amount or $630,000. Expenses incurred prior to startup of the plant have been capitalized as organizational expenses. These expenses are estimated at $1,204,797 and will be amortized on a straight line basis beginning in Year 2.

Accounts Receivable and Inventories

Accounts receivable are estimated to climb as sales escalate until they stabilize at 30 days sales. Normal industry terms are net 30. There has been no provision for uncollectible accounts. Inventories are projected to rise as the plant comes on stream, with raw materials equaling five days of production, work in progress anticipated to equal two days of production, and finished goods estimated at three days.

Accounts Payable

Accounts payable are estimated to be paid on a net 30 basis, except for items which, contractually, are to be paid on different terms and payroll, which is projected on a cash basis. In order to be conservative in projecting cash flow, no provision for accounts payable are shown in the projections.

Product Sales and Raw Material Costs

The pro forma financial statements reflect the following estimates provided in Task 4 (see Appendix E) for products and raw materials:

Grass (14% moisture)	$25.00/ton
Fuel Ethanol	$1.15/gallon
Carbon Dioxide	$9.00/ton
Lignin Fuel (dry basis)	$11.43/ton

Operating Costs

Variable operating costs are based on the following estimates provided in Task 4 (see Appendix E), all of which are per anhydrous (200 proof) ethanol gallon produced:

Chemicals	$0.09801
Water	$0.00006
Electricity	$0.15398
Boiler Fuel	$0.01535
Maintenance	$0.05183
Sewer	$0.00000

All costs have been inflated at a rate of 2% per year, starting in Year 3.

Plant Labor, Plant Management, and Administrative Costs

Salaries and wages required to operate and maintain the facility are included in the plant operating expenses. In Task 4 (see Appendix E) it was determined that the plant will employ 36 persons when it achieves full production. Total annual compensation, including 21% for benefits, was estimated to be $1,089,000 in Year 2 and is adjusted annually by increasing this cost by 2% per year.

Details of both plant and administrative personnel are provided on pages 7 to 11 of Appendix F.

Additional Fixed Costs

The following additional fixed annual costs are incorporated into the financial analysis:

Taxes and Insurance	$403,000
Miscellaneous Fixed Costs	$368,000

Federal Income Taxes

It is anticipated that the South Dakota biomass-to-ethanol facility will be set up as a limited partnership and, as such, there are no taxes charged directly to the partnership. The financial projections do, however, show a deduction for corporate income taxes at the 35% rate. It will be necessary to distribute to the partners an amount equal to the tax effect of the "pass through" earnings. Therefore, a deduction prior to the net income for income tax is shown.

Pro Forma -- Base Case

The Base Case Financial Statements are made up of the following (see pages 13 to 20, Appendix F):

Sources and Application of Funds (Year 1)
Sources and Application of Funds (Year 2)
Balance Sheet (Years 1 through 12)
Income Statement (Years 1 through 12)
Cash Flow Statement (Years 1 through 12)

Pricing Sensitivity Matrix - Average Annual Pre-tax Income (Years 3 through 12)
Pricing Sensitivity Matrix - Average Annual Cash Flow (Years 3 through 12)

Although the Base Case shows a steadily improving annual cash flow in the first 10 years of full operation, the average for Years 3 through 12 is only $319,195. The range is -$67,694 in Year 3 to $727,060 in Year 12.

The Base Case Income Statement only shows a profit in the last year displayed in the projections (Year 12). The average annual after-tax income is -$976,856 over the first ten years of full operation, representing a -2.20% annual return on investment. Cumulative earnings reach a low at the end of Year 11 of -$12,693,924.

Pro Forma -- Best Case Scenario

The Best Case Scenario incorporates the same assumptions as the Base Case with the following two exceptions (see pages 21 through 28, Appendix F):

(1) A $0.20 per anhydrous gallon, state sponsored producer incentive in included. This incentive caps at a maximum of $1,000,000 per year and $10,000,000 per facility. It is assumed that paperwork for the incentive would be submitted to the state on a monthly basis and that payment would be received within 30 days of submittal.

(2) The cost of the feedstock grass was lowered to $22/ton (from $25/ton), based on 14% moisture content.

The Best Case Scenario Financial Statements are made up of the following:

Sources and Application of Funds (Year 1)
Sources and Application of Funds (Year 2)
Balance Sheet (Years 1 through 12)
Income Statement (Years 1 through 12)
Cash Flow Statement (Years 1 through 12)
Pricing Sensitivity Matrix - Average Annual Pre-tax Income (Years 3 through 12)
Pricing Sensitivity Matrix - Average Annual Cash Flow (Years 3 through 12)

The state producers incentive and more favorable feedstock grass cost assumptions included in the Best Case Scenario have a dramatic effect on the cash flow projections. The average for Years 3 through 12 is $1,696,839 and ranges from $1,355,391 in Year 3 to $2,039,193 in Year 11. Income drops significantly after the state producers incentive is phased out after Year 11.

However, the Best Case Scenario Income Statement still shows a loss in the first four years of full operation. The average annual after-tax income is $2364,244 in Years 3 through 12, representing an average 0.82% return on investment. Cumulative earnings reach a low at the end of Year 6 of -$2,841,164, but do reach breakeven in Year 10.

Though the return on investment would be small, it does, however, show that with existing technology a biomass-to-ethanol plant in northeastern South Dakota could be profitable. This project was also done utilizing very conservative estimations. There is no doubt that continual advances in technology and process procedure could make such a venture even more attractive.

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Appendix A

Marketing Assessment (Task 1)

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SCREENING STUDY FOR UTILIZING FEEDSTOCKS GROWN ON CRP LANDS IN A BIOMASS TO ETHANOL PRODUCTION FACILITY

Task 1 - Market Assessment Report

Subcontract No. ACG-6-15019-01
Prime Contract DE-AC36-83CH10093

Prepared by
American Coalition for Ethanol
&
Anklam & Associates

for
United States Department of Energy's
National Renewable Energy Laboratory BioFuels Program

April 29, 1996

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

Task 1 - Market Assessment

Executive Summary

The evidence indicates ethanol produced from renewable sources is a practical component of reformulated motor fuel. The octane and oxygenate values have established a market value independent of price supporting subsidies. The market is growing. The projected demand for fuel ethanol in the year 2000 is 1.85 billion gallons and it could be as high as 2.28 billion gallons. This confirms that demand will be sufficient in the North Central Region to accommodate the 10 million gallons per year facility studied.

Western Switch Grass yields greater than 2.5 tons per acre provide values per acre equivalent to oilseed and row crops in the region selected for the study. Price of $29 to $42 per ton, FOB, field edge is practical for the farmer.

The price of fuel ethanol appears to be market driven, based upon inherent values rather than subsidy payments. The producer payments available in some states are essential to the survival of the small ethanol producer using corn as a feed stock.

The products produced by the proposed study project can be contracted for sale prior to the beginning of production. The quantities are small in comparison to the markets involved. Fuel ethanol as a blending component is distributed in a parallel system to motor fuels because of it polar properties. Ethanol as ETBE may move in the historic fuel distribution network.

The availability of crop insurance for WSG is essential for the farmer to obtain adequate operating capital from lenders. The use of insurance as a risk management tool is a major factor in bank financing of operating capital for many farmers. The price of WSG would be higher if insurance is unavailable at reasonable prices, i.e. $3 to $7 per acre.

The raw feed stock cost, availability of markets, and the technology, combine to provide a reasonable opportunity for a successful biomass to ethanol plant in the study area.

"There is one thing stronger than all the armies of the world, and that is an idea whose time has come."[1]

---

1 Victor Hugo.

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

Task 1 - Market Assessment

Last revision April 29, 1996

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

Task 1 - Market Assessment

Task objectives:

➢. Assess the markets for the facility's ethanol products that will provide a basis to support a decision to proceed with the project.

➢. Define the economic advantages of ethanol versus some other product option. Example: If the CRP is discontinued, consider any economic advantage that may exist for producing ethanol Feedstocks versus producing grain crops (for instance).

➢. Analyze the price trends for conventional ethanol sources and assess the product pricing impact that may result due to existing and planned regulations.

➢. Develop a preliminary marketing plan for ethanol that will include a price structure and assess existing and proposed federal and state tax incentives.

➢. Define ethanol product distribution and sale options.

➢. Assess potential availability and value of crop insurance to stabilize biomass Feedstocks supply and price.

<u>Basic Project Assumptions as Givens</u>:		
CRP Land in South Dakota	$1.8*10^6$ Acres	
Type of Grasses	Brohm	Western Switchgrass
Yield	2.5 tons/acre Minimum	5 tons/acre Maximum
Study Location Counties in SD	Brown, Marshall, and Day	
CRP Acreage in Study Area	200,000	
Gross Biomass to Ethanol Parameters:		
Input Biomass	350 tons/day bone dry	
Operational Days	330 days per year Max.	300 days per year Min.
Ethanol yield/ton of input	80 gallons 200 proof	100 gallons 200 proof

Last revision April 29, 1996

Annual Production	9.2 Million Gallons/Year	11.5 Million Gallons/Year
CO_2 Yield/ton of input	504 lb.	630 lb.
Biomass Boiler Fuel Lignin Yield/ton of input	500 lb.	500 lb.
Biomass Boiler Fuel Methane Yield/ton of input	53 Lb.	53 Lb.
BTU. of Boiler Fuel / lb. of Lignin	11,800	11,800
BTU / lb. of Methane	23,800	23,800
Boiler fuel Moisture Content	Unknown	Unknown
BTU/Gallon of ethanol demand	43,000	43,000
Co-Gen BTU to Kilowatt-hours	0.000293	
Boiler Efficiency	70%	

Specifications for denatured fuel ethanol

	Test Method	Specification
Apparent Proof, 60° F.	Hydrometer	
Man		200
Max.		203
Water, Mass Percent	ASTM E-203	
Max.		0.82%
Fuel Ethanol Content, (1)	ASTM D-5501	
Min. (2)		95%
Nonvolatile Matter mg /100 ml	ASTM D-381 Air Jet Method	
Max.		5mg
Chloride, mg / L	ASTM D-512 Method C	
Max.	Modified (3)	32mg
Copper, mg / L	ASTM-1688 Method C	
Max.	Modified (4)	.08mg
Acidity (as acetic acid),	ASTM D-1613	

Last revision April 29, 1996

Mass Percent Max.		.007
Appearance	Visual Examination	Clear and bright. Visibly free of suspended and/or settled contaminants.

(1) Denatured fuel ethanol shall contain a minimum of 20 pounds per 1000 bbls. (44 gal. / bbl.) of Dupont DCI-11, Petrolite Tolad 3222, or Nalco 5403.

(2) The fuel ethanol component of denatured fuel ethanol, excluding water, shall be 98 volume percent ethanol (C_2H_5OH) minimum, and shall not contain more than 0.5 volume percent methanol or total ketone, or both. The addition of materials, other than the permitted denaturants and corrosion inhibitors is prohibited.

(3) The modifications of Test Method D-512, Procedure C, consist of using 5 ml of sample, diluted with 20 ml of distilled water instead of the 25 ml sample specified in the standard procedure. The volume of the sample prepared by this modification will be slightly more than 25 ml. To allow for the dilution factor, report the chloride ion present in the fuel ethanol sample as five (5) times that determined on the sample.

(4) The modification of Test Method D-1688, Procedure D, consists of mixing reagent grade ethanol, (Which may be denatured according to BATF Formula 3A or 30) in place of water as the solvent or diluent for the preparation of reagents and standard solutions. *However, this must not be done to prepare the stock copper solution described in 39.1 of D-1688., because a violent reaction may occur between the acid and the ethanol, use water , as specified, in the acid solution part of the procedure to prepare the stock copper solution.* Use ethanol for the rinse and final dilution only.

The only denaturants permitted shall be unleaded gasoline, natural gasoline, rubber hydrocarbon solvent, or any combination of these, at a minimum of two (2) parts and a maximum of five (5) parts per 100 parts of fuel ethanol by volume. This specification prohibits the use of denaturants with an end boiling point higher than 437°F as determined by ASTM Method D-86.
These specifications cover tank car and tank truck deliveries to terminals for the purpose of blending into gasoline to produce motor fuel. At the time of blending with a gasoline, the allowable maximum water content will be 1.25 mass percent.

Task Objective 1.

➢ *Assess the markets for the facility's ethanol products that will provide a basis to support a decision to proceed with the project.*

Last revision April 29, 1996

Ethanol Market in the United States

History

Ethyl alcohol has been produced from grains by mankind for many centuries. Its primary role has been as a beverage, and/or an industrial solvent. The Arab oil embargo fostered a change in energy policy of the United States encouraging the manufacture of fuel for automobiles from renewable sources. Within the continental US., corn has been the lowest cost source of carbohydrate available for conversion to ethyl alcohol for fuel.

The initial impetus for the production of ethanol for fuel was to replace imported oil. Since then ethanol has found value as a gasoline blending component. Ethanol provides additional octane. Gasoline containing ethanol burns cleaner than unoxygenated gasoline. This provides an economical way to improve air quality in many of the densely populated areas of the United States. Several metropolitan areas have mandated the use of oxygenated fuels during much of the year to safeguard the health and welfare of their populace. Minnesota has mandated year round use of 2.7% oxygenated motor fuels for the Minneapolis, St. Paul metro area as of 10/1/95 and statewide by 10/1/97. The production of ethanol from renewable sources is heavily subsidized by both the federal and state governments.

Production

Ethanol is produced synthetically in the United States by the direct hydration of ethylene. In this process, concentrated ethylene reacts with vaporized water over a phosphoric acid impregnated catalyst.[1]
Ethanol is also produced by fermentation of carbohydrate with yeast to produce a beer. The alcohol is distilled from the beer, rectified to yield 190 proof or de-hydrated to 200 proof alcohol.

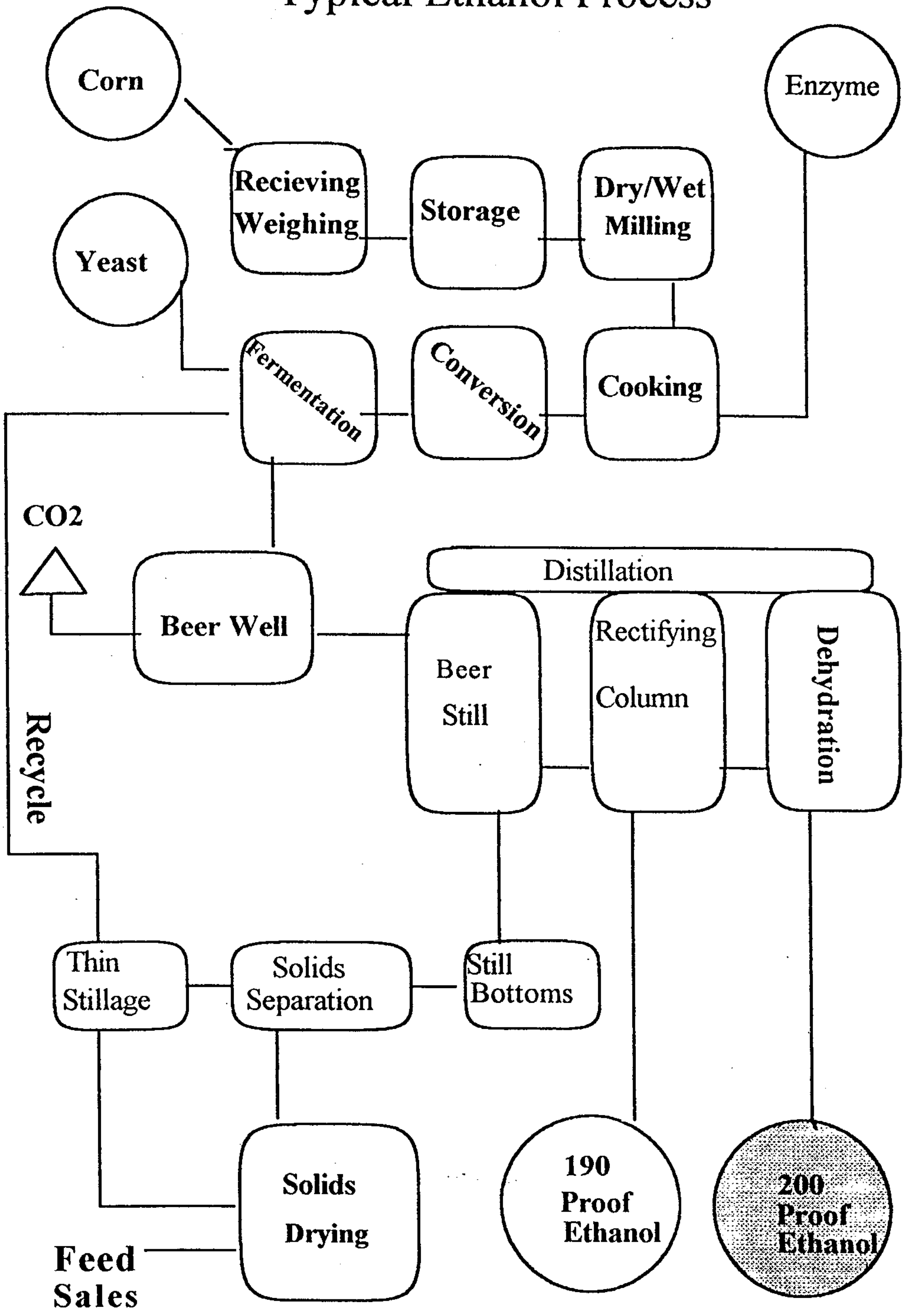
Changes in technology

The industry has continued to reduce the production cost of producing ethanol. The industry, by improved process design and economies of scale, have reduced the BTU's required to produce a gallon of ethanol from 120,000 BTU's in 1980 to 43,000 BTU's in 1991.[2]

Enzymes

Enzymes and yeasts have improved yield marginally. Most large producers grow their own yeast and continue to work with genetic engineered strains. The University of Florida's invented an enzyme that will produce ethanol from hemi-cellulose. The new enzyme promises to improve the potential overall yield from a bushel of corn. Bio-Energy International has purchased the Dundus, Minnesota, ethanol plant to use as a demonstration project and pilot plant.[3] This phase of the project has yet to develop into a viable industrial process.

Typical Ethanol Process



The National Renewable Energy Laboratory in Golden, Colorado has developed process and enzyme technology to convert biomass cellulose (wood chips, corn hulls and Switchgrass) to ethanol. It is contemplated that Conservation Reserve Program (CRP) acres will be released to grow biomass for conversion to fuel ethanol. The crop proposed is Western Switch Grass (WSG).

The WSG grown on marginal lands under contract may be harvested after seed set, field dried to 14 to 18% moisture and round baled for field storage. The bales will be transported to the refinery at scheduled delivery times throughout the year. Upon receipt the bales, they are process through a bale buster, screened for foreign material, feed into a mill for further size reduction. The mill outflow is passed through a 1/4 inch screen, overs returned for re-mill and the unders, flow into a plug flow mixer, combined with a solution of sulfuric acid to yield a mixture with bone dry solids of 25 to 35%.

The mixture is passed into a high pressure reactor, heated by direct steam injection to 160° C. for a dwell time up to ten minutes. The hydrolyzed WSG sol is flashed to atmospheric, releasing furfurol in the vapor phase, in the flash tank. The WSG sol pH is adjusted with lime (CaO). The WSG sol is passed into fermentation tanks connected in series and temperature controlled at 37° C. The cellulase hydrolyzes the sol to sugar and the ethanol fermenters convert the sugars to ethanol. A portion of the WSG sol is decanted for enzyme propagation. The fermentation to ethanol requires 2 to 7 days of dwell time, and is complete at 4.5 to 5 volume % ethanol.

The liquor is released from the fermenters into the beer well. Carbon dioxide is collected from the fermenters and beerwell for stripping of VOCs and release to the atmosphere or compressed for sale. The beer still separates the ethanol for rectification and dehydration. The still bottoms are passed to solids separation. The solids (Lignin, unfermentable sugars, soluble and insoluble inorganics) are used for fuel to generate steam and co-generate electric power for process use and sale to the grid. The liquid stream is partially recycle to the process and the remainder treated in an anaerobic/aerobic digester. The methane gas is returned to the boiler as fuel. and the water out flow return to process. There may be economic value in the soluble potassium phosphate and magnesium phosphate as liquid fertilizers, if concentrated to commercial strength. The settlable solids are landfilled, sold for fertilizers or sent to the boiler.

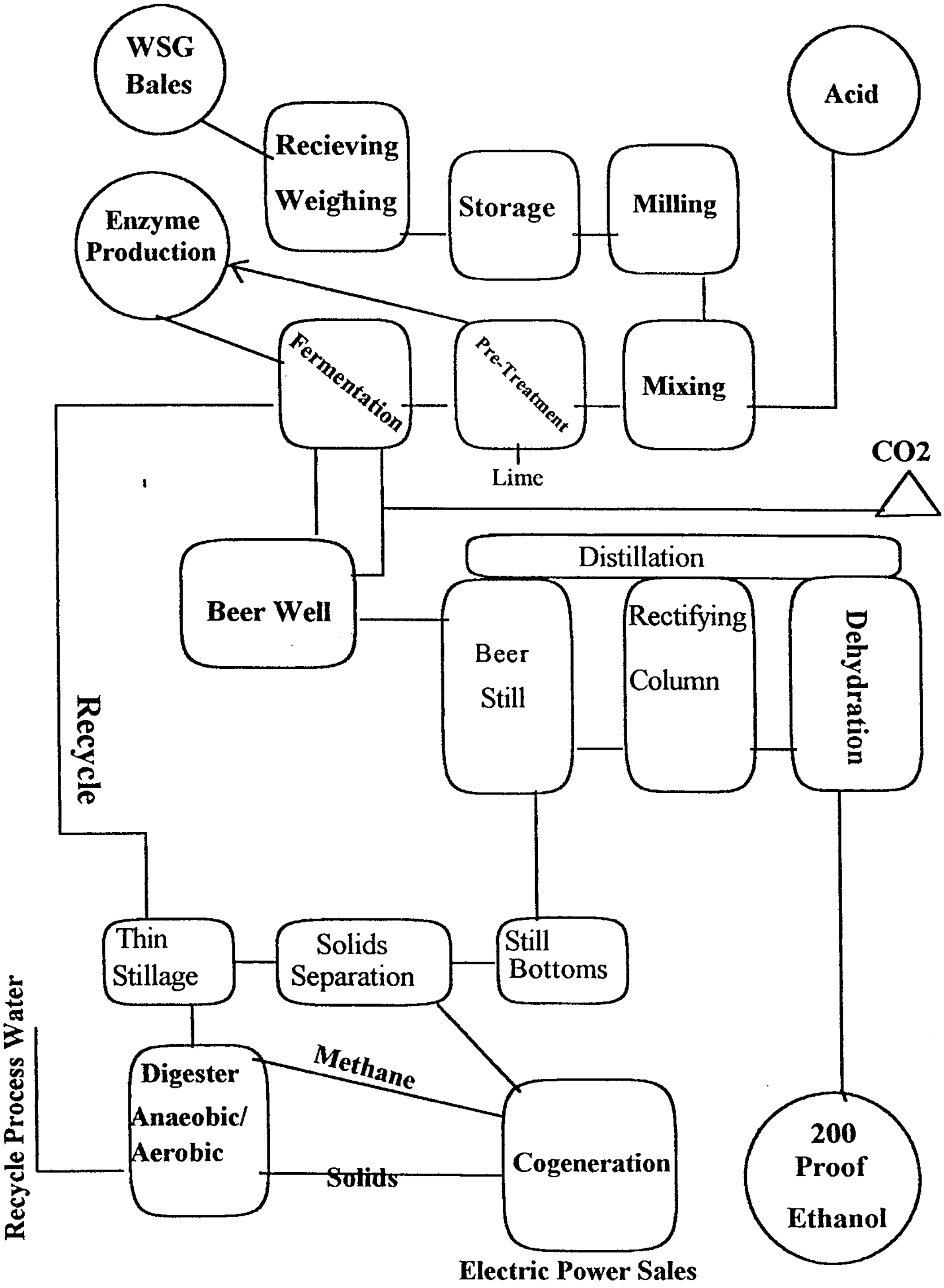
Market Segments

The non fuel market for ethanol continues to expand at a modest rate. Fermentation ethanol now supplies approximately 75% of the industrial demand, up from about 10% during the 1960's. It is unlikely that fermentation ethanol will replace synthetic entirely because of the quality requirement for some applications.

Beverage

Beverage alcohol use has continued to follow the 200 year downward trend in percapita consumption. The life style changes brought about by the baby boomers has stifled any growth in beverage alcohol. The media attention to the evils of spirits consumption has made beverage alcohol an easy target for social legislation. Federal taxes on beverage alcohol have increased

Biomass to Ethanol Process



New, very large markets may be on the horizon for ethanol. The oil refiners are now substituting ethanol in the production of ethers for blended oxygenates. Archer Daniels Midland announced February 6, 1996, the expansion of beverage and industrial ethanol capacity to 210 million wine gallons per year. This is in concert with lysine expansion and dry ethanol needs for ETBE production.[8] The potential for high purity dry ethanol could be as much as two or three billion gallons per annum. The paper industry is operating a prototype type pulp mill in New Brunswick, Canada, using a solvent process to remove the resins from the wood fiber. The process uses acetone, and acetone is manufactured on site using ethanol to produce the diethyl ketone. The biomass technology may accelerate this process by using pulpmill waste streams. The success of this process is dependent upon the comparative economics involved in improving the environmental problems of existing paper mills versus converting to solvent pulping. It is expected to take 30 to 40 years to convert a majority of the industry to the process.[9]

The production of calcium and magnesium acetate for road deicing rather than the current use of calcium or sodium chloride is another potentially large market. The acetic acid, essential to the process, may be made from ethanol.

Fuel ethanol production from corn grew (See Figure # 3) from 63 million wine gallons in 1975 to 1,342 million wine gallons in the period of September 1993 through August 1995. Figure #1 illustrates the consumption of fuel ethanol by state for the crop year 1994/95. Figure # 2 illustrates the consumption of fuel ethanol by county in the study's market region. The promotion of ethanol in reducing carbon monoxide emissions and as an octane enhancer has increased its use. The farm promotion groups have encouraged the use of fuel ethanol to expand their domestic market for corn. The use of corn for fuel ethanol production has reduced the cost of the US. farm program by consuming excess grain. The 1996 farm bill will drastically reduce the crop production controls, on most feed grain crops. This should bring into production acres for additional corn. The conversion of grain farming to the no-till process, and the consequent rotation requirements, will add additional acres to corn. The lower cost per acre of production may make this a preferred crop. The use of CRP acres to provide biomass for conversion to ethanol may provide an economically viable competitive renewable crop for conversion to ethanol. This has the addition benefit of maintaining highly eroding acres in soil holding grasses.

Fuel alcohol, when blended with gasoline in a ratio of one part ethanol and nine parts regular unleaded gasoline, to yield a 10% blend, increases the Reid Vapor Pressure by one pound. Fuel alcohol blended with a 10 pound Reid Vapor pressure unleaded gasoline yields a gasoline with a RVP of 11 pounds that exceeds the recommended 10 pounds RVP required by the Environmental Protection Agency. It is assumed the increase would cause greater evaporation of the fuel causing an increase in ozone concentration during the summer months, which is limited by the Clean Air Act. Figure # 5 depicts the seasonal demand for fuel ethanol.

from $35.00 per wine gallon to $55.00 per wine gallon[4] State taxes have increased also to various degrees. The historic price of beverage alcohol ranges from $1.45 to $1.85 per wine gallon, F.O.B. manufacturer, in Bond. Beverage alcohol must be made from grain. Synthetic or other biomass fermentation neutral spirits are not legal in the United States.[5]

Producers of distilled spirits use the fuel ethanol market to balance production. They sell excess ethanol capacity or off quality product for fuel use. Producers of distilled spirits and brewers of beer are also capturing spills and waste streams containing ethanol to reduce their volatile organic chemical emissions. The recovered ethanol is marketed for fuel use.

Industrial

The major non fuel markets for ethanol are solvents. In order of decreasing magnitude the segments are toilet and cosmetic preparations; coatings, inks and proprietary blends; detergents, disinfectants and flavors; processing solvents; pharmaceuticals for external use. The solvent market for ethanol is mature and is sensitive to the strength of the economy. Ethanol is subject to regulations as a volatile organic compound.

The chemical uses of ethanol are ethyl acrylate, vinegar, ethyl amines, glycol ethers and ethyl acetate. The ethanol used for these chemicals has declined due to competition from less expensive precursors and alternate processes.

Standard Denatured Alcohol (SDA) for industrial use continues to stagnate. There are a variety of denaturants approved by the BATF, which allow the ethanol to move in commerce untaxed.[6] Many required the maintenance of gauging records to prove proper use. The price of industrial ethanol ranges from $1.85 to $2.10 per wine gallon, F.O.B. Manufacturer.[7] There remains two producers of synthetic ethanol in North America since the construction of a world class flare gas plant by SABIC in Saudi Arabia.

Fuel

The manufacture of ethanol can be accomplished by the fermentation of carbohydrate from any source. The current cheapest economic source of carbohydrate for fermentation into ethyl alcohol in the United States is corn. Biomass as a source of carbohydrate for fermentation to ethanol may replace corn as the preferred feed stock.

The corn may be prepared for fermentation by either dry or wet milling processes. The dry mill process produces fewer coproducts than wet milling. This reduces the total possible revenue per bushel processed.

The Federal Fuel Excise Tax exemption, enacted as a result of the oil embargo, has expanded the manufacture of ethanol for blending as a fuel extender and as an octane component (111 octane). Fuel alcohol is manufactured by denaturing the pure 200 proof alcohol with up to five percent (5%) unleaded gasoline or natural gas condensate (See product specifications).

Figure # 1 Fuel Ethanol Consumption by State.
Millions of Gallons

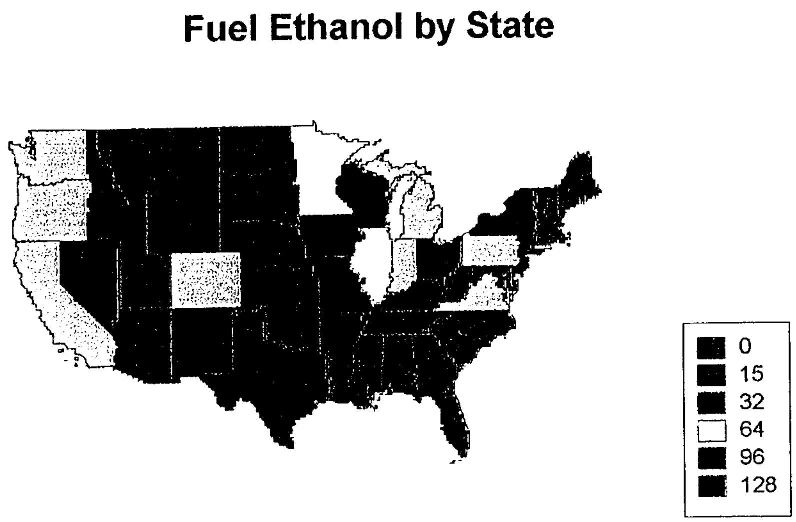
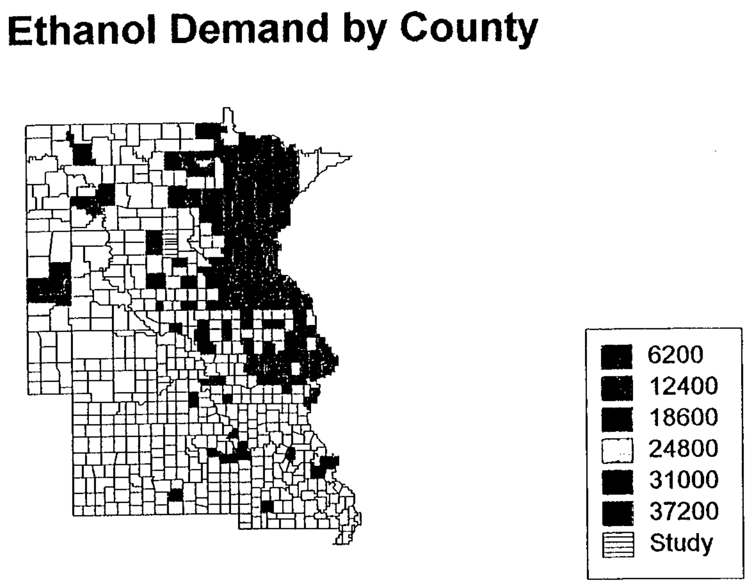


Figure # 2 Fuel Ethanol Consumption by County
100's of Gallons



The prices of fuel ethanol vary by territory. In the early years, it was loosely based upon the price of unleaded gasoline plus 54 cents, the amount of the Federal Excise Tax, less freight delivered to the distribution terminal. In spite of the formula, which is based on the Federal Ethanol Subsidy Program, supply and demand influences the actual prices. The 1990 through 1995 fuel ethanol in some markets was based upon the inferred formula of 1.45 times the price of unleaded gasoline per gallon , NY plus $0.39 equaled fuel ethanol dollars per gallon, midwest.

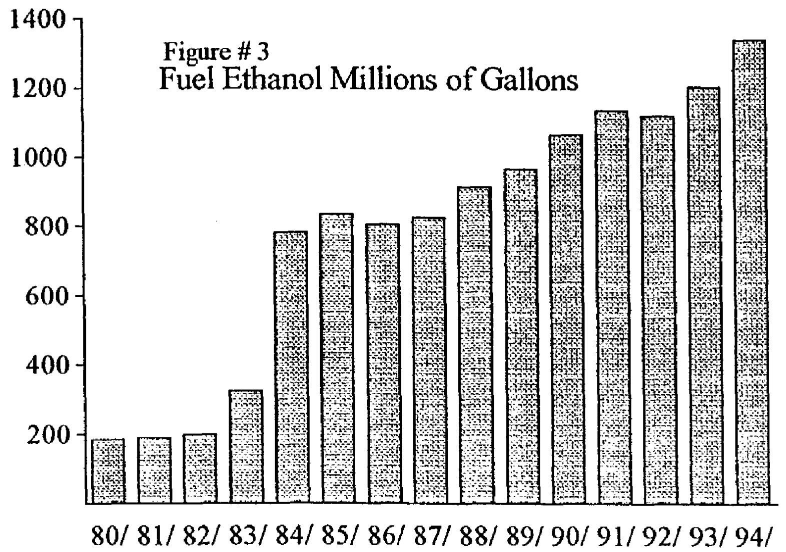
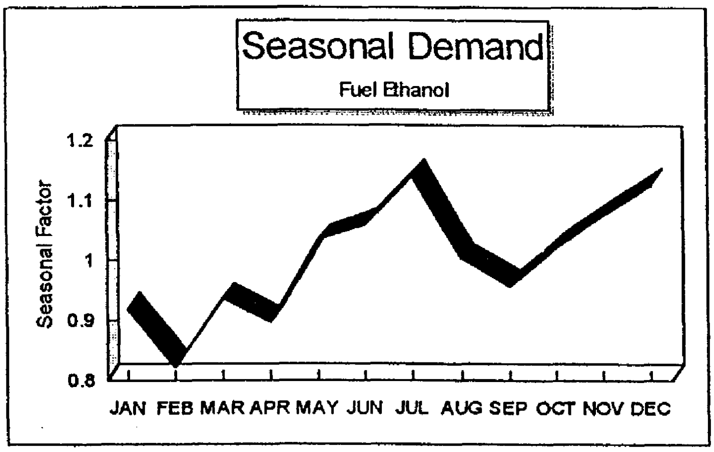


Figure # 5 illustrates the comparison among the federal calculated price, the fuel ethanol formula derived price and actual transactional fuel ethanol prices at midwest distributors' terminals. The actual prices are concentrated at two levels, with out regard to the untaxed price of gasoline. This has some correlation to the oxygenate value and the winter mandates. It also reflects the refiner distributor understanding of the octane and oxygen value of ethanol versus other blending additives.

Figure # 4 Seasonal Demand



The formulas for calculating ethanol value are based upon the percent ethanol in the blend and its corresponding federal tax rate per gallon.

Figure # 5 Fuel ethanol Pricing

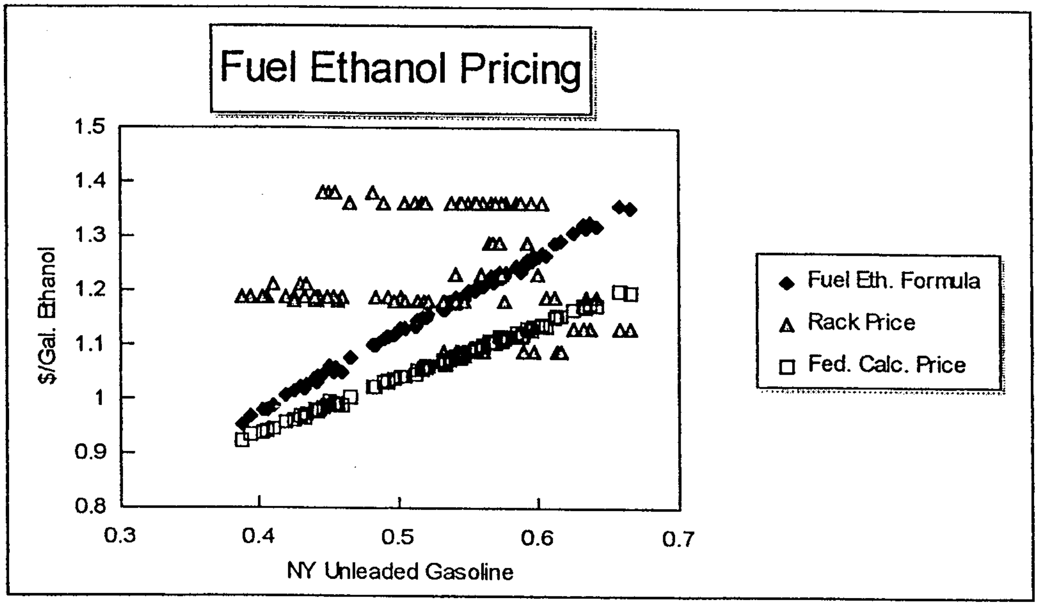


Table I. Fuel Ethanol Price Formulas

Incentive Price Formula for Fuel Ethanol				
	Unleaded	**10% Ethanol**	**7.7% Ethanol**	**5.7% Ethanol**
Federal Tax	0.14	0.09	0.10	0.11
Formula 1	(UG+.0141)-((UG*.9)+.087)/10/100=Ethanol Value			
Formula 2	(UG+.141)-((UG*.923)+.0994)/7.7/100=Ethanol Value			
Formula 3	(UG+0.141)-((UG*0.943)+0.1102)/5.7/100=Ethanol Value			
Unleaded @	$0.6126 WSJ Week of 12/18/95			
Ethanol Value		1.15	1.15	1.15

The oil industry and the commodity markets recognize oxygenated and non oxygenated gasoline. See the Wall Street Journal commodity page **OIL PRICES**.

The average cash price of non oxygenated gasoline was $0.5247 per gallon. The average cash price of oxygenated gasoline was $0.6126. The value of ethanol as oxygenate for the blending with non oxygenated gasoline is as follows.

	10% Ethanol	**7.7% Ethanol**	**5.7% Ethanol**
Ethanol Value	1.40	1.67	2.07

The actual prices charged by manufacturers of fuel ethanol vary widely depending on how well they understand the gasoline market. The small dry mill manufacturers on the edges of the corn belt are at the mercy of the refiner and distributor, who pit one small supplier against another. They then pocket the value margin. Several small producers considered creating a marketing company modeled on the sugar beet cooperatives and put the profit in their own pockets. They have not been successful in this effort.

The Federal Subsidy Program was critical to the survival of 100% fuel ethanol producers in the early years. If the Federal Subsidy Program is removed, fuel ethanol will compete directly with other petroleum based octane and oxygenate components. In recent times, MTBE, the principal competitive product, traded in the 80 - 97 cents per gallon range. Fuel ethanol may only trade at a modest premium to MTBE for it's oxygenate value or octane value. Ethanol of a quality for the manufacture of ETBE should be competitive with methanol at prices ranging from $1.44 to $1.61 per gallon delivered midwest refineries. Recently a major petroleum refiner in the Midwest has converted its ether process to ethanol, making ETBE rather than MTBE.

Oil refiners and pipeline companies are investigating entering the production of fermentation ethanol. The use of ETBE is economically viable in the Midwest now and may also be viable in other sections of the United State because of the ruling on the 5.4 cent tax credit pass through for ethanol used in the manufacture of ETBE.

➢ ***Define ethanol product distribution and sale options.***

Market Channels

Fuel, Chemical, Solvents, Beverage

The distribution channels for ethanol are multi-level. The chemical and solvent have overlapping channels. Fuel ethanol maintains a separate system. This is due to the nature of the market as well as the volume of material and regulatory requirements. Ethanol is a very polar molecule therefore, exhibits strong detergent properties. The cleaning characteristic of ethanol prohibits it use in petroleum or gas pipeline. The conversion of ethanol to ETBE results in a non-polar blending component.

Fuel Ethanol

The first level of distribution for fuel ethanol is direct to or from the refineries. The ethanol is moved directly to an ethanol gasoline blend at the processing plant or to a petroleum refinery for direct inclusion.

The second level of distribution of fuel ethanol is to common storage at a pipeline company fuel distribution terminal for inclusion as a rack item for customers blend requirement. The common storage is leased by the producer. The ethanol must meet the specification of the terminal for common storage. These specifications have proof, acidity, and clarity requirements.

Some medium and small ethanol production facilities have difficulty in meeting the terminal specifications due to the lack of adequate de-gassing of the ethanol. Many designers and contractors of fuel ethanol plants are unfamiliar with de-gassing technology. They do not include this equipment for economic and knowledge reasons. They also generally do not include adequate pH control to meet the neutral requirements. Therefore, this channel is precluded to many of the small producers.

The third level of distribution of fuel ethanol is via splash blend facilities located near to the pipeline distribution terminals or at the gasoline distributors facility. The fuel ethanol is sold directly to the distributor in tank truck or rail car for blending directly in the truck.

Table II and Figure # 6 depict the demand for ethanol in the United States.

Chemical and Solvents

The chemical and solvent use of ethanol is distributed in tank truck or rail car to Distilled Spirits Permit (DSP) holders for denaturing or direct use in chemical processes. The transfer of the ethanol is controlled by the BATF under the current law and federal regulations. They may or may not be moved in bond depending on the denaturant used and the permits in force.[10]

Beverage Ethanol

The beverage use of ethanol is distributed via truck or rail, barge, in bond, to DSP holders for blending and bottling whiskeys, gins, vodkas, and liqueurs. The transport and transfer of beverage ethanol is highly regulated and controlled by the BATF. The transport company must be licensed and bonded.

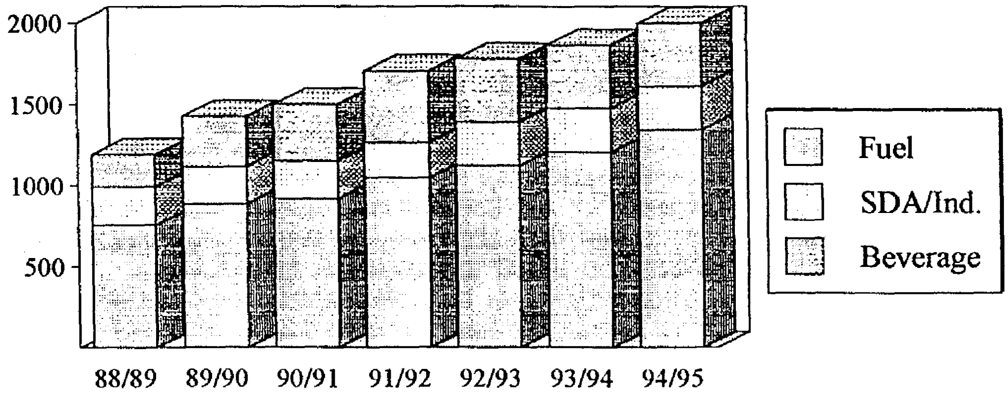
Table # 2 US Ethanol Demand

United States Ethanol Demand Millions of Wine Gallons per Year[1]

Year	Fuel	SDA/Ind.	Beverage	Total
88/89	755	236	201	1,192
89/90	884	231	310	1,425
90/91	918	230	351	1,499
91/92	1047	218	439	1,704
92/93	1121	267	389	1,777
93/94	1205	270	390	1,865
94/95	1342	265	390	1,997

[1] Department of the Treasury, Bureau of Alcohol, Tobacco and Firearms, Industry Compliance Division.

Figure # 6 Ethanol Demand History



➢ ***Analyze the price trends for conventional ethanol sources and assess the product pricing impact that may result due to existing and planned regulations.***

Prices

The fuel ethanol segment is the fastest growing. Growth of the market makes demand very elastic. Volume enters or exits without a noticeable effect on the price of the product. Prices of fuel ethanol can change on a daily basis in concert with the market for unleaded gasoline. If product was available, it easily moved into the market. The seasonal demand created by the mandates allowed an accumulation of stocks during the non mandate period as prefill contracts.

There is an advantage for the corn syrup producer to install ethanol capacity to offset the seasonal slack in sweetener demand. The producer can operate the grind at full rate through the winter months. This outlet for grind tends to eliminate the glut of sweetener and maintains the price of syrups at a higher level. The anti cyclic demand of the fuel market makes entry and exits easy for the corn syrup producer.

The disadvantage is the additional capital required to build the extra finishing capacity. The justification is the return on investment on overall assets employed as a result of the improved marginal income during the off season months. The marginal income for the wet miller makes them a formidable competitor for seasonal market share.

The beverage segment growth has stagnated. The quality requirements for neutral spirits are stricter than for fuel. The volume of beverage ethanol is relatively constant throughout the year. Beverage ethanol does not require dehydration after rectification and is sold at 190 proof. The barrier to entering the beverage market requires long lead times to achieve significant sales. Spirits produced from non-grain biomass is not lawful for beverage use in the United States.

The industrial segment requires a high purity product. It is 200 proof without odor, and water white. It is sold directly to distributors or to the end user, in bond or denatured. Quality can be critical to the chemical processor's reaction efficiencies. The demand tracks the trend of the general economy. The price leaders are USI Chemicals and Union Carbide. The products are priced on a quarterly basis and generally carry a premium to beverage. A new vendor must have a process that provides consistent quality products.

Ethanol acts as a commodity, therefore Quality, Consistency, Service and competitive prices are the significant items that establish the new entry in the market. Figure # 6 illustrates the volatility of the wholesale fuel market and as a consequence the price of fuel additives.

Figure # 6 Unleaded Gasoline

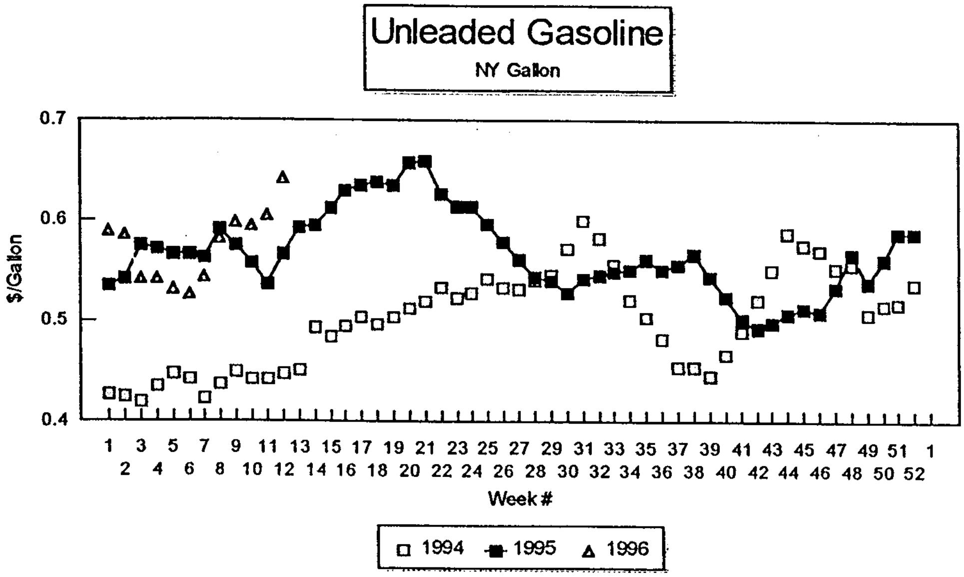


Table II Fuel Ethanol Projected Prices[11]

95% Confidence Limits

Unleaded Gas, NY Gallon $/Gallon	Projected Ethanol $/Gallon	Upper Ethanol $/Gallon	Lower Ethanol $/Gallon
0.40	0.95	1.03	0.81
0.45	1.01	1.10	0.87
0.50	1.08	1.18	0.93
0.55	1.15	1.26	0.98
0.60	1.22	1.33	1.04
0.65	1.28	1.41	1.10
0.70	1.35	1.49	1.16
0.75	1.42	1.56	1.22
0.80	1.48	1.64	1.25
0.85	1.55	1.72	1.33
0.90	1.62	1.79	1.39
0.95	1.69	1.87	1.45

Projected fuel ethanol prices are based upon the average price of unleaded gasoline (1980-1995) as reported in the Wall Street Journal and the average rack price of fuel ethanol Midwest locations. The R^2 of the regression is 0.954. The upper and lower bounds are equal to two sigma. The projected prices are depicted in Table II.

Projected beverage ethanol prices are based upon the average annual price of No. 2 Yellow Dent Corn (1989-1995) as published in the Wall Street Journal, cash prices and the average price of neutral spirits, Midwest producers. The R^2 of the regression is 0.0976. The upper and lower bounds are two sigma. The projected prices are depicted in Table III.

Table III Beverage Ethanol Projected Prices

Beverage Ethanol Projected Prices[12]

95% Confidence Limits

Beverage: $/Bushel	Projected $/Gallon	Upper $/Gallon	Lower $/Gallon
2.00	1.52	1.60	1.50
2.20	1.60	1.68	1.58
2.40	1.68	1.76	1.66
2.60	1.76	1.84	1.74
2.80	1.84	1.92	1.82
3.00	1.92	2.00	1.90
3.20	2.00	2.08	1.98
3.40	2.08	2.16	2.06
3.60	2.16	2.24	2.14
3.80	2.24	2.32	2.22
4.00	2.32	2.40	2.30

Projected industrial ethanol prices are based upon the average annual prices of ethanol (1989-1994) F.O.B. delivered Midwest distributor. The R^2 of the regression is 0.91. The upper and lower bounds are two sigma. The projected prices are depicted in Table IV.

Table IV Industrial Ethanol Projected Prices

Industrial Ethanol Projected Prices[13]

95% Confidence Limits

Year	Projected $/Gallon	Upper $/Gallon	Lower $/Gallon
1996	2.17	2.22	1.97
1997	2.24	2.29	2.04
1998	2.30	2.35	2.10
1999	2.37	2.42	2.17
2000	2.44	2.49	2.24
2001	2.51	2.56	2.31

Recovery Products

Table V

Expected Commercial Yield Per Ton Of Feed Stock	
Ethanol	504 lb.
CO_2	500 lb.
Lignin	500 lb.
Methane	53 lb.
Ash	116 lb.
Non Recoverable	327 lb.

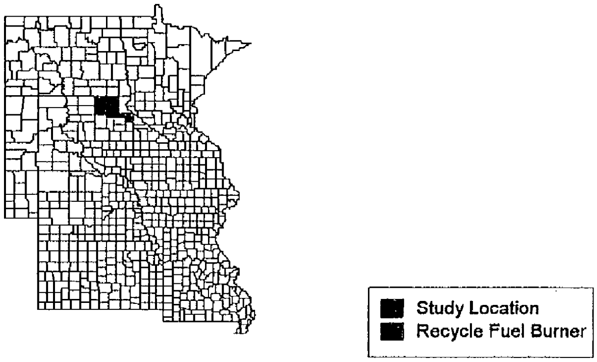
Table # 5 list the expected commercial yields using WSG as the feed stock. Recovery product sales can be significant contributors to gross revenues. The biomass ethanol process has three potential co-product revenue streams. They are combustible residue as a boiler fuel on site or recycled to electric power generation plant, co-generated electricity from excess to process needs, and carbon dioxide. The potential combustible residues at 80 gallons of ethanol yield are 87.5 tons per day of lignin and 9.3 tons of methane per day. OtterTail Power Company will purchase combustible material for boiler feed at a price of $0.50 per million BTUs, FOB their Grant County, South Dakota generation facility (See Figure # 10). Depending upon the physical site of the biomass plant this could provide a contribution of up to $1032 per day of operation.[14].

The co-generation of steam and electricity with the combustible residue may provide a revenue stream, by selling the excess electric power to either OtterTail Power Company or East River

Electric Power Cooperative. The rates are \$0.0143 per KWH[15] off peak and \$0.01145 per KWH[16] respectively. Preliminary calculations of heat excess to needs may produce up to 110,000 KWH per day. This may provide a revenue stream of \$1,200 to \$1,500 per day.

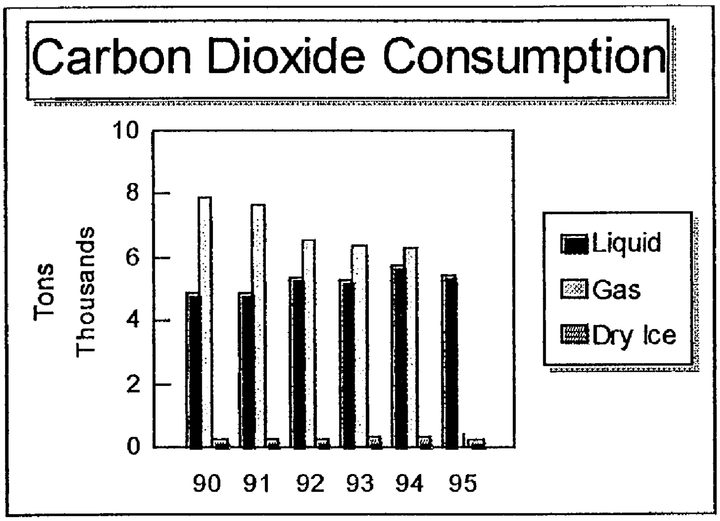
Figure #10 Recycle Fuel Burners

North Central Reg. by County



Carbon dioxide is a viable recovery product at production rates in excess of 100 tons per day. BOC Group, Inc. of Murray Hills, New Jersey, Liquid Carbonic Industries Corporation of Chicago, Illinois and Liquid Air Corporation of Walnut Creek, California, produce or market 85% of the carbon dioxide sold in the continental United States. Uncompressed carbon dioxide (CO_2) has an across the fence value of \$9.00 to \$12.00 per ton, when sold to a separate compression plant, owned by such carbon dioxide marketers or producers as Liquid Carbonic Industries Corporation, Koch Industries. or CARDOX.[17] The average price of uncompressed CO_2 for the period 1984 through 1994 was \$10.10 +- 1.21 per ton. The average price of liquid CO_2 for the period of 1984 through 1994 was \$51.51 +- 7.54 per ton, FOB compression plant.[18] The quoted price of carbon dioxide, liquid is \$110.00 per ton delivered in the North Dakota and South Dakota section of the North Cental region.[19] The prices of carbon dioxide are not expected to trade outside of the historic range due to competitive pressure from new market entries. Figure # 11 illustrates carbon dioxide consumption.

Figure # 11



The major markets for compressed fermentation carbon dioxide are carbonated beverages and flash freezing of vegetables. The Figure # 12 indicates food grade carbon dioxide users are located throughout the north cental region of the United States. Freight and electric power rates are the major factors in the delivered cost to the CO_2 consumer. The availability of internally generated electric power may make CO_2 an attractive coproduct.

Carbon dioxide is projected to continue its growth through the turn of the century.

Figure # 12 CO_2 By County

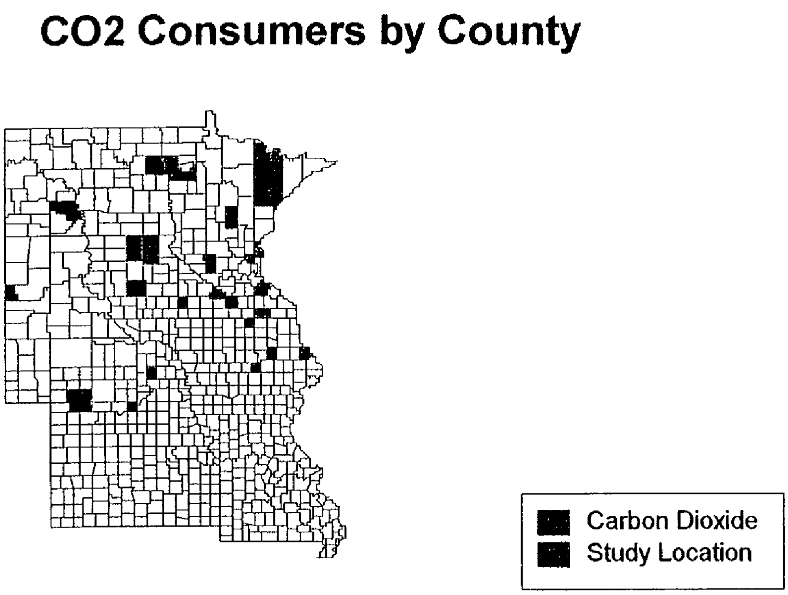
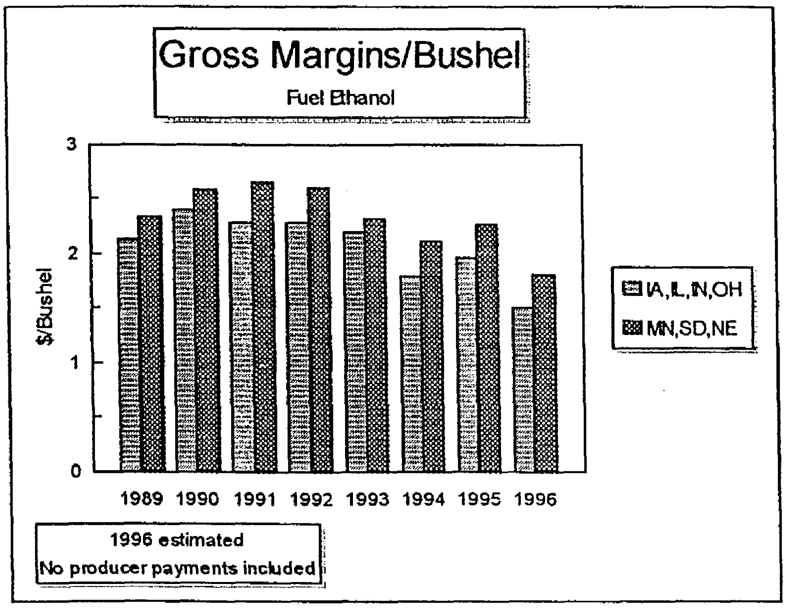


Figure # 13



The gross margin for fuel ethanol producers has declined as the price of corn has increase to very high levels (See Figure # 13). The producers in Minnesota, South Dakota and Nebraska have a margin advantage compared to the producers located in Iowa, Illinois, Indiana, and Ohio. This is due to the price of corn. The decline in margin for corn derived ethanol producers may provide an incentive for conversion of their plants to WSG biomass capability.

Incentives[20]

Blenders credits -

State	Gasoline Tax	Fuel Tax Exemption
Alaska	$0.18	$0.08
Arkansas	$0.185	$0.08
Connecticut	$0.28	$0.01
Hawaii	$0.16	Four (4) Percent
Illinois	$0.19	$0.0185
Iowa	$0.20	$0
Minnesota	$0.20	$.008/gallon 10/1/95-10/1/96
		$.005/gallon 10/1/96-10/1/97
		$0.00/gallon 10/1/97
Missouri	$0.13	$0.02
Ohio	$0.21	$0.015
Oregon	$0.24	$0.05
South Dakota	$0.18	$0.02
Washington	$0.23	$0.037
Wyoming	$0.09	$0.04

Producer Credits[21]

State	Producer Credit	Per Bushel Equivalent
Iowa	$900,000 one time grant.	
Kansas	$0.20	$0.50
Minnesota	$0.20	$0.50 Max. $3,000,000/year $30,000,000 cap for all producers
Missouri	$0.20	$0.50
Montana	$0.30	$0.75
Nebraska	$0.20	$0.50
North Carolina	State income tax credit up to 30% of the plant cost.	
North Dakota	$0.40	$1.00
South Dakota	$0.20	$0.50 Max. $1,000,000/year up to $10 million total

Federal Motor Fuel Excise Taxes $ per Gallon.[22]

Gasoline	0.141
Diesel Fuel	0.201
10% Ethanol Blend	0.087
7.7% Ethanol Blend	0.0994
5.7% Ethanol Blend	0.1102
Methanol Blend	0.0810
Propane	0.14
85% Methanol Qualified	0.0805
85% Methanol	0.071
Partially exempt; made from Natural Gas	
85% Ethanol Qualified	0.0865
85% Ethanol	0.071
Partially exempt; made from Natural Gas	

National Issues

The fight over market share for reformulated gasoline's will be hot and continuous. Secretary Browner announced in 1994 that the new reformulated gasoline will account for about one third of the gasoline sold annually in the United States. The total gasoline consumption in the United States is estimated to be 111 billion gallons per year. The EPA mandate would have guarantee that approximately one tenth of all gasoline sold in the US must contain a "renewable" oxygenate. Ethanol and ETBE are the only market ready substances now available to fit the bill.[23]

The Senate appropriation subcommittee voted 8 to 3 to prohibit the EPA from implementing the ethanol mandate. The amendment was voted on in the Senate August 3, 1994 and was defeated by a vote of 51 to 50, with the Vice President casting the tie breaker. [24] In September 1995, the Chairman of the House Ways and Means Committee Bill Archer of Texas proposed the elimination of the 5.4 cent per gallon tax break for ethanol blended fuels. House Speaker Newt Gingrich of Georgia deleted this provision.[25]

The effort to deny the market to ethanol will continue. The 5.4 cents in tax abatements afforded ethanol through the year 2000 will be attacked. The argument will be made that the mandate removes the need for government help. The second argument will be the need to reduce the drain on the federal budget. The third argument will be that the large manufactures no longer need the tax relief to return an adequate profit. It is opined the federal tax abatement for ethanol blended fuels will be significantly reduced or eliminated in the year 2000. The removal of the federal tax abatement will then make ethanol a direct competitor of MTBE on an oxygenate basis and to other octane components of gasoline. It is projected that splash blended fuel ethanol would be price at a premium to MTBE of 15 to 25 cents per gallon. Ethanol for ETBE would be priced at a premium to methanol of 31 to 42 cents per gallon.

The continuation of state producer payments will be critical to the survival of the small stand alone ethanol producer. The dry mill ethanol process will need to have a capacity in excess of 100 million gallons per year to compete with the wet mill integrated ethanol producer.

The Senate version of the 1996 Farm Bill allows any farmer, who participated in at least one farm program since 1990, to be eligible for fixed payments. They may plant on 85% of their land any mix of wheat, feed grains, cotton, rice, oilseeds, mung beans, lintels and industrial or experimental crops. There is a provision for renewing CRP acres at 34.52 million acres maximum, of which 975,000 may be CRP wetland reserve.

Should a farmer elect not to re-enroll CRP acres, he may grow Western Switch Grass as an experimental crop without jeopardizing his program payments.

State Issues

State producer credits and blenders' credits are under pressure from tight budget considerations. South Dakota currently has a 2 cent per gallon blender's credit, and a 20 cent per gallon producer credit for fuel ethanol produced in the state. The credits must be funded every year by the legislature, which always opens it to amendment or elimination. The producer credit is limited to a maximum of $1,000,000 per year per producer.[26] The funds available for the producer credit in 1995 are less than required and the funds available will be prorated between the current producers. The producer credit will be eliminated entirely in the near future due to the lack of funding sources.

North Dakota currently has a producer credit of 40 cents per gallon for ethanol produced and consumed within the state. The credit is funded at a maximum of 3,650,000 for the current two year term. Each producer may not exceed $950,000 in producer credits per year[27]

Minnesota's bender's credit is currently $0.008 per gallon of ethanol until October 1, 1996 when it will decline to $0.005 per gallon until October 1, 1997 when it ends. . The state also has a producers credit of 20 cents per gallon of ethanol produced in the state. The maximum credit allowed any one producer is $3,000,000 per year and a cap of $30,000,000 for all producers. Producers may continue to receive payment of $0.20 per gallon of ethanol for ten years or until the year 2000 whichever is later. There was an effort to raise the producer credit to 25 cents per gallon, but was vetoed by the governor. There is an addition credit available, up to $750,000 annually, paid at a rate of 1.5 cents per kilowatt hour of electricity generated with closed loop biomass in cogeneration ethanol facilities. It is the goal of the State to attain an annual production level of 220 million gallons of ethanol. The Minnesota incentive program ends June 30, 2010.[28]

Competitors

Petroleum

Most oil companies oppose any effort to improve the competitive position of ethanol as an alternate to petroleum based fuels for automobiles. The exceptions to this are the independent refiners that do not have significant oil field holdings. The independents have used ethanol's 111 octane rating to improve the throughput of their refineries. They accomplish this by producing a greater proportion of rafinates of 80 to 84 octane, which provide a greater yield per barrel, and blending with ethanol to meet the 87 octane specification for unleaded regular gasoline. The independents are located in the northern tier of states, in or adjacent to the corn belt. The majority of the early growth of ethanol blends occurred in the northern tier.

Methyl Tri-butylether is the primary competitor to ethanol as an oxygenate in reformulated gasoline. It is a non polar molecule formed as an ether from methanol and butene. These molecules are low cost and available streams at most refineries. This allows the blending of the oxygenate at the refinery and transported by pipeline to the distribution terminals. Many of the oil companies have added MTBE capacity to their facilities. Public opposition to the odor of MTBE oxygenated fuel arose in Wisconsin. Replacement of the MTBE with ETBE seems to have eliminated the odor.

Wet millers

The wet millers are the largest producers of ethanol. They supply ethanol to all segments of the ethanol market. The high fructose corn syrup (HFCS) producer uses the ethanol capacity to balance the seasonal demand of sweeteners. Ethanol is storable without degradation of content or quality. This allows the producer to use the front end grind capacity of the plant efficiently, without flooding the HFCS sweetener market during the winter months of low demand. The result is less pressure on HFCS prices. The marginal income derived more than offsets the idle ethanol capacity during the summer months.

The seasonal demand for fuel ethanol caused by EPA's effort to improve the air quality in the winter months with oxygenates helps the over all elasticity of the ethanol market. The winter demand for fuel ethanol allows the swing capacity of the seasonal producer to enter and exit the market with ease.

Dry millers

All of the dry mill ethanol plants are vulnerable to any change in producer payments or blender credits at the state level as well as improper site selection. The closing of South Point Ethanol and ADM Walhalla plants point out the folly of ignoring the effect of adequate local raw material supply in relation to the supply as a whole. Basis and a plant's effect upon the basis in a short supply year must be one of the risk assessments necessary to successful facilities..

Figure # 14 Ethanol Production Capacity

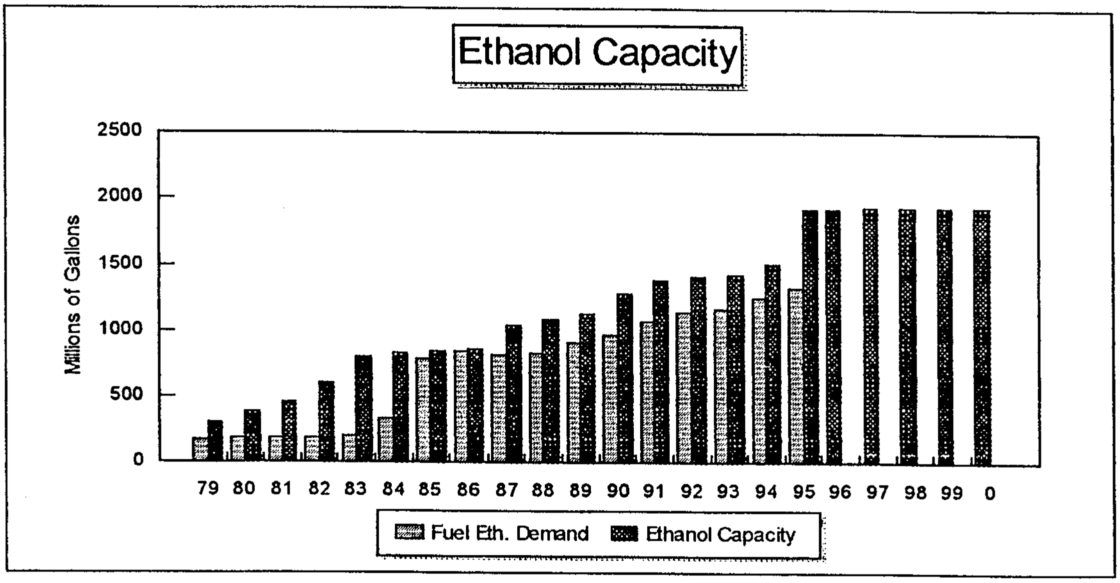


Figure # 14 depicts the known ethanol production capacity through the year 2000.

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Producers with relative market shares greater than one percent.

Relative market shares are equal to the capacity of the competitor divided by the capacity of the largest producer in the segment times 100.

Company	Ethanol
ADM	100
ALCAM	3
CPC	9
CARGILL	6
CHIEF ETHANOL	4
CORN PLUS	2
GPC	9
GEORGIA PACIFIC	1
HEARTLAND FUELS	1
HEARTLAND CORN PRODUCTS	2
HIGH PLAINS	5
ROQUETTE	4
SIMPLOT	1
MIDWEST SOLVENTS	12
MCP	9
MORRIS AG-ENERGY	1
NEW ENERGY	11
PORTALAS ENERGY	2
RAVEN	1
STALEY	6
WHITE FLAME	1
TEXAS EASTERN	7
USI CHEMICALS	7
UNION CARBIDE	19

Figure # 15 depicts the location of ethanol producers in Midwest study region.

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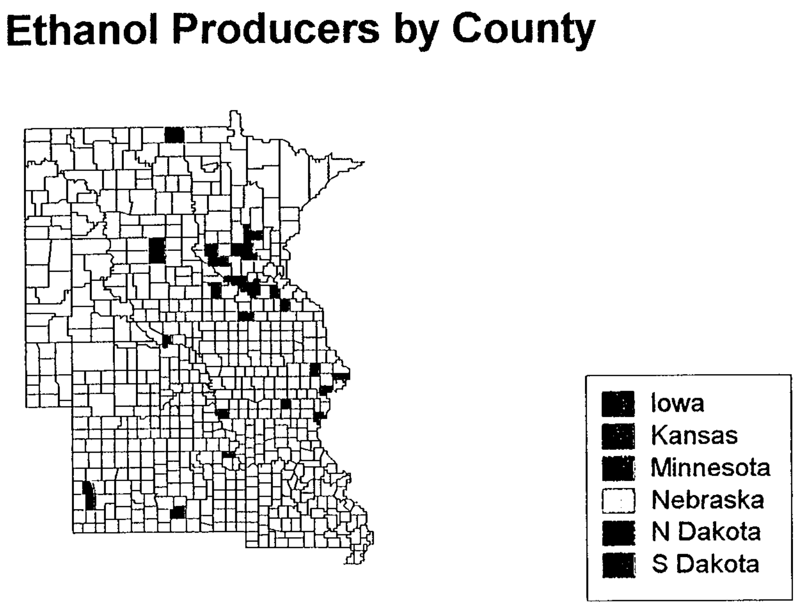
Figure # 15 Location of Ethanol Producers



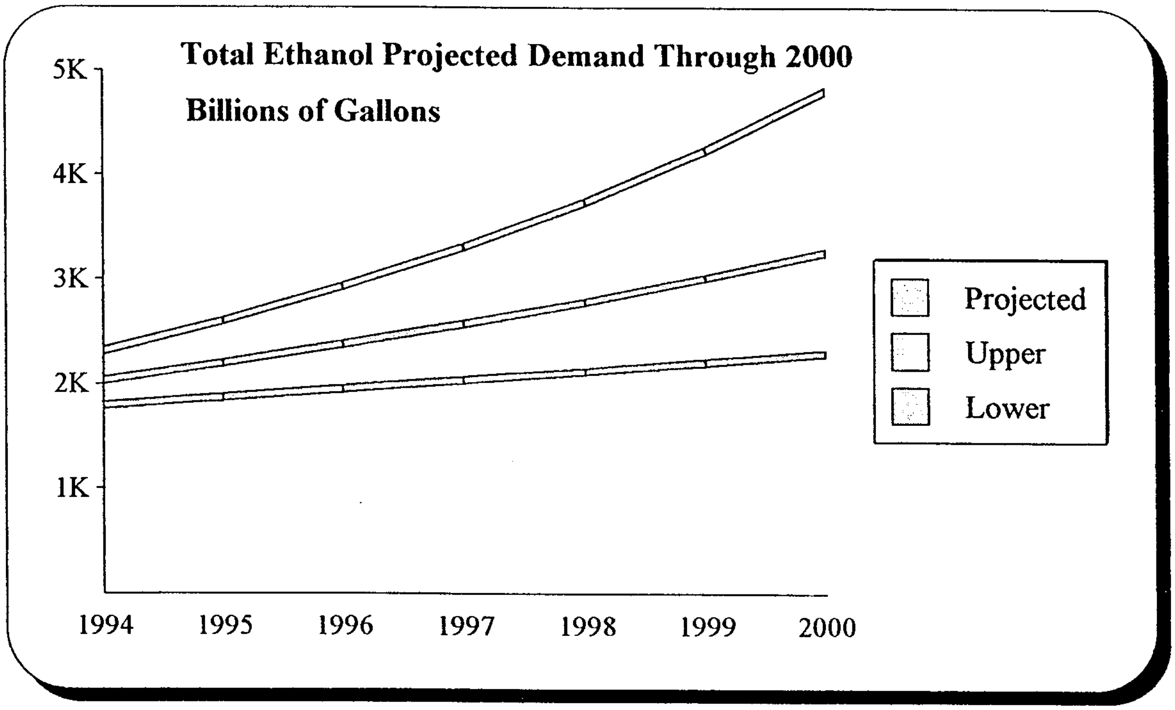
Projections

Table VI

Total Ethanol Projected Demand Through 2000. 95% Confidence Limits
Millions of Wine Gallons per Year

Year	Projected	Upper	Lower	Capacity
1995	2198	2600	1872	1927
1996	2377	2929	1952	1895
1997	2573	3306	2034	1895
1998	2784	3739	2119	1895
1999	3014	4236	2206	1895
2000	3264	4806	2297	1895

Figure # 16



Projected ethanol demand is based upon the annual consumption (1989-1995) in the United States. The R^2 of the regression is 0.9748. The upper and lower bounds are two sigma from the projected volumes. The projected demand is depicted in Table VI and in Figure 16.

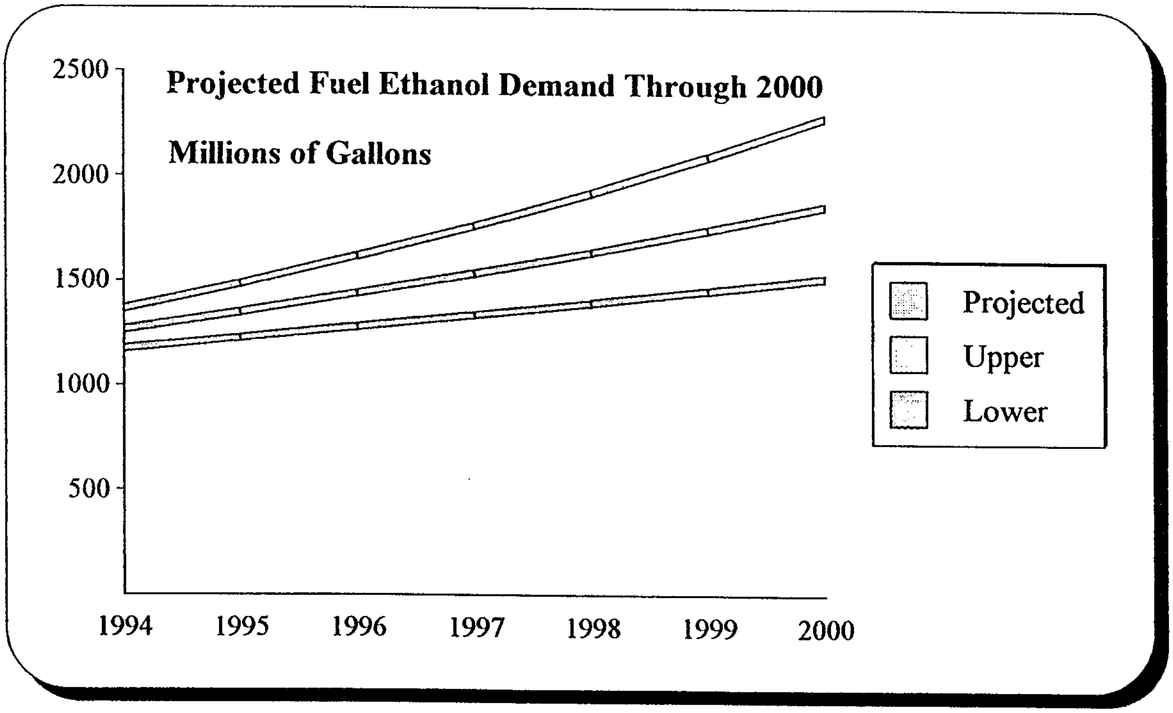
Table VII

Fuel Ethanol Projected Demand Through 2000[29]

95% Confidence Limits
Millions of Wine Gallons per Year

Year	Projected	Upper	Lower
1994	1265	1363	1174
1995	1349	1484	1226
1996	1438	1616	1280
1997	1534	1761	1335
1998	1635	1919	1393
1999	1743	2092	1453
2000	1859	2280	1515

Figure # 17



Projected demand for fuel ethanol is based upon the annual consumption (1989-1995) in the United States. The R^2 of the regression is 0.988. The upper and lower bounds are two sigma. The projected demand is depicted in Table VII and Figure # 17.

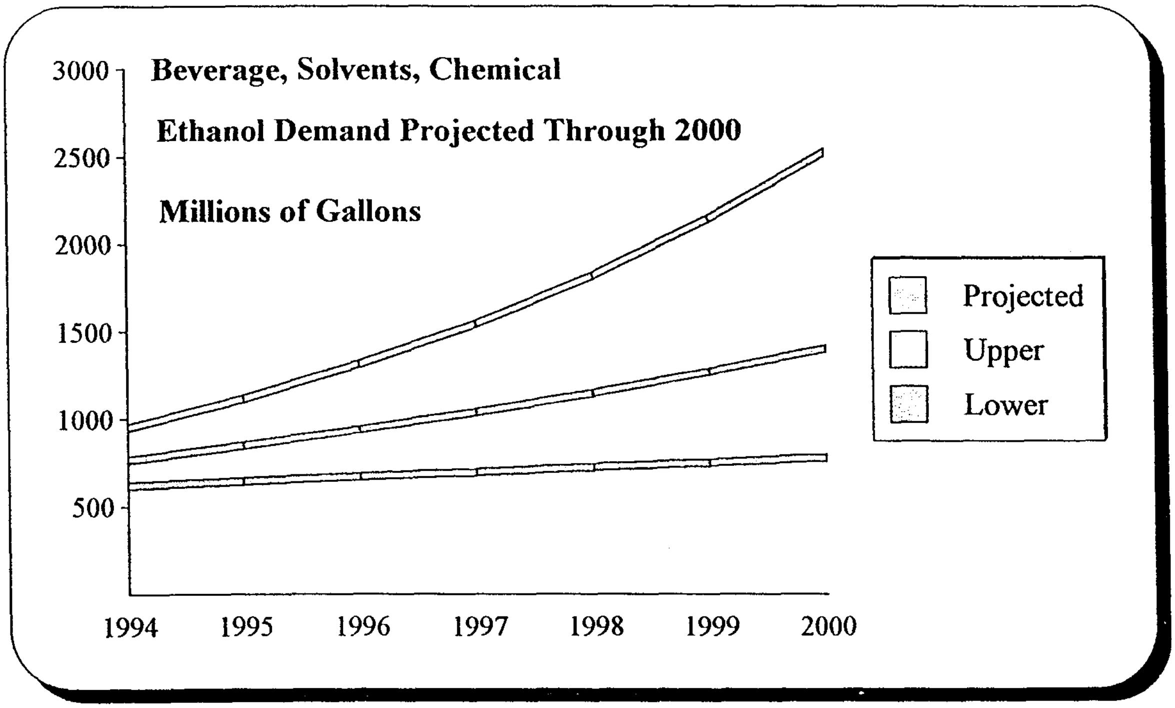
Table VIII

Beverage, Solvents, Chemicals Ethanol Projected Demand Through 2000.[30]

95% Confidence Limits
Millions of Wine Gallons per Year

Year	Projected	Upper	Lower
1994	768	951	620
1995	849	1116	646
1996	939	1313	672
1997	1039	1545	699
1998	1149	1820	726
1999	1271	2144	753
2000	1405	2526	782

Figure # 18



The projected demand for Beverage, Solvents and Chemical ethanol is depicted in Table VIII and in figure # 18.

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➢ ***Define the economic advantages of ethanol versus some other product option. Example: If the CRP is discontinued, consider any economic advantage that may exist for producing ethanol Feedstocks versus producing grain crops (for instance).***

Assumptions as Givens:

Conservation Reserve Program	Discontinued
Comparison Crops	Grasses, Corn, Soybeans, Sunflowers, Cash Rents
Yields	1993
Price basis	1993
Returns per Acre	Net of land and mortgage interest
Operating loan interest rate	9.5 %

The conversion of CRP acres from grass cover to field crops will dependent upon several factors. 1, The ownership status of the CRP acres, (Owner operator; Retired owner, Absentee owner); 2. Availability of operating cash or loans; 3. Capital cost associated with conversion.

In the decision making process, the owner operator may consider the prior use of the CRP acres, the revenue production of the alternative crops, the compatibility of present equipment owned, the capital cost of conversion and the availability of operating and capital loans from lenders. If the choices are corn, soybeans, sun flowers, biomass grasses, and cash rent, not withstanding any terrain considerations, the payout comparisons are:

Crop	Corn	Soybeans	Sun Flowers	Biomass grasses	Cash rents
Payout in Years	0.71	0.56	0.29	0.59	0.00

The lender will evaluate the history of the operator and the risk of the up front cost of conversion. Loans for the conversion of CRP acres will be made to owner operators who have demonstrated good management skills. Other operators will find capital for conversion difficult to obtain. They will rely upon the Agriculture Stabilization and Conservation Service (ASCS) as a lender of last resort.

The retired operator may sell the property to an operator at a price including consideration of the conversion cost, rent the property for conversion or contract for biomass grasses harvesting. If ownership is retained, then it appears converting to WSG will yield returns equal to corn or soybeans at prices greater than or equal to $29.00 per ton field edge would yield an attractive return. The absentee owner has the same choices as the retired owner.

The 1996 crop prices will bring marginal lands into production for corn, as the payout is less than one year. The revenue for soybeans and sun flowers does not dramatically change the payout from the 1993. The conversion from CRP to non grass crops will remain difficult for many owner operators. These acres will be available for biomass grass production. Conversion from CRP to non grass crops by retired owners and absentee owners will be effected by the sale or rental to large farm operations as marginal additions to crop lands. To bring these acres into biomass production, revenues per acre must equal or exceed the rental value by price per ton or yield improvement per acre. The average yield for grasses and hay in the counties specified in this study is 1.3 tons per acre. Switch Grass yields greater than two tons per acre are projected, and provide revenue incentives for the production of biomass for ethanol production. Nebraska field trials demonstrated yields up to 6.7 tons per acre for the North Plains region.[31]
At this writing there are no statistical data available on the ownership categories listed therefore, no projection can be made as to the potential disintermediation of CRP acres.

Table IX Revenue per Acre

Brown, Day, Marshall Counties, SD	**Corn**	**Soybeans**	**Sun Flowers**	**Grass/ Hay**	**Switch Grass**	**Cash Rent**
Yield[1]	74.00	23.40	13.47	1.30	2.60	1.00
Price/Unit[2] 1993 Basis	2.40	6.10	12.00	42.00	29.00	22.25
Gross Revenue	177.60	142.74	161.64	54.60	75.40	22.25
Federal Payments[3]	18.50	0.00	0.00	0.00	0.00	0.00
Total Gross	196.10	142.74	161.64	54.60	75.40	22.25
Planting[4]	8.00	7.00	7.00	7.00	7.00	
Seed	28.00	20.00	16.00	6.00		
Fertilizer[5]	48.00	10.00	27.00	10.00	10.00	
Fertilizer Application	5.00	5.00	5.00	2.75	2.75	
Cultivation	5.00	5.00				
Chemicals	26.00	26.00	14.00	3.00	3.00	
Chemical Application	3.00	3.00	3.25	3.00	3.00	
Harvesting	20.00	18.00	14.00	14.50	14.50	
Handling	9.00	7.00	9.00			
Operating Interest	15.00	9.00	9.00	3.20	3.20	
Insurance	8.00	6.00	6.00		5.00	
Total Cost	175.00	116.00	110.25	49.45	48.45	0.00

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Brown, Day, Marshall Counties, SD	**Corn**	**Soybeans**	**Sun Flowers**	**Grass/ Hay**	**Switch Grass**	**Cash Rent**
Revenue/Acre	21.10	26.74	51.39	5.15	26.95	22.25
Conversion capital Cost	15.00	15.00	15.00		16.00[6]	
Payout in Years	0.71	0.56	0.29	0.00	0.59	0.00

1 South Dakota Agriculture on the Move 1993-94, SDASS 1994.

2 South Dakota Agriculture on the Move 1993-94, SDASS 1994.

3 USDA Crop Report, Data Table 12, 1977-1994.

4 Doane's Agricultural Report Newsletter, Vol. 58, No. 2206, 1995.

5 Tracy, P. (22 February 1996) J.E.S. Farms, Pierre, SD .

6 Cost of seed included in conversion capital at $6.00 per acre.

Table X

Brown, Day Marshall Counties, SD	**Corn**	**Soybeans**	**Sun Flowers**	**Grass/ Hay**	**Switch Grass**	**Cash Rent**
Yield[1]	74.00	23.40	13.47	1.30	2.60	1.00
Price/Unit[2] 1996 Basis	3.20	6.50	12.00	55.00	42.00	22.25
Gross Revenue	236.80	152.10	161.64	71.50	109.20	22.25
Federal Payments[3]	0.00	0.00	0.00	0.00	0.00	0.00
Total Gross	236.80	152.10	161.64	71.50	109.20	22.25
Planting[4]	8.00	7.00	7.00	7.00	7.00	
Seed	28.00	20.00	16.00	6.00		
Fertilizer[5]	48.00	10.00	27.00	10.00	10.00	
Fertilizer Application	5.00	5.00	5.00	2.75	2.75	
Cultivation	5.00	5.00				
Chemicals	26.00	26.00	14.00	3.00	3.00	
Chemical Application	3.00	3.00	3.25	3.00	3.00	
Harvesting	20.00	18.00	14.00	14.50	14.50	
Handling	9.00	7.00	9.00			
Operating Interest	15.00	9.00	9.00	3.20	3.20	

Brown, Day Marshall Counties, SD	Corn	Soybeans	Sun Flowers	Grass/ Hay	Switch Grass	Cash Rent
Insurance	8.00	6.00	6.00		5.00	
Total Cost	175.00	116.00	110.25	49.45	48.45	0.00
Revenue/Acre	61.80	36.10	51.39	22.05	60.75	22.25
Conversion capital Cost	15.00	15.00	15.00		16.00	
Payout in Years	0.24	0.42	0.29	0.00	0.26	0.00

1 South Dakota Agriculture on the Move 1993-94, SDASS 1994.

2 South Dakota Agriculture on the Move 1993-94, SDASS 1994.

3 USDA Crop Report, Data Table 12, 1977-1994.

4 Doane's Agricultural Report Newsletter, Vol. 58, No. 2206, 1995.

5 Tracy, P (22 February 1996) J.E.S. Farms, Pierre, SD..

➢. *Develop a preliminary marketing plan for ethanol that will include a price structure and assess existing and proposed federal and state tax incentives.*

Marketing Strategy

The marketing strategy for the biomass to ethanol plant proposed for this study should be viewed to maximize the revenues and conserve the working capital. The scale of the facility, although capital intensive, is small vis a vis the markets for the finished products. The revenue producing products are fuel ethanol, uncompressed carbon dioxide and co-generated electric power from combustible process residues.

The fuel ethanol produced from the biomass plant will flow into the North Central Region in competition with the established producers. The biomass plant can elect to establish its own sales force or contract for marketing service.

Fuel Ethanol	Direct Sales	Contract Sales
Price	1.22/Gal.	1.22/Gal.
Sales Cost	0.015/Gal.	0.02/Gal.
Market Entry	0.02/Gal.	N/A
Freight	0.05/Gal.	0.05/Gal.
Net	1.135/Gal.	1.15/gal.

It appears contracts for sale for fuel ethanol will yield a higher net revenue to the project. This is due to the cost of entry for a new producer as the buyers pit the new supply against the established.. The direct method is projected to cost from $0.02 to $0.04 per gallon during the first year of operation. At a capacity of 10,000,000 gallons per year, the sale of fuel ethanol should be contracted with a distributor, whose territory covers the north central region, prior to the beginning of plant construction. Distributors with these capabilities are MILSOLV, Butler, Wisconsin, Koch Refining Company, Wichita, Kansas, or Heartland Fuels Division of Farmland Industries Cooperative.

Carbon dioxide may be sold across the fence to Koch Industries, Inc., Liquid Carbonic Industries Corporation, BOC Group, Inc., Liquid Air Corporation or CARDOX as uncompressed gas. This can be accomplished prior to the commencement of ethanol production. The range of price per ton is $9.00 to $12.00 per ton. Carbon dioxide may be sold directly to the bottler or distributor. The wholesale price of $44.00 to $59.00 per ton is attractive for a low cost new entry. Market penetration rate is projected at 3% per month of capacity. The break-even with the sale of uncompressed gas would occur during the mid part of the second year of operation. Adequate working capital is required to sustain the sales effort. This cost may be capitalized and amortized.

Excess electric power may be sold to East River Electric Power Cooperative or Otter Tail Power Company at established tariff rates in effect at the date of start up.

It is possible for all of the output of the biomass to ethanol plant be committed prior to the commencement of production. The gross revenues, net of sales cost and freight are projected at $12,160,000 plus any state producer incentive payments, for the first full year of production.

Fuel Ethanol	$1.15/Gal.	11,500,000
CO_2	$9.00/Ton	260,000
Electric Power	$1,200/Day	400,000
Gross Revenue		$12,160,000

➢. *Assess potential availability and value of crop insurance to stabilize biomass Feedstocks supply and price.*

Farmers who placed acreage into the Conservation Reserve Program, in general, were marginal operators on marginal land. The CRP program provided a better cash flow that may have enabled the farmer to survive in an ownership status. Farmers retiring from active farming used the CRP to even out the retirement income. The third group of operators used CRP as an asset management tool, maximizing their total returns per owned acre, by placing marginal property in the program.

The University of Minnesota School of Agriculture studied the cost of bringing CRP land into row crop production. They concluded it would require approximately $75 per acre in capital outlays to return Minnesota clay soils to production. This may include equipment and land improvements, for example, tile and erosion control. Bankers and farmers in South Dakota conclude the use of disk-lead chisel plow followed by no-till planting, estimate conversion of CRP at $12 to $15 dollars per acre.[32] Lenders evaluating operating loans will look at the operator experience, land quality, crop and crop programs. Lenders cannot require crop insurance however, they encourage it use as a risk management tool. They also look at the use of insurance as an indication of the management expertise of the operator.[33]

Crop insurance in critical to the availability of operating loans for biomass production.. Given that a lack of insurance would restrict the number of acres available for contracted biomass production, the price required to bring acres into WSG production greatly increase. It is estimated that 35 to 50 thousand acres of CRP land, in the specified counties, would be required to serve the needs of the project. A ratio of WSG ending stocks to disappearance of 40% would be required to assure supply of biomass in a short crop year. This is 35 to 40 percent of the CRP acres in the project area.

The price of biomass per ton must be equal to or higher than cash rents. WSG is an attractive alternate to row crops at $29.00 to $42.00 per ton, fob field edge. This is dependent upon a yield of 2.5 tons per acre or greater for Western Switch Grass.

Table XI

Biomass Contract Supply Demand Table				
CROP YEAR	1	2	3	4
CONTRACTED	50,000.00	37,000.00	37,000.00	37,000.00
HARVESTED	47,000.00	34,780.00	34,780.00	34,780.00
% HARVESTED	94.00	94.00	94.00	94.00
YIELD	2.60	2.60	2.60	2.60
SUPPLY:				
BEGINNING	0.00	33,354.00	34,936.00	36,518.00
PRODUCTION	122,200.00	90,428.00	90,428.00	90,428.00
IMPORTS	0.00			
TOTAL	122,200.00	123,782.00	125,364.00	126,946.00
DISAPPEARANCE:				
ALCOHOL	88,846.00	88,846.00	88,846.00	88,846.00
SEED	0.00	0.00	0.00	0.00
FEED	0.00	0.00	0.00	0.00
EXPORT	0.00	0.00	0.00	0.00
TOTAL DISAPPEARANCE.	88,846.00	88,846.00	88,846.00	88,846.00

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Biomass Contract Supply Demand Table				
CROP YEAR	1	2	3	4
ENDING STOCKS				
TOTAL	33,354.00	34,936.00	36,518.00	38,100.00
GOVT. OWNED				
RESERVE				
FREE				
RATIO END STOCK/DISSAP	37.54	39.32	41.10	42.88

Conclusions

The evidence indicates ethanol produced from renewable sources is a practical component of reformulated motor fuel. The octane and oxygenate values have established a market value independent of price supporting subsidies. The market is growing. The projected demand for fuel ethanol in the year 2000 is 1.85 billion gallons and it could be as high as 2.28 billion gallons. This confirms that demand will be sufficient in the North Central Region to accommodate the 10 million gallons per year facility studied.

Western Switch Grass yields greater than 2.5 tons per acre provide values per acre equivalent to oilseed and row crops in the region selected for the study. Price of $29 to $42 per ton, FOB, field edge is practical for the farmer.

The price of fuel ethanol appears to be market driven, based upon inherent values rather than subsidy payments. The producer payments available in some states are essential to the survival of the small ethanol producer using corn as a feed stock.

The products produced by the proposed study project can be contracted for sale prior to the beginning of production. The quantities are small in comparison to the markets involved. Fuel ethanol as a blending component is distributed in a parallel system to motor fuels because of it polar properties. Ethanol as ETBE may move in the historic fuel distribution network.

The availability of crop insurance for WSG is essential for the farmer to obtain adequate operating capital from lenders. The use of insurance as a risk management tool is a major factor in bank financing of operating capital for many farmers. The price of WSG would be higher if insurance is unavailable at reasonable prices, i.e. $3 to $7 per acre.

The raw feed stock cost, availability of markets, and the technology, combine to provide a reasonable opportunity for a successful biomass to ethanol plant in the study area.

"There is one thing stronger than all the armies of the world, and that is an idea whose time has come."[34]

Last revision April 29, 1996

[1] 1992 by the Chemical Economics Handbook-SRI International.

[2] The Clean Fuels Report, Volume 5, No. 2 April 93.

[3] Bio-Energy International Ltd., Gainsville, Florida 1993.

[4] Code of Federal Regulations, Alcohol, Tobacco Products and Firearms, 27, Parts 1 to 199, April 1, 1987.

[5] Code of Federal Regulations, Alcohol, Tobacco Products and Firearms, 27, Parts 1 to 199, April 1, 1987.

[6] Code of Federal Regulations, Alcohol, Tobacco Products and Firearms, 27, Parts 1 to 199, April 1, 1987.

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Appendix B

Current Status of the Technology (Task 7)

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SCREENING STUDY FOR UTILIZING FEEDSTOCKS GROWN ON CRP LANDS IN A BIOMASS TO ETHANOL PRODUCTION FACILITY

Task 7 - Screening Study Report

Subcontract No. ACG-6-15019-01
Prime Contract DE-AC36-83CH10093

Prepared by
American Coalition for Ethanol
&
Lawrence Wu

for
United States Department of Energy's
National Renewable Energy Laboratory BioFuels Program

April 11, 1996

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

Occurrence: Task 7--Screening Study Report
Deliverable Title: Current Status of the Technology

Prepared by: Lawrence Wu, Bloomington, IL
Date of Preparation: 11 April 1996

Subcontractor: American Coalition for Ethanol, Sioux Falls, SD
Subcontract Number: ACG-6-15019-01 under Prime Contract DE-AC36-83CH10093
Subcontracting Agency: National Renewable Energy Laboratory, Golden, CO

Preface

In 1994, there were over 1.8 million acres of CRP lands in South Dakota. This represented approximately 5 percent of the total U.S. cropland enrolled in the CRP. Nearly 200,000 acres of CRP lands were concentrated in northeastern South Dakota in three counties-- Brown, Marshall and Day. Most of the acreage was planted in Brohm Grass and Western Switchgrass.

Technology under development at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), and at other institutions, is directed towards the economical production of fuel-grade ethanol from these grasses.

The objective of this paper is to provide an review of current biomass-to-ethanol, and where possible, switchgrass-to-ethanol, technologies. The author found topics relating to this study in the technical literature to be under rapid growth. (As an example, of over 50 references cited in this review, nearly half were more recent than 1994.)

These data will be used in the preparation of the current work, "Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility," but should also provide a useful reference for parties interested in the implementation of the business plans developed by this project.

(It should be noted that the author has taken some liberty in excising information from cited references. In a few cases, direct quotations were taken without being so noted. This was done for the sake of brevity and with the understanding of the intent of this paper. Finally, not all references cited in the bibliography have been referenced within the body of the paper. This was done to give the reader knowledge of related articles that were considered outside the scope of this paper.)

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INTRODUCTION

The amount of fuel-grade ethanol produced from renewable sources has grown from practically zero in the mid-1970s to well over one-billion gallons of production two decades later. The USDA projected for 1995/96 that 563 million bushels of corn would be used to produce ethanol (Industrial Uses of Agricultural Materials, 1995). Roughly two-thirds of U.S. ethanol capacity is from wet-milling and one-third from dry-milling. Using the average conversion rate for the two processes as 2.525 gallons per bushel (Shapouri, and others, 1995), it can be estimated that over 1.4 billion gallons of fuel-grade ethanol will be produced in 1995/96.

As production has increased, the net energy value (NEV) of corn-derived ethanol rose from a negative 120,000 British thermal units (Btu) per gallon in 1981 (Hohmann and Rendleman, 1993) to a positive 16,000 Btu/gallon in 1995 (Shapouri, and others, 1995). The NEV factors in the energy cost of fertilizers, processing, conversion, yields, and energy credits associated with coproducts.

While in the United States ethanol is principally produced from corn and other high-starch grains, it can be made from any cellulosic materials such as wood, grasses, and waste paper. The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, Colorado, and other institutions, are actively investigating the cellulosic biomass to ethanol.

Cellulosic biomass, such as grasses grown on CRP acreage, represent a potentially abundant and economical feedstock for ethanol production. Conversion of waste cellulosic materials and agricultural residues into ethanol could produce up to 3.8 quads (1 quad = 10^{15} Btu) of energy each year. It has been estimated that the U.S. production potential for cellulosic ethanol to be between 12.4 to 26.5 quads (Lynd, and others, 1991). By comparison, the estimated 1.4 billion gallons of fuel-grade ethanol produced in 1995/96 represents 0.11 quads of energy.

A generalized block diagram for a biomass-to-ethanol facility is depicted in Figure 1 (Putcshe, V., 1996).

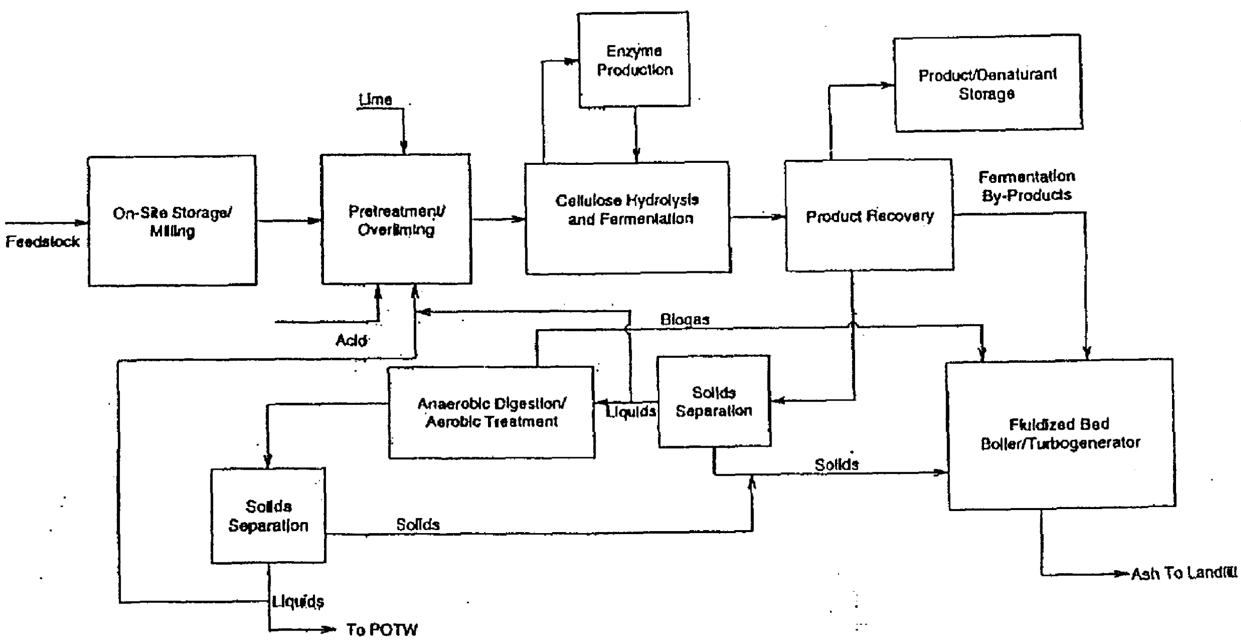

Figure 1. Biomass-to-ethanol block flow diagram.

Project Background

The CRP program, established in 1985, resulted in the enrollment of nearly 36 million acres of land prone to erosion and/or is highly environmentally sensitive. The first CRP contracts are due to expire in 1996. If the federal government is to continue the program a solution must involve keeping land out of production while reducing the existing CRP contract costs.

One possible option would allow farmers to harvest grasses from CRP acres and sell it to a biomass-to-ethanol facility. This would help keep farmers in the CRP and land out of tillage.

Project Objective

The objective of this study is to identify and evaluate a site in Brown, Marshall or Day counties, South Dakota which would have the greatest potential for the long-term of a financially viable biomass-to-ethanol production facility. The effort shall focus on ethanol marketing issues which would provide for long-term viability of the facility, feedstock and delivery systems, and preliminary engineering considerations for the facility.

If an acre of CRP land produces 2.5 tons of grass per year, it could produce the same ethanol yield as 100 bushels of corn from the same acre. Approximately 40,000 acres would be needed to produce enough feedstock for a 10 million gallon per year biomass-to-ethanol facility. In other terms, a biomass-to-ethanol facility processing 350 tons of grasses per day, yielding 100 gallons of ethanol per bone-dry ton (BDT) of grasses, in operation for 300 days would produce 10.5 million gallons of ethanol per year. At slightly lower yields, a facility processing 350 tons of grasses per day, yielding 80 gallons of ethanol per BDT of grasses, in operation for 330 days would produce 9.2 million gallons of ethanol per year (Wiselogel, 1996). This is the general scale of our projected biomass-to-ethanol facility.

Biomass-To-Ethanol Conversion

Biomass is composed of cellulose, hemicellulose, lignin and ash. Cellulose and hemicellulose are polymeric chains of six-carbon and five-carbon sugars. These components, when broken down to simple sugars, can be fermented to produce ethanol. Lignin can be combusted to produce process heat and steam or could be used to cogenerate electricity. A biomass-to-ethanol plant processing 350 tons of switchgrass (approximately six percent ash) per day would generate 21 tons of ash per day. A productive use for the ash will be desirable.

The differences from existing corn-derived ethanol production produce technical barriers to be overcome. A pretreatment of dilute acid is sufficient to break down hemicellulose into fermentable sugars. The conversion of cellulose to fermentable sugars is more difficult. The conversion (hydrolysis) of cellulose to sugars can be accomplished using dilute acids, concentrated acids or enzymes (cellulases).

Once hydrolyzed, another technical challenge lies with the effective fermentation of five-carbon sugars. Fermentation technology is being investigated using genetically-engineered organisms to convert five-carbon sugars and to improve the overall yield of ethanol from the available sugars.

Other issues germane to the probable successful operation of a biomass-to-ethanol plant (e.g., climate, switchgrass type, milling, storage, etc.) will also be discussed.

Hydrolysis

Hydrolysis converts cellulose and hemicellulose to fermentable sugars. This can be accomplished using acids or cellulase enzymes. According to Lynd, and others (1991), while enzymatic processes are at a much earlier state of development, in the absence of unforeseen breakthroughs in acid hydrolysis, research is likely to result in enzyme-hydrolysis technologies that are significantly cheaper than acid-based ones.

Dilute-Acid Hydrolysis

In 1986, Maloney, and others, numerically modeled the production of xylose by hardwood hemicellulose hydrolysis in co-current, counter-current, and percolation reactors using a combination of orthogonal collocation and finite difference methods. Their results are summarized in the Table 1 (Maloney, and others, 1986).

Table 1. Operating conditions and calculated reactor performance for minimum incremental cost.

Reactor Type	Co-current	Counter-current	Percolation
Entering Fluid Temp (°C)	242	160	160
Reactor Operating Temp (°C)	156	160	160
Acid Concentration, M	0.02	0.02	0.02
Wood Residence Time, min	58	65	---
Liquid Residence Time, min	62	70	85
Total Reaction Time, min	---	---	200
Reactor Xylose Yield, %	57	75	74
Hydrolysate Xylose Conc, %	4.8	6.4	4.4
Incremental Cost, $/gal ethanol	1.14	0.89	0.88

A year later, a two stage process was analyzed (Zerbe and Baker, 1987). They considered both the two-stage and percolation hydrolysis processes "reasonably" near commercialization. The advantages of the two-stage process included high concentration of product solutions and reduced capital requirements compared to percolation, but these advantages were offset to some extent by the higher yields of the percolation process.

It was shown that in a percolation reactor using hybrid poplar, step change of reaction temperature during processing improved sugar yield (Kim, and others, 1993). A two-stage, reverse-flow reactor with temperature change produced an additional five percent improvement in product yield over that of the best-case percolation reactor using temperature step change alone (Kim, and others, 1994).

Concentrated-Acid Hydrolysis

Moore-Bulls, and others (1989), reported conversion of cellulosic feedstocks to ethanol as 63 gallons/ton using dilute-acid hydrolysis versus 72 gallons/ton using concentrated-acid hydrolysis. Hardwoods and corn stover were used as feedstocks for the dilute- and concentrated-acid hydrolysis processes respectively. They obtained production costs of $1.69/gallon for concentrated hydrolysis and $1.81/gallon for dilute hydrolysis. It was concluded that costs could be reduced by recovering process acid, increasing fermentation efficiency, producing furfural as a byproduct, and integrating ethanol production with other industries.

Mellowes, and others (1992), reported using a two-stage sulfuric acid hydrolysis where a prehydrolysis step with dilute acid followed by hydrolysis in concentrated sulfuric acid produced sugar concentrations in the range of 3 to 4 percent. A hydrochloric acid process using a gas-phase hydrolysis followed by a liquid-phase, concentrated-acid hydrolysis yielded sugar concentrations of 7 to 9 percent.

Nguyen and Farina (1994), performed a series of corrosion tests to determine the performance and behavior of various construction materials in the presence of concentrated sulfuric acid at elevated temperatures. Test results showed that among the stainless steels tested, only Carpenter 20Mo-6 performed satisfactorily up to 70°C. Among nickel-based alloys, only Hastelloy B-2 had excellent corrosion resistance up to 100°C. Zirconium alloy Zr 702 provided excellent corrosion resistance to 100°C. Tantalum and KBI-40 provided excellent corrosion protection at all test temperatures.

Enzymatic Hydrolysis

Enzymes, which act as catalysts, operate slowly and are more expensive than acids. On-the-other-hand, sugar yields from enzymatic hydrolysis can approach 100 percent of the theoretical yield and advances in genetic engineering promise to lower the cost of enzymes (Hohmann and Rendleman, 1993).

Utilizing waste paper as a feedstock, enzymatic hydrolysis was performed by Sosulski and Swerhone (1993). They used Cellulase Tap Conc. (Amano International Enzyme Co., Japan) and Novozym-188 (Novo Nordisk Bioindustrials, Inc., Denmark) cellobiase added to 10% w/v suspensions of ground paper or pulp sludge to obtain constant enzyme concentrations of 8.7 filter paper units (FPU)/g cellulose and 2.5 cellobiase units (CBU)/1 FPU. Enzyme hydrolysis was conducted at 50°C with stirring at 100 rpm for 24 hours, followed by separation of hydrolysates from residues by filtration and resuspension of residues in buffer. A second portion of cellulase, 8.7 FPU/g cellulose, and suitable volumes of cellobiase were added. Hydrolysis of the residues was carried out for another 24 hours at 50°C.

Based on their preliminary laboratory experiments, it was reported that a high degree of hydrolysis of newsprint to glucose required low substrate concentrations, prolonged hydrolysis time and high enzyme loading. As enzymes had been reported to account for 60 percent of total process costs, they recommended their use should be minimized. Low concentrations of substrate would increase the capital cost of equipment and would yield low concentrations of sugars.

Cellulase use reductions are possible with the use of the ammonia fiber explosion (AFEX) process according to Dale, and others (1993). They reported on the effects of AFEX treatment of switchgrass (*Alamo cultivar*) and corn fiber on the rates and yields of sugar production at low enzyme levels (between 1 and 10 IU/gram dry substrate). Theoretical yields of total reducing sugars from both switchgrass and corn fiber (about 800 and 600 mg sugars/gram dry substrate, respectively) were reported after 24 hour hydrolysis at 5 IU/gram for switchgrass and 1 IU/gram for corn fiber.

Fermentation

Hemicellulose hydrolyzes easily into a variety of five-carbon sugars. Common strains of yeasts cannot ferment five-carbon sugars nor tolerate high concentrations of ethanol. This inability to convert a large portion of biomass into ethanol has led to advances in fermentation technology. Genetic engineering has allowed improvement to organisms enhancing their utility in converting five-carbon sugars, and in some cases six-carbon sugars and cellulose, into ethanol.

Zymomonas mobilis

Zymomonas mobilis has demonstrated ethanol yields of up to 97 percent of theoretical yield and ethanol concentrations of up to 12 percent w/v in glucose fermentation. In addition to the bacteriums high ethanol yield and tolerance, it shows high fermentation selectivity and specific productivity, the ability to ferment sugars at low pH, and considerable tolerance to the inhibitors found in lignocellulosic hydrolysates. Additionally, the distillers dried grain (DDG) from a *Zymomonas* fermentation is generally recognized as safe (GRAS) for use as an animal feed (Zhang, and others, 13 January 1995). With-respect-to biomass-to-ethanol conversions, the major drawback of *Zymomonas mobilis* is its inability to ferment xylose (a five-carbon sugar commonly found in hemicellulose).

Genetic engineering techniques inserted xylose metabolic pathways into a strain of *Zymomonas mobilis*. Zhang, and others (13 January 1995), reported after the introduction of four key genes, the new bacterium fermented a mixture of glucose and xylose at 95 percent of theoretical yield within 30 hours. Their continuing work seeks to optimize strain performance in commercial feedstocks.

A key element in the development of an advanced bioreactor system is the retention of high biocatalyst concentrations within the reaction environment that ensures intimate contact between substrate and biocatalyst. Webb, and others (1995), have modeled an immobilized biocatalyst that can be placed into a reaction environment that provides effective mass transport, such as a fluidized bed.

Bacillis stearothermophilus

It has been reported (Business Week, 23 May 1994) that a group at the Centre for Biotechnology at Imperial College, London have genetically engineered a strain of *Bacillis stearothermophilus* to produce ethanol from hemicellulose at 190°F. Agrol Ltd., of Hampshire, England has been formed to market the bacterium.

Escherichia coli

Quadrex Corporation developed a process to convert hemicellulose to ethanol using *Escherichia coli*. A joint venture between Quadrex and Bional Corporation was to build a 10 million gallon/year waste paper/pulp-to-ethanol plant in Moreau, New York (Business Week, 19 October 1992). According to information presented on the Internet (http://bankrupt.com/news.950206.html#QUADREX), on 6 February 1995, Quadrex announced the sale of its assets including its subsidiary, BioEnergy International L.C., in order to raise funds to meet creditor obligations.

Grasses

For elephantgrass and energycane grown in Florida, it has been reported that the highest annual yields were produced when stands were harvested one time at the end of the warm-growing season, compared to multiple cuttings. For the four bunchgrasses studied by Woodard and Prine (1993), annual dry matter yields ranged from 37 to 53 Mg ha^{-1}. In full season, for elephantgrass, 80 percent of the total plant dry biomass was in above-ground components while 20 percent was in rhizomes and roots.

Woodard, and others (1993), reported for the same aforementioned grasses that dry matter accumulation consistently showed a linear relationship with incoming total solar radiation. The higher dry matter yields from a single harvest was attributed to the ability of the bunchgrasses to maintain high levels of light interception and radiation-use efficiency over an extended period.

A study was performed on Alamo and "Cave-in-Rock" switchgrasses in Texas and Virginia. Biomass samples were analyzed for lignocellulose, crude protein, total ash, potassium, and calcium concentrations. Linear and nonlinear regressions were used to relate concentrations of constituents to cumulative degree days. The authors (Sanderson and Wolf, 1995) concluded that the close correlation between degree days and the composition of switchgrass could be used for predictive purposes. (See Appendix A for a complete copy of this paper.)

An investigation of switchgrass genotype and environmental interactions (G x E) was carried out with twenty elite switchgrass populations in Nebraska, Iowa and Indiana (Hopkins, and others, 1995). Plots were harvested at "heading," or the R_3 stage of maturity, when switchgrass produces large yields and would probably be best for biomass fuel feedstock. The switchgrass herbage was comprised of approximately 70 percent holocellulose.

Their populations differed significantly for holocellulose yield of regrowth. Their results indicated that when harvested at heading regrowth yields of some switchgrasses may be inadequate in some years to warrant harvesting. They state that switchgrass stands will normally remain in production for periods of 10 to more than 20 years. Failure to plant a high-yielding cultivar may cost a producer substantially during the life of the stand. At the same time, they state that production costs for different switchgrass populations are essentially the same. They conclude that the highest yielding populations adapted to the midwestern states for both forage and holocellulose yield are the cultivar Cave-in-Rock, its derived population, and some of the Nebraska populations.

Climate

The influence of degree days (Sanderson and Wolf, 1995) and should not be overlooked when evaluating the biomass yield potential of a given site. Similarly, precipitation is another key factor affecting yield. From data gathered over a 90-year period of the Park Grass Experiment in England (Silvertown, and others, 1994), rainfall in the growing period before the first hay cut (early-June to mid-July) increased the biomass and the proportion of grass in that cut on some of their plots not receiving nitrogen, but had less effect on biomass and favored other species on some of the nitrogen-fertilized plots. One conclusion they arrived at was that rainfall controls competitive interactions among the grasses, legumes, and other species within their test community, and the ratio of these components was affected by two mechanisms. (1) the preferential effect of rainfall on grass growth, and (2) the competitive suppression of legumes and other species when grass growth increases.

The objective of this study is to identify and evaluate a site in Brown, Marshall or Day counties, South Dakota which would have the greatest potential for the long-term of a financially viable biomass-to-ethanol production facility. Climate data, such as those available from the National Economic, Social, and Environmental Data Bank (16 August 1995), may provide critical siting considerations. Table 2 lists climate data for Aberdeen, South Dakota (Brown County) and Table 3 lists climate data for the Webster Water Department (Day County).

Table 2. 1990 Climate data for Aberdeen WSO AP, South Dakota.
Latitude: 4527N, Longitude: 09826W, Elevation: 1296.

Month	Temperature (°F)			Precipitation (inches)		
	Mean	Max	Min	Norm	Mean Days w/>0.01"	Mean Snow/Ice Days w/>1.0"
January	10.1	20.9	-0.6	0.37	6.4	2.4
February	16.7	26.9	6.5	0.47	5.9	2.1
March	29.8	39.8	19.8	1.34	7.1	2.1
April	45.2	57.3	33.0	1.95	8.2	0.9
May	57.1	69.7	44.5	2.41	9.4	0.1
June	66.6	78.8	54.3	3.15	10.3	0
July	72.8	85.9	59.6	2.75	8.4	0
August	70.6	84.4	56.8	2.13	8.1	0
September	59.6	72.9	46.1	1.86	6.3	0
October	47.3	60.4	34.2	1.12	5.0	0.3
November	30.3	40.5	19.9	0.59	5.6	1.6
December	15.3	25.4	5.3	0.41	6.1	1.9
Full Year	43.5	55.2	31.6	18.55	86.9	11.3

Table 3. 1990 Climate data for Webster Water Dept., South Dakota.
Latitude: 4520N, Longitude: 09732W, Elevation: 1850.

Month	Temperature (°F)			Precipitation (inches)		
	Mean	Max	Min	Norm	Mean Days w/>0.01"	Mean Snow/Ice Days w/>1.0"
January	10.1	20.5	-0.3	0.58	n/a	n/a
February	16.2	26.3	5.9	0.59	n/a	n/a
March	29.0	39.2	18.8	1.12	n/a	n/a
April	44.5	56.7	32.3	1.84	n/a	n/a
May	57.1	69.9	44.3	2.83	n/a	n/a
June	66.6	79.0	54.1	3.35	n/a	n/a
July	72.2	85.2	59.2	3.20	n/a	n/a
August	70.0	83.1	56.8	2.90	n/a	n/a
September	59.0	72.0	46.0	1.96	n/a	n/a
October	47.0	59.0	34.9	1.43	n/a	n/a
November	29.9	39.5	20.2	0.72	n/a	n/a
December	15.2	24.8	5.5	0.54	n/a	n/a
Full Year	43.1	54.6	31.5	21.06	n/a	n/a

n/a -- data missing.

Other Technical Issues

Feedstock

According to Wright (1995) the technological barriers to the sustainable commercial production switchgrass for energy are minimal but improvements to assure the availability of low-cost supplies are still needed. Demand for switchgrass seed for CRP plantings indicate that seed availability could be a problem during a period of rapid scale-up. Establishment of a new crop in a way that leads to optimal production in the first and second years requires attention for risk reduction. Also needed is development, testing and demonstration of optimal harvesting, and handling strategies for switchgrass crops that exceed the yields normally found with forage crops.

Milling

Before hydrolysis, biomass must be reduced in size to decrease heat- and mass-transfer limitations. In work performed by Schell and Harwood (1994), they determined the power requirements to reduce baled waste paper and switchgrass to particles approximately 3 centimeters long. The equipment used in their studies were a Saturn Model 62-40HT (149 kW, 200 hp) rotary shear shredder with 3.8 cm (1.5 inch) thick cutter blades and a Saturn Model 44-28HT (75 kW, 100) rotary shear shredder with 2.5 cm (1.0 inch) thick cutter blades. The units were manufactured by MAC Corporation, Grand Prairie, TX.

Their method was to feed the material by conveyor to the model 62-40HT shredder, then conveyed for a second pass through the model 44-28HT shredder. This material was collected in a hopper and fed for a third pass through the 44-28HT shredder. For the switchgrass, the first pass produced material 10 to 20 centimeters long. The second pass reduced the grass length to approximately 2.5 to 6 centimeters. No significant reduction is size was achieved on the third pass. The initial moisture content was 10 percent. The energy usage is summarized in Table 4.

Table 4. Energy usage for shredding switchgrass.

Switchgrass	Energy usage (kWh/Oven-dried ton)
First Pass	8.2
Second Pass	4.1
Third Pass	4.1

Storage

Work by Sanderson, and others (1995) investigated, (1) the loss of biomass during baling and transport of switchgrass, (2) the dry matter losses during storage of large round bales of switchgrass, and (3) determined the potential rainfall runoff from switchgrass bales to become a surface water pollutant.

Some of their results are presented in Tables 5 and 6. For eight bales, the average biomass loss during baling was 3.38 percent. Bale weight changes and biomass loss during handling and transport over 11 miles were only 0.4 percent of the bale weight.

Table 5. Biomass losses during 12 months of storage.

	Inside	Outside (sod)	Outside (gravel)
Initial bale weight (kg)	379	396	378
Final bale weight (kg)	385	375	363
Weight loss (kg)	0	21.8	14.6
Percent loss	0	5.5	3.9

Table 6. Concentration of water quality constituents in runoff water from three treatments (mg/L).
(Average of 12 samples collected between November 1993 and October 1994.)

Item	Sod Control	Plastic Control	Bales	Rainwater
Chemical Oxygen Demand	152	119	163	26
Total Solids	248	217	323	64
Fixed Solids	125	132	200	53
Volatile Solids	113	85	126	23
Total Dissolved Solids	179	171	213	59
Volatile Dissolved Solids	81	68	97	20
Fixed Dissolved Solids	91	102	107	57
NH_3 - N	2.68	2.02	3.31	0.40
Total Kjeldahl N	3.94	2.81	4.76	0.50

Burning

In a study of *Symphoricarpos occidentalis*, a common prairie shrub of the Northern Great Plains, Romo, and others (1993), observed its growth density increased two- to three-fold over preburn densities in the first two growing seasons following a burn.

Grassland communities dominated by *Festuca scabrella* or by *Stipa curtiseta* and *Agropyron dasystachyum* were experimentally burned (Redmann, and others, 1993). Peak green biomass was reached later in the season in burned plots relative to reference areas. Plant growth in the Spring of the second year after burning was more rapid in burned plots and peak biomass was reached earlier than in the reference plots. Autumn and Spring burning of *Festuca* grassland reduced peak green graminoid biomass production in the first and second years after burning. Autumnal burning had the most negative effect. Reductions in graminoid biomass after burning *Stipa-Agropyron* stands were smaller than in the *Festuca* community. Peak green biomass and total graminoid biomass in *Festuca* grassland recovered to the level of the reference plots two- to three-years after burning. Recovery was slower in the *Stipa-Agropyron* community.

Ash Composition

Biomass feedstocks of low inorganic composition (ash, K, Ca, Cl) are of more value in combustion systems. High alkali concentrations in the ash enhance the formation of fusible ash during combustion which could damage combustion equipment (Sanderson and Wolf, 1995).

NO_x

Measurements of NO_x emissions have been reported for biomass fueled plants in Sri Lanka (Tariq and Pruvis, 1995). The plants comprised air heaters and boilers ranging in size from 132 kW to 20 MW. Fuels included eucalyptus, rubber wood, fuelwood and processing residues such as rice husks and sugarcane bagasse. Moisture contents varied from 10 percent to over 50 percent and nitrogen contents from 0.08 percent to 0.4 percent. Average NO_x emissions were found to be 47g NO_2 GJ^{-1}. This compares favorably with data provided for natural gas emission limits in the United Kingdom in plants of 20 to 50 MW of 54g NO_2 GJ^{-1}.

Economics

According to an economic evaluation prepared by Reese, and others (1993), the U.S. agriculture sector can accommodate a large biomass industry of more than a billion tons of biomass crop per year. As shown in Table 7, their results estimated the diversion of cropland to accommodate biomass production. This diversion increased steadily in the high biomass yield scenario (HBY) scenario to about 10 million hectares and to roughly 18 million hectares in the low biomass yield scenario (LBY) scenario by the year 2030.

Table 7. Reductions of major cropland acreages resulting from biomass competition (million hectares).

	Corn	Wheat	Soybeans	Feed grains	Rice	Cotton	Total
Low biomass yield scenario (LBY)							
2010	0.84	0.53	0.69	0.19	0.02	0.06	2.33
2015	3.27	2.21	2.18	0.99	0.11	0.32	9.07
2020	6.47	4.63	4.54	2.07	0.21	0.64	18.56
2025	10.06	6.69	7.25	3.58	0.30	1.15	29.03
2030	15.00	10.27	11.59	5.64	0.40	1.84	44.75
High biomass yield scenario (HBY)							
2015	0.08	0.11	0.06	0.02	0.02	0.02	0.31
2020	2.70	1.76	1.85	0.65	0.12	0.20	7.28
2025	5.37	3.01	3.84	1.48	0.21	0.49	14.42
2030	8.99	5.46	7.15	2.61	0.31	0.86	25.39

Reese, and others (1993), state that the U.S. Department of Energy goal for a market price covering total costs of the average biomass crop producer as $37.48 per dry tonne. At that price, only their HBY becomes economic. None of the potential biomass crops in the LBY can earn a positive net return over variable cost investments at a market price of $37.48 per dry tonne.

Improvements in technology have significantly improved the economic reality of producing ethanol from biomass. As reported by Wyman (1994), the technological milestones can be summed up in Table 8.

Table 8. Relation of technology improvements to projected selling price of ethanol at the plant gate.

Year	Technology	$/liter	$/gallon
1980	SHF with QM9414 cellulase	0.95	3.60
1982	SHF with Rut C-30 cellulase	0.71	2.69
1985	SHF with Genencor 150L cellulase	0.59	2.24
1986	SHF to SSF	0.44	1.67
1989	Xylose conversion	0.34	1.29
1993	Improved integration	0.32	1.21

SHF: separate hydrolysis and fermentation, SSF: simultaneous saccharification and fermentation

A recent study suggests that an acre of switchgrass will produce 20.6 times the energy required to produce it if it is transported directly to an ethanol plant (Downing, and others, 1995). They state that while some research plots of switchgrass have yielded as high as 35 metric tons per hectare (MTH) 17 locations in the Midwest and Southeastern United States have averaged approximately 11 MTH. These yields are being produced without irrigation, without the annual cultivation and planting cycle of annual crops, and with nitrogen and phosphorous fertilizer requirements that are typically one-fourth to one-half those for corn production. They estimate that 11 to 22 MTH per year could be achieved with current switchgrass varieties and production techniques in better switchgrass growing regions.

Downing, and others (1995), continued on to report that recent investigations of switchgrass as an energy crop indicate that switchgrass added 8 MTH in below-ground root mass in just the top 75 centimeters of soil. The large standing pools of roots can equal or exceed annual above ground production and replace significant amounts of soil carbon.

Engineering

A number of papers contain information useful to the design of a biomass-to-ethanol production facility. Soslulski and Swerhone (1993) in their laboratory study on waste paper conversion discuss, (a) the affect of alkali and acid pretreatments, (b) surfactants, (c) single- versus two-stage hydrolysis, and (d) enzyme hydrolysis yields.

Lynd, and others (accepted for publication), relate, (1) cost summaries, (2) energy and utilities breakdown, (3) estimated process parameters, (4) ethanol cost and selling price summary, and (5) a sensitivity analysis for process improvements.

Ballerini, and others (1994), represented the only published paper identified containing a technical description of an operating biomass-to-ethanol facility. The plant converted poplar wood to ethanol and was located in Soustons, France. (See Appendix B for a complete copy of this paper.)

NREL Projects

A significant number of related projects are, at this writing, being conducted at the National Renewable Energy Laboratory (NREL), Golden, CO, or are under their sponsorship. A recent NREL publication (Biofuels: 1995 Project Summaries, 1996) provides current project summaries and their technical contacts. Selected project summaries have been included in Appendix C.

Opportunities for Improvement

Wyman (1994) discussed a number of areas where substantial opportunities exist to reduce the cost of producing ethanol from biomass. They include, (1) reduction of the milling power by 25 percent through optimized approaches to size reduction, (2) improving the yield of sugars from hemicellulose hydrolysis from about 80 percent to over 90 percent, (3) innovative pretreatment designs or alternative approaches to increase the digestibility of the cellulose, minimize the degradation of hemicellulosic sugars during pretreatment, and reduce energy requirements for pretreatment, (4) improve yields of ethanol from xylose from about 70 percent to over 90 percent through better fermentative organisms, (5) reduce conversion times from two days to only one day or less, (6) eliminate the requirement for inoculum preparation to seed hemicellulose conversion vessels, (7) use xylose converting organisms which can tolerate higher ethanol concentrations and can tolerate various byproducts created during pretreatment steps, (8) improve the pretreatment step to make cellulose more accessible to enzymes, as well as through the enzymatic hydrolysis step by increasing enzyme activity, (9) reduce the cost of cellulase by higher productivities and titers, (10) improve cellulase specific activity by reducing the amount of enzyme required to achieve a given sugar, (11) extending the lifetime of enzymes by cost-effective enzyme recovery, (12) cellulose conversion would benefit by insuring propagation of fermentative organisms in the ethanol production vessel, thereby eliminating the need for seed fermentation vessels for inoculum preparation, (13) improving the ethanol concentrations from the current levels of 4 to 5 percent to 8 to 12 percent, (14) reduce power requirements in areas such as air compressors, vessel mixing and size reduction, (15) integrate the entire ethanol process from front to back, and (16) continue to improve the feedstock production and collection activity. Feedstock costs under $2/million Btu could be achieved though enhanced biomass productivity.

Wyman (1994) concludes that process engineering studies have shown that a combination of improvements as he discussed could reduce the projected selling price of ethanol from the current level of $1.22 per gallon to about $0.67 per gallon. Such a price would be competitive with gasoline derived from oil at about $25 per barrel without tax incentives for the ethanol.

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Appendix A*

Switchgrass Biomass Composition during Morphological Development in Diverse Environments

Matt A. Sanderson and Dale D. Wolf

Published in Crop Science, 35: 1432-1438 (1995)

Appendix B*

Ethanol Production from Lignocellulosics:
Large Scale Experimentation and Economics

D. Ballerini, J.P. Desmarquest, J. Pourquie, F. Nativel, and M. Rebeller

Published in Bioresource Technology, vol. 50 (1994); pp. 17-23.

*Full-text report not included due to copyright restrictions

Appendix C

Selected Biomass-to-Ethanol Projects

Published in "Biofuels: 1995 Project Summaries"
National Renewable Energy Laboratory, Golden, CO
DOE/GO10096-198
DE95009283
January 1996

Alternate Pretreatment Study—Ammonia Recycled Percolation

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Auburn University
Auburn, AL 36849

Principal Investigator: Y.Y. Lee

Telephone: (334) 844-2019

Contract Numbers: XAW-3-11181-02; XAW-4-14170-01

Contract Period: 1/93–8/95

Contract Funding (Source):
FY 1993: $114,422 (DOE)
FY 1994: $168,334 (DOE)

Objective:

Identify and develop pretreatment approaches that can improve ethanol production process performance and cost over the NREL base-case dilute sulfuric acid pretreatment process.

Approach/Background:

Pretreating lignocellulosic biomass is a key step in a successful biomass-to-ethanol conversion process. Until 1992, resources were focused on a dilute sulfuric acid pretreatment process, which has become part of the NREL base-case ethanol process. The process has several areas for improvement. This subcontract is one of several established to conduct research and development on other promising pretreatment processes. Ammonia recycled percolation (ARP) pretreatment has not yet been reported in the literature.

Status/Accomplishments:

We studied the ARP pretreatment process and established near-optimum conditions for milled whole-tree hybrid poplar, switchgrass, and a corn stover/corn cobs mixture. Hybrid poplar delignified as much as 50%, the corn stover/corn cobs mixture 80%, and switchgrass 85%. Concomitantly, hemicellulose was removed by 50%–60% for all three feedstocks. Solids pretreated were highly digestible. The ARP process was readily adaptable to SSF for ethanol production. Toxicity tests of the pretreatment effluents, after removing ammonia and precipitating lignin, showed that as much as 60% strength of the effluents could be used without significant adverse fermentation effects. Material balance on ammonia showed that the ammonia consumption was 0.02g NH_3/g dry biomass. The process generated sulfur- and sodium-free lignin that could become a valuable by-product.

To increase the fractionation of xylan and lignin, a pretreatment scheme that uses autohydrolysis (hot-water treatment), dilute-acid percolation, or hydrogen peroxide treatment before the ARP, was explored. The additional pretreatment step before the ARP process showed enhanced hemicellulose removal and recovery, and increased the extent of delignification, which showed the possibility of fractionating biomass almost completely.

Major Project Reports: See bibliography.

Summary Date: September 1995

Kinetic and Modeling Investigation of Dilute-Acid Pretreatment

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Auburn University
Auburn, AL 36849

Principal Investigator: Y.Y. Lee

Telephone: (334) 844-2019

Contract Number: XAW-3-13441-01

Contract Period: 7/91–2/96

Contract Funding (Source):
FY 1992: $113,361 (DOE)
FY 1993: $109,646 (DOE)
FY 1994: $126,330 (DOE)
FY 1995: $103,820 (DOE)

Objective:

Understand the effects of operating variables on yields of xylose from hemicellulose in NREL's two-stage dilute sulfuric acid pretreatment process and provide analytical support to NREL in-house and subcontracted research staff to chemically analyze biomass samples.

Approach/Background:

When lignocellulosic biomass is pretreated, hemicellulosic sugars (primarily xylose) are released. We can determine the relationship between particle size, temperature, residence time, acid concentration, and xylose yield by conducting experimental and modeling studies. This study uses hybrid poplar, yellow poplar, switchgrass, and corn stover to establish kinetic models that predict yields of xylose through dilute sulfuric acid pretreatment. By incorporating the obtained kinetic models, process operating models that describe a two-stage, reverse-flow percolation process can be developed and simulated to give the optimum operating conditions. Up-flow percolation reactor configurations that account for intraparticle and interparticle mass and heat transfer phenomena, are being investigated.

Status/Accomplishments:

We developed kinetic models that describe the release of xylose and oligomeric xylose during dilute-acid pretreatment. These models, based on experimental data and theoretical kinetic analysis, demonstrate that the use of a two-stage pretreatment scheme allows for variable temperature profiles that greatly enhance the process performance. The models dealt with four percolation reactor configurations, and gave the best performing reactor configuration.

Work is ongoing to improve the process operating models by incorporating the generation of oligomeric xylose as an intermediate product, mass and heat diffusion factors, and nonideal flow characteristics to more accurately predict dilute-acid pretreatment process performance. As oligomeric xylose is received as an intermediate product, secondary hydrolysis of converting oligomer to its monomer by temperature holdup and enzyme were investigated, and the best conditions of the secondary hydrolysis determined.

The kinetic work on dilute-acid pretreatment and hydrolysis of yellow poplar that employ extremely dilute acid is ongoing.

Analytical service to NREL in-house and subcontracted research personnel was also provided. Liquid samples were analyzed for glucose, xylose, arabinose, galactose, mannose, acetic acid, furfural, hydroxylmethyl-furfural, and solubilized lignin. Solid samples were analyzed for glucan, xylan, arabinan, galactan, mannan, Klason lignin, acid-soluble lignin, and total ash. The enzymatic digestibilities of certain samples were determined.

Major Project Reports: See bibliography.

Summary Date: September 1995

Alternate Pretreatment Study—Dilute Acid and Organosolv

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Colorado State University
Fort Collins, CO 80523

Principal Investigators: H. Schroeder and J. Linden

Telephone: (970) 491-7768

Contract Numbers: XAW-3-11181-04;
XAW-4-14320-01

Contract Period: 1/93–12/95

Contract Funding (Source):
FY 1993: $ 99,830 (DOE)
FY 1994: $100,247 (DOE)

Objective:

Identify and develop pretreatment approaches that can improve ethanol production process performance and cost over the NREL base-case dilute sulfuric acid pretreatment process.

Approach/Background:

Pretreating lignocellulosic biomass is a key step in a successful biomass-to-ethanol conversion process. Until 1992, resources were focused on a dilute sulfuric acid pretreatment process, which has become part of the NREL base-case ethanol process. It is technically effective and economically promising, but has several areas for improvement, including reduced yields of furfural and hydroxyl-methyl furfural from, respectively, xylose, glucose, and reduced yields of other substances that may be toxic to cellulase enzymes and ethanol-fermenting yeasts; reduced levels of xylan remaining in pretreated solids; enhanced enzymatic digestibility of pretreated solids; and reduction or elimination of gypsum. This subcontract is one of several established to conduct research and development on other promising pretreatment processes. Phosphoric acid pretreatment and oxalic acid pretreatment with or without the presence of methanol were contracted to be studied.

Status/Accomplishments:

Pretreatment experiments of milled hybrid poplar, switchgrass, and corn stover/corn cobs mixture using dilute phosphoric acid and oxalic acid were conducted. Oxalic acid caused notable reactor corrosion and so was excluded from further study. Prehydrolyzates from organosolv runs using methanol showed high toxicity to yeast. Efforts are now directed toward dilute phosphoric acid and phosphoric acid-catalyzed organosolv pretreatments that use ethanol as the organic solvent.

Major Project Reports: See bibliography.

Summary Date: September 1995

Installation, Shakedown, and Operation of NREL Pretreatment Reactors

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80401-3393

Principal Investigator: M. Berggren

Telephone: (303) 279-4501

Contract Number: YAC-4-14107-01

Contract Period: 2/95–2/96

Contract Funding (Source):
FY 1995: $153,278 (DOE)

Objective:

Prepare standardized dilute-acid pretreated biomass solids and prehydrolyzates for NREL in-house research groups and subcontractors and conduct pretreatment research runs.

Approach/Background:

Several NREL research groups and subcontractors require pretreated biomass solids or liquors for research activities. Generating consistent pretreated solids and liquors for use is desirable. To ensure large quantities of consistent products are prepared, a 100-L ("paddle") and a 170-L ("Jaygo") reactor were designed and fabricated. These reactors, along with a laboratory-scale percolation reactor, are also used for pretreatment research. Hazen Research, Inc., was selected to operate these systems.

Status/Accomplishments:

The paddle and the percolation reactors have been installed and shaken down. Switchgrass, milled hybrid poplar, yellow poplar sawdust, mixed sawdust, and rice straw have been pretreated in the paddle reactor. Pretreatment products have been supplied to NREL and to subcontractors for evaluation. Preliminary pretreatment testing has begun using the percolation reactor. The Jaygo reactor is being shaken down and installed.

Major Project Reports: None.

Summary Date: September 1995

Optimization of Dilute-Acid Pretreatment of Selected Biomass Feedstocks

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Oregon State University
Corvallis, OR 97331-6602

Principal Investigators: M. Penner and A. Hashimoto

Telephone: (503) 737-6513

Contract Number: XR-2-11186-1

Contract Period: 10/92–1/96

Contract Funding (Source):
FY 1993: $120,081 (DOE)
FY 1994: $154,504 (DOE)

Objective:

Establish optimal dilute sulfuric acid pretreatment conditions for selected biomass feedstocks that will result in maximum yields of ethanol equivalents (ethanol equivalents being proportional to the sum of the fermentable sugars produced in the course of pretreatment and glucose produced through enzymatic saccharification of the pretreated solids).

Approach/Background:

Previous research has shown that removing hemicellulose by dilute sulfuric acid prehydrolysis of lignocellulosic biomass renders cellulose accessible to cellulase enzymes. The extent of prehydrolysis depends on temperature, time, and acid concentration, and the reaction can be modeled as two parallel pseudo first-order reactions through which xylose is produced and (partially) degraded to nonfermentable compounds. The enzymatic digestibility of the remaining cellulose is, for a number of hardwoods, agricultural residues, and herbaceous crops, directly related to the extent of hemicellulose removal from the pretreated material. Potential ethanol yield depends on both the yield of xylose from hemicellulose and the enzymatic digestibility of the cellulose. Thus, a high yield of xylose and a high cellulose enzymatic digestibility are essential for economic viability. Milled hybrid poplar, switchgrass, and a corn stover/corn cobs mixture were selected for this study.

Status/Accomplishments:

Pretreatment experimental runs that varied temperature (140°–180°C), acid concentration (0.6–1.2 wt %), and time (0.5–60 min) were conducted for milled hybrid poplar, switchgrass, and a corn stover/corn cobs mixture. A matrix of 50–60 data points was generated for each feedstock. Kinetic models were developed and apparent optimum conditions for maximum yields of xylose identified. Mass balances around the pretreatment operation were established. Pretreated solids produced under optimum conditions were tested in SSF studies for ethanol yields. The prehydrolyzates produced under optimum conditions are being tested for their fermentation toxicity.

Major Project Reports: See bibliography.

Summary Date: September 1995

Pretreatment of Lignocellulosic Materials by Pressure Cooking in Water

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Purdue University
West Lafayette, IN 47907

Principal Investigator: M.R. Ladisch

Telephone: (317) 494-7022

Contract Number: XAC-4-13511-01

Contract Period: 9/94–1/96

Contract Funding (Source):
FY 1994: $149,217 (DOE)

Objective:

Characterize and develop a pH-controlled hot-water pretreatment process.

Approach/Background:

Pretreating lignocellulosic biomass is a key step in a successful biomass-to-ethanol conversion process. Numerous pretreatment techniques, including physical, chemical, and biological means, have been studied, and many are effective. None, however, has been commercialized. Currently, a number of pretreatment approaches, all of which (except this project), involve the use of one or more chemicals as catalyst, are supported for investigation by DOE through NREL. This project represents a different approach, in that high-temperature water treatment is to be used. A small amount of a chemical (a base) will be applied, only enough to control the pretreatment environment to near neutral conditions (pH 5 to 7). Thus, the chemical added is not to catalyze pretreatment reactions. Waste newsprint and yellow poplar sawdust are contracted to be studied.

Status/Accomplishments:

After initially testing several reactor configurations, a Parr Instrument stirred pressure reactor was found to be suitable for the project and has been procured. A semiautomatic pH control system is being installed. Concomitantly, experimental runs of newsprint and sawdust are being conducted.

Major Project Reports: None.

Summary Date: September 1995

Alternate Pretreatment Study—Lime Pretreatment

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Texas A&M University
College Station, TX 77843-3124

Principal Investigator: M. Holtzapple

Telephone: (409) 845-9708

Contract Number: XAW-3-11181-03

Contract Period: 8/93–4/96

Contract Funding (Source):
FY 1993: $118,667 (DOE)
FY 1994: $ 99,902 (DOE)

Objective:

Identify and develop pretreatment approaches that could improve ethanol production performance over the observed NREL base-case dilute sulfuric acid pretreatment process.

Approach/Background:

Pretreating lignocellulosic biomass is a key step in a successful biomass-to-ethanol conversion process. Until 1993, resources were focused on a dilute sulfuric acid pretreatment process, which has become part of the NREL base-case ethanol process. Although technically effective and economically promising, this process has several areas for improvement, including reduced yields of furfural and hydroxylmethyl furfural from xylose and glucose, respectively, and reduced yields of other substances that may be toxic to cellulase enzymes and ethanol-fermenting yeasts; reduced levels of xylan remaining in pretreated solids; enhanced digestibility of pretreated solids; and reducing or eliminating gypsum. This subcontract is one of several established to conduct research and development on other promising pretreatment processes. Lime pretreatment of milled switchgrass, whole-tree hybrid poplar, and corn stover/corn cobs mixture was contracted to be studied.

Status/Accomplishments:

During the first year we studied lime pretreatment of switchgrass. We conducted experiments that varied residence time, temperature, lime loading, water loading, and biomass particle size to determine the optimum or near optimum pretreatment conditions. The project is now in its second year, and investigates lime pretreatment of milled hybrid poplar and corn stover/corn cobs mixture.

Major Project Reports: See bibliography.

Summary Date: September 1995

Identify Inhibitory Components in Dilute-Acid Pretreated Lignocellulosic Materials

Directing Organization:
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0323

Principal Investigator: R. Helm

Telephone: (703) 231-4088

Contract Number: XAC-5-13363-01

Contract Period: 11/94–10/96

Contract Funding (Source):
FY 1991: $180.000 (DOE)

Objective:

To conduct detailed compositional analyses of solid and hydrolyzate fractions of a selected dilute-acid pretreated biomass feedstock and identify the inhibitory compounds that adversely affect fermentation performance. This information will be used to develop strategies to alleviate inhibition of fermentation performance.

Approach/Background:

Relatively poor conversion of neutralized dilute-acid pretreated hardwood feedstocks is attributed to the presence of inhibitory compounds that deleteriously affect the microorganisms used to ferment biomass sugars to ethanol. Suspected inhibitors include compounds present in raw biomass and those formed or released during pretreatment. To develop an economical biomass-to-ethanol process, the composition of dilute-acid pretreated biomass feedstocks must be characterized, and inhibitory compounds, their inhibition mechanisms, and their probable fates in an integrated biomass-to-ethanol process identified.

Status/Accomplishments:

High-pressure liquid chromatography, gas chromatography, and gas chromatography/mass spectrometry are being used to identify and quantify suspected inhibitory compounds present in dilute-acid pretreated mixed hardwood sawdust solids and hydrolyzate liquor. The first year's work focused on analyzing the hydrolyzate liquor. In addition to acetic acid, hydroxyl-methyl-furfural, and furfural, suspected inhibitors include gallic acid, vanillin, protocatechuic acid, sinapic acid, coniferyl alcohol, and syringaldehyde. Hydrolyzate liquor fractions and individual putative inhibitory compounds are also being tested for toxicity to growth and xylose fermentation using NREL's recombinant *Zymomonas*. The near-term goal is to develop a list of putative inhibitory compounds ranked in order of their concentration in pretreatment liquor and their relative toxicity. Second-year efforts will focus on identifying additional inhibitory compounds and characterizing the toxicity of previously identified inhibitory components to growth and fermentation using *Saccharomyces cerevisiae*.

Major Project Reports: None.

Summary Date: September 1995

Alternate Pretreatment Study—Alkaline Peroxide Extrusion

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Xylan, Inc.
510 E. South Street
Mankato, KS 66956

Principal Investigator: G. Tyson

Telephone: (913) 378-3890

Contract Number: XAW-3-11181-05; HAW-4-14167-01

Contract Period: 1/93–6/95

Contract Funding (Source):
FY 1993: $98,673 (DOE)
FY 1994: $89,677 (DOE)

Objective:

Identify and develop pretreatment approaches that could improve ethanol production performance over the observed NREL base-case dilute sulfuric acid pretreatment process.

Approach/Background:

Pretreating lignocellulosic biomass is a key step in a successful biomass-to-ethanol conversion process. Until 1992, resources were focused on a dilute sulfuric acid pretreatment process, which has become part of the NREL base-case ethanol process. It is technically effective and economically promising, but has several areas for improvement, including reduced yields of furfural and hydroxyl-methyl furfural from, respectively, xylose and glucose, and reduced yields of other substances that may be toxic to cellulase enzymes and ethanol-fermenting yeasts; reduced levels of xylan remaining in pretreated solids: enhanced enzymatic digestibility of pretreated solids; and reduction or elimination of gypsum. This subcontract is one of several established to conduct research and development on other promising pretreatment processes. Alkaline peroxide extrusion pretreatment of whole-tree hybrid poplar chips, coarsely milled switchgrass, and a coarsely milled corn stover/corn cobs mixture were contracted to be investigated.

Status/Accomplishments:

Using the optimal pretreatment conditions known to the contractor, the alkaline peroxide extrusion pretreated hybrid poplar, upon simultaneous saccharification and fermentation produced an ethanol yield of 32% of theoretical conversion, based on cellulose available in the pretreated solids. With switchgrass and a corn stover/corn cobs mixture, the ethanol yields were, respectively, 33% and 48%.

Major Project Reports: See bibliography.

Summary Date: September 1995

Cofermentation Biocatalyst Development

Directing Organization:
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigators: S. Picataggio and M. Zhang

Telephone: (303) 384-6107

Contract Number: DE-AC02-83CH10093

Contract Period: 11/94–10/95

Contract Funding (Source):
FY 1995: $747,000 (DOE)

Objective:

Develop novel microorganisms that can rapidly and efficiently coferment the hexose and pentose sugars in lignocellulosic hydrolysates to ethanol.

Approach/Background:

Sensitivity analysis of the base case biomass-to-ethanol process indicates substantial savings in capital and operating costs associated with advanced process designs in which hexose and pentose sugars are simultaneously cofermented to ethanol. There are microorganisms that can efficiently ferment the glucose component in cellulose to ethanol; however, because there is no suitable biocatalyst, converting the pentose sugars such as xylose and arabinose in the hemicellulose fraction is more difficult.

Simultaneously cofermenting these sugars is further hindered by the repressive effect of the glucose liberated during enzymatic hydrolysis of cellulose. A comprehensive survey identified the bacteria *Zymomonas mobilis* and *Lactobacillus* as promising microorganisms for further development as cofermentation biocatalysts.

Status/Accomplishments:

A new strain of *Z. mobilis* has been metabolically engineered to simultaneously coferment the glucose and xylose—prominent in many lignocellulosic feedstocks—to ethanol. Engineered strains that demonstrate the best cofermentation performance in sawdust hydrolysate were identified for scaleup to the PDU. The substrate utilization range of this new biocatalyst has been further expanded for fermenting the arabinose commonly found in agricultural residues such as corn fiber and in herbaceous energy crops such as switchgrass. In a first step to develop a thermotolerant ethanologenic cofermentation biocatalyst, a strain of *Lactobacillus* with superior resistance to dilute-acid hydrolysates at elevated temperatures and the ability to ferment many other sugars commonly found in lignocellulosic feedstocks, including glucose, cellobiose, mannose, and arabinose, has been metabolically engineered to produce lactate from xylose at near-theoretical yield.

Major Project Reports: See bibliography.

Summary Date: September 1995

Cofermentation Process Development

Directing Organization:
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigators: S. Picataggio and J. McMillan

Telephone: (303) 384-6107

Contract Number: DE-AC02-83CH10093

Contract Period: 11/94–10/95

Contract Funding (Source):
FY 1995: $484,000 (DOE)

Objective:

Develop and evaluate advanced process designs based on the use of xylose-fermenting strains of *Zymomonas mobilis* to rapidly and efficiently coferment the glucose and xylose in lignocellulosic feedstocks to ethanol.

Approach/Background:

Sensitivity analysis of the base-case biomass-to-ethanol process indicates substantial savings in capital and operating costs associated with advanced process designs in which the hexose and pentose sugars in lignocellulosic feedstocks are simultaneously cofermented to ethanol. Several microorganisms can efficiently ferment the glucose component in cellulose to ethanol, but converting pentose sugars, such as xylose, in the hemicellulose fraction is more difficult. Recently, NREL scientists metabolically engineered a new strain of the bacterium *Z. mobilis* that can simultaneously coferment the glucose and xylose—prominent in many lignocellulosic feedstocks—to ethanol.

Status/Accomplishments:

Research is being conducted to develop advanced processes to coferment the predominant hexose and pentose sugars in lignocellulosic feedstocks to ethanol. Using metabolically engineered strains of *Z. mobilis* developed at NREL, cofermentation processes based on simultaneous saccharification and cofermentation (SSCF), separate hydrolysis and cofermentation (SHCF), and hybrid SSCF/SHCF configurations are being evaluated using statistically designed experiments and response surface analysis. Preliminary cofermentation processing conditions that maximize the ethanol yield and concentration from dilute-acid pretreated hardwood sawdust and minimize the fermentation time will be established for scaleup to the process development unit.

Major Project Reports: See bibliography.

Summary Date: September 1995

Demonstrate Direct Microbial Conversion (DMC) Process

Directing Organization:
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Thayer School of Engineering
Dartmouth College
Hanover, NH 03755-8000

Principal Investigator: L. Lynd

Telephone: (604) 646-2231

Contract Number: XAC-5-15162-01

Contract Period: 3/95–2/96

Contract Funding (Source):
FY 1995: $110,000 (DOE)

Objective:

Demonstrate an integrated direct microbial conversion (DMC) process on a relevant feedstock using a mixed culture of *Clostridium thermosaccharolyticum* and *Clostridium thermocellum*.

Approach/Background:

The DMC process is considered a promising advanced technology for biomass conversion because it consolidates all bioprocessing steps into a single unit operation, with significant savings in capital and operating costs; and it uses high temperatures, thus reducing cooling requirements, product recovery costs, and the risk of contamination. The DMC process utilizes a mixed culture of two thermophilic bacteria, *C. thermocellum* and *C. thermosaccharolyticum*, to convert cellulosic biomass to ethanol. The DMC process is not yet economically attractive, however, because these bacteria conduct mixed-acid fermentations and exhibit low ethanol selectivity. Also, biomass sugar conversion has yet to be demonstrated at practical substrate concentrations using cost-effective nutrients and actual pretreatment hydrolyzates.

Status/Accomplishments:

Research is being conducted to develop a process medium based on the use of commercial components (e.g., corn steep liquor, molasses, yeast extract) that supports xylose fermentation by *C. thermosaccharolyticum* at moderate to high xylose feed concentrations and demonstrates a reproducible continuous DMC process for wastepaper sludge supplemented with D-xylose using a mixed culture of *C. thermocellum* and *C. thermosaccharolyticum*. A steady-state continuous culture that completely utilizes a 50 g/L xylose feed has been reproducibly demonstrated with *C. thermosaccharolyticum*. Previous efforts to completely utilize 50 g/L xylose were unsuccessful, so this represents a significant achievement. Complete utilization of a 75 g/L xylose feed is now being pursued. Research on the second objective is being directed at developing a feed delivery system that will enable concentrated wastepaper feedstock slurry to be delivered to a continuous reactor.

Major Project Reports: See bibliography.

Summary Date: September 1995

Continuous Bioreactors for Conversion of Paper Sludge to Ethanol

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Thayer School of Engineering
Dartmouth College
8000 Cummings Hall
Hanover, NH 03755-8000

Principal Investigator: L. Lynd

Telephone: (604) 646-2231

Contract Number: to be determined

Contract Period: 11/95–10/96

Contract Funding (Source):
FY 1996: $100,000 (DOE)

Objective:

Evaluate the technical and economic feasibility of producing ethanol from paper sludge using a continuous simultaneous saccharification and fermentation process and on-site cellulase production.

Approach/Background:

Paper sludge, a waste material from the paper industry, is a particularly attractive ethanol feedstock because of negative feedstock cost, much-simplified technology compared to a grass-roots plant, and the availability of an extensive infrastructure that can provide utilities at incremental cost. Continuous bioreactors generally, and the recently patented continuous solids-retaining bioreactor in particular, may offer an effective response to the challenges associated with processing sludge into ethanol.

Continuous cellulase production will be investigated because it should result in higher productivity relative to batch or fed-batch operations.

Status/Accomplishments:

This project is expected to commence in November 1995.

Major Project Reports: None.

Summary Date: September 1995

Pentose Sugar Transport in *Zymomonas*

Directing Organization:
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Ohio State University
Columbus, OH 43210

Principal Investigator: T. Conway

Telephone: (614) 688-3518

Contract Number: XCF-5-14328-01

Contract Period: 1/95–1/97

Contract Funding (Source):
FY 1994: $125,000 (DOE)

Objective:

Evaluate the transport of pentose sugars in wild-type and xylose-fermenting strains of *Zymomonas mobilis*.

Approach/Background:

Sensitivity analysis of the base-case biomass-to-ethanol process indicates substantial savings in capital and operating cost associated with advanced process designs in which the hexose and pentose sugars in lignocellulosic feedstocks are simultaneously cofermented to ethanol. Recently, NREL scientists metabolically engineered a new strain of the bacterium *Z. mobilis* that can simultaneously coferment the glucose and xylose—prominent in many lignocellulosic feedstocks—to ethanol. Information on pentose sugar transport in this strain is essential to further develop superior biocatalysts and processes to simultaneously coferment these sugars to ethanol.

Status/Accomplishments:

Research is being conducted to determine the kinetics of xylose and arabinose transport in wild-type and metabolically engineered strains of *Z. mobilis* in the presence and absence of glucose, and to evaluate the substrate specificity of individual *Z. mobilis* transport systems. This research will identify the primary systems responsible for pentose sugar transport and determine the conditions under which these transporters are most active. Research may also suggest strategies by which pentose transport systems can be altered to maximize the rate of pentose transport. Research conducted during the first year will provide the foundation for attempts to improve the efficiency of pentose transport in recombinant *Z. mobilis*, which will be the focus of the second year of research.

Major Project Reports: None.

Summary Date: September 1995

Evaluate Inoculum Preparation Techniques for Cellulose Conversion to Ethanol

Directing Organization:
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Southern Research Institute
P.O. Box 55305
Birmingham, AL 35255-5305

Principal Investigator: D. Rivers

Telephone: (205) 581-2000

Contract Number: YAP-3-11206-01

Contract Period: 8/93–10/95

Contract Funding (Source):
FY 1991: $141,000 (DOE)

Objective:

Determine the conditions that maximize the rate and extent of yeast cell mass production during seed preparation and the ethanol production rate during simultaneous saccharification and fermentation (SSF), while minimizing seed fermentation energy needs and the lag phase in SSF.

Approach/Background:

Yeast seed cultivation techniques, including those used at industrial scales, will be identified and evaluated to determine their effect on SSF performance. The most promising techniques will be selected for further optimization. The effects of nutrient composition, aeration, and agitation during seed cultivation on SSF ethanol productivity will be quantified. Strategies will be developed to minimize seed cultivation requirements while maintaining optimal cell growth and product formation. Aerobic and anaerobic batch, fed-batch, and continuous seed fermentations will be considered.

Status/Accomplishments:

Parameters for yeast seed production and use in SSF were investigated using *Saccharomyces cerevisiae* D_5A. Results indicate that 1% (w/v) glucose is adequate to produce the quantity of yeast seed required for SSF, and that a 2.5% (v/v) seed inoculum is sufficient to produce the required quantity of yeast cells in an 8-hour residence time. However, using corn steep liquor (CSL) as the sole nutrient source for both seed production and SSF, 7-day SSF yields on either pure Avicel cellulose or pretreated poplar were less than 10% of theoretical. In contrast to the subcontractors findings, research conducted at NREL has shown CSL to be an adequate sole nutrient source for seed production and high-yield SSF.

Major Project Reports: None.

Summary Date: September 1995

Cofermentation Medium for *Zymomonas*

Directing Organization:
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
University of Toronto
Toronto, Ontario, Canada M5S 1A8

Principal Investigator: H. Lawford

Telephone: (416) 978-7096

Contract Number: AAP-4-11195-03 (Phase II)

Contract Period: 3/95–3/96

Contract Funding (Source):
FY 1994: $100,000 (DOE)

Objective:

Define process conditions that incorporate the use of commercial nutrient sources that maximize cell yield in seed preparation and ethanol yield and productivity in cofermentation of glucose and xylose by a xylose-fermenting strain of *Zymomonas mobilis*.

Approach/Background:

Sensitivity analysis of the base-case biomass-to-ethanol process indicates substantial savings in capital and operating cost associated with advanced process designs in which the hexose and pentose sugars in lignocellulosic feedstocks are simultaneously cofermented to ethanol. Recently, NREL scientists metabolically engineered a new strain of the bacterium *Z. mobilis* that can simultaneously coferment glucose and xylose—prominent in many lignocellulosic feedstocks—to ethanol. Information on the commercial nutrient sources and process conditions that maximize cell yield, ethanol yield, and productivity are essential to the development of a cost-effective cofermentation process.

Status/Accomplishments:

Research is being conducted to determine the nutrient requirements for growing and cofermenting glucose and xylose by a selected xylose-fermenting strain of *Z. mobilis*. Subsequent research will identify inexpensive commercial nutrient sources and process conditions that maximize cell yield in seed preparation and ethanol yield and productivity in a batch simultaneous saccharification and cofermentation (SSCF) process for converting the glucose and xylose present in pretreated hardwood sawdust.

Major Project Reports: None.

Summary Date: September 1995

Genetic Engineering of Xylose-Fermenting Yeasts

Directing Organization:
U.S. Department of Energy (DOE)
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
University of Wisconsin
Madison, WI 53706

Principal Investigator: T. Jeffries

Telephone: (608) 231-9453

Contract Number: XAU-4-11193-02

Contract Period: 11/93–11/95

Contract Funding (Source):
FY 1995: $95,000 (DOE)

Objective:

To develop an improved ethanologenic yeast that can efficiently ferment xylose when genetic engineering techniques are applied.

Approach/Background:

Efficiently converting the xylose in the hemicellulose fraction to ethanol remains one of the economic bottlenecks in the current conversion scheme. *Candida shehatae* and *Pichia stipitis* can ferment xylose, but at rates and yields less than required for commercial production. This work is directed toward increasing the ethanol yield and productivity of these yeasts by overexpressing and deleting selected genes, evaluating their xylose fermentation performance, and implementing strategies that maximize anaerobic fermentation yield.

Status/Accomplishments:

Using a genetic transformation system based on complementing a uracil-requiring mutant, the *P. stipitis* xylose reductase (XYL1) gene, the *Zymomonas mobilis* alcohol dehydrogenase (ADH2) gene, and the *Saccharomyces cerevisiae* pyruvate decarboxylase (PDC1) and alcohol dehydrogenase (ADH1) genes have been introduced into *P. stipitis*. *P. stipitis* strains that carry XYL1, PDC, or PDC and ADH genes demonstrated as much as a 22% increase in ethanol volumetric productivity and a 32% increase in ethanol yield compared to the control strain. Furthermore, genes have been successfully replaced in the *P. stipitis* genome for the first time. This advance establishes the techniques necessary for targeted inactivation of the PDH $E^1\alpha$ (pyruvate dehydrogenase $E^1\alpha$ subunit) and CYC1 (cytochrome c) genes that are believed to adversely affect the ethanol yield and anaerobic growth. Subsequent research will be directed toward simultaneously expressing and inactivating selected genes to improve ethanol productivity and maximize anaerobic fermentation yield.

Major Project Reports: See bibliography.

Summary Date: September 1995

Cellulase Development

Directing Organization:
U.S. Department of Energy (DOE)
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigator: S. Thomas

Telephone: (303) 384-6187

Contract Number: DE-AC04-83CH10093

Contract Period: 10/92–10/95

Contract Funding (Source):
FY 1993: $1,317,000 (DOE)
FY 1994: $1,555,000 (DOE)
FY 1995: $ 840,000 (DOE)

Objectives:

- Purify, characterize, and compare cellulases from a variety of organisms to determine which have the highest specific activity, the best match to anticipated process hydrolysis and fermentation conditions, and the ability to act synergistically to enhance the rate of cellulose hydrolysis
- Develop cost-effective, highly productive, industrially acceptable, genetically engineered organisms for the production of well balanced, multi-enzyme cellulase systems to efficiently and completely hydrolyze cellulose.

Approach/Background:

Identifying extremely active cellulase enzymes to depolymerize cellulose is an important first step in developing an economical enzyme production process. Cloning selected cellulase genes from microorganisms that produce high specific-activity cellulases at very high levels in appropriate hosts will permit production of the most effective cellulase systems. The ability to select and overproduce these cellulases will significantly lower the cost of producing cellulases, significantly increase the rate of lignocellulosic biomass hydrolysis, or both, thereby reducing the cost of producing ethanol.

Status/Accomplishments:

Purified enzymes supplied by subcontractors associated with this activity, and our own work, have permitted extensive comparative biochemical studies to be carried out, resulting in the ability to rationalize which genetic constructions should be built. Several endo- and exoglucanase, and β-glucosidase genes cloned at NREL and elsewhere function in heterologous host bacteria, such as *Escherichia coli*, *Streptomyces lividans*, and *Bacillus subtilis*. The gene for the highly active, thermotolerant *Acidothermus cellulolyticus* E1 endoglucanase has been completely sequenced, permitting the construction of several expression vectors for this endoglucanase in *E. coli*, *S. lividans*, and *Pichia pastoris*. The *P. pastoris* system can produce more than 1 gram of the E1 endoglucanase per liter of culture.

Major Project Reports: See bibliography.

Summary Date: September 1995

Fungal Cellulases

Directing Organization:
U.S. Department of Energy (DOE)
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigator: M. Himmel

Telephone: (303) 384-6299

Contract Number: DE-AC04-83CH10093

Contract Period: 11/94–10/95

Contract Funding (Source):
FY 1995: $210,000 (DOE)

Objectives:

- Assess the relative efficacy of commercially available cellulase preparations on programmatic feedstock materials, including pretreated hardwood sawdusts and agricultural residues
- Establish relationships with cellulase manufacturers and make them aware of the need for developing inexpensive and effective sources of cellulase for converting biomass to ethanol
- Furnish guidance to cellulase manufacturers willing to devote resources to developing effective and cost-efficient cellulase preparations customized for use in biomass conversion processes.

Approach/Background:

The technology for producing an effective and economical cellulase for use in first-generation biomass conversion technology will approximate that used by commercial enzyme manufacturers. The filamentous fungus, *Trichoderma reesei*, is the production organism for most cellulase manufacturers, although cellulases from other fungi are also available. The many cellulase preparations available commercially differ in terms of the organism, the fermentation conditions, and the downstream processing steps used to concentrate, stabilize, and package the preparation. Whether any of these variables significantly affect the quality of these preparations for use in biomass conversion processes is not known. However, the cellulose component of feedstock materials derived from different sources is not equally digestible after equivalent pretreatments.

Status/Accomplishments:

An apparatus has been designed and tested with cellulosic substrates that permits nearly complete saccharification while eliminating reaction products from the reactor to minimize the effects of product feedback inhibition, thus maximizing reaction kinetics. This apparatus has been used with various combinations of purified endo- and exoglucanases and shows clear differences in the relative performance of different enzyme cocktails.

High-level contacts have been made with each major cellulase manufacturer in North America. The need for large quantities of effective and inexpensive cellulase preparations in the near term has been made clear to each of them. We are continuing to develop these relationships.

Major Project Reports: None.

Summary Date: September 1995

Cellulase Structure

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Section of Biochemistry,
Molecular and Cell Biology
Cornell University
Ithaca, NY 14853

Principal Investigator: P.A. Karplus

Telephone: (607) 255-5701

Contract Number: XAH-5-15113-01

Contract Period: 3/95–3/96

Contract Funding (Source):
FY 1995: $ 75,000 (DOE)

Objective:

Crystallize a pure preparation of the *Acidothermus cellulolyticus* E1 endoglucanase catalytic domain and elucidate its three-dimensional structure at the highest possible resolution using x-ray crystallography techniques. Help NREL researchers plan approaches to genetically improve this endoglucanase.

Approach/Background:

Genetically improving an enzymatic activity can best be approached in a directed fashion if a reliable three-dimensional crystal structure is known for the target protein. X-ray crystallography provides the only known approach to the solution of this problem for a protein the size of the E1 catalytic domain.

Status/Accomplishments:

Crystals of the E1 catalytic domain have been produced and subjected to x-ray bombardment. The data collected have been refined into an excellent model for the 358 amino acid protein with a resolution of approximately 2.4 Å.

Major Project Reports: None.

Summary Date: September 1995

Cellulases from *Thermomonospora fusca*

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Section of Biochemistry,
Molecular and Cell Biology
Cornell University
Ithaca, NY 14853

Principal Investigator: D.B. Wilson

Telephone: (607) 255-5706

Contract Number: XAC-3-13260-01

Contract Period: 4/93–6/96

Contract Funding (Source):
FY 1991: $ 94,878 (DOE)
FY 1991: $124,852 (DOE)
FY 1994: $ 90,439 (DOE)

Objectives:

- Purify and characterize large quantities of active endo- and exoglucanases from the cellulolytic bacterium, *Thermomonospora fusca*
- Isolate and characterize cellulase genes from *T. fusca*
- Design and construct recombinant microbial overexpression systems for selected cellulases
- Genetically improve the biochemical characteristics of the E_2 endoglucanase via protein engineering.

Approach/Background:

T. fusca is a thermotolerant bacterium that produces endo-β-1,4-glucanases with very high specific activities. It is also one of the few known bacterial systems that expresses active, highly synergistic exo-β-1,4-glucanases. Proteins are purified by classical chromatography techniques from native and recombinant cultures of microorganisms.

Status/Accomplishments:

Milligram quantities of several endoglucanases and an exoglucanase have been purified from native and recombinant sources by standard chromatographic techniques. A 1.0-Å resolution x-ray crystal structure has been solved for the *T. fusca* E_2 endoglucanase. The x-ray model is being used to guide experiments designed to alter and improve the biochemical characteristics of the E_2 protein. Mutants in 15 residues have been constructed and are being characterized. *T. fusca* genes for six endo- and exocellulases have been cloned, sequenced, and expressed in *Streptomyces lividans*.

Major Project Reports: See bibliography.

Summary Date: September 1995

Cellulases from *Clostridium thermocellum*

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Department of Chemical Engineering
University of Rochester
Gavett Hall, Room 206
Rochester, NY 14627

Principal Investigator: J.H.D. Wu

Telephone: (716) 275-8499

Contract Number: XAC-3-13419-01

Contract Period: 8/93–12/95

Contract Funding (Source):
FY 1993: $106,080 (DOE)
FY 1994: $ 99,215 (DOE)

Objectives:

- Purify and characterize large quantities of active endo- and exoglucanases from the cellulolytic anaerobic bacterium, *Clostridium thermocellum*
- Isolate and characterize cellulase genes from *C. thermocellum*
- Develop genetically engineered expression systems for *C. thermocellum* cellulases.

Approach/Background:

C. thermocellum produces a cellulase system that consists of more than a dozen polypeptides, which function together as a tightly associated particulate system (cellulosome) at the bacterial cell surface. This strategy for cellulose degradation is common to many anaerobic cellulolytic organisms and provides an important alternative to the freely soluble cellulases being investigated by other subcontractors.

Status/Accomplishments:

A genomic library of *C. thermocellum* DNA has been constructed in *Escherichia coli*. Genes for the anchorage and scaffolding protein, CelL, and a key catalytic subunit, CelS, have been cloned and sequenced. Recombinant CelS has been characterized, and represents a novel class of exoglucanase. An important endoglucanase gene, *celD*, has been cloned and expressed in a recombinant system to purify large quantities of the CelD protein for biochemical characterization at NREL. An expression system has also been developed for the *celS* gene.

Major Project Reports: See bibliography.

Summary Date: September 1995

Cellulases from *Microbispora bispora*

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Department of Microbiology
Rutgers University
Lipman Hall, Room 333A
New Brunswick, NJ 08903

Principal Investigator: D. Eveleigh

Telephone: (908) 932-9829

Contract Number: XD-2-11201-01

Contract Period: 1/92–12/95

Contract Funding (Source):
FY 1991: $89,979 (DOE)
FY 1991: $62,880 (DOE)
FY 1994: $74,557 (DOE)

Objectives:

- Purify and characterize large quantities of active endo-β-1,4-glucanases, exo-β-1, 4-glucanases, and β-D-glucosidases from the cellulolytic, thermotolerant bacterium, *Microbispora bispora*
- Isolate and thoroughly characterize cellulase and β-glucosidase genes from *M. bispora*
- Design and construct recombinant expression systems for *M. bispora* cellulases and β-glucosidases.

Approach/Background:

M. bispora is a thermotolerant, composting bacterium that produces high specific-activity endo-β-1, 4-glucanases, and a cellobiase activity that is extremely resistant to product feedback inhibition by glucose. Proteins are purified by classical chromatography techniques from native and recombinant cultures of microorganisms.

Status/Accomplishments:

Milligram quantities of endoglucanase A have been purified from a recombinant source by standard chromatographic techniques and supplied to NREL for testing. The *M. bispora* genes for one endoglucanase and two β-glucosidases have been cloned and sequenced.

Major Project Reports: See bibliography.

Summary Date: September 1995

Cellulases from *Thermotoga neapolitana*

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Department of Microbiology
Rutgers University
Lipman Hall, Room 333A
New Brunswick, NJ 08903

Principal Investigator: D. Eveleigh

Telephone: (908) 932-9829

Contract Number: XC-2-11179-01

Contract Period: 08/92–12/95

Contract Funding (Source):
FY 1991: $30,000 (DOE)
FY 1991: $67,498 (DOE)
FY 1994: $76,315 (DOE)

Objectives:

- Purify and characterize large quantities of active endoglucanases and 1,4-β-D-glucosidases from the bacterium *Thermotoga neapolitana*
- Isolate and characterize endo-β-1,4-glucanase and β-D-glucosidase genes from *T. neapolitana*
- Design and build genetically engineered over-expression systems for *T. neapolitana* cellulase genes.

Approach/Background:

T. neapolitana is a hyperthermophilic eubacterium isolated from a deep-sea ocean vent that produces highly thermotolerant, very high specific-activity endo-β-1,4-glucanases. Proteins are purified by classical chromatography techniques.

Status/Accomplishments:

Milligram quantities of *T. neapolitana* endoglucanase B have been purified by standard chromatographic techniques and supplied to NREL for testing.

Major Project Reports: See bibliography.

Summary Date: September 1995

Compositional Analysis of Biomass Samples

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Hauser Chemical Research, Inc.
5555 Airport Boulevard
Boulder, CO 80301

Principal Investigator: D. Timmons

Telephone: (303) 443-4662

Contract Numbers: RAC-4-14108; RCF-4-14270

Contract Period: 3/94–4/96

Contract Funding (Source):
FY 1994: $228,880 (DOE)
FY 1995: $185,940 (DOE)

Objective:

Use an outside analytical testing laboratory to provide precise and accurate compositional analysis of routine lignocellulosic samples of interest to the ethanol project. This analytical information will supplement the more complex and nonroutine analyses conducted by the Chemical Analysis and Testing (CAT) Task. The data will be used by ethanol project research groups to meet specific technical objectives defined in the annual operating plan.

Approach/Background:

Routine feedstock, pretreated biomass, and the solid fraction of fermentation residues are to be analyzed for total solids, acid-insoluble and acid-soluble lignin, cellulose (as glucose), hemicellulosic sugars, starch, and ash. Pretreatment liquors and the liquid fraction of fermentation samples are to be analyzed for total and total dissolved solids, cellobiose, monomeric and total sugars, organic acids, glycerol, hydroxyl-methyl furfural, and furfural. During the course of these analyses, established CAT Task Laboratory Analytical Procedures and the QC protocols described in the ethanol project quality assurance program must be followed. The results of each group of analyses are reported to the CAT Task for evaluation and data reduction.

Status/Accomplishments:

Two hundred eleven samples were analyzed during the first year. Assay reproducibility and analysis turnaround time consistently met or exceeded expectations. The overall sample load for the second year is expected to be significantly higher, but improvements made to methods and reporting requirements have streamlined the process and reduced the overall analysis cost per sample.

Major Project Reports: See bibliography.

Summary Date: September 1995

Develop and Maintain Project QA/QC Program

Directing Organization:
U.S. Department of Energy (DOE)
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigator: C. Ehrman

Telephone: (303) 275-4444

Contract Number: DE-AC04-83CH10093

Contract Period: 10/93–10/95

Contract Funding (Source):
FY 1994: $170,000 (DOE)
FY 1995: $161,000 (DOE)

Objective:

Develop, implement, and monitor a project-wide QA/QC program that will result in the highest possible level of work quality, reproducibility, and utility.

Approach/Background:
The goal of a strong research program to produce high-quality data via well-designed experimental protocols and analytical measurements is usually reached when the experimental work is conducted within the confines of good QC practices. The ethanol project quality assurance program was developed and implemented with this goal in mind. The program is based on a detailed quality assurance plan (QAP) designed to be the foundation for the quality assurance program.

Status/Accomplishments:

A major step in developing the quality assurance program was designing and writing the QAP, which guides research and analytical activities by describing policies, goals, areas of responsibility, specific QC activities, standard analytical procedures, a system of quality experimental planning, and the means to document these activities. The concepts, protocols, and tools contained in the QAP are purposely flexible so they can be tailored to meet the needs of each experimental group.

A multistep implementation strategy for the quality assurance program was initiated to assimilate the plan into daily activities of the project, both in-house and subcontract. Established analytical procedures have been updated to include rigorous QC criteria, and, as new methods have been developed, they have undergone a stringent validation and documentation process. New conformance evaluation and method verification standards have been identified and validated as tools for assessing the quality of generated analytical results. Current efforts are being directed toward helping individual research groups with issues or problems they may have encountered when implementing their procedures.

Major Project Reports: See bibliography.

Summary Date: September 1995

Analyze Complex Samples and Develop Methods

Directing Organization:
U.S. Department of Energy (DOE)
1000 Independence Avenue, SW
Washington, DC 20585

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigator: C. Ehrman

Telephone: (303) 275-4444

Contract Number: DE-AC04-83CH10093

Contract Period: 10/92–10/95

Contract Funding (Source):
FY 1993: $300,000 (DOE)
FY 1994: $464,000 (DOE)
FY 1995: $502,000 (DOE)

Objective:

Analyze complex samples and develop and validate methods in response to new analytical needs to support ethanol project activities.

Approach/Background:

Ethanol project researchers require reliable analytical data to evaluate feedstocks, process intermediates, and end products from biomass conversion and assess the effectiveness of each stage of the process. By analyzing complex samples to develop standard analytical methods and produce precise and accurate data, we provide a certified analytical service to meet project research goals. High-quality analytical data are acquired via analytical measurements and protocols that meet the QC principles established in the quality assurance plan. Submitted samples are analyzed by a highly trained team that uses Laboratory Analytical Procedures (LAPs) and methods developed and validated specifically in response to a new analytical need. This information is used to meet the technical objectives of the research groups within the project.

Status/Accomplishments:

During FY 1994, we processed 134 chemical analysis work orders, which represented more than 1600 samples from project researchers, subcontractors, and CRADA partners. To date in FY 1995, more than 100 work orders and almost 1400 samples have been processed. The work requests involved a wide range of analyses that used LAPs and newly developed and validated methods. Because of stringent QA/QC criteria, the analytical results are considered to be of the highest quality.

Changing project needs and new problems often require that we develop innovative analytical approaches, procure new instruments (and concurrently develop instrumental procedures), and enhance procedures. Such efforts have enabled us to validate a series of new or enhanced methods for analyzing samples. We developed methods that use high-performance anion exchange chromatography with pulsed amperometric detection to analyze carbohydrates, sugar reversion products, and degradation products. An instrumental technique was developed to determine carbon, hydrogen, and nitrogen in biomass samples, which can be directly applied to the determination of the protein content of feedstock and process samples. An advanced method for analyzing ethanol in fermentation samples with complex matrices has been developed using a gas chromatograph equipped with a head-space analyzer. A laser diffraction instrumental technique was developed to determine the particle sizes of various biomass samples.

We have also tried to enhance the scope of standard methods and verify methods for use with new biomass samples. For any protocol that has potential for becoming a routine analytical test, the final step is to document the procedure in LAP format. Six new procedures and six enhanced or expanded procedures were validated, documented, and distributed as additions to the CAT Task LAP Manual. Five standardized analytical methods have been incorporated as standard test methods by the American Society for Testing and Materials.

Major Project Reports: See bibliography.

Summary Date: September 1995

Process Integration

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigators: C. Hatzis, F. Keller, and Q. Nguyen

Telephone: (303) 384-6215

Contract Number: DE-AC04-83CH10093

Contract Period: 3/94–9/95

Contract Funding (Source):
FY 1994: $ 440,000 (DOE)
FY 1995: $1,525,000 (DOE)

Objective:

Ensure a fully integrated process functions reliably and economically when operated on realistic lignocellulosic feedstocks. Based on laboratory results, this work introduces operational realities that a fully integrated commercial process will face.

Approach/Background:

Our three-pronged approach is based on the need to obtain the engineering data to design a commercial process and to transfer this information to industry.

1. Based on performance data from the research program and process engineering needs from in-house and CRADA projects, perform conceptual process design and economic analysis to define the most economic processing options for a commercial facility
2. Conduct experiments that use realistic feedstocks in a fully integrated, bench-scale process that mimics the physical and chemical interactions in a commercial process
3. Guide the design, operation, and optimization of a pilot plant (process development unit), which will demonstrate a chemically and mechanically integrated biomass conversion process and develop design data for the engineering demonstration unit.

Yellow poplar is the most abundant waste material from sawmill operation in the Ohio valley region, and the techniques developed with it can be readily transferred to other hardwood species and certain herbaceous materials; therefore, its sawdust was chosen as a standard feedstock for evaluation.

Status/Accomplishments:

In addition to bench-scale testing conducted under CRADAs,we worked on pretreatment and simultaneous saccharification and fermentation of yellow poplar sawdust.

Through a series of pretreatment, enzymatic hydrolysis, and fermentation experiments, standard methods were developed to store and handle feedstock and pretreated material to ensure comparison testing is done on the same basis. A quick method that uses epifluorescence was developed to monitor yeast cell viability. We are evaluating various techniques for detoxifying the inhibitors in wood prehydrolyzates.

Bench-scale fermentors, pretreatment equipment, and a batch prehydrolysis system were set up, and commissioning is under way. This system will improve the pretreatment capability and flexibility at bench scale.

A new and improved continuous stirred-tank bioreactor system was assembled. It can handle high solid loading, is sterilizable in place, and has on-line data acquisition and control. It will be integrated with the bench-scale pretreatment equipment and the Sunds hydrolyzer, and used for long-term continuous runs.

Major Project Reports: None.

Summary Date: September 1995

Process Development Unit (PDU)

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
John Brown Engineers and Constructors
300 South Riverside Plaza
Suite 1100
Chicago, IL 60606

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401-3393

Principal Investigators: B. Duff, Q. Nguyen, and G. Philippidis

Telephone: (303) 384-6862

Contract Number: YS-2-1161-1 and in-house

Contract Period: 3/94–9/95

Contract Funding (Source):
FY 1994: $ 586,000 (DOE)
FY 1995: $ 670,000 (DOE)

Objectives:

- Design, build, and operate a 1-ton-per-day biomass-to-ethanol facility that will be used to collect scaleup data to design a 40- to 100-ton-per-day biomass-to-ethanol engineering demonstration unit (EDU)
- Prepare the PDU for demonstration of the NREL Amoco CRADA process in the pilot plant.

Approach/Background:

NREL's integrated bench-scale research investigates chemical interactions among the biomass-to-ethanol process steps to determine overall process performance for small-scale equipment. However, this equipment is not large enough to accurately model a large commercial or near-commercial plant. This is especially true in technologies such as this one, in which solids are processed and recycling is necessary. The equipment size presents physical limitations on the range of operating conditions and physical pneumonia that can be investigated.

With the PDU, individual process steps and overall process configuration can be developed using equipment large enough to investigate a full range of realistic operating conditions and observe the various equipment-size dependent phenomena.

Because the eventual goal is commercialization, new ethanol production technology will be tested for NREL's industrial partners in the PDU.

Status/Accomplishments:

Phase II equipment was installed. Startup activities and initial experimental investigations are ongoing. Numerous modifications were made to improve operability, reliability, and capability. These include steam, air, process water, feedstock handling, pretreatment reactor, fermentor controls, and passivating stainless steel vessels to increase their corrosion resistance to the process fluid. Three experimental runs that incorporate pretreatment and SSF were successfully completed using hardwood and Amoco CRADA feedstock. The ethanol distillation was also tested successfully after an integrated run in early September 1995.

Phase III equipment is being designed and procured. The Phase III equipment will improve the operability and capability of the plant: aerobic capability for enzyme production, added cooling capacity, automated feed system for the pretreatment reactors, backup power system, fermentor exhaust condensers, chiller, larger cooling water system, clean in place system, and kill system for using recombinant organisms in the plant.

Major Project Reports: None.

Summary Date: September 1995

Feedstock Shredding, Storage, and Delivery in Support of the Process Development Unit (PDU) and Feedstock Knife Milling and Handling in Support of the Biofuels Program

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: J. Mielenz

Telephone: (303) 275-4489

Contractor:
Hauser Chemical Research, Inc.
5555 Airport Boulevard
Boulder, CO 80301

Principal Investigator: K. Ammon

Telephone: (303) 443-4662

Contract Number: TCF-4-14177-01

Contract Period: 9/94–3/96

Contract Funding (Source):
FY 1994: $131,815 (DOE)
FY 1995: $ 98,250 (DOE)

Objective:

To receive, store, and shred lignocellulosic feedstock and ship to NREL as required for PDU operation. The subcontractor will also knife mill lignocellulosic feedstock and ship to NREL as required for other programmatic activities.

Approach/Background:

When operating, the PDU converts 1 dry ton per day of feedstock to ethanol, but it does not have enough space and equipment to handle large quantities of feedstock. This subcontract provides the intermediate staging steps necessary to ensure continuous feedstock delivery to the PDU. The subcontractor receives and stores feedstock, then shreds it (if required) and delivers it to the PDU at the required rate.

Status/Accomplishments:

The subcontractor has procured a warehouse facility for receiving and storing feedstocks. The shredder and knife mill have been installed and are operated by the subcontractor's personnel.

Major Project Reports: None.

Summary Date: September 1995

Dilute Acid Pretreatment and Simultaneous Saccharification and Fermentation (SSF) of Hybrid Poplar and Switchgrass

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: A. Wiselogel

Telephone: (303) 275-4466

Contractor:
Environmental Research Center
Tennessee Valley Authority (TVA)
CEB 1C-M,
Muscle Shoals, AL 35660

Principal Investigator: M. Bulls

Telephone: (205) 386-3075

Contract Number: DAC-4-14212-01

Contract Period: 9/94–11/96

Contract Funding (Source):
FY 1994 $150,000 (DOE)
FY 1995 $102,000 (DOE)

Objective:

Determine the effects of genetic and environmental variability on pretreatment and simultaneous saccharification and fermentation (SSF) of hybrid poplar and switchgrass.

Approach/Background:

NREL is evaluating a range of herbaceous and woody plant materials to determine their potential as feedstock for ethanol conversion. There are several sections to this evaluation, including the effects of genetic and environmental variability on the ethanol conversion process; the effect of feedstock type on the ethanol conversion process; the pretreatability of feedstocks; and the fermentability of feedstocks after pretreatment.

Status/Accomplishments:

TVA has completed the evaluation criteria for approval necessary to start work on experimental samples. Currently, the first block of hybrid poplar samples are completing compositional, pretreatment, and SSF analysis.

Major Project Reports: See bibliography.

Summary Date: September 1995

Effects of Ambient Environment on the Storage of Switchgrass in Iowa for Biomass-to-Ethanol and Thermochemical Projects

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: A. Wiselogel

Telephone: (303) 275-4466

Contractor:
Iowa State University
Agronomy Department
Ames, IA 50011

Principal Investigator: I. Anderson

Telephone: (515) 294-9651

Contract Number: XAC-3-13277-03

Contract Period: 6/93–12/93

Contract Funding (Source):
FY 1993: $49,449 (DOE)

Objective:

Determine the impacts of proposed storage methods on switchgrass for biomass-to-ethanol and thermochemical fuels research.

Approach/Background:

This subcontract is the last phase of a three-phase study to determine storage and handling impacts on feedstock quality. The first phase used several harvesting methods, the second focused on sources of variation in feedstock quality, and this phase will provide climatic information and supplemental handling data.

Status/Accomplishments:

Switchgrass has been harvested. The storage phase of the research is in its fifth month, and switchgrass samples from the first quarter-year of storage have been sent to NREL for analysis. Weather and bale environmental data are being collected and analyzed.

Major Project Reports: See bibliography.

Summary Date: April 1994

Effects of Ambient Environment on the Storage of Switchgrass in Texas for Biomass-to-Ethanol and Thermochemical Projects

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: A. Wiselogel

Telephone: (303) 275-4466

Contractor:
Texas A&M University Research Foundation
Box 3578
College Station, TX 77843

Principal Investigator: M. Sanderson

Telephone: (817) 968-4144

Contract Number: XAC-3-13277-01

Contract Period: 6/93–5/95

Contract Funding (Source):
FY 1993: $67,809 (DOE)

Objectives:

- Determine the effects of storage on switchgrass composition
- Determine biomass loss caused by harvesting and baling
- Determine the amount and constituents of runoff water from bales
- Develop an energy balance
- Study the use of near infrared reflectance spectrophotometry (NIRS) as a rapid-analysis technique to measure feedstock quality.

Approach/Background:

This subcontract is the last phase of a three-phase study to determine the storage and handling effects on feedstock quality.

Status/Accomplishments:

The results of this work indicate that losses of biomass during baling are about 1%–5%, depending on moisture; dry switchgrass has greater losses. There were no significant differences between outside storage treatments for the variables of weathered layer thickness and dry matter loss. Analysis of rain runoff from the bales indicated it does not differ from rain runoff obtained from pasture land. NIRS was used as a rapid analysis technique, and produced mixed results. The accuracy of NIR composition predictions may be increased by developing separate curves for hardwoods and grasses.

Major Project Reports: See bibliography.

Summary Date: September 1995

Effects of Ambient Environment on the Storage of Switchgrass in Kentucky for Biomass-to-Ethanol and Thermochemical Projects

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: A. Wiselogel

Telephone: (303) 275-4466

Contractor:
College of Agriculture
University of Kentucky
Lexington, KY 40546-0091

Principal Investigator: M. Collins

Telephone: (606) 257-7310

Contract Number: XAC-3-13277-02

Contract Period: 6/93–12/93

Contract Funding (Source):
FY 1993: $45,000 (DOE)

Objectives:

- Determine the impacts of proposed storage methods on switchgrass for biomass-to-ethanol and thermochemical fuels research
- Determine the impacts of plant structure on drying ratés.

Approach/Background:

This subcontract is the last phase of a three-phase study to determine the effects of storage and handling on feedstock quality. The first phase used several harvesting methods, the second focused on sources of variation in feedstock quality, and this phase will provide climatic information and supplemental handling data.

Status/Accomplishments:

Switchgrass was harvested and analysis of environmental and cultural impacts on drying rates is complete. The storage phase of the research is in its fifth month, and switchgrass samples from the first quarter-year of storage have been sent to NREL for analysis. Weather and bale environmental data are being collected and analyzed.

Major Project Reports: See bibliography.

Summary Date: April 1994

Effects of Ambient Environment on the Storage of Switchgrass in Virginia for Biomass-to-Ethanol and Thermochemical Projects

Directing Organization:
U.S. Department of Energy (DOE)
through the
National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard
Golden, CO 80401-3393

Project Manager: A. Wiselogel

Telephone: (303) 275-4466

Contractor:
Department of Agricultural Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0303

Principal Investigators: J. Cundiff and L. Marsh

Telephone: (703) 231-7603

Contract Number: XAC-3-13277-04

Contract Period: 6/93–3/95

Contract Funding (Source):
FY 1993: $34,289 (DOE)

Objectives:

- Determine the effects of storage on switchgrass composition
- Determine the effects of rain damage on feedstock quality
- Determine biomass loss caused by harvesting and baling.

Approach/Background:

This subcontract is the last phase of a three-phase study to determine storage and handling effects on feedstock quality. The first phase used several harvesting methods, the second focused on sources of variation in feedstock quality, and this phase will provide climatic information and supplemental handling data.

Status/Accomplishments:

The study was completed in March 1995, and pointed out how important equipment costs are to the production cost of biomass crops. By maximizing equipment use, cost can be reduced approximately 40%. Other experimental results provide information and data on how storage affects dry matter loss and switchgrass quality.

The amount of weathering that occurred in a bale was not affected by wrapping material (string or net), and had reached maximum depth within the first 4 months. However, string-wrapped bales lost significantly more dry matter. Bales made with more than 22% moisture or wrapped with string had significant changes in composition based on acid detergent fiber and nondetergent fiber.

Major Project Reports: See bibliography.

Summary Date: September 1995

Appendix C

Feedstock Production and Delivery System (Task 2)

Prepared by: Trevor Guthmiller, American Coalition for Ethanol

American Coalition for Ethanol - PO Box 85102 - Sioux Falls, SD 57104

SCREENING STUDY FOR UTILIZING FEEDSTOCKS GROWN ON CRP LANDS IN A BIOMASS TO ETHANOL PRODUCTION FACILITY

............Task 2 - Feedstock Production and Delivery System.............

Subcontract No. ACG-6-15019-01
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Prepared by
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for
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Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Facility

Occurrence #3: Task 2 – Feedstock Production and Delivery Systems

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Preface

In 1995 there were about 1.78 million acres of Conservation Reserve Program (CRP) lands in South Dakota and over 36 million CRP acres in the United States. The 1.78 million acres enrolled in South Dakota represented approximately 5 percent of the total U.S. cropland enrolled in the CRP program. Nearly 200,000 of those acres were concentrated in northeastern South Dakota in three counties – Brown, Marshall and Day.

Technology under development at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), and at other institutions, is directed towards the economical production of fuel-grade ethanol from the grasses, such as those commonly found on CRP acres.

The objective of this paper is to summarize and describe the available biomass feedstocks in the study area (Brown, Marshall and Day Counties) and to give an objective analysis of the price that a biomass-to-ethanol production facility would have to pay to ensure an adequate supply of biomass feedstock would be delivered to the processing plant.

(It should be noted that the author has taken some liberty in excising information from cited references. This was done for the sake of brevity and with the understanding of the intent of this paper.)

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1.0 CRP Biomass Shed: Description

1.1 Summary

A total of 190,635 acres are enrolled in the Conservation Reserve Program in Brown, Marshall and Day Counties in Northeastern South Dakota. That is out of a total of 1.78 million acres enrolled in the State of South Dakota in 1995.[1]

1.2 Background Information / Sources of Information

Information for this report was supplied by the South Dakota Agricultural Statistics Service, the South Dakota division of the Farm Service Agency and South Dakota State University Extension Service. Other information came from the 1992 Census of Agriculture as well as discussions with various local extension agents and farmers.

1.3 Assumptions

The following is a list of assumptions and considerations used in determining other factors in this report. The figures were arrived at with the help of extension service personnel with backgrounds in this area.

- Corn is approximately ½ grain and ½ stalk and leaves. Therefore if an acre of corn yields 100 bushels, at 56 lbs. per bushel, it would also yield 5,600 pounds of biomass or 2.8 tons of corn stover per acre. At a 50% recovery rate there would be approximately 2300 lbs. per acre (1.15 tons) available biomass. This report uses numbers associated with corn planted for grain. The 1990-1994 five year average for corn yield in the three county study area is 82.21 bushels per acre.

- Wheat is approximately 55% grain and 45% plant. Therefore if wheat yields 40 bushels per acre, at 60 lbs. per bushel, it would yield about 2,160 lbs. of biomass per acre. However, since only about ½ of that is recoverable, there would be about 1,080 lbs. per acre (.54 tons) available biomass. This report uses numbers associated with both spring and winter wheat. The 1990-1994 five year average for wheat yield in the three county study area is 33.31 bushels per acre.

- CRP lands, though untested for yield in the project study area, would most likely yield approximately 2.5 tons per acre of biomass with minimal management.

There have been no yield studies done on CRP acres in the study area. Based on discussion with extension personnel, as well as with individuals with agronomy backgrounds, and area landowners, it is believed that CRP acres in the study area could yield on average 2.5 tons per acre with minimal management, including the incorporation of fertilizer.

Currently, South Dakota State University has simulated CRP plots that they are using to compile data from relative to yields from CRP acres. One experiment includes separate fields of cool season grasses and warm season grasses and one with a mixture of cool and warm season grasses. The fields will have four nitrogen fertilizer rates and will be sampled from late June to late September in 1996 and 1997. Their second experiment, six plots in eastern South Dakota, will compare switchgrass, intermediate wheatgrass and canarygrass. Data collection will begin in late 1996 on those plots. For both experiments, yields will be determined and samples will be separated to determine botanical composition. Total herbage samples will be analyzed for quality traits and for analysis of feedstock conversion to ethanol.[2]

The results of these tests will provide a more accurate picture of the yield potential of CRP acres in South Dakota. Beyond the fact that switchgrass and other grasses commonly grown on CRP are untested in the study area, there has been some research done that pertains to yield in other parts of the country. A study done in North Dakota found that switchgrass yielded 9.2 metric tons per hectare, which roughly to translates 3.35 tons per acre.[3] A similar study in Pennsylvania found yields of 12.3 metric tons per hectare, or roughly 4.48 tons per acre.[4]

Fred Anklam, for his report as part of this project, reported that Oak Ridge National Laboratory has documented yields for switchgrass as high as 6.7 tons per in Nebraska field trials.[5] Kevin Kephart, an Assistant Professor of Plant Science, Forage Management and Physiology at South Dakota State University estimated realized harvest switchgrass yields of 2.75 to 3 tons per acre (unmanaged) in the study area. He also estimated realized harvest yields of 1.5 to 2 tons per acre (unmanaged) for cool season grasses that are planted on CRP acres in the study area.

Based on those results, as well as from discussions with agronomy experts in the State, I conservatively estimate that yields from CRP acres in the study area with minimal management would be 2.5 tons per acre, with the potential of at least 4 tons per acre.

1.4 CRP Acres Enrolled / Contract Descriptions

A vast number of acres are enrolled in the Conservation Reserve Program in Brown, Marshall and Day Counties in northeastern South Dakota. Table 1 outlines how many acres are in the program in each county in the study area along with the year they were enrolled.

Table 1 - Acres Enrolled in the CRP Program in the Study Area by Year[1]

County	Acres Enrolled in the CRP Program by Year						
	1986	1987	1988	1989	1990		
Brown	2,106	16,184	5,719	14,704	26,729		
Marshall	585	18,182	9,211	7,624	6,212		
Day	6,607	30,287	9,132	21,013	14,054		
Total	**9,298**	**64,653**	**24,062**	**43,341**	**46,995**		**Total Currently**
						Not	**Currently**
	1991	1992	1993	1996	**All Years**	Renewed	**Enrolled in CRP**
Brown	1,521	145	516	50	**67,674**	756	**66,918**
Marshall	78	975	370	171	**43,408**	1,620	**41,788**
Day	294	1,705	234	243	**83,569**	1,640	**81,929**
Total	**1,893**	**2,825**	**1,120**	**464**	**194,651**	4,016	**190,635**

The first sign-up period for the CRP program was March 3, 1986 to March 14, 1986 and was for program year 1986, meaning those acres would be taken out of production in the spring of 1986 through the fall of 1995, making those acres eligible to be put back into production in the spring of 1996. The government then offered one year extensions in 1995 at the same rate to those contract holders as the fate of the CRP program was then being decided by Congress.

A second sign-up period was held in May of 1986. Generally, sign-ups were low in 1986 as farmers were unfamiliar with the program. After a short time farmers generally became more aggressive about trying to get acres into the program. It is not accurate to say that all the acres signed up in 1988, for example, will be eligible to come out of the program in 1998 (actually October 1, 1997, based on the government's October 1 - September 30 fiscal year), since the government let farmers choose either the current program year or the following one during the sign-up period. This choice was allowed during the sign-ups held from 1986 through 1990. Generally sign-up periods were held in February and July during those years with the February sign-ups for the current fiscal year and the July sign-ups for the next fiscal year.

As an example, a farmer could have gone into the local Agricultural Stabilization and Conservation Service (ASCS) office (today part of the Farm Service Agency) on February 9, 1987 and signed a contract for the current year (fiscal year 1987) meaning he would enroll those acres that Spring, or he could have signed a contract for the next program year (fiscal year 1988) meaning the contract would have taken effect October 1, 1988, and he would have had to plant a cover crop either that fall if possible or in the spring of 1989.

Therefore, it is hard to look at Table 1 and determine exactly when those acres are eligible to come out of the program. Table 1 can be used as a general guideline, however. It does, however, fairly accurately show that many acres will be eligible to come out of the CRP program between now and the year 2000.

1.5 Findings

The United States Congress has just recently (March 1996) passed a Farm Bill that reauthorizes the Conservation Reserve Program (CRP) and allows the United States Department of Agriculture to enroll up to 36.4 million acres (the current amount enrolled) in the program. The President has signed the bill and though there are disagreements between the Congress and the Administration on various parts of the 1996 Farm Bill, the CRP program has strong support among members of both political parties, as well as by environmental and wildlife organizations. Farmers currently in the program can withdraw land if the acres are not classified as environmentally sensitive. Future sign-ups for the program will be targeted for the most environmentally sensitive and highly erodible land. The contracts for the majority of land enrolled in South Dakota are set to expire between 1997 and 2000.

In addition to the reauthorization of the CRP program, the new Farm Bill also gives the U.S. Secretary of Agriculture the authority to devise regulations regarding the use of forage from CRP lands as an energy crop. The forage on the CRP acres as they exist today would be immediately available for use, given such use was accepted by the government, which owns the contracts with the landowners. The grasses that were planted on CRP acres were not selected with a biomass industry in mind and have not been managed to any extent, so therefore the yields and processability may currently be low, however, they would provide an adequate feedstock as the producers and the processors become more sophisticated.

Usage of the forage from CRP lands is not new. CRP lands have been allowed by the government to be harvested and grazed for livestock raising purposes in the past in various areas to address livestock forage shortages.

2.0 The CRP Program: Today and Tomorrow

2.1 Summary

A total of 190,635 acres are enrolled in the Conservation Reserve Program in Brown, Marshall and Day Counties in Northeastern South Dakota, the study area for this project. In the United States approximately 36.4 million acres are enrolled. In South Dakota, there are about 1.78 million acres enrolled in the program. A variety of grasses have been planted on CRP acres in the study area, with the main concern being that they provide cover and prevent noxious weeds from taking hold. The CRP acres in the study area have been planted to three primary feedstocks[6]:

- intermediate wheatgrass / alfalfa
- smooth bromegrass / alfalfa
- switchgrass

2.2 Other Options for CRP Acres

With the current low world stocks of most major grain commodities, which has resulted in relatively high prices for these commodities, there will be the temptation to put many of the CRP acres back into grain production. Also, when farmers look to enroll acres back into the program they will most likely be asked to accept a lower contract price then they had previously received. Those two factors - high commodity prices and lower CRP contract amounts - may result in a decrease in enrolled acres as farmers put them back into tillage to produce corn, soybeans and wheat, etc. With the development of a biomass-to-ethanol industry in the area, many producers may be persuaded to keep unenrolled acres out of tillage and possibly contract them to produce biomass for a local biomass-to-ethanol facility.

Benefits to the farmer/landowner for such an arrangement would be twofold: they would be able to gain income from those acres with relatively low inputs, capital investment and maintenance; plus their contract to produce biomass would no doubt be shorter than the 10 years the CRP contracts have required, allowing them to more quickly react to changing market conditions. Analysis by the farmers/landowners will be made primarily on an economic basis.

2.3 The Future of the CRP Program

The 1996 Farm Bill, as passed by Congress and signed by the President, will allow farmers to reenroll land in the program for another 10 years, while allowing them to opt out after 5 years, should they so choose. The option to opt out after 5 years has been extended to current contract holders as well.

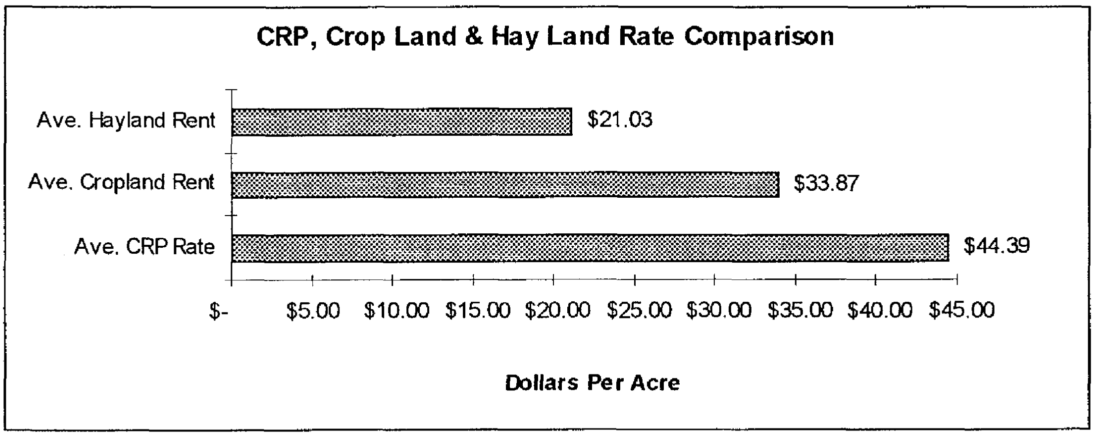
A limited amount of CRP acres (possibly a significant amount in South Dakota) that are not re-enrolled in the program upon their expiration and not put back into tillage may be left in grasses to be used for forage for livestock feed. A small amount may be utilized strictly for fee-hunting purposes. South Dakota has been cited as being one of four states where it is most likely that CRP acres will not be reemployed as crop acres at the conclusion of the program.[7]

With the inclusion of the CRP program in the new Farm Bill, the odds are very strong it will continue to be around for at least 7 years, the supposed length of this Farm Bill. After that, based on 10 year contracts, some form of CRP land will be around for at least 17 years, or until 2012. With the broad-based support the program has from environmental, agricultural and wildlife organizations, it is likely to be around in some form for quite some time.

One change that is likely to be seen, however, is that contract amounts will most likely be adjusted to reflect more accurate land values. This will be done by making CRP contract payments more closely align with local crop land cash rental rates.[8] Chart 1 shows that in the study area CRP contract rates average about $10 per acre higher than local cropland rental rates. Farm Service Agency personnel have indicated a desire to change that as they consider it an unnatural discrepancy. In fact, the bid caps for South Dakota acres have already been lowered. Additionally, many of the previously enrolled acres will no longer qualify for enrollment in the CRP program as the emphasis is shifted to the environmental impact and wildlife impact of the affected acres. The program has always had an environmental outlook, but the recent changes make the requirements even more stringent. Therefore, it is likely that we have seen the high point of the CRP program in South Dakota in terms of number of acres for at least the rest of this decade.

Chart 1 illustrates the differences between the average CRP contract rates and the average crop land and hay land rental rates in the study area (this is also addressed in more detail in Table 4 on page 14). The main thing the chart shows is that the current CRP rates are much higher than local crop and hay land rental rates. Since the CRP contract rates will be going down it will mean farmers will need to make a choice as to what to do with their land when their current CRP contracts expire.

Chart 1 - Average CRP, Crop Land, & Hay Land Rate Comparison[1,10,14]



The implications of these changes in the CRP program are important. It means that when the current contracts expire, contract holders in the study area may be allowed to re-enroll the land, however they also may be asked to accept a payment of about $10 less per acre than they had previously received. A good portion of them will most likely refuse, unless the land is so marginal that they have little chance of attaining the average cash rental revenue amount by any other means, such as renting the land out, or farming it themselves.

The bottom line is that because of the reauthorization of the Conservation Reserve Program by Congress, there will be a significant number of CRP acres for quite some time. However, because of the changes in the program, it is also likely that there will be a significant number of acres that will be brought back in agricultural production of some sort.

Given that the CRP program will be around for at least 17 years, with the new changes farmers/landowners will have more options for those acres:

1. re-enroll them in CRP and collect the prescribed payments from the government
2. keep them out of CRP and put them back into tillage to plant cash crops
3. keep them out of CRP and out of tillage to utilize the grasses for livestock forage
4. keep them out of CRP and harvest the grasses for energy production
5. re-enroll them in CRP and harvest and sell a portion of the grasses for energy production and collect lower payments from the government (if allowed by the government)
6. re-enroll them in CRP and harvest and sell a portion of the grasses for energy production while collecting the full contract amount from the government (if allowed by the government).

Farmers/landowners will most likely incorporate a combination of the above into their plans. It is conceivable to believe that landowners would be very open to looking for ways to keep land previously in the CRP program out of tillage and an option to harvest the biomass to use as an energy crop would be looked at favorably, given favorable payment rates.

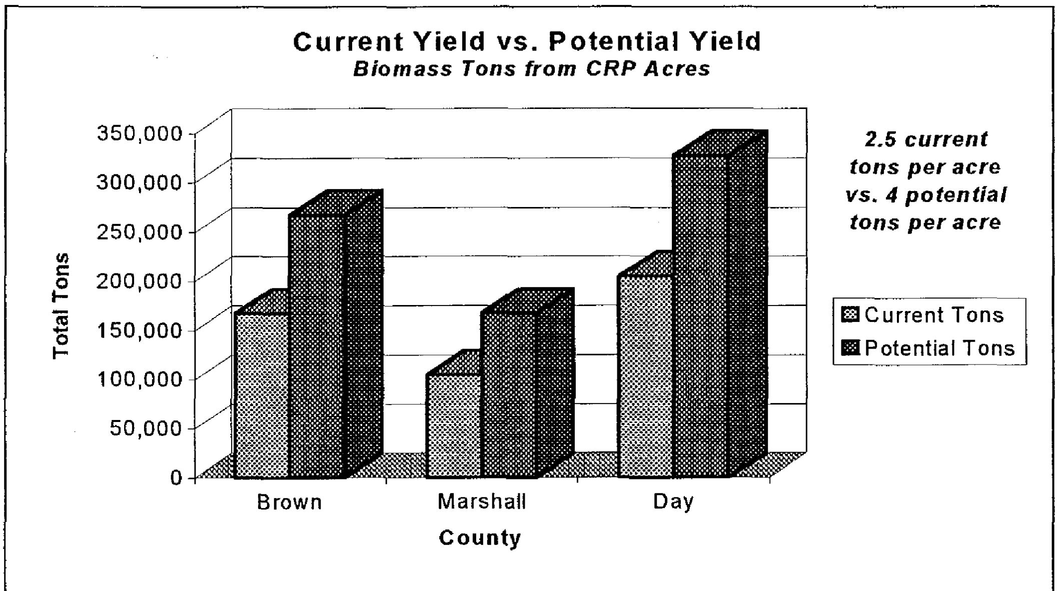
The last option is one that has been discussed among policy makers in Congress and one that would be extremely beneficial to a new biomass-to-ethanol facility as it would allow farmers to remain in the CRP program and then still allow them to sell the forage from those acres for a profit to a biomass-to-ethanol plant. Benefits to the biomass processing plant would be that the cost of the feedstock would be reduced because the government would be paying part of that cost.

3.0 Maximum Potential Supply from CRP Biomass Shed

3.1 Summary

Based on the 190,635 acres currently enrolled in the CRP program in the study area and an estimated average yield of 2.5 tons per acre, 476,588 tons of forage would be available for biomass-to-ethanol processing. By utilizing a higher proportion of warm season grasses, such as switchgrass, and applying simple management techniques, average yields could most likely be raised to at least 4 tons per acre, making the maximum potential supply from the CRP shed about 762,540 tons. Chart 2 illustrates the total current and potential yields of biomass from CRP acres in the study area based on the estimated current yield of 2.5 tons of biomass per acre and the estimated attainable yields of 4 tons of biomass per acre.

Chart 2 - Current Biomass Yields and Potential Yields



Politically and environmentally it would be unfeasible to utilize (harvest) all the CRP acres in a given area. Environmental and wildlife organizations support the CRP program because it provides important habitat for a variety of wildlife. The cutting and harvesting of all of those acres would mitigate those benefits, potentially costing the support for the program, and its government payments, by those wildlife organizations. However, given the option of seeing those acres put back into annual crop production or kept out of tillage and used to produce biomass for conversion to energy, the wildlife and environmental organizations would no doubt support the biomass option. A more feasible approach would be only to harvest ¼ to ½ the CRP acres in any given area in any given year. Given a large enough number of available acres and effective management this would provide the best solution for all interested parties, and should the CRP program be modified by the government to allow for harvesting for energy production a limit like this would most certainly be implemented.

Cutting only a percentage would still mean that the land would remain out of tillage, preserving environmental benefits as well as supporting acceptable habitat for wildlife. By effective management, such as fertilization, the effective number of acres used to produce the necessary amount of biomass feedstock could be lowered, further reducing any concerns of environmental and wildlife organizations.

The cutting of the feedstock would most likely be done in August and September. This would be after the nesting season of resident ducks, geese and pheasants, thereby ensuring support from the wildlife community. From a more practical standpoint, the August and September time frame is generally open for area farmers being it is after the wheat harvest ends and before the harvesting of corn and soybeans begins.

Yields would be dependent on the types of grasses planted as well as the management of the field. It has been proven that warm season grasses, such as switchgrass, will generally produce greater yields than cool season grasses, while having a fairly low nutrient requirement. The use of nitrogen to boost yields could further increase production.

Based on current estimates of using 350 tons of biomass per day for 330 days to produce ethanol in the study area, about 115,500 tons of biomass would be needed. At the current estimated yield of 2.5 tons per acre, only about 24% of the current CRP-based biomass 476,588 tons available in the study area (see Table 3 on page 13) would be needed. This would be a reasonable amount to begin with. Efficiencies would be expected to increase in future years as farmers became more knowledgeable of practices used to increase the yield of biomass crops.

4.0 Additional Biomass Sources

4.1 Summary

In addition to the grasses grown on CRP acres, there are a number of other potential sources for biomass feedstock that could be utilized in a biomass-to-ethanol facility in Northeastern South Dakota. Other potential sources include:

- corn stover
- prairie hay
- wheat straw

Besides an abundance of CRP acres in Northeastern South Dakota, there is an abundance of land used to provide hay. According to the 1992 Census of Agriculture, there are about 179,253 acres of hay land in Brown, Marshall and Day Counties, almost equal to the number of CRP acres. Those acres produced about 375,905 dry tons of hay in 1992, averaging 1.97 tons per acre.[9]

Corn stover would also be a potential feedstock source for a biomass-to-ethanol facility in the region. On average (1990-1994) there were 220,800 acres of corn planted in Brown, Marshall and Day Counties.[10]

In addition, there are on average (1990-1994) 444,120 acres planted to wheat in those counties, and the straw could be baled and utilized as a feedstock as well.[11] Table 2 outlines the number of acres that are available in the study area with the potential to produce a biomass feedstock. It is really quite substantial, amounting to over one million acres in a three county area.

It is not anticipated that other feedstocks such as corn stover or wheat straw would be used by the biomass to ethanol production facility, as their use would have an as yet undocumented affect on production time and ethanol yield. It is, however, important to note their abundance in the study area because of its potential to be used given the right circumstances.

Table 2 - Acres of CRP, Hay, Corn & Wheat in Study Area Counties[1,9,10,11]

County	Enrolled (1995)	Acres Harvested			Total
	CRP	Hay (1992)	Corn (1990-1994)	Wheat (1990-1994)	
Brown	66,918	92,387	134,060	239,800	533,165
Marshall	41,788	44,153	53,820	85,620	225,381
Day	81,929	42,713	32,920	118,700	276,262
Total	**190,635**	**179,253**	**220,800**	**444,120**	**1,034,808**

Table 3 reflects the potential tons of biomass available in the study area that could conceivably be used in a biomass-to-ethanol production facility. The figures are based on the biomass yield assumptions in section 1.3 of this report and actual yield data for each county in the study area. This shows that there is a substantial biomass resource that is already present in the study area.

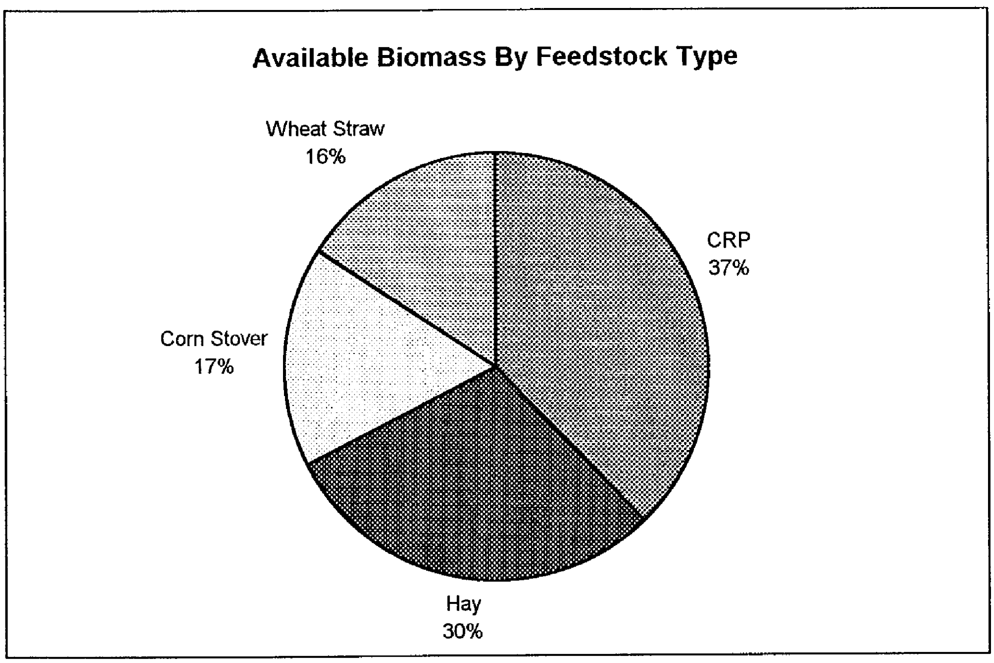
Table 3 - Tons of Biomass Available in Study Area Counties

County	Biomass Tons Potential				Total
	CRP	Hay (1992)	Corn (1990-1994)	Wheat (1990-1994)	
Brown	167,295	182,290	129,194	107,802	586,581
Marshall	104,470	87,070	51,928	40,340	283,808
Day	204,823	106,545	28,961	51,439	870,389
Total	**476,588**	**375,905**	**210,083**	**199,581**	**1,262,157**

There are no large municipalities in the study area, and hence the opportunity to use additional feedstocks such as waste paper or yard waste would not be present, since the volume would be negligible and there is currently no significant and separate collection process for those products. Based on the available tons of biomass from agricultural sources it would not seem any other sources would be necessary.

Chart 3 is based on the results of Table 3 and illustrates the various types of biomass feedstock, and the percentage of the overall biomass shed they represent, that are present in the study area.

Chart 3 - Available Biomass By Feedstock Type in the Study Area



The bottom line is that the available biomass resources in the study area would be more than sufficient to support a biomass-to-ethanol plant that would process 115,000 tons per year to start.

5.0 Feedstock Costs

5.1 Summary

To ensure adequate supply of feedstock, the price paid to the feedstock producers would have to be enough to encourage them to keep the land out of tillage (i.e. not planted to corn, wheat, sunflowers or some other cash crop) should it not be enrolled in the CRP program, and additionally, enough to make it worth their while to harvest, store and deliver it to the processing site. To ensure that this plant will be able to survive, it must be able to purchase an adequate amount of biomass feedstock even with no CRP program in effect, though it would be hoped that the CRP program could be modified to allow selective harvesting of biomass for energy production with no penalty to land owners.

Overall, the number of acres in the study area that could provide feedstock for a biomass to ethanol facility is more than sufficient to make operation of such a facility possible. As it stands, for the proposed facility, only about 24% of the acres currently in CRP would be needed to provide feedstock for the plant. Additionally, out of the entire biomass shed, CRP acres account for only 37% of the potential feedstock shed (see Chart 3 on page 13). Therefore, if the CRP program was suddenly dismantled by the government, and all of the CRP acres were put back into production, there would still be 63% of the biomass shed available. Plus, much of the CRP would most likely go into corn, wheat or hay production, which would increase the biomass shed for those crops, so any loss of the CRP biomass shed would be incremental, based on what it was converted to.

5.2 Delivered Feedstock Costs

Table 4 details the average CRP contract rates, cropland and hayland rental rates in the study area. As expected, the rates in the three counties in the study area are substantially similar to each other. This will allow us to use the averages for future references.

Table 4 - Average CRP Contract Rate, Cropland and Hayland Rental Rates in the Study Area[1,12,14]

County						
	Ave. CRP Rate		Ave. Cropland Rent (1995)		Ave. Hayland Rent (1995)	
Brown	$	44.26	$	35.70	$	19.50
Marshall	$	44.78	$	33.70	$	21.80
Day	$	44.13	$	32.20	$	21.80
Total	**$**	**44.39**	**$**	**33.87**	**$**	**21.03**

The best approach to guarantee a delivered feedstock would be to contract with landowners for the biomass from a certain number of acres. Enough acres would have to be contracted in order to guarantee an adequate supply of biomass. This would satisfy the wildlife organizations because then they would know up-front specifically how much land was going to be cut. Based on initial specifications for the proposed plant, 115,500 tons (350 tons per day for 330 days) would need to be delivered the first year. At estimated yields of 2.5 tons per acre, approximately 46,200 acres would need to be contracted out of the current 190,635 enrolled in the CRP program in the study area, or about 24%. It is not beyond reason to believe landowners would like to keep at least 24% of those acres out of tillage for various reasons, should they be able to derive some income from them. Should the required yield not be achieved, additional biomass such as hay and corn stover could be purchased on an as-needed basis.

During the first year of operation, it would be expected that about 52,000 acres would actually be contracted for, in order to ensure an adequate supply. This would still only amount to about 27% of area CRP acres. I would be estimate that about 93% of the contracted acres would be harvested, with 7% unable to be harvested due primarily to inevitable weather related obstacles. Degradation of the feedstock while being stored would have a negligible effect on the cost to the plant, since the farmer would be responsible for delivering the 2.5 tons per acre. For simplicity, we have accounted for its effects in the 7% unharvested figure.

Regarding degradation of the feedstock, a study in Texas in 1993 found a degradation rate for a bale of switchgrass to be 4.7% (average outside, experiment 3) over 12 months on 838 pound bales.[13] It has been documented in previous studies that degradation increases as the diameter of the bale decreases (since the degradation comes primarily on the outside few inches), therefore the larger the bale the less overall degradation. Bales used in the study area will primarily be at least 1,000 pounds. Also, since only a fraction will be unused the full 12 months, the degradation will be incremental, and therefore, will have less of an impact. Given this information, we can assume that degradation will have a small impact on the farmer and an even smaller impact on the biomass-to-ethanol processing facility which is purchasing delivered tons. Even given its estimated minimal impact, the degradation issue would still deserve to be addressed should opportunities arise.

At 2.5 tons per acre delivered, that means about 120,900 tons would be harvested of which 115,500 would be utilized the first year. This would leave ending stocks of 5,400 tons, or approximately enough feedstock for 15 operational days. A lower amount of carryover would be needed in future years as farmers became more secure with the facility and its operating future.

Table 5 outlines the average cost to the farmer to manage, harvest and transport the biomass feedstock to a biomass-to-ethanol processing facility. Naturally, the cost to farmers would vary substantially depending on the capital costs, management abilities and proximity to the processing plant.

Table 5 - Average Cost Per Acre to Fertilize, Harvest and Transport CRP Biomass[14]

Cost Per Acre	
Windrowing	$ 8.56
Baling	$ 7.64
Stack Moving	$ 6.71
Fertilizing	$ 13.95
Labor	$ 10.39
Interest on Capital	$ 2.84
Transportation	$ 1.20
($3.00 per 20 ton stack	
per mile, average 20 miles)	
Total	**$ 51.29**

The total cost in Table 5 closely corresponds with the total cost numbers in Tables IX and X of the Task 1 Market Assessment Report as compiled by Fred Anklam for this study ($51.29 vs. $48.45). The main difference was Anklam's inclusion of insurance costs, and omission of transportation costs. Anklam also included a charge of $7 per acre for planting, which we have omitted because we are assuming the land has already been planted and we will be utilizing primarily existing feedstocks (in addition, the planting expense would be a one-time expenses and Table 5 looks at the average annual cost per acre that a farmer would incur).

Anklam's analysis went on to conclude that at $42.00 per ton the farmer would have virtually the same revenue per acre growing and selling biomass as he would with corn, with much less input or capital costs and time invested. This analysis seems to correspond with figures published in 1989 by the Department of Agricultural Economics and Department of Agronomy at Perdue University in Indiana from work done by their Herbaceous Biomass Project. Their project found that a price of $39.60 per ton would allow a farmer to recoup the cost of production and a profit on switchgrass.[15] This was for their location in Indiana. For comparison purposes to our study area we have to realize that land values are undoubtedly higher in Dubois County in Illinois than in our study area and hence the cost per ton farmers in the study area would need to cover expenses and make a profit would likely be lower, making the projected cost per ton range developed in this section ($38.27 - $20.52) reasonable, given the accompanying circumstances.

The current average CRP contract rate in the study area is $44.39 per acre. The farmers are receiving this amount every year with essentially no input cost. If they were to apply fertilizer in the spring, make one cutting in the fall, bale and transport it they would have costs of approximately $51.29 per acre, as described in Table 5, making the minimum contract needed $95.68 ($44.39 + 51.29) per acre based on 2.5 tons per acre (or $38.27 per ton) to equal what they are currently earning from the government. This would most likely be the scenario for land that would be pulled out of the CRP program in order to be used to produce a biomass feedstock for energy production if the government would not allow its use in the program. Producers would be paid the $38.27 per ton for any additional biomass above the 2.5 tons per acre achieved, or conversely, docked a similar amount for production less than 2.5 tons per acre.

Should a producer not be in a government program it would be important to note that there would be no way to actually control how he allocated his acres. He may choose to not manage his acres to lower time and input costs while sacrificing yield and still deliver the contracted amount of tons by harvesting a greater number of acres. The target goal of 2.5 tons per acre would only be a guideline for establishing a realistic cost basis.

Should the government allow the producer to remain in the CRP program and harvest the forage to be used to produce energy, there would most certainly be a limit per field which he would be able to harvest. At most, he would likely be allowed to harvest half of any given CRP field.

It would be necessary that a good percentage of the contract be paid up-front, at least the first few years in order to account for the skepticism of the farmers and their reluctance to commit acres and expenses to an untried and untested venture. Local farmers can relate many stories of crops being planted (such as Jerusalem artichokes) with the promise of cash in the fall, only to realize there was no one there to purchase the crop as promised. After a few years of successful operation an up-front cash payment could probably be discounted or even discontinued, but funds should be budgeted for this up-front expense at least the first two years.

Groups like the American Coalition for Ethanol continue to believe that the government will allow some sort of use of the biomass grown on CRP lands to produce ethanol in the future. If that were to happen, it is most likely that the farmers in the area of a biomass to ethanol production facility would remain in the CRP program and qualify for some level of government support. It is even possible that farmers will be allowed to harvest and sell the forage from their CRP acres as an energy crop with no reduction in their CRP contract payments.

It should be noted Table 4 shows the average cropland rent in the study area is $33.87 per acre, or more than $10 per acre less than the average CRP contract. It is typical that the lands put into the CRP program were some of the more marginal acres, suggesting that the local market rental rate would be at $33.87 per acre or lower. Adding the $51.29 per acre expense of the harvesting and transporting of the biomass onto that figure and you have a contract rate of $85.16 per acre ($34.06 per ton). At that rate the economics become even more friendly. As of the writing of this report, grass hay was selling for between $14.00 and $17.00 per bale in Marshall County (800-1000 lb. Bale). Essentially this is confirmation that the area should easily support feedstock costs of $38.27 per ton or less, possibly substantially less.

In order to quantify the projected feedstock costs for the plant we have put together spreadsheets that outline how the cost of the feedstock affects the total feedstock expense the plant will have. To conservatively project the cost of the feedstock we have based our projected costs on the three costs in Table 4 (CRP contract rate, crop land rent and hay land rent), adding the expenses from Table 5 to those numbers to come up with the amounts that will likely be needed to contract for the biomass production from those acres. The high case scenario in Table 6.1 assumes a contract rate of $95.68 per acre (CRP contract rate plus fertilizing, harvesting and delivering costs). Table 6.2 assumes a contract rate of $85.16 the first year (crop land rent plus expenses) and Table 6.3 assumes a contract rate of $72.32 per acre the first year based on average hay land rent plus expenses for the study area. These per acre rates would be tied to 2.5 tons per acre for actual per ton costs of $38.27, $34.06 and $28.93 respectively (high, middle, low).

Table 6.1 - Cost of Delivered Biomass Feedstock: Years 1-5 (High Case)

Delivered Feedstock Costs: Years 1 - 5 (High Case)					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Acres Contracted	52,000	49,000	50,500	50,000	48,750
Rate / Acre (CRP + Exp.)	$ 95.68	$ 95.68	$ 99.50	$ 103.33	$ 110.97
Expected Yield	2.5	2.5	2.6	2.7	2.9
(tons per acre)					
Contract Rate Per Ton	$ 38.27	$ 38.27	$ 38.27	$ 38.27	$ 38.27
Total Acres Harvested (93%)	48,360	45,570	46,965	46,500	45,338
Total Tons Harvested	120,900	113,925	122,109	125,550	131,479
Contract Cost	$ 4,975,360.00	$ 4,688,320.00	$ 5,024,750.00	$ 5,166,500.00	$ 5,409,787.50
Cost Per Ton Delivered	$ 41.15	$ 41.15	$ 41.15	$ 41.15	$ 41.15
Dockage for Undelivered	$ 139,310.08	$ 131,272.96	$ 135,281.73	$ 133,946.30	$ 130,581.08
Total Feedstock Cost	**$ 4,836,049.92**	**$ 4,557,047.04**	**$ 4,889,468.27**	**$ 5,032,553.70**	**$ 5,279,206.42**
Operating Days	330	330	340	340	345
Tons Used Per Day	350	350	360	370	380
Total Tons Used	115,500	115,500	122,400	125,800	131,100
Ending Stocks (Tons)	5,400	3,825	3,534	3,284	3,663

Table 6.2 - Cost of Delivered Biomass Feedstock: Years 1-5 (Middle Case)

Delivered Feedstock Costs: Years 1 - 5 (Medium Case)					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Acres Contracted	52,000	49,000	50,500	50,000	48,750
Rate / Acre (Crop Rent + Exp.)	$ 85.16	$ 85.16	$ 88.56	$ 91.96	$ 98.77
Expected Yield	2.5	2.5	2.6	2.7	2.9
(tons per acre)					
Contract Rate Per Ton	$ 34.06	$ 34.06	$ 34.06	$ 34.06	$ 34.06
Total Acres Harvested (93%)	48,360	45,570	46,965	46,500	45,338
Total Tons Harvested	120,900	113,925	122,109	125,550	131,479
Contract Cost	$ 4,428,320.00	$ 4,172,840.00	$ 4,472,280.00	$ 4,598,000.00	$ 4,815,037.50
Cost Per Ton Delivered	$ 36.63	$ 36.63	$ 36.63	$ 36.62	$ 36.62
Dockage for Undelivered	$ 123,992.96	$ 116,839.52	$ 120,407.54	$ 119,207.41	$ 116,225.04
Total Feedstock Cost	**$ 4,304,327.04**	**$ 4,056,000.48**	**$ 4,351,872.46**	**$ 4,478,792.59**	**$ 4,698,812.46**
Operating Days	330	330	340	340	345
Tons Used Per Day	350	350	360	370	380
Total Tons Used	115,500	115,500	122,400	125,800	131,100
Ending Stocks (Tons)	5,400	3,825	3,534	3,284	3,663

Table 6.3 - Cost of Delivered Biomass Feedstock: Years 1-5 (Low Case)

Delivered Feedstock Costs: Years 1 - 5 (Low Case)					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Acres Contracted	52,000	49,000	50,500	50,000	48,750
Rate / Acre (Hay Rent + Exp.)	$ 72.32	$ 72.32	$ 75.23	$ 78.12	$ 83.90
Expected Yield	2.5	2.5	2.6	2.7	2.9
(tons per acre)					
Contract Rate Per Ton	$ 28.93	$ 28.93	$ 28.93	$ 28.93	$ 28.93
Total Acres Harvested (93%)	48,360	45,570	46,965	46,500	45,338
Total Tons Harvested	120,900	113,925	122,109	125,550	131,479
Contract Cost	$ 3,760,640.00	$ 3,543,680.00	$ 3,799,115.00	$ 3,906,000.00	$ 4,090,125.00
Cost Per Ton Delivered	$ 31.11	$ 31.11	$ 31.11	$ 31.11	$ 31.11
Dockage for Undelivered	$ 105,297.92	$ 99,223.04	$ 102,283.87	$ 101,266.67	$ 98,727.16
Total Feedstock Cost	**$ 3,655,342.08**	**$ 3,444,456.96**	**$ 3,696,831.13**	**$ 3,804,733.33**	**$ 3,991,397.84**
Operating Days	330	330	340	340	345
Tons Used Per Day	350	350	360	370	380
Total Tons Used	115,500	115,500	122,400	125,800	131,100
Ending Stocks (Tons)	5,400	3,825	3,534	3,284	3,663

I have estimated that the plant would increase utilization of feedstock by 13.51% by the end of year 5 due to increased operational days, as well a through greater efficiencies in processing speed (tons used per day). Such gains in processing efficiency are typical in new ethanol plants as the learning curve is overcome and typical start-up bugs are worked out. It is anticipated that similar gains in the efficiency of processing would be seen in a biomass to ethanol production facility. Since this is an untried venture, greater processing efficiency would result from inevitable gains in knowledge about the process. That knowledge would then translate to greater production efficiency. Production efficiency gains would most likely come from natural improvements in enzymes as well as familiarity with overall operating procedures by the processing plant personnel as well.

Even with that increase in use of feedstock from 115,500 tons per year to 131,100 tons per year we would still be most likely need to contract for 6.25% less acres in year 5 than year 1 due to expected increases in

yields attributable to increased management (fertilization, greater concentration of warm season grasses, etc.).
The feedstock cost tables illustrate the fact that there is just over a $1.18 million difference between the total annual feedstock costs in the high and low case scenarios. The prospective range of feedstock costs of $38.27 to $28.93 per ton developed in this report corresponds quite closely with the range of $42.00 to $29.00 that Anklam summarized would be practical for the farmer.[16] Even with adding a transportation allowance of $1.20 per acre to Anklam's estimate, bringing the range to $42.48 to $29.48, the numbers still correspond quite closely.

Optimally, the Government will hopefully allow farmers to harvest a percentage of their CRP acres to be used for energy production while not penalizing the landowner in the form of reduced CRP payments. Given this scenario, the cost of the feedstock would be reduced even further. The best case scenario would be that farmers in the CRP program would harvest, store and deliver the biomass feedstock for essentially their costs ($51.29) since their CRP payment would still be covering their taxes and other capital costs. This scenario would result in feedstock costs of about $20.52 per ton. This would reduce feedstock costs to the plant significantly from the other. Total feedstock cost in year 1 under this scenario would be $2,592,401 compared to $3,655,342 in the low case scenario. Table 6.4 analyzes the costs under the scenario where the government allows farmers to harvest CRP acres for energy production with no penalty.

Table 6.4 - Cost of Delivered Biomass Feedstock: Years 1-5 (Best Case / No Cut in CRP Payments)

Delivered Feedstock Costs: Years 1 - 5 (Best Case / No Cut in CRP Payments)					
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Acres Contracted	52,000	49,000	50,500	50,000	48,750
Rate / Acre (Hay Rent + Exp.)	$ 51.29	$ 51.29	$ 53.34	$ 55.40	$ 59.52
Expected Yield	2.5	2.5	2.6	2.7	2.9
(tons per acre)					
Contract Rate Per Ton	$ 20.52	$ 20.52	$ 20.52	$ 20.52	$ 20.52
Total Acres Harvested (93%)	48,360	45,570	46,965	46,500	45,338
Total Tons Harvested	120,900	113,925	122,109	125,550	131,479
Contract Cost	$ 2,667,080.00	$ 2,513,210.00	$ 2,693,670.00	$ 2,770,000.00	$ 2,901,600.00
Cost Per Ton Delivered	$ 22.06	$ 22.06	$ 22.06	$ 22.06	$ 22.07
Dockage for Undelivered	$ 74,678.24	$ 70,369.88	$ 72,521.88	$ 71,814.81	$ 70,038.62
Total Feedstock Cost	**$ 2,592,401.76**	**$ 2,442,840.12**	**$ 2,621,148.12**	**$ 2,698,185.19**	**$ 2,831,561.38**
Operating Days	330	330	340	340	345
Tons Used Per Day	350	350	360	370	380
Total Tons Used	115,500	115,500	122,400	125,800	131,100
Ending Stocks (Tons)	5,400	3,825	3,534	3,284	3,663

Table 6.4 reveals that under this scenario the total cost to the processing plant for feedstock would be about $2.59 million the first year. That is a major reduction from even the low cost case scenario developed in Table 6.3 which showed a first year feedstock cost of $3.66 million. However, given recent hay prices in the area it would not seem unreasonable.

6.0 Maintaining Biodiversity in the Feedstock

6.1 Summary

Biodiversity in any environment is important, as it is in the biomass shed in the study area for this project. Biodiversity is important in order to ensure a stable and long-term feedstock supply. Currently, there is biodiversity in the feedstock supply, as the grasses planted on CRP acres contain a mixture of switchgrass, smooth bromegrass, intermediate wheatgrass, canarygrass and alfalfa, etc.. Because the maximum amount of current CRP acres that would be needed to supply a proposed biomass-to-ethanol plant amount to only about 24% of the acres available, there is no great chance that the biodiversity of the CRP shed would be threatened. Even if 50% of the acres in the CRP shed were planted to switchgrass, there would still be over 230,000 acres of other grasses.

Biodiversity could be encouraged by working with the area farmers to ensure that no one feedstock grass type was predominant. This could be accomplished by working with the local county extension officials and agronomy organizations to make sure that a variety of seed stocks were available each year. Continued research and refinement of grasses optimized for yield and ethanol conversion would also result in changing grass types at a slow and manageable pace.

It could also be theorized that a mixture of cool and warm season grasses would be beneficial in order to provide stabilization of feedstock resources, since no one type of grass does well in all types of climatic conditions. This philosophy would help encourage biodiversity as well.

7.0 Farm Management's Impact on Yield, Soil Management and Harvesting

7.1 Summary

Farm management would no doubt have an impact on yield, soil management and harvesting. While, as noted, there have been no yield studies done on CRP acres in the study area, some conclusions can be drawn.

First off, on average, research by Oak Ridge National Laboratory and others has shown that perennial warm season grasses such as switchgrass would provide a substantially greater yield per acre than cool season grasses grown on the same acre. The seed stock and plant varieties that were chosen for most CRP acres in the study area were for the most part selected because of seed price, seed availability and ability of the cover crop to deter noxious weeds. Secondly, soil management would be more comprehensive, as it is under any management program. Thirdly, harvesting techniques would most likely be an extension of current hay harvesting techniques.

7.2 Farm Management Impact on Yield

By giving farmers a consideration of yield of the plant variety instead of the price of the seed, we would most likely see increased amounts of switchgrass planted. Until a market is developed for the feedstock from untilled acres, other factors such as seed price will continue to be considered the primary factors by farmers when making decisions about what to plant as a perennial cover crop on CRP acres.

Generally we can say quite confidently that management, even if minimal, will have an overall net positive impact on the yield attained.

7.3 Yield Impacts of Soil Management

By basing contracts on acres and yield, we would be encouraging farmers to manage their acres with the overall goal of producing the greatest potential amount of feedstock from those acres at the lowest possible cost. This is essentially their same approach to raising corn and wheat, etc. Based on their experience with raising corn and wheat, farmers would look to area agricultural chemical suppliers to do soil tests and analysis to determine if there were any relative soil nutrient deficiencies as well as to determine at what rate they could increase yields at a greater rate of return than the increased cost any additional ag chemicals. It is most likely that current CRP acres are nitrogen deficient, based on preliminary research done by South Dakota State University.[2] We would most likely see small amounts of nitrogen be applied to contracted acres in the spring in order to ensure a minimum of 2.5 tons per acre yield.

Since the soil needed to produce the feedstock for a biomass-to-ethanol plant would remain untilled, there would be very little other soil management, like is needed with most other crops. Switchgrass is known for its low nutrient requirements and its strong root system.

7.4 Management Impacts on Harvesting Techniques for Biomass

Harvesting techniques for harvesting biomass would for all intents and purposes be the same as used to harvest hay in the study area. Since the harvest would most likely be in the fall, the grass could be cut with a swather which would put it in a nice windrow (it could also be mowed). It would dry fairly easily and then would most likely be baled into large round bales weighing between 1000 and 1500 pounds each. The bales would then either be stacked in the field or loaded directly onto a hay hauler or a truck for transportation to the plant or an on-farm storage area.

Due to the large amount of biomass needed to operate the plant, storage will be an issue. A practical approach would be to have a substantial amount of the feedstock stored adjacent to the facility. The rest would be stored by the farmers either in the fields or in their hay yards. A good amount would likely be stacked at the end of their fields near the road, making the loading of the truck relatively easy. Like with many agricultural cooperatives, the contracts for the feedstock would include a provision regarding delivery. If practical, farmers could be required to deliver their feedstock at different times throughout the year. A relationship with a local trucking company would most likely be cultivated so that there would be one central transportation agency that would be responsible for the majority of the feedstock deliveries.

Assuming one bale equals ½ ton and one truckload will contain 22 bales (minimum), it will take about 32 truckloads per operating day to supply the needs of the plant (this is a conservative estimate since most trucks will carry about 25 bales). This would be a substantial amount of work for a trucking firm and one that would be appreciated by the owner/operators for its consistency, as well as by the drivers because the logistics would allow them to be home every evening. Working with one firm would be beneficial because it would take the biomass processing facility and the farmers out of the transportation business, while supplying a trucking firm with steady and consistent income.

Storing some of the feedstock on-site would be practical for many reasons, including reducing transportation inefficiencies as well as ensuring a back-up supply should transportation be disrupted. Since transportation may be disrupted during certain periods in the winter due to adverse weather, an on-site supply would be essential to keep the plant operating. Also, since favorable transportation rates could most likely be obtained in "off-peak" periods it may be economically feasible for the farmers to have it delivered when the trucks are not needed to haul the fall harvest for instance. This would require that a certain amount of storage space be available near the plant. Another approach that may be taken would be to do something similar to what sugarbeet producers do, and have centralized collection drop-off points at a few designated areas in the region.

If there were large collection points, either at the biomass-to-ethanol facility site or at drop-off points, it would allow for some simple management of the storage, such as storing the bales on thin beds of gravel and in stacks, which would reduce degradation.

8.0 Potential Environmental Benefits and Hazards of a Managed Biomass Shed

8.1 Summary

Any time a biomass shed is managed, you add environmental risks to the equation. Too much fertilizer could be applied, too much herbicide could be applied, tillage could result in erosion from wind and water, etc. However, the risks of managing the biomass shed contained on CRP acres seems minimal compared with the potential impact of putting those acres back into tillage.

There is no doubt that there are environmental benefits to keeping acreage out of tillage. Erosion and runoff are significant reduced, plus carbon is replenished in the soil. Tillage versus non-tillage is the comparison that needs to be looked at in this situation. By giving farmers a market for perennial grasses it will encourage them to keep environmentally sensitive lands out of tillage. The downside of managing those CRP acres for increased yield is minimal. Agricultural fertilizers and chemicals, such as nitrogen and various herbicides, will most likely be added to boost yields per acre and control weeds. Trying to reduce environmental impacts would be one of the goals of this effort. That is why it would be beneficial to contract with farmers based on acres. This would signal to them that it would be unnecessarily costly to fertilize or intensively manage non-contracted acres. Therefore, based on the presumptions of this study, only about 24% of the CRP acres in the study area would be "managed", limiting any potential negative impact of land management.

Another factor relevant to this report is that South Dakota farmers are among the most conservative in the use of fertilizer and chemicals. In 1994, out of four area states (SD, IA, MN and NE), South Dakota corn farmers applied nitrogen to the lowest percentage of acres (92%, 98%, 96% and 98% respectively). The average rate of application was also lower in South Dakota; 64 pounds per acre versus 80, 68, and 72 pounds per acre for Iowa, Minnesota and Nebraska farmers respectively. Herbicide numbers were similar, with South Dakota corn farmers applying herbicide to 93% of their acres versus 99% in Iowa, 98% in Minnesota and 97% in Nebraska.[17]

Spring wheat acres reveal a similar trend, though even more pronounced. South Dakota wheat farmers applied nitrogen to 79% of their acres, versus 91% for Minnesota wheat farmers and 91% for North Dakota wheat farmers. South Dakota wheat farmers applied herbicide to 83% of their acres while the numbers were 98% and 96% for Minnesota and North Dakota wheat farmers respectively.[18]

This trend would most likely be replicated in the approach of farmers in the study area to managing their biomass acres, whether in the CRP program or not. By setting the yield goals (through contract prices) at attainable levels (2.5 tons per acre in the first two years) we would not encourage over-management. By encouraging growth in the yield goals we would be allowing for expansion of the processing plant's usage while keeping the amount of overall acres needed essentially stable.

Impacts on wildlife and habitat would have to be considered as well. Jan Beyea with the National Audubon Society and Kathleen Keeler with the University of Nebraska published an important paper in 1991 that addressed the issue of managed biomass production for energy production from the naturalist's perspective.[19] The main environmental concerns they cited were as follows:

1. Pressure for competing uses of a finite amount of land. An increase in demand for biomass products would intensify pressure to convert uncultivated land, such as forest and rangeland to biomass farming
2. Exacerbation of global climate problems, should commercial biomass be grown on a nonsustainable basis or replace natural ecosystems with crops which store less carbon.

3. Pollution of the environment from waste products of the biomass industry.
4. Declines in wildlife if grazing lands, croplands and commercial forests are supplanted by expanded agriculture and silviculture for biomass production.
5. Destruction of what some look upon as "wastelands": wetlands, deserts, riparian areas, noncommercial forests. Currently, these lands are not used principally for economic purposes and, therefore, are the last vestiges of prime wildlife habitat outside of state and federally protected lands. If, in the future, they become economically viable for biomass production, the wild species they support will likely decline dramatically.
6. Spread of genetically engineered organisms to unintended locations, where they may become pests or destroy the integrity of parks, wildlife refuges and wilderness areas.

Most of their fears would not be applicable to any changes a biomass-to-ethanol plant would bring to any location in the study area for this project. Regarding their first concern, their fear is that if the United States decided to switch to an alcohol-based transportation system it would mean a huge increase in managed acres. That assumption is beyond the scope of this study and is also highly unlikely. Ethanol will most likely for many years to come only supplement petroleum used as a transportation fuel, not substitute for it. Regarding their second concern, the potential for biomass production in this area would encourage farmers to keep land out of tillage and to utilize plant species known for their ability to replenish carbon in the soil by taking it out of the atmosphere, thereby assisting addressing global climate problems. Also, since biomass production and harvesting takes less inputs (fuel, fertilizer, etc.) than traditional cash crop farming that these acres would be used for otherwise, there would be a net positive effect on the environment in that way as well.

Their third concern is applicable to any type of processing. Waste from a biomass-to-ethanol plant in the study area will be minimal. If the lignin produced in the biomass-to-ethanol process is burned on site there would be some ash to dispose of, but it would most likely contain only organic materials at non-toxic levels. This ash could be either land-filled or distributed out over local farm fields and utilized for its nutrient value. If the lignin were sold to an existing power plant it would be in the same situation. Either way, it would still have no net increase in waste disposal, as the power generated by the lignin would offset the coal that would be needed to be burned to supply the same amount of power and therefore reduce the ash from not burning the corresponding amount of coal. Since lignin is very low in sulfur there would seem to be a net benefit to the environment in that aspect as well.

Their fourth concern is dependent upon the perspective in which it is taken. As opposed to leaving land in the CRP program and not managing or harvesting it, there would be some natural decline in wildlife habitat and therefore most likely wildlife if the same land were managed and harvested. However, as has been mentioned, the real benefit to wildlife comes from keeping the land out of tillage, which a biomass-to-ethanol plant in the study area would encourage.

Their fifth concern would seem to deal with a situation that would arise, many years into the future, if ever. Essentially, as the feasibility of biomass-to-ethanol production improves, the industry is going to seek the most accessible, readily available and economic sources of feedstocks. Those lands listed in the fifth concern would be some of the last to become economically viable due mainly to the logistical and transportation costs of obtaining a biomass feedstock from them. Their sixth concern is not really applicable to this study, at least initially, since the main types of feedstocks identified are already being grown and are native to the area. Should some new plant species be developed that is not native to the area, then the introduction of that species would have to be closely watched and monitored, however, that does not seem realistic, since switchgrass, which is native to the study area, and the entire Northern Great Plains, is an acceptable feedstock for biomass-to-ethanol processing in the study area.

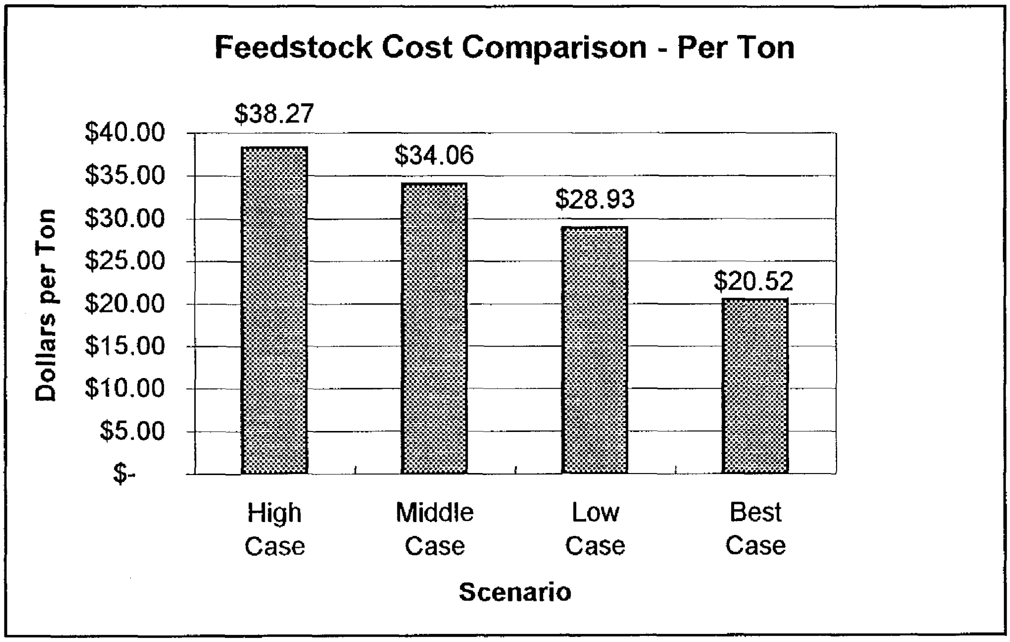
9.0 Conclusion

9.1 Summary

After review of the information regarding the availability of potential feedstocks for a biomass-to-ethanol facility, we conclude that there is more than enough procurable biomass materials available to adequately supply a moderate sized biomass-to-ethanol production facility in the study area. Furthermore, because of the large amount of current unutilized biomass feedstock materials it is doubtful that the location of such a processing facility in the study area would raise the cost of the feedstock in any significant way, which would have a negative impact on the processing facility, as well as potentially on local livestock producers.

Chart 4 graphically illustrates the projected feedstock costs a biomass-to-ethanol plant would most likely need to pay in order to obtain an adequate supply of feedstock. The range is from $20.52 per ton to $38.27 per ton based on different economic and CRP program scenarios.

Chart 4 - Projected Per Ton Feedstock Cost Comparison by Scenario



The price needed to obtain an adequate supply of biomass feedstock for such a processing plant would most likely be between $28.93 and $38.27 per ton, although it could be as low as $20.52 per ton, given the right circumstances, namely cooperation by the federal government in supporting the use of biomass grown on CRP acres for energy production.

The number associated with the high case cost scenario in Chart 4 would be applicable should the CRP program be revised to allow all current acres back in and give farmers the same contract rate as they previously held. Then, that high case amount would need to offered in order to get farmers to withdraw from the program and manage, harvest and deliver the biomass feedstock to a processing facility in the study area.

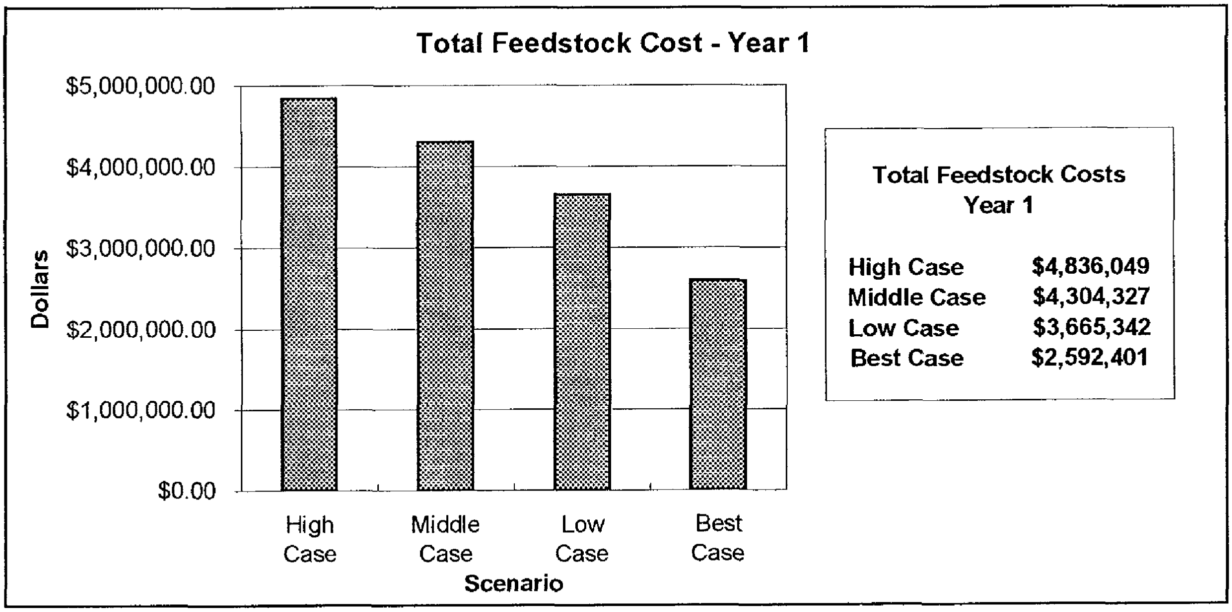
The number associated with the middle case cost scenario in Chart 4 would be applicable if all the CRP acres were locked up, with no one withdrawing and the government not allowing any harvesting for energy production, under any circumstances. The number listed as the middle case cost in Chart 4 would be the approximate price point that would need to be reached in order to get farmers to switch from other cash crops to biomass production.

The number listed as the low case cost scenario in Chart 4 would be the amount needed to obtain hay from hay land or, most likely, for biomass from land that had been withdrawn from the CRP program (or not allowed to reenroll) that farmers wanted to remain out of tillage, yet still earn some income from. This would seem the most likely scenario. This is also the price point that would allow the biomass-to-ethanol plant to obtain all the hay needed as well, should CRP acres not be an option. It would most likely encourage some new biomass production which would have a leveling effect on hay prices.

The number listed as the best case scenario in Chart 4 would be applicable should the government allow farmers to cut at least a portion of their CRP acres to be used for energy production with no penalty. There does seem to be a chance of this being allowed given the work being done in Congress in support of expanding biomass-to-energy production in the United States. This price would also enable the biomass processing plant to purchase a lot of hay as well, however, it would most likely not encourage any new biomass production if CRP acres were unusable and therefore most likely increase local hay prices.

The actual cost per ton would have a dramatic impact on the total feedstock cost to the processing plant, as outlined in Tables 6.1 through 6.4. The total cost for the feedstock for the processing plant in year 1 of operation under the various scenarios is illustrated in Chart 5.

Chart 5 - Total Feedstock Cost - Year 1



It is anticipated that the plant would have expenses for feedstock of approximately $4 million annually, however, it could be as low as $2.6 million given the right circumstances.

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Appendix D

Screening Study Report (Task 3)

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SCREENING STUDY FOR UTILIZING FEEDSTOCKS GROWN ON CRP LANDS IN A BIOMASS TO ETHANOL PRODUCTION FACILITY

...............Task 3 - Screening Study Report...............
Subcontract No. ACG-6-16644-01
Prime Contract DE-AC36-83CH10093

Prepared by
American Coalition for Ethanol
&
Broin & Associates

for
United States Department of Energy's
National Renewable Energy Laboratory BioFuels Program

September 6, 1996

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

OCCURRENCE: TASK 3 - SITE SELECTION

Subtask 3.1 - Establish Processing Facility for Site Selection Requirements
Subtask 3.2 - Screen Available Sites for Match with Facility Requirements
Subtask 3.3 - Develop Budgetary Capital and Operating Costs Based on Process Considerations
Subtask 3.4 - Evaluate Site-Specific Issues Relative to Permitting and Community Interests
Subtask 3.5 - Evaluate and Rank Final Sites

Prepared by: Darwin VandenBerg, Sioux Falls, SD
& Rob Broin, Sioux Falls, SD
Date of Preparation: September 6, 1996

Subcontractor: American Coalition for Ethanol, Sioux Falls, SD
Subcontract Number: ACG-6-15019-01 under Prime Contract DE-AC36-83CH10093
Subcontracting Agency: National Renewable Energy Laboratory, Golden, CO

Preface

Brown, Marshall, and Day Counties in northeast South Dakota has had about 200,000 acres of cropland enrolled in the federal Conservation Reserve Program (CRP) in recent years. Bromegrass and Western switchgrass are currently planted on most of these CRP acres. Grasses such as Western switchgrass have been investigated as Herbaceous Energy Crops (HEC's).

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL), along with other institutions, has technology under development which is directed toward the economical production of fuel grade ethanol from biomass. HEC's such as Western switchgrass, grown on CRP acres, are being considered as economical sources of biomass.

The objective of this paper is to define the minimum requirements for a biomass-to-ethanol production facility which can be built somewhere in the study area of Brown, Day, and Marshall Counties. Issues concerning this facility will be reviewed and a suitable site will be selected within the study area.

For the purposes of site selection, utility and chemical requirements were preliminarily estimated to facilitate the site selection process, with the understanding that a more detailed analysis of these requirements would be accomplished in the upcoming Task 4.

The design for this facility has been modeled after the process described in a 1994 report prepared for NREL, titled "Biomass to Ethanol Process Evaluation," which was submitted by Chem Systems. Sizes and flows have been altered to reflect the change in product output; the body of either this report or of Task 4 will address the changes or departures made from the Chem Systems model.

(It should be noted that the authors have taken some liberty in excising information from the cited references. This was done for the sake of brevity and with the understanding of the intent of this paper.)

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Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

TASK 3 - SITE SELECTION

Subtask 3.1 - Establish Processing Facility for Site Selection Requirements

Feedstock Supply Quantities and Quality Mix

Delivered Feedstock

For the proposed biomass-to-ethanol processing plant, the minimum feedstock supply quantity has been set at 350 bone dry tons per day (BDTPD). From Task 1 of this study, the moisture content of the feedstock is specified to be in the 14-18% range. In determining the actual tons per day that the facility will need to process, a value of 0% moisture will be assumed to be equivalent to bone dry tons (for the purposes of this report, all feedstock weights should be assumed to be bone dry, with the exception of any discussion concerning the harvesting, storage, and milling of the feedstock).

Using the minimum value of 14% moisture for the field dried feedstock, it can be calculated that the actual feedstock requirement is about 407 tons per day. From Task 2 of this study, a value of 2.5 tons of feedstock harvested per acre will be used, which corresponds to 2.91 tons per acre at 14% moisture. At the planned 330 days of plant operation per year, this would require a total of 46,155 Conservation Reserve Program (CRP) acres.

From discussions with bale handlers and movers in the study area, the switchgrass is expected to be delivered on trucks each carrying 18 to 20 tons (32 to 38 round bales). Delivery costs were given as $3.00 per loaded mile. Bales should be bound with sisal twine, which can pass directly through the milling operation and the process. The bales are estimated to weigh an average of 1,100 pounds apiece. This is equivalent to a raw material feed rate of about 740 bales per day, or about 30.8 bales per hour.

The round bale handlers have also advised that each spring, weight restrictions are imposed on area roads because of frost. This prohibits the use of the heavy truck loads during the "frost months." This obstacle will be overcome by using either partially loaded trucks, or smaller trucks during the spring. Also, the contracts with area farmers should be arranged so that winter and spring deliveries are from areas closer to the plant than summer and fall deliveries.

Effect of Moisture

It is understood that any feedstock moisture content above 14% will result in a marked increase in energy consumption for the milling process. In practice, the facility should be capable of processing a wide moisture range feedstock because controlling the actual moisture content will be difficult. To some degree, the milling operation can blend high moisture feedstock with low moisture feedstock, resulting in material feed to the process that meets specifications. Rejection of feedstocks for slightly high moisture content would only serve to increase the acreage required to provide the feedstock, alienate producers, and increase delivery distances and associated costs.

Delivered bales would be weighed and enough core samples would be taken to determine the average moisture content. To discourage farmers from baling grasses that have not been properly field dried to the specified range, contracts with grass producers should have provisions to pay farmers based on the bone dry equivalent. Moisture levels detected above 18% would result in a payment reduction according to a penalty structure defined in the contract.

Variations in Feedstock

Feedstock type has been specified as Western Switchgrass, which is a warm-season grass. In the study area of Brown, Day, and Marshall Counties of northeast South Dakota, the predominant major vegetation types are big bluestem, little bluestem, switchgrass, and indiangrass in the Tall Grass Prairie region (in the east and southeast portion of these counties), and Western wheatgrass, big bluestem, and porcupine grass in the Tall Grass Transitional region (in the west and northwest portion of these counties).[1]

Many other types of grasses, such as a common cool-season grass known as bromegrass, have been introduced to the area. In northeast South Dakota alone, more than 34 varieties of nine cool-season and five warm-season grass species have been released by various state Agricultural Experiment Stations, Soil Conservation Plant Materials Centers, and private industry.[2]

Warm-season grasses are preferred because cool-season grasses are usually dormant in warm summer weather, resulting in low forage production. When it has been seeded, switchgrass frequently includes bluestems, indiangrass, and sideoats grama in the mixture (all are warm-grass species). Switchgrass also has a tendency to support an undergrowth of Kentucky bluegrass and vegetation of the sedge variety. Sometimes, the perennial legume alfalfa is mixed in because it grows well with grasses, supplying nitrogen to them.[1] Consequently, the biomass processing facility needs to be able to process a mixture of grasses until farmers have established enough of a more homogeneous dedicated feedstock supply system within a reasonable distance from the plant.

Existing Switchgrass

Existing switchgrass is predominantly found in lowland types of regions, where its production yields can be much higher than found on drier lands. Most of the lowlands of the three counties in this study are in Day County. Combining this information with the vegetation types by region identified above and the general slight increase in precipitation toward the east (see climate data from Task 7), it is expected that most of the potential for any existing switchgrass on nearby CRP acres would be found in Day County, decreasing toward the northwest.

Feedstock Degradation

It is expected that there will be varying amounts of feedstock degradation from the time of harvest to the time of processing, which we estimate may be as long as ten months for some feedstocks. Some factors that contribute to feedstock degradation are harvesting practices, weather conditions, storage methods, microbial decomposition, and transportation.

From Task 2, enough on-site storage area will be provided to supply the biomass-to-ethanol plant for 15 days, which should be adequate to keep the facility operating during those periods where feedstock deliveries could be decreased due to inclement weather, short-term reductions to the labor pool, or other factors. Degradation will occur mainly during the storage period at the farm field edge, with lesser amounts occurring during transportation. Because of the design of the storage facility, and the short residence time of the feedstock, further degradation at the on-site storage area is expected to be minimal. Farmers will be encouraged to employ good storage practices, since they will be paid by weight (bone dry basis) and quality of the feedstock upon delivery to the processing plant.

Ethanol and Byproduct Production Rates

Feedstock Composition

The composition of the switchgrass feedstock, which is classified as a Herbaceous Energy Crop (HEC), is 45% cellulose, 30% hemicellulose, 15% lignin, and 10% other components.[3] If all of the cellulose and hemicellulose were converted into their respective hexose and pentose sugars, there would remain 25% lignin and other components, or 500 pounds per ton of feedstock.

Ethanol Production Rate

The biomass-to-ethanol production plant is sized to produce 10 million gallons of 200 proof ethanol per year. The plant would operate 330 days per year, 24 hours per day, requiring an ethanol production rate of about 30,303 gallons per day. At the previously stated feedstock supply rate of 350 tons per day (bone dry basis), and ethanol weighing 6.62 pounds per gallon (specific gravity = 0.794 g/ml at 15 degrees C), this translates to an ethanol production rate of about 86.58 gallons (573.2 pounds) per ton of feedstock. In other terms, the 200 proof ethanol flow rate will be about 21 gallons per minute.

The output of fuel ethanol from this facility will be higher. If gasoline is used as a denaturant at the maximum concentration of 5%, the total output could be as much as 10,526,316 gallons per year (see specifications for denatured fuel alcohol in Task 1).

Carbon Dioxide Production

This facility would produce a considerable amount of carbon dioxide. The ratio of carbon dioxide formation to ethanol formation is calculated to be about 0.961.[4] Therefore, this plant will produce about 550.8 pounds of carbon dioxide per ton of switchgrass feedstock. Provisions will be made to strip the organic compounds from the carbon dioxide stream with process scrubber units, and the scrubbed carbon dioxide will then be further purified at a carbon dioxide processing plant adjacent to the ethanol facility. From there it will be sold to acceptable markets, such as those identified in Task 1 of this study.

Lignin and Other Components

Of the remaining 500 pounds per ton of feedstock, theoretically 300 pounds per ton would be lignin. The lignin is expected to be around 40% solids concentration after separation. This would be about 750 pounds of lignin/water boiler fuel per ton of feedstock, which would be sent to a recycle fuel burner nearby. The actual weight will be higher than this theoretical figure, due to the addition of sludge from the wastewater treatment operations.

In this process design, the use of the nearby recycle fuel burner was selected over the integration of cogeneration facilities for at least the first several years of plant operation. Analysis indicates that the sale of the lignin coproduct is the best option at this time. The selected plant site will be able to support the addition of the cogeneration facilities at any time after the processing plant has begun to operate. Cogeneration should be looked at more closely after there have been more technological improvements made to smaller scale cogeneration plant design and operation.

The 200 pounds of other components per ton of feedstock would be organic compounds which were present in the initial feedstock charge. Fermentation byproducts from the processing operation, along with the unfermented portions of the cellulose and hemicellulose, should add another 217.5 pounds of liquids and solids per ton of feedstock. About 1/3 of these materials will be removed in the separation process along with the lignin. The remaining 2/3 of these organic compounds will be treated in an anaerobic digester and an aerobic biotreater to remove the Biological Oxygen Demand (BOD) and the Chemical Oxygen Demand (COD) from the wastewater.

The anaerobic digester, as part of the wastewater treatment system, will produce a gas mixture. Gas generated from the digestion of organic waste is colorless, flammable, and contains roughly 30-40% carbon dioxide and trace amounts of hydrogen, nitrogen, and hydrogen sulfide.[5] Biogas produced at a rate of 0.35 pound per pound of organic wastes would yield a total of about 97.4 pounds per ton of feedstock. The remainder of the gas is the nontoxic gas methane; the entire gas mixture supplements natural gas as fuel for the process boiler. This gas would be used as fuel for the high pressure steam boiler. At 23,800 BTU per pound, the methane fraction of the biogas would provide some 23.7 million BTU per hour, which could reduce natural gas requirements of the process boiler by 53%.

The digester would also produce about 181 pounds of sludge per ton of feedstock. Solids from these operations will be blended with the lignin mixture for shipment to the recycle fuel burner. The total estimated dry weight of the combined solids fractions is 620 pounds per ton of feedstock; at 40% solids, the shipping weight would be about 1550 pounds of lignin coproduct per ton of feedstock. To reduce the plant water requirements and to reduce wastewater discharge rates, as much of the treated wastewater as possible will be recovered and recycled back into the process.

Environmental Emission Characteristics

Air Emissions

Emissions from a facility of this type are expected to be low. The 200 proof ethanol, the fuel ethanol, and the gasoline denaturant storage and custody transfer systems will be designed to reduce the potential for any fugitive emissions. Using low pressure storage tanks, floating roofs, and/or storage tank carbon dioxide blanketing will accomplish this. An Air Quality Permit would be required for process vent and boiler stack emissions.

Carbon Dioxide

The bulk of the carbon dioxide coproduct will be sold, except a small portion which may be used on-site for providing storage tank blanketing. The process scrubbers will remove more than 95% of any volatile organic compounds (VOC's) from this process stream. If there are any releases of carbon dioxide, they would be governed by the conditions of the Air Quality Permit.

Solids

All solids generated by this biomass-to-ethanol facility are, for the initial design without cogeneration, shipped off-site as fuel for burning in a nearby coal fired power plant. Any solids, including sludges from the wastewater treatment operations, will be blended with the lignin residue to constitute a fuel coproduct.

Wastewater

Wastewater will be recovered and recycled to the greatest feasible extent. The BOD and COD of any effluent discharged will be reduced, with an anaerobic digester, an aerobic biotreater, and associated equipment, to levels below acceptable limits as defined by Water Quality Standards. This would require a Surface Water Discharge Permit, or a Pretreatment Industrial Users Permit if the discharge goes to a municipal treatment facility.

Storm Water

Site layout will be designed to properly manage storm water. The Storm Water Runoff Permit will govern conditions for water releases in this category.

Area Requirements

Preferred Acreage

The desired acreage of the biomass-to-ethanol plant site is a minimum of 40 acres and a maximum of 80 acres, and the selected site should be entirely on one side of any road to reduce any possibility of conflict with traffic. The site should be on the same side of a road as the railroad, and must be of sufficient elevation to reduce the possibility of seasonal flooding.

Preferred Shape

The most likely shape will be square or rectangular, with the possibility of some useable acreage being reduced by railroad or highway right-of-ways or other physical features. Parcels of odd shape and size within the stated acreage values could be appropriate if they conform to all other requirements.

Drainage Characteristics

Good drainage from the site is very important. Due to storm water discharge requirements of the facility, either a natural pond or stream on the site would be desirable. Otherwise, a suitable portion of the site should have a sufficient grade to simplify the construction of an artificial pond and a drainage outlet. Preferably, the natural or artificial pond will have a nearby outlet which is already continuously flowing. Runoff from much of the level portion of the site, which would contain the feedstock storage area, the milling area, the prehydrolysis area, the fermentation area, offices, laboratories, boiler and utility area, distillation area, the solids handling area, and the product storage area, would be managed to control the rate of discharge from the pond.

Other Characteristics

If all other requirements can be met, consideration must be given to selecting the site which would have the least amount of environmental impact. The preferred site would not be, for example, in proximity to any Federal, State, or County wildlife or recreation areas. If the site is in or near a town, it must be in an appropriately zoned area, with thought given to reducing any related burdens upon the citizenry.

Utility and Chemical Requirements

Water

Water requirements were estimated to average 175 gallons per minute (252,000 gallons per day), with potential short periods of use up to 240 gallons per minute (345,600 gallons per day). In addition, plans are to provide for additional capacity, up to a total of 360 gallons per minute (518,400 gallons per day), to accommodate any future expansion.

Developing excess water capacity is prudent because obtaining water at any large volume in the study area is difficult. The water requirements of this facility are quite large in comparison to most users in the area. In fact, the water usage of this one plant is larger than water usage by any single town in the entire study area, except for Aberdeen, in Brown County. Aberdeen, which is by far the largest city in the study area, has a current moratorium on granting new water services.[6]

Surface water reservoirs or well fields near their particular community meet the water requirements of some towns in the study area. Some privately owned wells supply water for domestic, irrigation, and stock needs. Many communities and private parties, however, are supplied or supplemented with domestic water from WEB Water Development or Brown-Day-Marshall (BDM) Rural Water Systems.

WEB is a network of water pipelines which delivers domestic water from its source on Lake Oahe, a large reservoir on the Missouri River more than 80 miles west of Aberdeen, to customers in the study area. The study area is, however, at the eastern limit of the WEB distribution system. Consequently, most of the water pipe sizes available are too small to provide enough water for a biomass-to-ethanol processing plant. Even the largest supply lines available would be marginal for adequate flow rates. WEB would likely need to make expensive upgrades for their pump stations and water treatment facilities to provide the requested service; in addition, WEB specifically will not supply any services for fire protection water.[6] Therefore, WEB Water Development is not considered a likely source of process water.

BDM is a similar system which supplies domestic water to customers in the study area. The water is supplied from two 8" wells located near Britton in Marshall County, drawing from the James Aquifer. Their largest guaranteed flow is 50 gallons per minute.[7] For the same reasons as given for WEB, BDM will not be considered for process water.

Most existing wells or well fields in the study area are currently operating near either the upper limits of their capacity, or they are too small to meet the proposed plant water requirements. Consequently, the only remaining options for water supplies would be either from surface waters or from a large well.

In Marshall County, the surface water supply includes several small intermittent streams and numerous marshes, ponds, and lakes, which cover 7% of the County. Most of the precipitation is returned to the atmosphere by evaporation and transpiration, which greatly reduce the amount of water available in the area.[8]

In Day County, lakes cover about 6% of the County's surface and surface drainage is mainly internal with a minor amount leaving the County. The most important streams are Antelope, Mud, and Pickerel Creeks. Drainage on the western slope of the Coteau des Prairies would go mainly into the tributaries of the James River and would be carried out of the County. Drainage water in the interior of the Coteau would all go into closed depressions such as potholes and minor lakes and perhaps into the major lakes.[9]

The Coteau des Prairies is a geographical plateau which includes all but roughly the western quarter of Day County.

The James River and its tributaries form the natural drainage network of Brown County. The principal tributaries to the James River within Brown County are the Elm River and Moccasin Creek, both of which join the James River from the west. Mud Creek, which drains the southeastern part of Brown County, joins the James River from the east, in Spink County. Except for the Elm River, which receives discharge from ground-water storage and reservoir releases for the city of Aberdeen water supply, the major streams commonly have no water flow in late summer, fall, and winter. There are no natural lakes in the County.[10]

It is evident that very few possible sites within the study area can meet the process plant water demands strictly from surface water supplies.

The remaining source of water supply would be to drill a well to get groundwater from subsurface aquifers. Detailed information on all the aquifers in the three counties in the study area is available from the Geological Surveys; however, since they cover the entire three county study area, they will be looked at further after the site selection process has defined smaller geographic areas. Test drilling and evaluation of the aquifer characteristics would precede large-scale development of ground water in the vicinity. Water from any source in the region is of wide ranging quality, but is usually of poor quality; therefore, this would be evaluated as well.

Steam

Steam will be produced using a process boiler fired by natural gas, supplemented with biogas generated from wastewater treatment operations. Steam requirements of the biomass-to-ethanol plant are estimated to total about 40,000 pounds per hour of high pressure steam. The boiler will carry a rating of 250 psig, and will be sized to provide the necessary volume. Note that this process uses high pressure steam only, since there will be no cogeneration facility that provides excess quantities of low pressure steam.

Natural Gas

Since cogeneration facilities are not planned on, at least for the initial phase of construction, natural gas was selected as the boiler fuel, supplemented with biogas produced at the plant site. The gas requirement for the facility is estimated to be 44.6 million BTU per hour. Considering the biogas input, a minimum of 20.9 million BTU per hour of natural gas will need to be supplied to the plant. The natural gas supply will be sized to provide enough fuel, however, to run the process boiler in the event that no biogas is available. The only high pressure gas pipelines in the area are owned by Northern Border Pipe Line (NBPL) and Northern Natural Gas (NNG).[11]

Subsequent review of the South Dakota Public Utilities Commission's Natural Gas Pipeline System map reveals that those high pressure natural gas lines are in southern Brown County and west central Day County. Marshall County does not have any gas lines. The preferred site will be found close to one of these high pressure pipelines because a direct tap into them would result in a lower cost for the natural gas. The economics are more favorable than if the fuel was purchased through Northwestern Public Service, which is the local gas utility company.

Alternate Fuels

Propane or Liquefied Petroleum Gas (LPG) can be used as backup or supplement if necessary. The best access to bulk propane delivery is along a major railroad line or near the city of Aberdeen. Coal would be available along a major railroad in this area but is not being considered for this plant.

Lignin Coproduct

Until a cogeneration facility is operational at the biomass-to-ethanol plant site, rail or truck lines will ship the coproduct fuel lignin to Otter Tail Power Company's Big Stone Power Plant, about seven miles east of Milbank, Grant County, South Dakota, off U.S. Highway 12. The Big Stone plant is about 105 miles east of Aberdeen. Each full day of operation, the biomass plant will generate some 271 tons of a mixture of lignin, water, and solids from wastewater treatment. At 330 days of operation, the yearly fuel coproduct production would be about 89,430 tons.

The Big Stone Power Plant has a daily burn of 5,000 to 6,000 tons of coal, and can burn residues such as the lignin coproduct at up to 7% of the coal burn. The plant is not so much concerned with the moisture content of biomass residues as with the handling characteristics of the residue.[12] Since the annual production of the fuel coproduct is less than 5% of the power plant annual coal burn, the power plant has the capacity to handle all of the coproduct. Handling characteristics of the residue largely depends on the moisture content and can be manipulated to optimize the desired characteristics. A test burn of two to three days duration might be required to support modifications to Big Stone Power Plant's Air Quality Permit.[12]

Electrical Power

Initial electric power requirements were estimated to be 3000 kW, with the plant requiring transformers for 4160 V three phase, 480 V three phase, and 120/240 V single phase services. The load factor is estimated at 80%. It appears that procuring electrical power will not be a problem because most of the electrical transmission lines follow corridors in which the preliminary potential plant sites are also found.

East River Electric Power Cooperative services the eastern half of South Dakota through a system of Rural Electric Cooperatives, Municipal Systems, and Investor-Owned Utilities.[13] Depending on the final site selection, electric service would be provided through Northern Electric Cooperative, Lake Region Electric Cooperative, a municipal electric (in the towns of Groton, Hecla, or Langford), Montana-Dakota Utilities Company, Otter Tail Power Company, or Northwestern Public Service Company. The proper party or parties can be consulted after site selection has been made.

Chemicals

Most chemical requirements will be met through commercially available sources, and depending upon the required quantities, are delivered to the plant site by truck or rail. Some of the chemicals, such as cellulase enzyme, will be produced at the plant site.

Special Transportation Requirements

Railroads

Railroad service is considered essential for a processing plant of this type and size. The quantity of ethanol produced, and the location of the primary markets (identified in Task 1), makes the use of large scale surface transportation necessary. Rail service will also be utilized for delivery of those raw materials which are consumed in larger quantities.

Examining the probability of railroad closure for a given site is important. In the earlier part of this century, railroads had an important role in transportation in South Dakota, and many lines crisscrossed the state. In more recent years, many rail lines have been abandoned. Therefore, looking at highway maps, especially older ones, is risky for finding railroads in current service.

In 1976, the South Dakota Legislature repealed several sections of state law which imposed unnecessary regulatory and expense burdens on railroads. The 1979 legislature repealed much of the law which called for regulation of railroad practices and rates. Many of the remaining regulatory responsibilities were transferred from the Public Utilities Commission to the Department of Transportation. In 1979 the Division of Railroads had identified the lines which provide essential service. After this core system was identified, resources were directed towards retaining these lines.[14]

Part of the railroad core system is found within the study area. One such line's northern terminus is in Aberdeen, Brown County, and extends south. Another core line goes east-west through Aberdeen in southern Brown County and through Day County. A recent map shows that several other lines are within the study area.[15] One extends northeast from Aberdeen toward Rutland, ND; this line passes through Marshall County near Britton. Several other lines come into a single town within the study area and terminate.

Highways and Roads

A good quality primary road is desirable to simplify the shipping and receiving of raw materials and products. U.S. Highway 12 goes east-west through Day County and southern Brown County, including the city of Aberdeen. This road roughly follows the Burlington Northern core rail route. No roads follow the northeast rail route, but it frequently crosses paved county roads. The core rail line going south from Aberdeen is on a paved road parallel to and one mile east of U.S. Highway 281.

For local deliveries including that of the Western switchgrass feedstock, all of the counties within the study area have a reasonably well-developed system of primary and secondary roads. From the aspect of feedstock delivery, all potential plant sites will have an adequate road system. As previously mentioned, weight limits on area roads during the frost season in the spring will cause some minor difficulties.

Pipelines

Pipelines for this facility may be possible in several areas, but this is dependent on final site selection. One could be the water supply, which has been previously discussed. WEB water pipelines are likely too small to meet the demands of this plant. The plant may choose to have a private well or well field, or a private pipeline may be an option if an acceptable supply of surface water is found nearby.

If treated wastewater and storm water discharge in proximity to the plant site is not possible, having a private pipeline which delivers this water to a suitable nearby location may be possible.

Finally, if the plant should be near enough to a large user of carbon dioxide, building a delivery pipeline between the two plants may be possible. In this area, this scenario would be highly unlikely.

Special Storage Requirements

Feedstock

The feedstock for this facility does have some special storage requirements. It is planned to have a pole barn type building large enough to house a 15-day supply of feedstock, a conveyor system to move the feedstock to the milling area, and room to maneuver tractors and other material handling equipment. The ends of this building may be enclosed but the sides will be open. This arrangement will simplify the unloading of feedstock delivery trucks, the interim storage of the feedstock, and the placement of the feedstock bales on the conveyor.

The floor of the feedstock storage area will be concrete or a bituminous surface. This has been included in the design because of the large volume of traffic that will be seen due to truck unloading and conveyor loading activities. If the feedstock were allowed to be stored on grass that surface would be destroyed in short order. If the floor surface were gravel, material handling would improve, but too many rocks and foreign materials would find their way to the milling area. The rocks and foreign materials may lead to costly damages to the milling area equipment.

It is expected that some feedstock will come in with soil, gravel, snow, ice, and a variety of other foreign objects attached to it. The hard floor surface will help ease cleanup and removal of these foreign objects from the storage area. The hard floor and the roof overhead will also limit further degradation of the feedstock, and provide some degree of protection from the elements for the people who will be continuously working in this area.

Chemical Storage

Chemical storage requirements will not be out of the ordinary for an industrial plant of this size and type. Bulk quantities of chemical raw materials and the ethanol product will be stored in an outdoor tank farm. If a bulk raw material is subject to freezing, however, its storage tank may be located indoors. Smaller quantities of chemicals will be stored indoors in dedicated storage areas, and moved as needed to their point of use.

Coproduct Storage

The coproducts will have storage requirements that are not out of the ordinary. For the lignin fuel coproduct, there will be a separate building where solids from the digesters will be blended with the lignin from the process. From this storage area, the lignin fuel will be pushed into a hopper and conveyed to rail cars or trucks for eventual transport to the Big Stone Power Plant near Milbank. The layout of this area will accommodate the changes necessary for delivering the fuel to a future on-site cogeneration facility.

The ethanol plant will have an adjacent processing plant which will further purify, compress, and store the carbon dioxide. This plant would be owned by others, and will be positioned to provide access to trucks and rail lines for custody transfer.

Subtask 3.2 - Screen Available Sites for Match with Facility Requirements

Before any research was done for Task 3, several regions within the study area were quickly pre-judged to have the most likely potential for a biomass-to-ethanol processing plant, which would use switchgrass as a feedstock. The selected regions were around the towns of Aberdeen and Groton in Brown County, Webster in Day County, and Britton in Marshall County. Factors identified through subsequent research will determine if these regions are suitable, or if other areas can meet the minimum requirements for the facility.

Factors Limiting Site Suitability

Feedstock Availability

Day County statistically has the largest share of CRP acres, followed by Brown County and then Day County (refer to Table 1 of Task 2). The density of CRP acreage is also highest in Day County (an area of 1,013 square miles), with about 81 CRP acres per square mile. Marshall County (an area of 888 square miles) has a CRP density of about 47 acres per square mile, and Brown County (an area of 1683 square miles) has a CRP density of about 40 acres per square mile.

Since a square mile contains 640 acres, more than 12.6% of Day County is CRP acreage. Marshall County is about 7.4% CRP acres; Brown County is about 6.2% CRP acres. Combining this information with the findings on existing switchgrass in Subtask 3.1, it becomes apparent that, for purposes of site selection concerning current and future availability of nearby feedstocks, southeast Day County can be considered the best. Feedstock availability will generally decrease as one goes to northwest Brown County.

Recreation and Environment

For this facility to have a minimum negative impact on the public (such as increased traffic, visible air emissions, increased water flows in local streams, etc.), the preferred site should be selected away from towns, in areas of lower population density. The best plant site would also be a reasonable distance from public recreation areas, wildlife management areas, etc. For more detailed discussion on these subjects, refer to Subtask 3.4.

Area Requirements

In much of the study area, it is unlikely that the most suitable land found for a plant site is currently for sale. This is because it is most likely a part of an existing farm. In 1992, the average farm sizes were 942 acres in Brown County, 779 acres in Day County, and 997 acres in Marshall County.[16] At some point, landowners would be approached with an offer to buy some of their land. There are some lands which may be currently available near a town industrial park or next to existing industrial facilities.

The selected site will require a drainage outlet for storm water and treated waste water. In a rural area, the site will need to have either a drainage ditch or a natural stream bed to carry these waters to a suitable location. A pipeline to a nearby drainage outlet is a possibility. If the site is near a town, or in an industrial park, it may be possible to use local treatment plants or lagoons as the outlet.

Water

It would be difficult to obtain the required quantities of water for this facility no matter the location within the study area. Most lakes are too small to provide enough water, and even the large ones are susceptible to rapid draw-down. Few natural lakes exist west of Pierpont, in Day County, and they will not be considered as water supplies.

All streams in the area flow intermittently, except the James River. A new water right permit from a surface water source, such as a river, will require a low flow bypass to satisfy downstream prior rights. Additionally surface water use from a river may be subject to shut off orders during low flow periods.[17] Huron, a city with a population of about 12,500 some 76 miles south of Aberdeen, will sometimes exercise their prior water rights because the James River is their source of supply.[18] Therefore, the James River will not be considered as a process water supply.

Municipal and rural water pipeline systems will not be considered for water supplies. Aberdeen, the only city likely to be capable of supplying water to an industrial plant of this size, has a current moratorium on new water services. The WEB and BDM pipeline systems in the study area are not developed enough to support a large volume water user.

This plant will probably be supplied with well water, which is possible to obtain in most of the study area. The preferred site should not be near existing wells unless it is certain that there is not a reduction in their water production, as this may violate existing water rights. The well should also be in an area protected from flooding. The new facility must obtain the water rights, or transfer them if they are existing.

Natural Gas

Because biogas generated on-site cannot supply all of the boiler fuel needs, the facility will be near a natural gas pipeline. The gas utility serves the towns of Aberdeen, Bristol, Ferney, Groton, Holmquist, and Webster in the study area, which are all near the high pressure gas pipeline. A direct tap into the high pressure gas main is preferred because lower fuel costs can be negotiated.

If alternate fuel such as propane or LPG can be obtained in bulk quantities and stored on-site at the new plant, the requirements for natural gas may be relaxed somewhat.

Electrical Power

A location in proximity to an electrical transmission corridor will provide an adequate electrical power source. These transmission corridors, as a rule, follow major transportation routes. Electrical power can, however, be found in most locations within the study area. Associated costs are likely to increase as one moves farther away from the main distribution system.

Railroads

As mentioned in Subtask 3.1, access to railroad service is essential for this facility. The best biomass-to-ethanol plant site will be along a core railroad. These would include the east-west railroad (operated by Burlington Northern) passing through Brown and Day Counties, and the railroad going south out of Aberdeen. The railroad line going northeast out of Aberdeen toward Britton will not be used because it is not part of the core railroad system, and is therefore considered too risky to use. No other railroads in the study area can be considered.

Highways and Roads

While primary roads are not necessary for feedstock delivery, having a major highway for purposes of raw materials, products, and coproducts shipping and receiving is desirable. U.S. Highway 12, a major highway, runs parallel to the core east-west railroad. Highway 12 from Aberdeen to Interstate 29 has been considered for future development and possible expansion to a four-lane expressway type highway.[19] This would not negatively impact site selection because all sites will be on the same side of the highway as the railroad, and highway expansion generally occurs on the other side.

The plant site will have at least a secondary road which intersects U.S. Highway 12 nearby. This is due to the fact that the plant site entrance will not be from Highway 12, but from the intersecting road. This arrangement will minimize any problems with traffic on the major highway that may be associated with the shipping and receiving operations of the biomass-to-ethanol facility. Any location not having a suitable secondary access road will be removed from consideration.

Other Considerations

For delivering the lignin fuel coproduct to the Big Stone Power Plant, especially if using trucks for transport, a location in Day County is favored. Locations in Brown County or Marshall County are farther away.

The availability of a work force should be considered. Due to the technical nature of the work performed at this plant, some of the employees would need to be skilled or semiskilled professionals. The greatest potential for the required labor resources would be in a larger town such as Aberdeen. In a rural area such as this, however, employees will travel considerable distances for a good job, or they may even elect to relocate closer to their work.

Exclusion of Unacceptable Sites

In this section, the various factors limiting site selection will be examined to define a geographical area containing potential sites. This will be accomplished by first applying the most limiting factors, and then examining the remaining factors.

Railroad Access

The most important limiting factor is the requirement for this facility to have access to a railroad. As already discussed in Subtask 3.1, and earlier in this Subtask, only a core railroad can be considered safe in terms of its long-term viability. Two core railroads are in the study area - one going east-west through Aberdeen (Brown County) and through Day County, and another one which goes south from Aberdeen. The only potential sites will be found along these corridors. This effectively rules out the vast majority of the study area, including Britton and all of Marshall County.

Drainage Features

The second most important limiting factor is access to adequate drainage for the facility. It has been shown that a very limited drainage system is available in eastern Day County. In addition, because of limited or lack of drainage, thousands of small lakes, marshes, and potholes have formed there; this has led to the major development of public recreation and wildlife areas. Therefore, any site east of State

Highway 27 just east of Andover, in Day County, will not be considered. This rules out the region around Webster.

Feedstock Supply

Another important limiting factor is the availability of feedstock. Since Day County has about twice the density of CRP acres compared to Brown County, and has the greater likelihood of switchgrass growing on those CRP acres, the east is considered to have better potential sites than the west. Taking this a step further, no sites will be considered west of Groton, because the distance required to transport feedstocks will become unnecessarily great. This eliminates all of the Aberdeen area, which essentially is located too far west to be central to feedstock supplies within the study area.

Highway Access

Highway access is important; however, this is not a problem since U.S. Highway 12 runs parallel to the previously selected core rail system. It does become a site selection factor because the site should be on the same side of the highway as the railroad. The railroad is on the south side of the highway until about three miles west of Groton, where the railroad crosses U.S. Highway 12 and continues into Aberdeen on the north side.

Secondary Limiting Factors

The availability of boiler fuel is an important factor. Alternate fuels such as propane or LPG would be available along the core rail line, but the best boiler fuel (until a cogeneration facility is built) would be natural gas. Areas without a natural gas supply within a reasonable distance will not be considered. In this case, however, none of the remaining areas for plant sites can be ruled out, because all of them are considered to be close enough to a high pressure gas line.

Brown County east of Aberdeen is a very flat area, part of a geographical feature known as the Lake Dakota plain. Drainage from this area is very gradual, therefore forming very wide flood plains next to many ditches, creeks, streams, and rivers. Caution must be exercised to ensure that no plant sites will be considered within such a flood plain. A map indicating the locations of flood prone areas will be used to accomplish this.[20] Western Day County slopes down toward Brown County, and there are few if any flood plains there.

Some remaining factors include water supply, electrical supply, and environmental issues. They can be evaluated further after the actual site has been selected. The water supply will be from a well or a well field. The quality and quantity of the water supply will need to be evaluated, and also its effect on other wells in the area.

Major electrical transmission lines follow the same corridor that the core railroad and U.S. Highway 12 are in, so obtaining the required service would be no problem. The appropriate provider can be contacted after site selection has been made.

While environmental factors are considered to be very important, they will apply regardless of the location of the plant. Consideration at this stage will be directed toward minimizing the environmental impact.

Initial Outcome of Selection Process

After applying the most critical factors as described above, three of the four originally selected areas have been removed from consideration. These are the areas in and around the towns of Aberdeen, Britton, and Webster. The city of Groton remains as a possibility, while a region of possible plant sites can be further defined as being on the railroad side of U.S. Highway 12, between the city of Groton and State Highway 27 in western Day County (three miles east of Andover).

When sites are evaluated along the remaining area, other factors will become important. These include the density of nearby sensitive receptors and physical features of the site; they will be considered when looking at the individual sites.

Identification of Potential Sites

The study area was visited to locate suitable sites with the previously defined qualifications. Following is a brief description of these sites, starting in the Groton area and going east.

A potential site was located in Sections 19 and 30 of Groton Township. Part of this site is within the Groton city limits and is zoned for industrial use. It is, however, in very close proximity to the town itself. Another site just southeast of Groton was found in Section 29. Mud Creek flows directly through this property.

Proceeding east, all of the area until just west of the town of Andover was eliminated. This was done because the railroad track maintains extremely high grade as it approaches the hills to the east. Because of the elevation of the track, it would be difficult to put in a spur track for the ethanol plant. Access to the land on the south side of the tracks is too restricted for truck traffic.

A potential site is located about one-half mile west of Andover, in Section 4 of Andover Township. Several potential sites, also in Andover Township, can be found several miles east of Andover. They are located in Sections 1 and 12. These areas are more remote, and are located on the slope leading to the Coteau des Prairies above. Drainage arrangements would not be difficult to make here, as the western slopes will all eventually drain into Mud Creek. Any site east of here would not have adequate natural drainage.

Three more sites were identified just to the south of the previously discussed sites. One is in Section 13 and two are in Section 24 of Andover Township. The features of these sites are similar to the nearby sites to the north. While the sites on the hill slope are more remote, they are visibly closer to the region of higher densities of feedstock, and they have superior drainage features.

Summarizing the sites described above, there are a total of eight sites which have been identified which meet the minimum requirements for site selection for a biomass-to-ethanol plant. These eight sites will be ranked later, in Subtask 3.5.

Subtask 3.3 - Develop Budgetary Capital and Operating Costs Based on Process Considerations

Process Design and Equipment Requirements by Area

Area 100: Switchgrass Handling and Milling

Diesel powered forklifts will be used to set 1,000 to 1,200 pound round bales of switchgrass feedstock on a chain drag conveyor that runs the length of a large storage building. The side walls of the building will be completely open to insure adequate ventilation. The drag conveyor transports the bales to one end of the building, where hydraulic rams roll each bale off the conveyor and into the hopper of one of four identical shredding/milling lines. Each hopper is mounted above Mac Corporation Saturn shredders, which break up the bales and discharge the partially shredded switchgrass, twine, and foreign matter to conveyors that have rock traps and magnetic separators incorporated into their design.

The shredded switchgrass in each line passes through a second Saturn shredder and then to an ABB Raymond air impact hammermill. Vibrating screens in each of the four lines separate feedstock particles over one-quarter inch in size, and send them back to the impact mill. Milled switchgrass, from each of the three shredding/ milling lines that will be in operation at any given time, is pneumatically conveyed to a storage/metering bin with a live bottom and a weigh belt feeder. A pneumatic dust collection and baghouse system keeps the dust in the area to a minimum. Collected dust is recycled back to the milled feedstock for subsequent processing.

Area 200: Prehydrolysis

A pug mill mixer mixes the metered milled grass with dilute sulfuric acid at 30% solids concentration, compared to 35% solids in Chem Systems' report. The sulfuric acid concentration will be adjusted to maintain an acid concentration of approximately 0.85% of the total water present during prehydrolysis. The mixture discharged from the pug mill mixer then goes into the first of two plug screw feeders, arranged in series, which are part of a Sunds Defibrator prehydrolysis system. Steam is added to raise the temperature to 360 degrees F.

The slurry passes from the pressurized digester of the prehydrolysis system into a flash vessel. The flashed steam is piped to the distillation area for condensation in a stripper column reboiler. The condensed steam is then sent to the waste treatment area for further processing. The 230-degree F slurry drops to the bottom of the flash vessel where it is continuously diluted with backset, recycled water, and scrubber water to a 15 to 18 percent solids concentration. Slaked lime is mixed with water to form a 50% calcium hydroxide slurry. This mixture is added to the product stream to neutralize most of the acids in the milled switchgrass slurry, and to raise the pH to fermentation levels.

The neutralized hydrolyzate is pumped to a batch fermenter. For a few hours out of each day as needed, the stream will be diverted to fill seed fermenter(s) for the pentose and hexose fermentations and to fill cellulase production batch fermenter(s).

Area 300: Batch Fermentation of Xylose and Cellulose SSF

Chem Systems' process design has been modified, for the purposes of this task, to provide batch fermentation of both the pentose and hexose sugars plus saccharification of the cellulose with cellulase while the mash resides in a single vessel. This can be accomplished simultaneously by inoculating the mash with a microorganism that can ferment both types of sugar, or by inoculating the mash with two different microorganisms simultaneously, or at different times. In either case, the cellulase enzyme and accompanying broth from cellulase production will be added to the fermenter as well. Eight 600,000 gallon stainless steel fermenters will provide up to seven and one-half days of total fermentation time.

A 20,000 gallon seed fermenter will be provided for each of the possible two microorganisms that will be used. Two trains of three successively smaller seed fermenters will be provided for growing suitable populations of microorganisms. Based on Broin and Associates' experience with fermenter mixing in corn dry mill fuel ethanol plants, mixing requirements have been significantly reduced from the model used by Chem Systems.

The vents of all fermenters are tied together and routed to a direct contact water scrubber. Fresh cold water flows down through the scrubber, picking up ethanol, other condensibles, and entrained particles from the carbon dioxide. The scrubber water is sent to the distillation area to recover the ethanol, is used for part of the mash dilution (refer to description of Area 200), or is sent to wastewater treatment for digestion and biogas production. The scrubbed carbon dioxide is piped to a purification and compression plant (owned by others), next to the ethanol plant.

Area 400: Cellulase Production

Cellulase production is carried out in batch fermenters and a fungus such as *Trichoderma reesei* is grown in batch seed fermenters. No changes were made to Chem Systems' model.

Area 600: Distillation, Dehydration, and Centrifugation

Distillation is carried out in a continuous atmospheric binary distillation column. Because of the low concentration of ethanol in the beer, the stripper section is larger in diameter than the rectifying section of the column. The four to 6% by weight ethanol beer is first preheated in a precondenser on the column overheads, then heated in an interchanger with the column bottoms to 200 degrees F. Heat to drive the column comes from three reboilers, one that condenses 200 proof ethanol, one that condenses the flash vapors from prehydrolysis, and one that condenses boiler steam. The required reflux ratio to achieve 190 proof ethanol will be approximately 5.2 to one.

Fusel oils and other fermentation byproducts are drawn off from the rectifying section, and purified by cooling, dilution, and phase separation. The concentrated fusel oils and other impurities are either added to the 200 proof for eventual sale as fuel ethanol, or sent to wastewater treatment for biogas production (see Area 800). The ethanol and water separated from the fusel oils and other impurities are recycled back to the rectifier.

The 190 proof ethanol from the column overheads is revaporized and superheated before it enters the vapor phase molecular sieve. Condensing the 200 proof ethanol exiting the sieve provides part of the heat needed to drive the distillation column. The 200 proof ethanol is cooled and pumped to storage tanks (see Area 700). The sieve regenerate is recycled to the rectifying section of the distillation column.

The still bottoms are cooled to 190 degrees F in an interchanger, and then centrifuged to concentrate the lignin to a 40% solids cake. The wet lignin cake will be blended with sludge from wastewater treatment, then loaded onto a truck or rail car for transport to a nearby recycle fuel burner. One-half of the centrate is sent to Area 200 as backset. The other half the centrate is sent to wastewater treatment.

Area 700: Tank Farm

A shift tank with one day's worth of 200 proof ethanol capacity is connected by piping to the distillation area. Each day, the ethanol is transferred to one of two large storage tanks. Following each transfer, gasoline from the denaturant tank is added to the ethanol storage tanks to reach a 5% denaturant concentration. Piping also connects a low proof ethanol storage tank, with enough capacity for two days, to the distillation area to compensate for different operational rates of the molecular sieve and distillation column.

Area 800: Wastewater Treatment

Wastewater treatment design is similar to the design used by Chem Systems. Anaerobic treatment is the first step and generates biogas containing methane for combustion in the boiler. Energy obtained from the condensation of distillation column overheads will provide for any heating needs of the anaerobic digester.

The effluent from the anaerobic digester will be further treated in an activated sludge aerobic treatment system. Approximately 50% of the effluent from the aerobic treatment system will be recycled back to the plant. The remaining 50% will be discharged to surface waters.

Area 900: Utilities

A gas fired, 250 psig water-tube boiler will burn a blend of biogas and natural gas to provide steam for the process, and for building heat. Cooling towers and a mechanical chiller will provide cooling. Chilled water will only be used where required. A reverse osmosis system will purify the incoming water for use in the boiler and cooling towers. Rotary screw air compressors with refrigerated dryers and various filters will provide air for instrumentation and fermentations.

Preliminary Capital Cost Estimate

The preliminary cost estimate for the island of process equipment for the biomass-to-ethanol production facility is $27.7 million. Included in this estimate are costs for the following: buildings, concrete, and structures; process and inventory equipment; electrical; instrumentation; mechanical equipment and piping; and other construction related costs.

This cost estimate does not include site and site improvement costs such as surveying, soil boring, site engineering, site work contracts, water storage and supply, natural gas supply system, rail spurs, site security fences, road improvements, and related site improvement costs. It also does not include other project-related equipment and costs, such as maintenance equipment, radio equipment, spare parts inventory, laboratory equipment, office equipment and furnishings, or engineering fees. A contingency and other soft costs have not been included.

Facility Operating Requirements

The annual facility operating costs, less utility costs, have also been estimated, and they total more than $6 million. Over $3.3 million of the operating costs would be for the switchgrass feedstocks. Remaining contributing costs are for chemicals, maintenance, supplies, services, and payroll. The following chart gives a more detailed cost breakdown, along with factors used in the estimates.

Table 1 - Biomass-to-Ethanol Production Facility Operating Cost Estimate, Year One

REQUIREMENT		QUANTITY/HR	QUANTITY/DAY	UNITS	PRICE	COST/DAY	COST/YEAR
FEEDSTOCK							
14 to 18% moisture mixed grass hay in 1000 to 1200 lb. bales: (14% moisture basis)		16.96	407.00	ton	Per Task 2: $28.93/BDT, or $24.88 per 14% ton	$10,126	$3,341,666
UTILITIES							
BOILER FUEL							
Steam required (lb/hr):	40,000						
Boiler efficiency:	86.0%						
Total fuel required:		44.65	1,071.63	MMBtu			
Methane from anaerobic digester:		23.70	568.80	MMBtu			
Natural gas required:		20.95	502.83	MMBtu	T.B.D.		
ELECTRICITY							
Connected HP:	8,131						
Utilization:	83.0%						
KW per utilized HP:	0.43						
Average KW required:	2,902	2,902	69,647	KWH	T.B.D.		
WATER	gpm						
Total fresh water required:	175	10,500	630,000	gallons	T.B.D.		
SEWER OR OUTFALL							
Sanitary:		1,500	36,000	gallons	T.B.D.		
Cooling tower blowdown:	22	1,320	31,680	gallons	T.B.D.		
R.O. reject:	35	2,100	50,400	gallons	T.B.D.		
Treated process wastewater:	80	4,800	115,200	gallons	T.B.D.		
TOTAL	137	9,720	233,280	gallons			
CHEMICALS							
DENATURANT (at 5% level in fuel alcohol)			1,595	gallons	$0.65	$1,037	$342,104
SULFURIC ACID (98% H2SO4)		684	16,408	pounds	$0.06	$984	$324,882
SLAKED LIME (Ca(OH)2)		509	12,221	pounds	$0.04	$489	$161,315
WATER, BOILER, TOWER TREATMENT CHEMICALS						$575	$189,750
MISCELLANEOUS CHEMICALS, INGREDIENTS, NUTRIENTS, YEAST						$235	$77,550
MAINTENANCE, SUPPLIES, SERVICES							
REPAIRS, UPKEEP						$1,018	$335,800
MISCELLANEOUS SUPPLIES, SERVICES						$553	$182,500
OPERATION LABOR							
PAYROLL PERSONNEL	36					$2,727	$900,000
OTHER PAYROLL COSTS	21.0%					$573	$189,000

(Based on 330 operating days per year) (T.B.D. = To Be Determined)

Subtask 3.4 - Evaluate Site-Specific Issues Relative to Permitting and Community Interests

South Dakota is very interested in maintaining and improving the quality of the environment for the citizens of the state. State officials are available to help new and existing businesses to take the steps necessary to ensure that local, state, and federal regulations are followed. Much of the information in the overviews of environmental permits and environmental regulations that follow was culled from a guide provided by the Department of Environment and Natural Resources (DENR).[21]

Environmental Permits

NPDES/Surface Water Discharge Permits

To clean up municipal and industrial wastewater pollution of United States waters, Congress in 1972 passed the Federal Clean Water Act. The National Pollutant Discharge Elimination System (NPDES) Permit Program was a result of the Act; its purpose is to control the amount of pollution that can be discharged and to protect the beneficial uses of all lakes and streams. On December 30, 1993, the Environmental Protection Agency (EPA) transferred authority for this program to South Dakota. The regulations are found in the Administrative Rules of South Dakota (ARSD) 74:03:17-26.

South Dakota has three types of permits from this program. The first type is a Surface Water Discharge Permit, which would be required for the biomass-to-ethanol plant. This permit is for the discharge of pollutants from a "point source" into pipes, ditches, streams, etc. Point sources for the plant will include cooling tower blowdown, boiler blowdown, and wastewater treatment effluent.

A second type of permit is the Pretreatment Industrial Users Permit, which is issued to industries that discharge process wastewater to a sanitary sewer. This permit would not be required for the ethanol production facility unless the selected site exercises any option to discharge effluents into a municipal wastewater treatment facility.

The third type of permit is the Storm Water Permit, which would be required for this facility. This permit is issued to an industry or construction site, and its purpose is to develop a plan to prevent or reduce runoff of pollutants from entering waters of the state during a storm event.

Applications for these types of permits must be submitted to the DENR at least 180 days prior to any discharge. The DENR will make recommendations on the permit application, and publish it in a local newspaper for a 30-day public comment period. Permits can then be issued if no one contests the recommendations within that time frame. Storm water permits, however, are usually issued as general permits which require a notice of intent.

Solid Waste Permit

Regardless of whether the lignin fuel coproduct is shipped to Big Stone Power Plant, or is utilized on-site as fuel for cogeneration purposes, a Solid Waste Permit will not be required for this facility. This is because the power plant already has the required permit. When a future cogeneration plant generates ash that needs to be landfilled, then the landfill would already have the required permit.

Air Quality Permit

Congress enacted a series of Clean Air Acts in the 1960's to protect the public from air pollution, and directed the EPA to establish an air quality program. The EPA regulations consist of outdoor ambient air quality health standards, source specific emission limitations, and testing and monitoring requirements. The EPA has empowered South Dakota to carry out the federal regulations. Air pollutants which are regulated in South Dakota include particulate matter, sulfur dioxide, nitrogen oxide, carbon oxide(s), lead, and volatile organic compounds.

The Clean Air Act Amendments of 1990 also requires South Dakota to regulate 189 toxic air pollutants, and as the regulation for each of these becomes final at the federal level, the state adopts the rule by reference. Air quality regulations are found in the ARSD 74:36:01-15, and statutes are in South Dakota Codified Law (SDCL) 34A-1. Federal rules adopted by the state are found in the ARSD 74:36:01-15, and are usually adopted from the Code of Federal Regulations (40 CFR Part 1-80).

An Air Quality Permit should be applied for a minimum of 180 days before any anticipated discharge. Allowing much more time would be prudent, however, because potential changes in design could require revisions to the permit, or that one of several public and governmental agency reviews will result in delays in receiving a permit. While plant construction can begin without a permit, it would be in violation of regulations to begin any operations without final permit approval.

Water Rights Permit

Though water is regarded as the property of the people of the state, a water rights holder has legal rights to make personal and beneficial use of the public's resource. Water rights remain in effect indefinitely, if they have not been forfeited because of disuse or abandonment. All water uses in South Dakota require water rights permits, and are subject to the doctrine of prior appropriation, which originated in 1881 by the territorial legislature. The 1907 state legislature affirmed the doctrine. Legislation passed in 1955 gave authority to issue permits to the Board of Water Management, which is made up of citizens appointed by the governor.

Existing conditions of the final site selected will determine what is necessary to obtain water rights. An application must be filed with the Chief Engineer of the Water Rights Program, who will then make recommendations to the board. Permit application types include those amending existing permits or rights; those which reserve water for future use; those which control flooding or modify water courses; and those which claim vested water rights.

Water rights will only be issued if four requirements are met. First, it must be shown that unappropriated water is available. Second, it must be shown that the proposed diversion can be developed without unlawful impairment of existing rights. Third, the proposed use must be a beneficial use, and finally, the proposed use must be in the public's interest.

Due to the water requirements of the biomass-to-ethanol facility, and the difficulty in obtaining water in the study area, a water rights permit should be secured before any substantial planning is done at the selected site. Denial of water rights at the selected sight could force the use of an alternate site for the facility.

Environmental Regulations

Drinking Water

If a municipal water supply is not available at the selected plant site, BDM or WEB will likely be used to provide the domestic water needs of the facility, although they cannot meet the process water needs. This is because of the Safe Drinking Water Act of 1974. South Dakota assumed enforcement of the Act in 1983, and has adopted state drinking water statutes and regulations. Regulations that apply to drinking water are 40 CFR 141-142, SDCL 34A-3A, and ARSD 74:04:05, 74:04:06, and 74:04:07.

Because the facility would employ more than 25 persons for more than 60 days per year, these laws would classify the facility as a public water system. Different classes of public drinking water systems are used, with each type of system regulated differently to make the regulations less burdensome. Even so, well water would need routine testing for bacteriological and chemical quality standards. BDM and WEB domestic water is regulated, and already meets all applicable standards. Therefore, the facility would not be responsible for complying with domestic water standards if it uses a municipal water supply, or one of the two rural water suppliers.

Hazardous Waste

Congress in 1976 passed the Resource Conservation and Recovery Act (RCRA), giving the EPA authority to regulate the management of industrial wastes. RCRA ensures that all industrial wastes are minimized and handled properly. If the wastes are not reused or recycled, they must be disposed of in a way that does not endanger public health or the environment. Regulations in South Dakota's Hazardous Waste Management Act are adopted by reference to 40 CFR Parts 260-279, and are no more stringent than the federal regulations. They are found in SDCL 34A-11, and ARSD 74:28.

To the greatest possible extent, the biomass-to-ethanol facility will reuse and recycle its process streams and treated waste streams. Hazardous wastes are not expected to be generated. The DENR must be notified if more than 200 pounds of hazardous waste is generated in one calendar month, however. The DENR will then send the facility a notice with an identification number, which will be required before shipping any wastes to a permitted hazardous waste facility.

SARA Title III

Congress in 1986 passed the Superfund Amendments and Reauthorization Act (SARA). Title III of SARA is also known as the Emergency Planning and Community Right to Know Act, which gives the public the right to know what chemicals are stored in their communities. State and local governments are also required to identify hazardous chemicals and to develop response plans for any releases of these materials in their area. Federal regulations concerning SARA Title III can be found in 40 CFR 300-355; SDCL 1-50 contains related state statutes.

Many provisions have been set forth which define reporting requirements for businesses which store any type of hazardous material. These provisions are beyond the scope of this report, although it is certain that the biomass-to-ethanol facility will be subject to reporting requirements for some raw materials and products (e.g., sulfuric acid).

Spill Reporting

South Dakota has a Regulated Substance Program which details the steps to be taken if a listed substance is spilled or released. This program was developed to reduce the potential that groundwater, surface water, or human health might be threatened. Laws that apply to releases and spills are SDCL 34A-12 and the ARSD 74:34. The ethanol production facility will be subject to these laws.

Underground Storage Tanks/Aboveground Storage Tanks

Congress in 1987 established regulations which apply to underground storage tanks. The South Dakota DENR administers the federal program, and has also included regulations for most aboveground storage tanks. Storage tank statutes can be found in SDCL 34-A-2-98, 99, 100, and 101. The ARSD 74:03:28, 29, and 30 outline the requirements for storage tanks. The facility will be subject to these laws, and will be required to register many of its tanks with the state.

Water and Wastewater Operator Certification

The proposed facility has a wastewater treatment system consisting of an anaerobic digester, an aerobic biotreater, and associated equipment. If the total BOD is higher than 85 pounds per day, the facility must employ a certified wastewater treatment operator. A voluntary certification program in place since 1954 was replaced by mandatory certification passed in 1970 by the South Dakota State Legislature. The intent of the laws, which are found in the ARSD 74:21:01-02 and in SDCL 34A-3, is to protect the owners' investment in their facilities, and to protect public health and environmental quality.

Water Quality Certification

To maintain, restore, and protect the nation's waters, Congress passed the Federal Clean Water Act of 1972. Many states also developed additional water quality standards. South Dakota's water quality certification program, which is sometimes called "401 certification," allows the state to verify that any activities that have the potential to exceed water quality standards or impact water quality are done in the least damaging practicable manner, and are in conformance with all requirements. Laws regarding water quality certification are found in SDCL 34A-2-33,34 and in the ARSD 74:03:02:55-57.

The biomass-to-ethanol plant has the potential to dump or discharge pollutants into the waters of the state, and therefore must comply with water quality standards. Since the law requires that a public notice period must precede any activity which requires a water quality certification, this function should be investigated early in the project to allow interested parties the chance to comment on the proposed project.

Environmental & Community Impact Issues

Wetlands

The source of much of the following wetlands information is a 1987 outdoor recreation plan from the South Dakota Department of Game, Fish, and Parks.[22]

The prairie wetlands area, found at the eastern edge of the remaining study area in Day County, plays an important role in water conservation, with many benefits for both urban and rural citizens. These benefits include the recharging of groundwater; stabilizing stream flows; support of commercial and sport fisheries; provision of a wildlife habitat; removing pollutants from the water by trapping sediments; and the storage of flood waters by slowing the migration of runoff into rivers and lakes. Wetlands also provide many annual outdoor recreational opportunities, including hunting, fishing, trapping, bird watching, photography, and boating.

The prairie wetlands provide cover for hundreds of game and nongame wildlife species, and is perhaps the most important wildlife habitat found in South Dakota. In the contiguous 48 states, 87% of the ducks breed in the prairie pothole states (Iowa, Minnesota, North Dakota, and South Dakota); of these four states, South Dakota is usually ranked number two in waterfowl production. The prairie pothole region is considered the most critical waterfowl breeding habitat in North America.

Because of urban, agricultural, and rural development, about 35% (700,000 acres) of the original South Dakota wetlands have been converted to other uses. More than 80% of those wetlands lost were east of the James River. The Coteau des Prairies, the Lake Dakota Plain, the James River, and the James River Lowlands are among the wetlands in the study area which are found on an EPA priority list for wetlands protection in South Dakota.

One goal of the South Dakota wetlands program is to protect and restore wetlands by increasing the number of wetlands that are already under state or federal ownership or control. Another goal is to reduce or eliminate drainage projects and to restore wetlands in selected wetland areas. The abundance of wetland areas in the study area provided some reasoning for excluding much of the eastern portions of Marshall and Day Counties for potential plant sites earlier in this task.

Wildlife/Threatened and Endangered Species

The recently submitted eastern South Dakota expressway feasibility study[19] lists the following species of birds as endangered in the area along Highway 12: the Least Tern, the Bald Eagle, the Peregrine Falcon, and the Eskimo Curlew. The Piping Plover is the only bird listed as threatened. One mammal identified as endangered is the Gray Wolf, and the only plant identified was the Western Prairie Fringed Orchid, which is a threatened species.

The referenced study was for an expressway connecting Aberdeen to Interstate 29. Since the proposed facility will only use a minute fraction of the area that the expressway would, and since the potential sites are primarily agricultural lands, it is unlikely that there will be a negative impact on these species.

Known Site Competing Uses

The Burlington Northern railroad runs through all of the selected properties. Except the westernmost site south of Groton, the potential sites are in agricultural areas, with no buildings on them. Within the James River valley, most areas are highly desirable for farmland. For many potential plant sites, conversion of prime farmland to industrial use will be required. This facility by its nature must be in an agricultural area, and few sites are suitable that do not contain farmland.

Site Zoning Restrictions

A conditional use permit may have to be obtained to allow agricultural products processing at the site. The project will conform to the land use plans and zoning ordinances of the city of Groton, Day County, or Brown County, depending on final site selection. Part of the site south of Groton is within the city limits, and is zoned for industrial use.

Residential Density

Part of the site in Section 30 of Groton Township is within the city limits of Groton. A significant concentration of residences are found in the area, although the plant site is on the opposite side of the railroad tracks. The city-owned portion of this land is zoned for industrial use, and no residences are on it. The site in Section 29 of Groton Township is farther away, about half a mile to the southwest of Groton.

The site in Section 4 of Andover Township is only about half a mile west of the small community of Andover. The residential density at the remaining five sites is extremely low, since they are all in an agricultural area on the slope leading up to the Coteau des Prairies.

Sensitive Nearby Receptors

Most of the potential plant sites are in more remote areas. Consequently, few sensitive receptors are found nearby. The two sites near Groton are close to a denser residential area, but are in areas zoned for industry or agriculture. The site just west of the town of Andover is not only close to the town, but two cemeteries are even closer. Other than previously mentioned, no historical landmarks, scenic views, parks, trails, recreational areas, schools, or churches have been found near any of the potential sites.

Other than Groton and Andover, most of the sites are in rural settings, and it is unlikely that the proposed biomass-to-ethanol facility will impose many negative impacts on these communities. While some dust, odors, and noise will be associated with the construction and operation of this facility, all emissions would be in conformance with the specific provisions of the required permits. If the top site selected is in proximity to a residential area, additional steps can be taken to reduce the impact. The preferred plant site would be east of any nearby towns or residences, taking advantage of prevailing wind patterns to reduce chances that dust, odors, or noise would migrate toward the towns. Fermentation processes can produce odors which may be noticeable but are generally not considered objectionable.

Water effluents from any one of the proposed facility sites would eventually make its way into Mud Creek, which then flows southwest until it joins the James River in Spink County. All discharged water would meet standards according to the conditions of the appropriate permits.

The size of the production facility may produce a negative visual impact for many residents. Plants at this scale are not common in this area, and the plant will overshadow the farms and small communities nearby.

An increase in traffic will be associated with the operation of this facility. Besides the transportation requirements for plant employees, increased truck traffic will be associated with the shipping and receiving of feedstocks, chemical raw materials, products, and coproducts. A major increase in the average daily traffic will be seen on the secondary road connecting the plant entrance to U.S. Highway 12. This road would likely need to be upgraded to service the facility. Since U.S. Highway 12 is already a major transportation corridor, the increase in average daily traffic on it will be low.

A facility such as a a biomass-to-ethanol plant would also have many positive impacts. Benefits would include increased availability of jobs in the area and improvement of utilities and community services. Other than the city of Aberdeen, most towns in the study area have been experiencing a steady decline in population in recent years. The city of Groton, for example, recognizes the potential benefits an industrial facility could bring, and welcomes new business ventures.

Subtask 3.5 - Evaluate and Rank Final Sites

Eight potential sites for a biomass-to-ethanol plant were identified in Subtask 3.2. For the purposes of further site evaluation, these eight sites will be more accurately described, and given a corresponding letter. Sites identified as A and B are near Groton in Brown County, and sites identified as C, D, E, F, G, and H are near Andover in Day County. The eight sites will be ranked in order of preference.

Description of Final Sites

Site A is in Sections 19 and 30 of Groton Township, due south and next to the city of Groton. Part of the site in Section 19, about 20 acres, is owned by Gerald Rix. A smaller portion is owned by the city of Groton. In Section 30, the ideal site may include portions of a 39.16 acre tract and a 117.64 acre tract which Marguerite Kronberger owns. The elevation of these properties is about 1,300 feet above sea level.

Site B is in Section 29 of Groton Township, about one-half mile southeast of the city of Groton. Mud Creek is flowing through the northwest corner of this property, which is a 130 acre tract owned by Kent and James E. Oliver. The land elevation is about 1,300 feet.

Site C is in Section 4 of Andover Township, about one-half mile due west of the town of Andover. A minor branch stream draining into Mud Creek crosses this property, which is a 155 acre tract owned by Schuring Farms. The land elevation is about 1,450 feet.

Site D is in Section 1 of Andover Township, about two miles east and one-half mile south of Andover. Minor branch streams drain this elevated land into Mud Creek. The tract is at an elevation of about 1,545 feet. Tract size is 257 acres and is owned by Petersen Farms.

Site E is next to and south of Site D, in Section 12 of Andover Township. It is a 149 acre tract of land, at an elevation of about 1,545 feet, and is owned by Ida Bingen. Drainage features are similar to those of Site D.

Site F is in Section 13 of Andover Township, about one and one-half miles east and two and one-half miles south of Andover. It is a 149 acre tract at an elevation of about 1,600 feet, and is owned by Randy Zimmerman. Minor branch streams drain this land into Mud Creek.

Site G is in Section 24 of Andover Township. The northeast corner of this property is adjacent to the southwest corner of Site F. The elevation is also at 1,600 feet, and it is a 309 acre tract owned by Raymond Olson. Drainage is the same as for Site F.

Site H is in Section 24 of Andover Township. It is due south of Site F and due east of Site G. The elevation of this land is about 1,600 feet and has the same drainage features as Sites F and G. This property is a 145 acre tract owned by Bradley Morehouse.

Since Sites D and E are adjacent, they are identical for all practical purposes. They will be considered as equal properties for purposes of site selection, and referred to as Site DE. Similarly, Sites F, G, and H are also adjacent and considered equal; they will collectively be called Site FGH.

Pros and Cons of Final Sites

Since all eight of the remaining sites meet most requirements of the proposed biomass-to-ethanol plant such as presence of a core railroad, a major highway, feedstock availability, natural gas, electricity, and drainage requirements, most issues that remain will involve environmental and local concerns. In this section, each site will be evaluated regarding its advantages and disadvantages. It was previously determined that the water supply would be a problem anywhere in the area, and this will be addressed accordingly.

Site A

One principal advantage of this site is the possibility of working with the city officials in Groton, who are interested in and committed to development. They are considering making improvements to their sewage treatment system, and it may be possible to work with them to construct a facility with enough wastewater treatment capacity for the city and the biomass-to-ethanol plant. In addition, Groton has switched its water supply from a city-owned well to WEB Water Development. Since then, the city has idled their artesian well, which can supply up to 413,000 gallons of water per day. This exceeds the current estimated plant requirements. The well is more than 1,000 feet deep, and draws water from the Dakota Aquifer.[23] Several opportunities exist for the city of Groton and a large processing facility to engage in mutually beneficial projects.

Another advantage is that part of the site is zoned for industrial use. It does not appear that zoning issues would present any problem on the adjacent lands that make up Site A. Other advantages include the proximity of drainage into Mud Creek, the increased availability of a nearby workforce (in Aberdeen and in Groton), and the general availability of utilities. Locations south and east of communities are also considered an advantage because prevailing wind patterns will carry odors or clouds of steam away from the city.

The James River drainage area encompasses all or part of 23 counties. It drains 12,609 square miles or over 8 million acres of land in South Dakota. This represents 16.3 percent of the total land in the state. The slope of the valley is .493 feet per mile and the average slope of the river is .280 feet per mile. The majority of the Basin lacks good drainage features. This is due to the slight variance in elevation and limited slope of the river. Much of its drainage is non-contributing and remains in small swales and basins. The concept of flooding in the James River Valley is unique. Its length, lack of significant gradient, and the meandering profile of the stream impede the movement of water. Because the river is so sluggish and the valley relief slight, flood water tends to spread out for great distances across farmland. Low lying areas fill up with water and remain through part or all of the summer.[24]

A major disadvantage of Site A is the fact that it is in the James River Basin, which is an area that is prone to periodic flooding. Floods could pose many problems for plant operation, including difficulty in getting feedstock to the plant. The majority of the flood damage is to roads, bridges and fences. Flood action can erode road shoulders and bridge approaches.[24] Though flood insurance is available as a mitigative measure, it does not remove an area from the dangers of flooding. Except flooding, other natural disasters (blizzards and winter storms, tornados, earthquakes, droughts and insects, or prairie fires) would pose an equal threat to all of the potential sites.

Another disadvantage of this site includes its proximity to the city of Groton. The proposed facility, with its large profile, will seem to overshadow the city. The visual impact will likely be uncomfortable for many residents. It may also be a disadvantage that the land required to make up this site is currently owned by three different parties, increasing the likelihood of all parties agreeing on the purchase.

Site B

While this site is not physically connected to Site A, it is only about a mile away. Consequently, the advantages and disadvantages are essentially the same. The elevation of both properties is about 1300 feet above sea level. Portions of both sites are less than ten feet above the elevation of Mud Creek. Some parts also appear on the flood insurance rate map.[20] It may be of some concern if the soils, due to the proximity of surface water, are not suitable for constructing foundations for large structures. One additional advantage that both sites have might be the fact that they are in Brown County. The Aberdeen Development Corporation, though primarily interested in projects in Aberdeen, is available to provide assistance anywhere in Brown County.[25]

Site C

Site C, has the advantage of increased drainage capability, because it is on the low end of the slope leading to the Coteau des Prairies. The elevation here is about 150 feet higher than that of Sites A and B.

Disadvantages of this site are the fact that it is west of the small town of Andover instead of the preferred east, and its visual impact upon local citizens. In addition, the Andover Cemetery and the All Saints Cemetery are both very close to this site.

Site DE

The elevation of this site is considered a major advantage. Though it is only about twelve miles east of Groton, this site is nearly 250 feet higher. Drainage from this area would flow down the slope to the Lake Dakota Plain below, meandering through both Andover and Groton. This site is more than two miles from the town of Andover, thereby reducing the possibility of a negative visual impact. In fact, the site is also about one-half mile off U.S. Highway 12, reducing the impact as seen by commuters. Since there are really two sites here, with separate owners, the chances of obtaining one of these properties will be increased.

The 1985 Food Security Act authorized the U.S. Department of Agriculture (USDA) to contract with private landowners to place their highly erodible and other environmentally sensitive cropland into permanent vegetation for a 10-year period in exchange for an annual rental payment.[26] Because one intention of the CRP Program was to protect highly erodible land, it is not surprising that the CRP density is higher in Day County, where the land is obviously more susceptible to erosion than in Brown County. These sites are visibly closer to the switchgrass feedstocks than the sites to the west, and this is a very important factor.

There are several disadvantages associated with this site. Road upgrades to the plant site will become a factor, due to the distance of the site from Highway 12. It was also noted that crop irrigation was being used in the area, raising the possibility that there may be a conflict with water rights with a nearby party.

Site FGH

Most advantages and disadvantages of this site are the same as for Site DE. The elevation is even higher; at 1600 feet, it is about 50 feet higher than Site DE, and more than 300 feet higher than the two sites near Groton. This site also has electrical transmission lines running directly across it. Domestic water from

WEB Water Development was observed nearby (about two miles south). Since this site is farther south than all of the other sites, this also places it closer to the high pressure natural gas lines.

This site would also require more road upgrades, as it is about one and one-half miles from County Road 27 and U.S. Highway 12. Also, the drainage from this area appears to go into a less desirable branch of Mud Creek, one that passes through Amsden Lake on its way to the James River. A State Water Access Area and a State Game Production Area are at Amsden Lake.[27] This is the only site where the surface waters pass through such an area, because the area immediately west of here is lacking any natural lakes. Since the site is more than four miles away from Amsden Lake, it would not necessarily prevent the facility from obtaining the Surface Water Discharge and Storm Water Permits.[17] However, if there is a potential problem with discharging to Amsden Lake, a pipeline or ditch constructed along the railroad could divert the water downhill toward Site DE, where the drainage is into a more preferred branch of Mud Creek.

Very little is known about storage capacity or permeability of the Dakota Formation as a whole and no known hydraulic or pumping tests have been performed in Day County. By far most of the Dakota wells are located in the James Basin region of Day County with very few found on the Coteau des Prairies because the wells on the highlands have to be pumped with a required water lift of 500 feet in places; in addition the permeability of the Dakota Formation decreases eastward with an increase of shale and silt in the material. Although data are scant, well yields can also be expected to drop toward the east as well.[9]

As mentioned earlier in this task, the water availability and quality must be carefully evaluated at any potential site due to the uncertainty of obtaining the desired product. It is not necessarily an advantage for the Groton site, for example, because of their existing well water supply. This is because holding a Water Rights Permit could be just as advantageous for the facility, and it also would not be subject to compensating Groton for the water used. Also, it is already known that the Groton well water is of poor quality.

Final Ranking of Sites

Broin & Associates' has determined that the most preferred site for a biomass-to-ethanol facility within the study area of Brown, Day, and Marshall Counties in northeast South Dakota is the site identified as Site DE.

The remaining sites are ranked in order of decreasing preference: Site FGH, Site B, Site A, and Site C. For any of these sites, however, much work would need to be done to ensure that the facility's water requirements would be met. Also, it is the possible that the owners of any one of these sites will not be interested in selling. Either of these factors could require the investigation of sites other than the preferred site.

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Appendix E

Refine Budgetary Capital and Operating Cost for Preferred Site (Task 4)

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SCREENING STUDY FOR UTILIZING FEEDSTOCKS GROWN ON CRP LANDS IN A BIOMASS TO ETHANOL PRODUCTION FACILITY

Task 4 - Refine Budgetary Capital and Operating Cost for Preferred Site

Subcontract No. ACG-6-16644-01
Prime Contract DE-AC36-83CH10093

Prepared by
American Coalition for Ethanol
&
Broin & Associates

for
United States Department of Energy's
National Renewable Energy Laboratory BioFuels Program

October 31, 1996

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

OCCURRENCE: TASK 4 - REFINE BUDGETARY CAPITAL AND OPERATING COSTS FOR PREFERRED SITE

Prepared by: Darwin VandenBerg, Sioux Falls, SD
& Rob Broin, Sioux Falls, SD
Date of Preparation: October 31, 1996

Subcontractor: American Coalition for Ethanol, Sioux Falls, SD
Subcontract Number: ACG-6-15019-01 under Prime Contract DE-AC36-83CH10093
Subcontracting Agency: National Renewable Energy Laboratory, Golden, CO

Preface

Brown, Marshall, and Day Counties in northeast South Dakota has had about 200,000 acres of cropland enrolled in the federal Conservation Reserve Program (CRP) in recent years. Bromegrass and Western switchgrass are currently planted on most of these CRP acres. Grasses such as Western switchgrass have been investigated as Herbaceous Energy Crops (HEC's).

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL), along with other institutions, has technology under development which is directed toward the economical production of fuel grade ethanol from biomass. HEC's such as Western switchgrass, grown on CRP acres, are being considered as economical sources of biomass.

The design for this facility has been modeled after the process described in a 1994 report prepared for NREL, titled "Biomass to Ethanol Process Evaluation," which was submitted by Chem Systems. Sizes and flows have been altered to reflect the change in product output; changes or departures made from the Chem Systems model will be discussed in the process area descriptions included in this report.

The objective of this paper is to review and refine the capital and operating costs for a biomass-to-ethanol production facility, which is proposed to be built on the site previously identified in Task 3. Major process equipment will be defined, and a $\pm$ 30% budgetary capital cost estimate accounting for direct and indirect costs will be presented. An operating cost estimate will be presented, also with an accuracy of $\pm$ 30%.

(It should be noted that the authors have taken some liberty in excising information from the cited references. This was done for the sake of brevity and with the understanding of the intent of this paper.)

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Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

TASK 4 - BUDGETARY CAPITAL AND OPERATING COST ESTIMATE

Process Description and Equipment Requirements by Area

Area 100: Switchgrass Handling and Milling

This area was by necessity changed from the Chem Systems design, due to the changing of the specified feedstock from wood chips to switchgrass. Most of the materials of construction in this area would be of carbon steel fabrication. Please refer to the Process Flow Diagram on Page 9 and the following text for a general description of this area and its operation:

Feedstock Delivery

Round bales of switchgrass (each bale weighs approximately 1,100 pounds) are delivered to the facility on trucks carrying 18 to 20 tons each. The trucks are weighed before and after delivery to determine the total delivered weight. A representative feedstock sample is taken to the facility laboratory and analyzed with a microwave moisture analyzer. The actual moisture content combined with the delivered feedstock weight will be used to figure out a fair payment to each individual producer based on the bone dry equivalent. A penalty should also be assessed, according to a previously and contractually defined structure, for moisture levels above 14%. The trucks empty their loads into the bale shed, which is large enough to store a 15-day supply of feedstock for the plant.

Round Bale Handling and Storage

A diesel powered forklift will be used to set the round bales of switchgrass feedstock on a chain drag conveyor that runs the length of the bale shed. Bales are used approximately in the same order in which they were received, limiting their duration in storage to no more than 15 days when the plant is in operation. The side walls of the building will be completely open to insure adequate ventilation. The drag conveyor transports the bales to one end of the bale shed and into the adjacent milling building. In an automated staging area, the bales are fed into the feed hopper of one of four identical shredding/ milling lines (three of which will be in operation at any given time).

Shredding, Milling, and Conveying

Each hopper is mounted above Mac Corporation Saturn Model 62-40HT primary shredders, which shred the bales into pieces 10-20 cm long[1] and discharge shredded switchgrass, twine, and foreign matter to conveyors (one for each line). Rock traps and magnetic separators installed in each of these conveyors remove rocks and foreign metal. Shredded switchgrass then passes through a secondary set of Mac Corporation Model 44-28HT Saturn shredders, which reduce the switchgrass to 2.5-6 cm long pieces.[1] Demonstration testing has proven that each line is capable of processing baled switchgrass at a rate of 6-8 tons per hour.[2]

The shredded switchgrass is then sent through ABB Raymond #63 air impact hammer mills. These mills would reduce the switchgrass to a 1-2 mm particle size. Dust collection equipment, particle size classifiers, and oversize particle return to the hammer mill are sized and supplied by ABB Raymond in compact units. The sizing of the impact mills should be regarded as a rough estimate only. ABB Raymond has said that they have never tested switchgrass in these mills. They recommend a full scale test in their test facility to learn what capacity they can achieve with the mill installed there; then they can scale up to the mills required to achieve the desired capacity.[3]

Milled switchgrass is moved by dilute phase pneumatic conveying equipment to a hopper/mixer which keeps the feedstock free-flowing and provides a homogenous mix. From the mixer, feedstock advances to a weigh belt feeder, and is then conveyed to Area 200 for pretreatment. A dust collection and baghouse system keeps dust in the area to a minimum. The dust that is collected is recycled back to the hopper/mixer for subsequent processing.

Area 200: Prehydrolysis

Most equipment and piping in the prehydrolysis area would be constructed of stainless steel, except where its use is prohibited by the corrosive action of sulfuric acid under high temperatures and pressures. Please refer to the Process Flow Diagram on Page 10 and the following text for a general description of this area and its operation:

Feed Preparation and Prehydrolysis

An on-line microwave moisture analyzer continuously measures the moisture content of the milled switchgrass from Area 100. This will allow a controlled value of bone dry equivalent feedstock to be delivered to the process. In a pug mill mixer, water and sulfuric acid are mixed with milled switchgrass. The sulfuric acid flow will be adjusted to maintain an acid concentration of approximately 0.85% of the total water present during prehydrolysis.

The mixture is discharged from the pug mill mixer into the first of two plug screw feeders, arranged in series, which are part of a prehydrolysis package from Sunds Defibrator. High pressure steam is added to raise the temperature to 374 degrees F. The process stream will exit the hydrolyzer system at a 30% total solids concentration, compared to 35% total solids in Chem Systems' report. Residence time is carefully controlled to an estimated four minutes. Capability to vary the temperature and residence time will be incorporated to allow the facility to optimize the conditions of the prehydrolysis process. This is necessary because the sugars will begin to degrade soon after they have been formed, resulting in low yields.

The Sunds Defibrator system was originally quoted for us with a 15 minute retention time and the wetted materials were of 316 stainless steel. Reducing the retention time reduces the size of the equipment and therefore the cost of the system. However, since Sunds Defibrator declined to revise their budget estimate for the new parameters, we are using the original prehydrolyzer estimate for the purposes of this study. This estimate may not be excessive for a smaller system, since the more realistic construction of carbon steel with zirconium 705 cladding would likely offset the savings which might be realized from smaller equipment.

Under the stated process conditions, constructing this equipment from 316 stainless steel is not prudent, because it is subject to severe corrosion in the presence of sulfuric acid. The service life of 316 stainless steel is estimated to be less than one year, and possibly as little as six months.[4] Process internals cannot be made from a clad material, and would have to be made from zirconium 705. The prehydrolyzed slurry is blown from the pressurized horizontal digester through a high pressure shutter type blow valve and into a flash/neutralization tank.

Flashing and Neutralization

Flashed steam is piped to the distillation area and condensed in a stripper column reboiler; the condensate contains contaminants (e.g., furfural) and is sent to the equalization tank in waste treatment (Area 800). Switchgrass slurry at 230 degrees F drops to the bottom of the flash chamber of the flash/neutralization tank, where it is continuously diluted with backset and recycled water, then drains into the lower sump of the flash/neutralization tank. Fifty percent calcium hydroxide slurry from a slaked lime/water slurry tank is also added to the lower sump. The slurry neutralizes most of the acids in the milled switchgrass slurry, and raises the pH to 5.0 to 5.5 for the cofermentation process (Area 300). The total solids concentration of the product stream leaving the flash/neutralization tank is maintained at 15 percent.

The neutralized hydrolyzate is cooled to 90 degrees F and pumped to batch fermenters. For a few hours out of each day as needed, the hydrolyzate stream will be diverted to fill seed fermenters for *Zymomonas mobilis* cultures (see Area 300) and to fill cellulase production batch fermenters for *Trichoderma reesei* cultures (see Area 400).

Area 300: Batch Simultaneous Saccharification and Cofermentation (SSCF)

The yearly 200 proof ethanol production level of 10 million gallons was based on an overall conversion efficiency of holocellulose to ethanol of 85.5%. Most process equipment and piping in this area would be constructed of stainless steel; however, the fermenters themselves will be constructed of carbon steel, which is adequate since the pH level should never fall below 5.0. The Process Flow Diagram on Page 11 and the following text generally describe the fermentation area and its operation:

Fermentation

Chem Systems' process design has been modified to provide for a simultaneous saccharification and cofermentation (SSCF) process operating in the batch mode. Saccharification of the pretreated cellulose from Area 200 with cellulase plus cofermentation of both the pentose and hexose sugars occurs while the mash resides in a single vessel. Broin & Associates' experience in the design, engineering, construction, and operation of fuel ethanol plants brings us to the conclusion that the benefits of batch fermentation outweigh any benefits of a continuous fermentation process. Continuous fermentation processes are susceptible to significant losses if the fermenters become contaminated. This is particularly important as the scale of the facility is increased, or if the fermentation rate is slow, as the case is here. In a batch operation, potential losses would be limited only to each fermenter which becomes contaminated.

Cellulase enzyme and accompanying broth from cellulase production (see Area 400) will be added to the mash in the fermenters. The mash would also be inoculated with a strain of the metabolically engineered, ethanol-producing bacterium *Zymomonas mobilis*. While *Z. mobilis* has been used as a natural fermentative agent for many years, it could only ferment hexose sugars until this strain was developed. The recently developed strain can ferment both pentose and hexose sugars. This xylose-fermenting *Z. mobilis* is capable of achieving high ethanol yield, productivity, and concentration.[5] Six 600,000 gallon carbon steel fermenters will provide up to five and one-half days of total fermentation time. The temperature of the fermenters will be closely controlled using chilled water or cooling tower water (depending on the season), circulating through coils inside each fermenter. The beer well is also constructed of carbon steel and is similar to the fermenters, except that it does not need cooling coils.

The vents of all six fermenters and the beer well are tied together and routed to a direct contact water scrubber. Fresh cold water flows down through the scrubber, picking up ethanol, other condensables, and entrained particles from the carbon dioxide. The scrubber water is sent to the distillation area to recover the ethanol, is used for part of the mash dilution, or goes to wastewater treatment for digestion and biogas production. The scrubbed carbon dioxide is piped to a purification and compression plant placed next to the ethanol plant. A third party would own the carbon dioxide plant. With this type of arrangement, the 96.4 tons per day (from Task 3, page 3) of carbon dioxide produced can be sold to the third party.

***Zymomonas mobilis* Seed Fermentation**

Four successively larger seed fermenters, the largest being 20,000 gallons, will be provided for sustaining a culture of *Z. mobilis*. A pH of 5.5 to 6.0 will be maintained to optimize cell growth over ethanol production.

Area 400: Cellulase Production

Most process equipment and piping in this area would be constructed of stainless steel. The Process Flow Diagram on Page 12 and the following text generally describe the cellulase production area and its operation, which is essentially the same as Chem Systems' model:

***Trichoderma reesei* Seed Fermentation**

The fungus *Trichoderma reesei* produces the enzyme cellulase, which necessary to complete the hydrolysis of cellulose from the pretreatment step. The simple sugars formed are then simultaneously fermented by *Z. mobilis*. Two trains of successively larger batch seed fermenters are used to propagate cultures of *T. reesei*. A 20,000 gallon sterile feed batch tank is used to blend hydrolyzate, recycle water, backset, and steam. Every two days this tank is pumped to one of two identical aerated cellulase batch fermenters, along with the contents of one of the batch seed fermenters.

Cellulase Batch Fermentation

For cellulase batch fermentation, two identical aerated fermenters are used, each with a staggered cycle time of four days. One fermenter is filled as described in the paragraph above, and the other fermenter is pumped to the cellulase holding tank every 48 hours. The cellulase holding tank, at 40,000 gallons, is sized for four days of cellulase storage.

Area 600: Distillation, Dehydration, and Centrifugation

Most of the process equipment and piping in this area would be constructed of stainless steel. The Process Flow Diagram on Page 13 and the following text generally describe the distillation, dehydration, and centrifugation area and its operation:

Distillation

Distillation is carried out in a continuous atmospheric binary distillation column. Because of the low concentration of ethanol in the beer, the stripper section is larger in diameter than the rectifying section of the column. The four to 6% by weight ethanol beer is first preheated with energy from the column overheads precondenser, then heated in an interchanger with the column bottoms to 190 degrees F. Heat to drive the column comes from three reboilers, one that condenses 200 proof ethanol, one that condenses the flash vapors from prehydrolysis, and one that condenses boiler steam. The required reflux ratio to achieve 190 proof ethanol will be approximately 5.2 to one.

Fusel oils and other fermentation byproducts are drawn off from the rectifying section, and purified by cooling, dilution, and phase separation. Concentrated fusel oils and other impurities are either added to the 200 proof for eventual sale as fuel ethanol, or sent to wastewater treatment for biogas production (see Area 800). Ethanol and water separated from the fusel oils and other impurities are recycled back to the rectifying section of the distillation column.

The 190 proof ethanol from the column overheads, after being condensed in an interchanger by beer from Area 300, is further cooled by supplying heat to the anaerobic digester and as required by cooling tower water. Most of the cooled 190 proof ethanol is used for column reflux.

Dehydration

The remaining 190 proof ethanol is revaporized and superheated before it enters the vapor phase molecular sieve. Condensing the 200 proof ethanol exiting the sieve provides part of the heat needed to drive the distillation column. The 200 proof ethanol is cooled and pumped to storage tanks (see Area 700). The regenerate stream from the sieve is recycled to the rectifying section of the distillation column.

Centrifugation

The still bottoms are cooled to 190 degrees F in an interchanger, and then pumped to a bank of three centrifuges, two of which are running at any given time. The whole stillage is centrifuged to remove and concentrate the lignin to a 40% solids cake. Approximately one-half of the centrate, or thin stillage, goes to Area 200 as backset. The remaining thin stillage is sent to the equalization tank in wastewater treatment (see Area 800).

The lignin cake will be blended with sludge from wastewater treatment, then loaded onto a truck or rail car for transport to a nearby recycle fuel burner. The total weight of the lignin fuel coproduct has been refined from Task 3, to an estimated 238 tons per day. The yearly fuel coproduct production would be about 78,540 tons per year, or approximately 3.9% of Big Stone Power Plant's annual coal burn. The total estimated dry weight of the combined solids fractions would be 544 pounds per ton of feedstock, or 190,400 pounds per day. The fuel (dry basis) contains 11,800 BTU per pound (from Task 1, page 2), and will be sold to a recycle fuel burner until a future cogeneration plant is built on the site.

Area 700: Tank Farm

Most process equipment and piping in this area would be constructed of carbon steel. The following text generally describes the tank farm operation, the design of which Broin & Associates' has considerable experience within the size range applicable to this facility:

A shift tank with one day's worth of 200 proof ethanol capacity is connected by piping to the distillation area. Each day, the ethanol is transferred to one of two large storage tanks. Following each transfer, gasoline from the denaturant tank is added to the ethanol storage tanks to reach a 5% denaturant concentration. Piping also connects a low proof ethanol storage tank, with enough capacity for two days, to the distillation area to compensate for different operational rates of the molecular sieve and distillation column.

Ethanol is shipped out by truck and by rail. Denatured fuel alcohol is produced at a rate of 31,898 gallons per day (from Task 3, page 3).

Area 800: Wastewater Treatment

Wastewater treatment is not an exact science, therefore the accuracy of most estimates are suspect. This facility is no exception. There are too many unknowns regarding the exact quantities, biodegradabilities, and number of species of organics which require treatment. Because of this, most wastewater treatment facilities are designed with considerable flexibility. Since first order reaction kinetics are generally applicable to the biodegradation process, one way to change the capacity of the system is to change the operating temperature.

The wastewater generated by this biomass-to-ethanol facility is, however, expected to be highly treatable. Lignin is a natural aromatic organic polymer which cannot be easily processed by wastewater treatment. While it is not very treatable, most of the lignin will be removed by centrifugation in Area 600. Much of the remaining wastes are of polysaccharide origin, resulting in high biodegradability.

Most process equipment and piping in this area would be constructed of carbon steel, with the treatment basins being of concrete construction. The Process Flow Diagram on Page 14 and the following text generally describe the wastewater treatment area and its operation:

Equalization Tank

Wastewater is collected in a 150,000 gallon equalization tank, which is sized for a 12 hour detention time. This vessel is used to sample and condition the wastewater before it is sent to the anaerobic digesters. If necessary, anhydrous ammonia is added to provide nitrogen for the microorganisms in the digester. The pH is also controlled; if the alkalinity of the wastewater going into the treatment system is too high, the bacteria will form more organic acids and carbon dioxide, and less methane.

Phosphorus and other trace elements necessary for efficient biological operation of the wastewater treatment process are monitored and adjusted as required. Equalized wastewater flows to the anaerobic treatment system.

Anaerobic Digestion

Anaerobic treatment is accomplished in an anaerobic reactor sized for 90% reduction of the biochemical oxygen demand (BOD) using a 30 day detention time. The reactor has a capacity of about 7.8 million gallons (205' x 205' x 28' total depth, including a 3' headspace). It is divided into two separate cells, which can be operated in parallel, series, or individually to meet the requirements of the facility. It is expected that the anaerobic treatment will be conducted in the mesophilic temperature range of 85-100 degrees F. Additional capacity, if required, could be realized by operating the reactor in the thermophilic range of 120-130 degrees F. The heating requirements in Area 800 will be provided for with a closed loop system, using energy obtained from the condensation of distillation column overheads in Area 600.

The reactor is covered by a 42,025 square foot membrane cover. Biogas generated in the reactor is collected under the membrane cover and is sent to the facility boiler at low pressure. Roughly 62.5% of the biogas is methane, which contains 960 BTU per cubic foot. The amount of methane generated is estimated at 1,036,202 cubic feet per day, which would provide about 41.45 million BTU per hour for the facility boiler. Using a density of 0.7168 g/L, the methane generated calculates out to be 1932 pounds per hour, or about 132.5 pounds per ton of bone dry feedstock. Note that these figures have been refined from the Task 3 figures based on more recent and complete analysis.

The sludge production estimate from the anaerobic digester has also been refined. The estimate of waste solids (dry basis) produced is about 16,433 pounds per day (684.7 pounds per hour, or about 47 pounds per ton of feedstock). Waste solids are drawn off from the digester(s) as a sludge containing 3-5% solids. The sludge is centrifuged to produce a 40% solid waste which is blended with the lignin from Area 600. The centrate is pumped to the aerobic treatment system.

Aerobic Treatment

The effluent from the anaerobic digester will be further treated by the extended aeration activated sludge process. The aerobic reactor is sized at about 2.6 million gallons for 90% reduction of the BOD with a 10 day detention time (140' x 140' x 21' total depth, including a 3' headspace). It is also constructed with two cells to lend flexibility to the process. The aeration equipment which supplies oxygen to the process is also sufficient for mixing requirements.

Two activated sludge sedimentation tanks, or clarifiers, are provided for system flexibility. Each 30' diameter sedimentation tank is sized for an upflow velocity of 400 gallons per square foot per day. Biological solids are dropped out in these sedimentation tanks. Some of these solids are returned to the aeration reactor as Return Activated Sludge (RAS), which keeps the reactor inoculated. The remaining portion of the solids are sent to the anaerobic reactor as Waste Activated Sludge (WAS). Much of the WAS is biological cell mass and is decomposed in the anaerobic reactor. An estimated 6320 pounds per day (dry basis) of WAS should contribute about 632 pounds per day of the total waste solids removed from the anaerobic reactor.

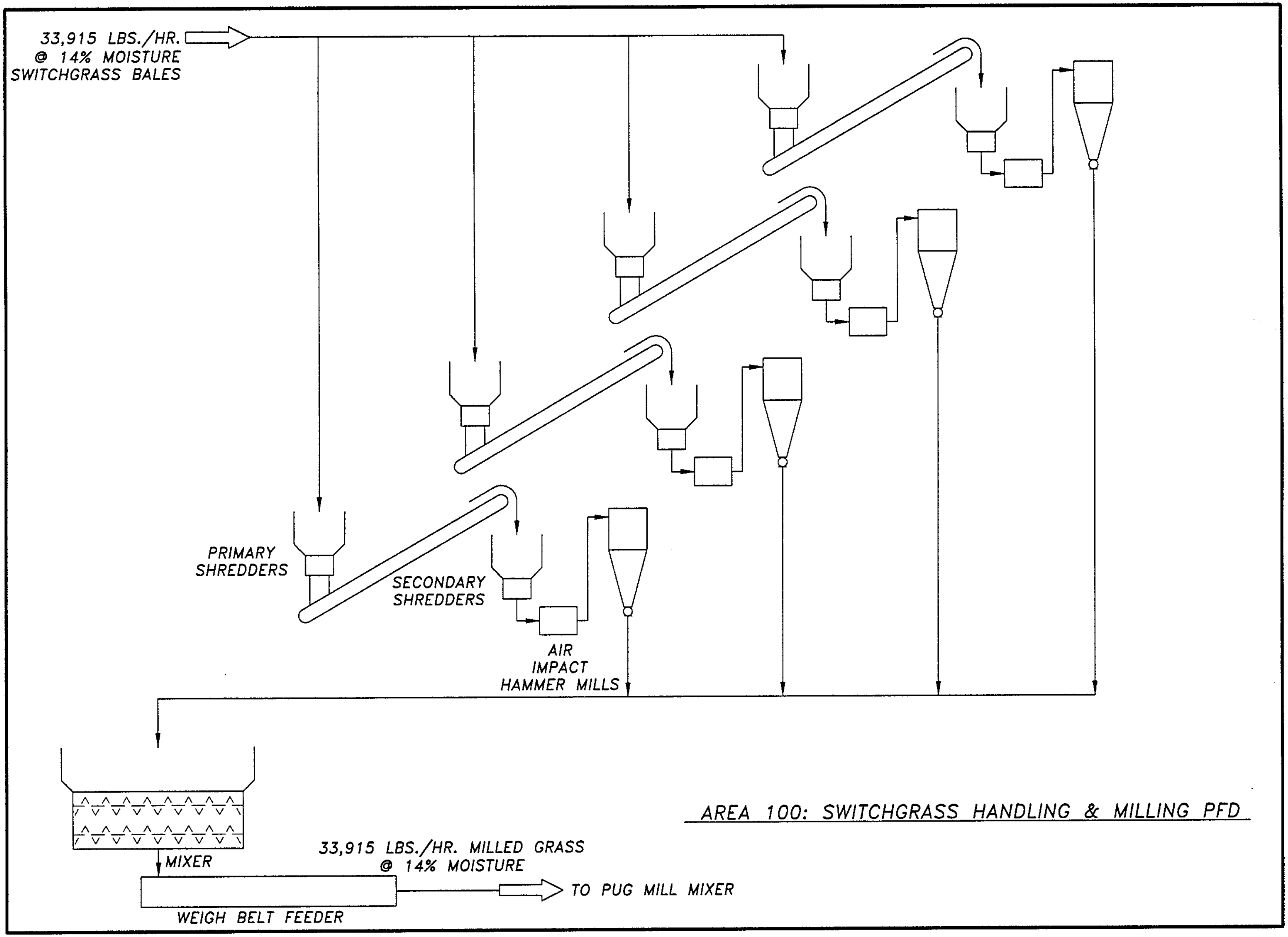
Most of the clarified effluent from the aerobic treatment system will be recycled back to the plant. Any treated water which is not recycled is discharged to surface waters. For the proposed site, the effluent would find its way into Mud Creek via numerous minor branch streams. Consideration should be given to the construction of a future holding pond for the effluent. As previously discovered in Task 3, water supplies are difficult to develop within the study area. Therefore, a holding pond would provide a valuable source of irrigation water for local crop producers.

Area 900: Mechanical Equipment and CIP

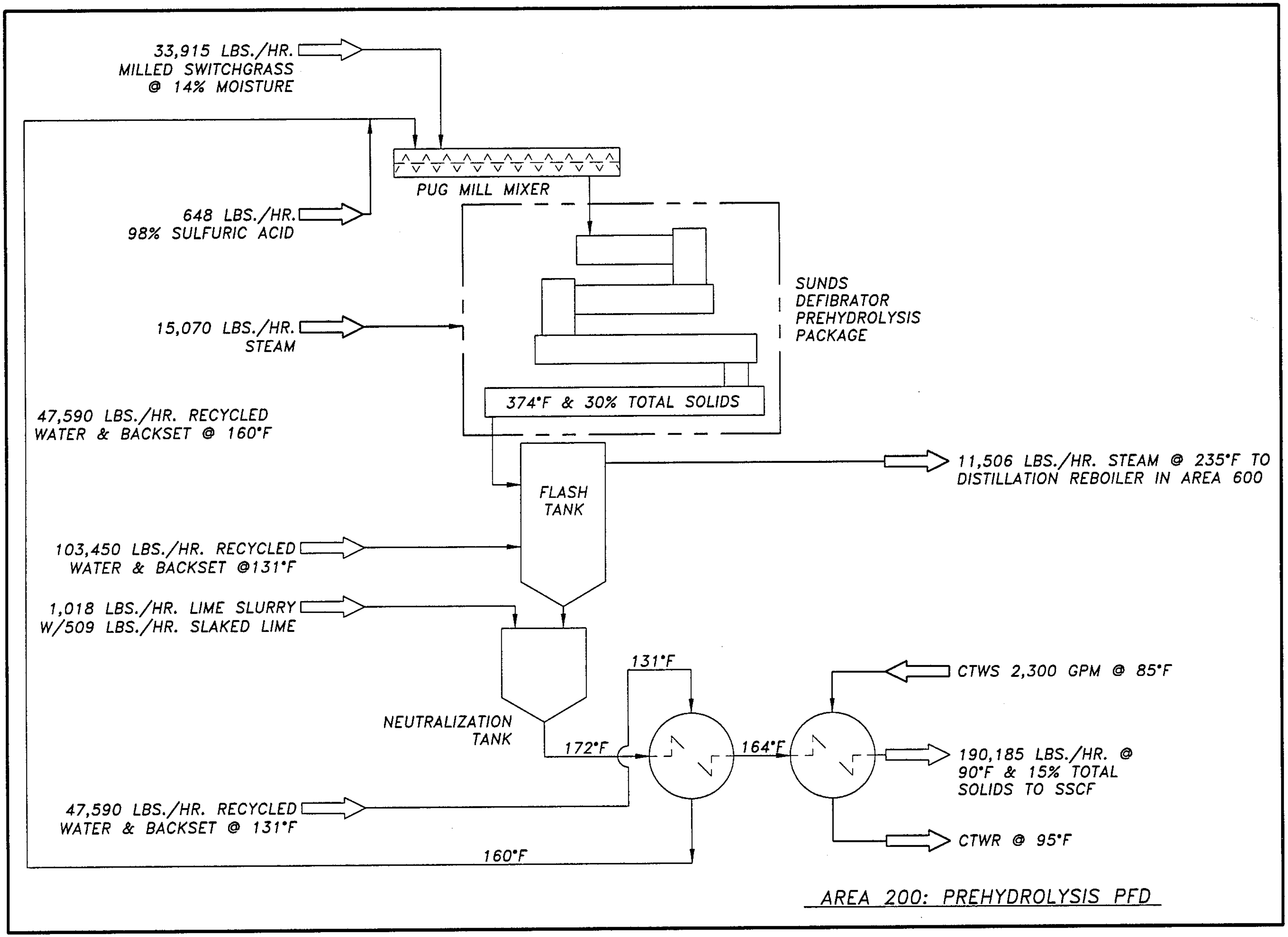
Steam for the process and for building heat will be provided by a gas fired, 250 psig water-tube boiler. Fuel for the boiler will come from three sources, the main source being biogas which is generated by the anaerobic reactor in Area 800. The methane portion of the biogas could supply 41.45 million BTU per hour to the boiler, or about 86.4% of the total projected fuel requirement of 48 million BTU per hour. Natural gas will be used when there is not enough biogas to meet the demand. Economics dictate that a backup propane system be installed to provide fuel when the gas utility interrupts the natural gas service.

Domestic water will be provided by a connection to WEB Water Development's supply system. A well will be developed to supply process water to the facility. A reverse osmosis system will purify the well water for use as make-up water in the boiler and cooling towers. Counter-flow cooling towers and a centrifugal chiller will provide process cooling. Chilled water will only be used when required, typically in the warm summer months. Rotary screw air compressors with refrigerated dryers and various filters will provide air for instrumentation, fermentations, and utility uses. Other mechanical equipment includes a fire pump and sprinkler system, boiler and water treatment equipment, and clean-in-place (CIP) equipment.

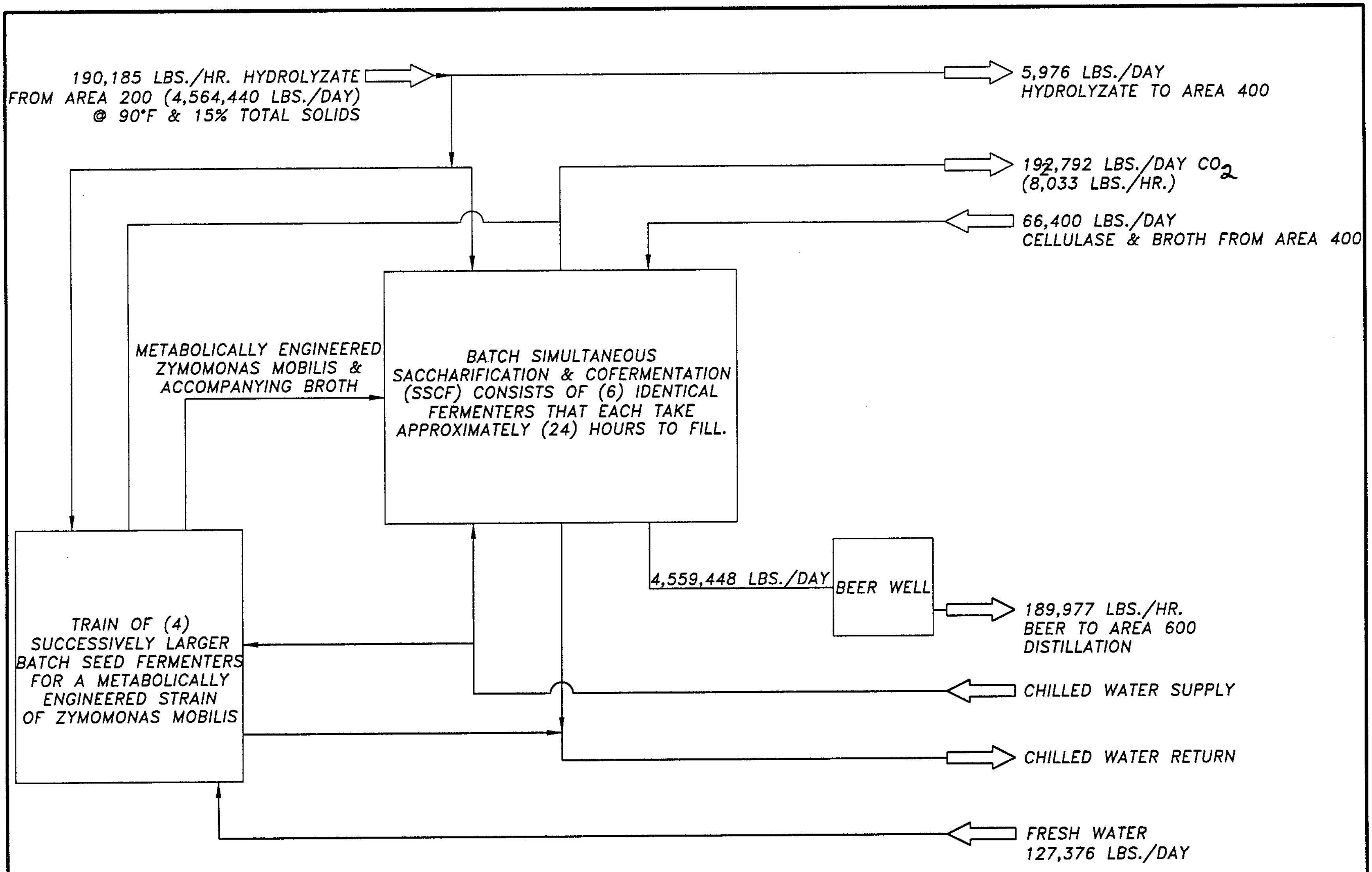
Provisions have been made for an annex to the mechanical room to house cogeneration equipment at a future date. Once the SSCF process technology has been proven at this commercial scale, the added cogeneration plant would meet the plant requirements for steam and electricity. Excess electricity produced would be sold to the electric utility. The lignin coproduct would be used as the fuel for the cogenerator. In the interim, the lignin coproduct is to be used as fuel at Otter Tail Power Company's Big Stone Power Plant near Milbank, Grant County, South Dakota, about 70 miles east of the biomass-to-ethanol plant site.



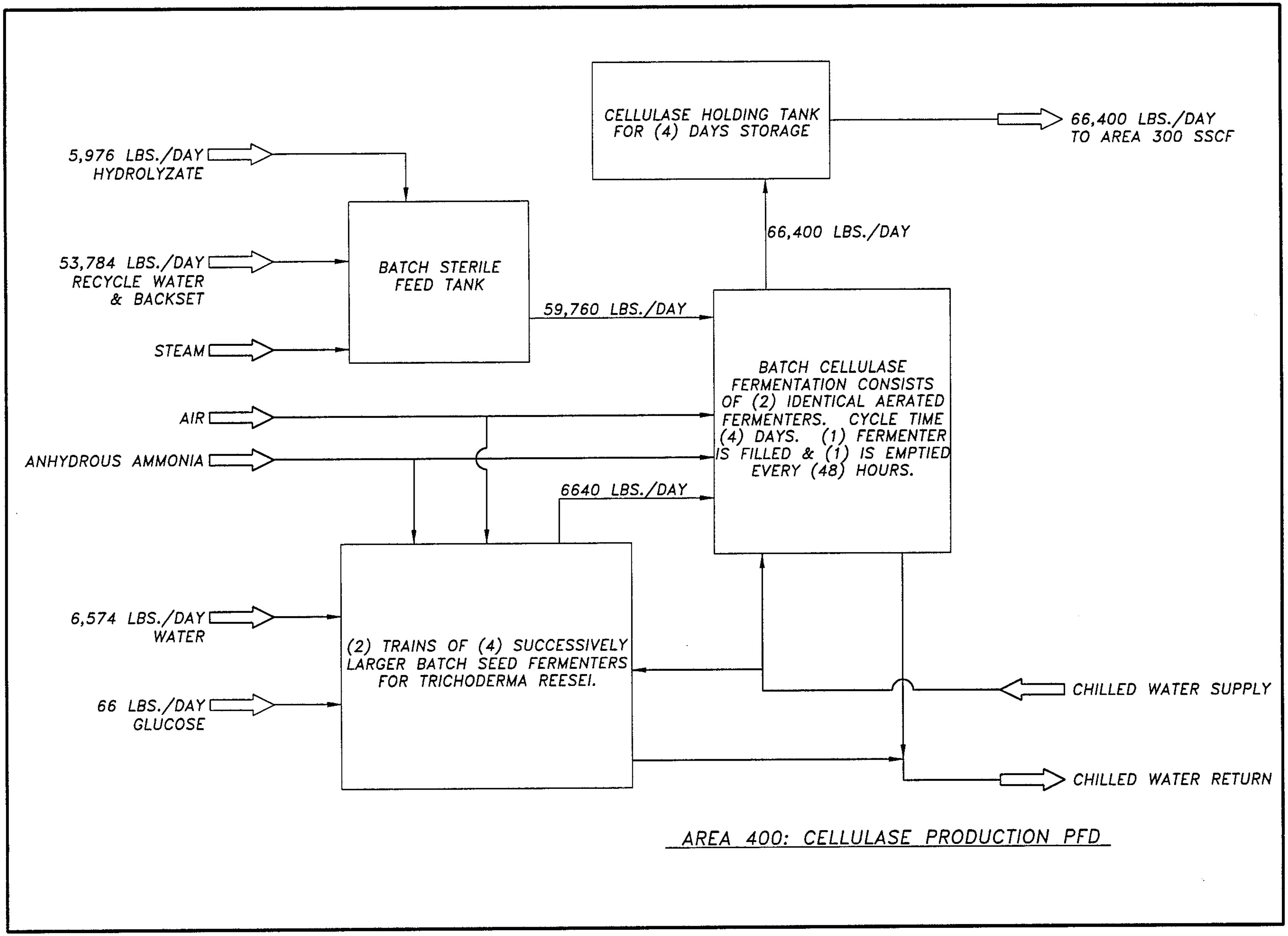
AREA 100: SWITCHGRASS HANDLING & MILLING PFD



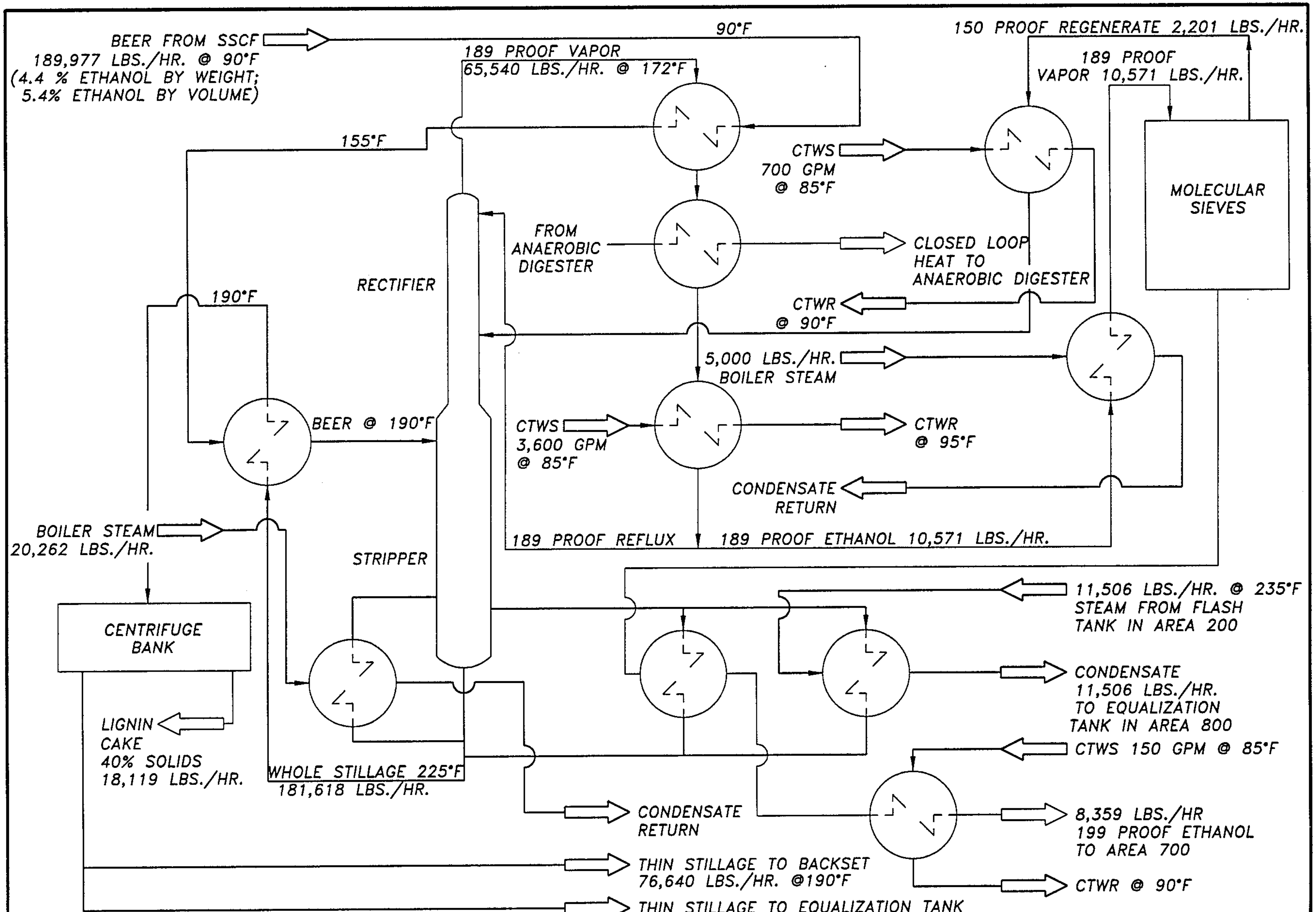
AREA 200: PREHYDROLYSIS PFD



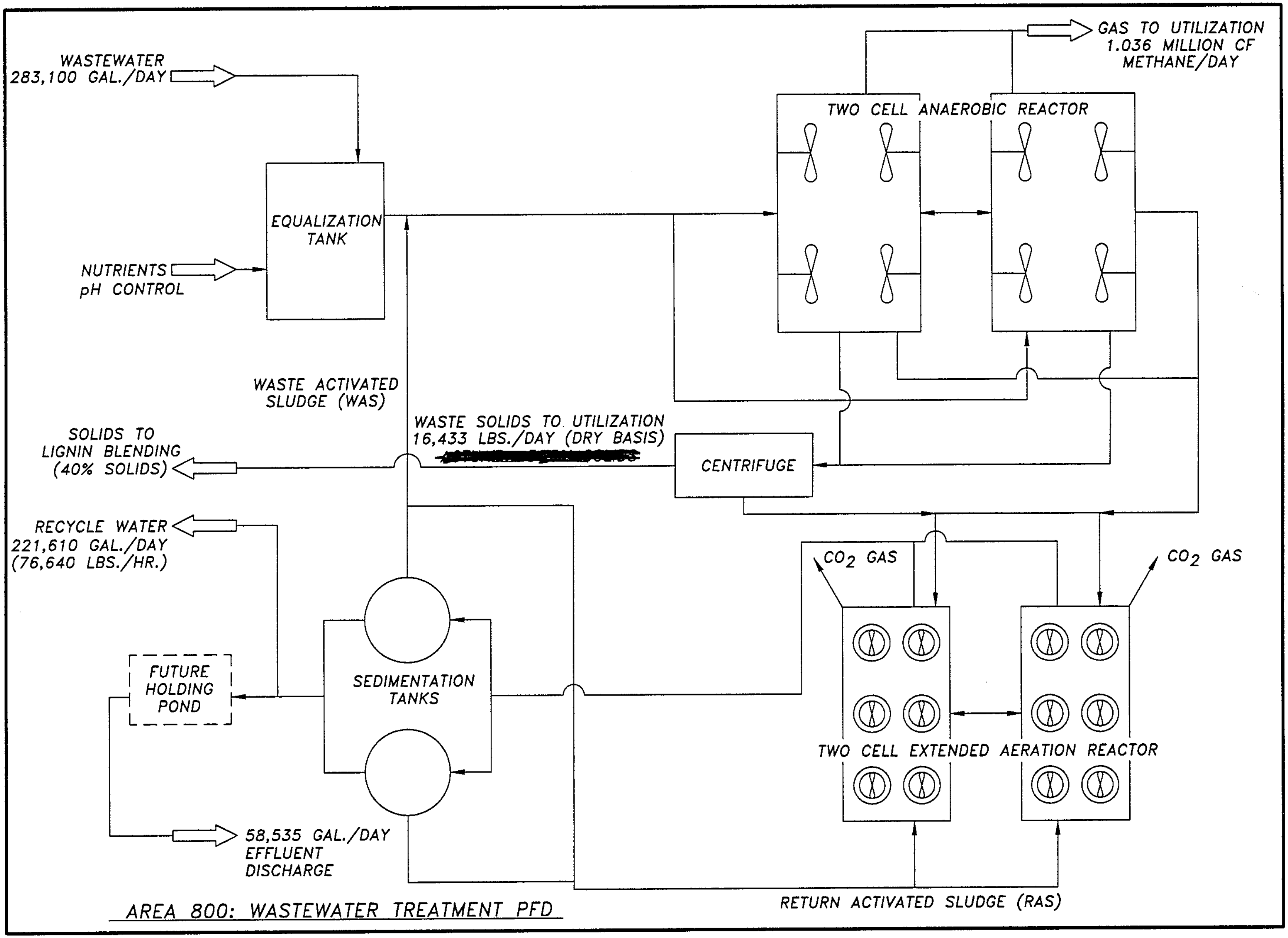
AREA 300: BATCH S.S.F. FERMENTATION PFD



AREA 400: CELLULASE PRODUCTION PFD



AREA 600: DISTILLATION, DEHYDRATION, & CENTRIFUGATION PFD



AREA 800: WASTEWATER TREATMENT PFD

Recommendations for Additional Investigations

Milling Methods

Before the hydrolysis step, biomass is first reduced in size to decrease heat- and mass-transfer limitations.[1] The milling process is energy intensive, and overall process economics would improve significantly if the milling requirements could be reduced. Future investigations and advancements in processing methods may warrant reevaluation of the milling requirements before this plant is built.

Prehydrolysis Equipment and Processes

Broin and Associates feel that alternatives to the Sunds Defibrator horizontal hydrolyzer system should continue to be evaluated. Simplifying the internals would greatly reduce the system cost. However, any such equipment must provide adequate agitation to allow saturated steam to penetrate the entire cross section of the plug material flow to ensure a uniform cook. Alternatives to sulfuric acid, such as nitric acid, should also be investigated.

The process of ammonia fiber explosion (AFEX) should also continue to be evaluated as it applies to switchgrass processing. AFEX pretreatment has been demonstrated to markedly improve the saccharification rates of numerous herbaceous crops and grasses.[6] Hydrolysis of the holocellulose has been reported at more than 90% of the theoretical yield. A distinct advantage of this pretreatment method is that the prehydrolysis equipment could be constructed of much more conventional materials, possibly even carbon steel. Another advantage would be that the effect of some components that inhibit fermentation (e.g., acetic acid) would be reduced. Because it is the protonated form of the acid that is inhibitory, the toxicity of acetic acid increases at lower pH.[7]

Neutralization Methods

We strongly suggest that alternatives to the use of calcium oxide or calcium hydroxide be evaluated. The formation of the practically insoluble salt calcium sulfate from the neutralization process will cause many problems including solids buildup in the fermenters, fouling of heat exchange surfaces, and handling and disposal concerns. For example, the use of anhydrous ammonia for neutralization would result in the formation of ammonium sulfates, which are quite soluble in water. The use of sodium hydroxide would yield sodium sulfate salts, which are also much more soluble than calcium sulfate.

Another alternative, which was previously mentioned, is to use nitric acid in the prehydrolyzer instead of sulfuric acid. With nitric acid, calcium hydroxide could continue to be used for neutralization, since the resulting salt, calcium nitrate, is soluble in water. Sodium and ammonium nitrates are also quite soluble in water. For the purposes of this study, the use of sulfuric acid and calcium hydroxide was retained, since at this time it is not clear what the net effect of alternate acid/base combinations would be on the fermentation process.

Other Uses for Lignin

There are some alternatives to the use of lignin as fuel which may be evaluated, including its use as a raw material for the production of other chemicals. Lignin can be used as a source of vanillin, syringic aldehyde, and dimethyl sulfoxide. It has been used as an extender for phenolic plastics, to strengthen rubber (especially for shoe soles), as an oil mud additive, to stabilize asphalt emulsions, and to precipitate proteins.[8]

Capital Cost Estimate

Our capital cost estimate for major process equipment for the biomass-to-ethanol production facility is \$14.781 million, with an accuracy of ±30%. Please refer to TABLE 1 - BIOMASS TO ETHANOL FACILITY ESTIMATED COSTS BY AREA, on Page 17, for a list of the major equipment in each of the process areas previously discussed in this report. The estimates for each item listed are from vendor budget quotations and/or our own current and previous experience in the design, engineering, construction, operation, and maintenance of fuel ethanol plants with capacities ranging up to 15 million gallons per year.

The total cost estimate, with an accuracy of ±30%, for the fuel ethanol facility is \$40,496,160. A breakdown of the costs for different project areas can be found on Page 19, in TABLE 2 - BIOMASS TO ETHANOL FACILITY ESTIMATED DEVELOPMENT COSTS. This estimate is inclusive of all costs for the entire facility, including all direct costs and indirect costs requested for Task 4. The only exceptions, which are not included, are for "soft" costs such as business development costs, business operation costs during construction, financing costs, interest during construction, etc.

TABLE 1 - BIOMASS TO ETHANOL FACILITY ESTIMATED EQUIPMENT COSTS BY AREA

AREA 100 GRASS HANDLING AND MILLING

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	ESTIMATED COST	
Forklift	--	--	1	$47,000	$47,000	
Payloader	--	--	1	$85,000	$85,000	
Chain conveyor and staging equipment	150	32 bales/hr.	1	$280,000	$280,000	
Saturn Model 62-40HT Shredder	200	6 ton/hr.	4	$166,000	$664,000	
Conveyor with rock trap and magnet	20	6 ton/hr.	4	$11,000	$44,000	
Saturn Model 44-28HT Shredder	100	6 ton/hr.	4	$94,500	$378,000	
ABB #63 Impact Mill system	200	6 ton/hr.	4	$375,000	$1,500,000	
Pneumatic conveying system	75	18 ton/hr.	1	$30,000	$30,000	
Large capacity mixer	20	4 ton	1	$28,000	$28,000	
Weigh belt feeder	20	18 ton/hr.	1	$20,000	$20,000	
	SUB-TOTAL:					$3,076,000

AREA 200 PREHYDROLYSIS

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	COST	
Pug mill mixer	150	18 ton /hour	1	$45,000	$45,000	
Sunds Defibrator Pre-hydrol. System	1760	350 BDT/D	1	$3,445,000	$3,445,000	
Flash and neutralizing vessel & pump	50	12,000 gal.	1	$33,000	$33,000	
Lime storage, mixing, metering system	80	75 ton	1	$65,000	$65,000	
Sulfuric acid storage, metering system	2	15,000 gal.	1	$45,000	$45,000	
Recycled water tank and pump	25	100,000 gal.	1	$65,000	$65,000	
Hydrolyzate - water interchanger	0		1	$70,000	$70,000	
Hydrolyzate coolers	0		1	$110,000	$110,000	
	SUB-TOTAL:					$3,878,000

AREA 300 BATCH SSCF (SIMULTANEOUS SACCHARIFICATION AND COFERMENTATION)

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	COST	
C.S. batch fermenter w/ mixer, coils, and cleaning system	75	600,000 gal.	6	$217,000	$1,302,000	
C.S. Beer well with mixer, cleaning system	75	750,000 gal.	1	$232,000	$232,000	
Fermenter transfer pump	100	--	1	$14,000	$14,000	
Seed fermenter w/ mixer and coils	10	20,000 gal.	1	$32,000	$32,000	
Seed fermenter transfer pump	10	--	1	$4,000	$4,000	
Smaller seed fermenter set & rel. items	15	--	1	$30,000	$30,000	
CO2 scrubber system	2	--	1	$27,000	$27,000	
	SUB-TOTAL:					$1,641,000

AREA 400 CELLULASE PRODUCTION

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	COST	
SS fermenter w/ mixer, pump, H.E., cleaning system	25	20,000 gal.	2	$48,000	$96,000	
Smaller seed fermenter set & rel. items	25	--	2	$35,000	$70,000	
Sterile feed tank, mixer, pump	25	20,000 gal.	1	$40,000	$40,000	
Cellulase hold tank, mixer, pump	25	40,000 gal.	1	$60,000	$60,000	
Other miscellaneous tanks, equip.	50	--	1	$160,000	$160,000	
	SUB-TOTAL:					$426,000

AREA 600 DISTILLATION, DEHYDRATION, CENTRIFUGATION

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	COST
S.S. binary distillation column for 5% beer			1	$235,000	$235,000
Beer feed, stillage, reboiler,and reflux pumps	225		1	$42,000	$42,000
Binary condenser(1) and pre-condensers(2)			1	$155,000	$155,000
Binary re-boilers(3)			1	$320,000	$320,000

TABLE 1 - BIOMASS TO ETHANOL FACILITY ESTIMATED EQUIPMENT COSTS BY AREA (CONT.)

AREA 600........(continued)

Beer stillage interchanger			1	$71,000	$71,000	
Fusel decanter system	2		1	$9,000	$9,000	
190 run-down vessel			1	$5,500	$5,500	
Vapor phase molecular sieves (3)			1	$84,000	$84,000	
Sieve regen condenser			1	$24,000	$24,000	
Sieve vaporizer			1	$15,500	$15,500	
Sieve miscellaneous heat exchangers			1	$7,000	$7,000	
Sieve system pumps(3)	18		1	$9,500	$9,500	
Sieve system miscellaneous vessels			1	$9,000	$9,000	
Vent scrubber and pump	2		1	$11,000	$11,000	
Horizontal bowl decanter centrifuge	250	200 gpm	3	$630,000	$1,890,000	
Thin stillage receiver and pump	30		1	$13,000	$13,000	
Material handling system for piling lignin	50	13 ton/hr.	1	$44,000	$44,000	
Lignin load-out system	40	80 ton/hour	1	$46,000	$46,000	
Diesel loader			1	$80,000	$80,000	
	SUB-TOTAL:					$3,070,500

AREA 700 ETHANOL TANK FARM

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	COST	
Low Proof Tank		60,000 gal.	1	$36,000	$36,000	
Ethanol Shift Tank		39,000 gal.	1	$21,000	$21,000	
Denatured Ethanol Tank		175,000 gal.	2	$89,000	$178,000	
Denaturant Tank		16,000 gal.	1	$9,500	$9,500	
Pumps and load-out equipment	45	--	1	$41,000	$41,000	
	SUB-TOTAL:					$285,500

AREA 800 WASTEWATER TREATMENT

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	COST	
Equalization tank, mixer , and pump	35	150,000 gal.	1	$172,000	$172,000	
Mixers for Anaerobic Reactor	25		8	$18,750	$150,000	
Aeration Equipment	60		12	$25,000	$300,000	
Mechanisms for Sedimentation Tanks	20		2	$20,000	$40,000	
Sludge centrifuge and related equip.	60		1	$250,000	$250,000	
	SUB-TOTAL:					$912,000

AREA 900 MECHANICAL EQUIPMENT AND CIP

DESCRIPTION	H.P.	CAPACITY	QUAN.	EST. PRICE	COST	
250 psi Water Tube Boiler & related equip.	150	60,000 lb./hr.	1	$460,000	$460,000	
Counter-flow cooling tower	120	3,500 ton	1	$190,000	$190,000	
Cooling tower pumps	150	3,000 gpm	3	$14,000	$42,000	
Centrifugal Chiller	360	500 ton	1	$79,000	$79,000	
Compressed air equipment	190	750 cfm	1	$56,000	$56,000	
CIP system tanks, pumps, and rel. equip.	50		1	$56,000	$56,000	
Water filtration and R.O. equipment	100		1	$260,000	$260,000	
Chemical water & boiler treatment equip.	2		1	$18,000	$18,000	
Propane system, Air-gas Mixing	25		1	$81,000	$81,000	
Fire pump and sprinkler system	200		1	$240,000	$240,000	
Water supply pumps	50		1	$10,000	$10,000	
	SUB-TOTAL:					$1,492,000
		TOTAL EQUIPMENT:				$14,781,000

OTHER ELECTRICAL REQUIREMENTS

DESCRIPTION	H.P.	QUAN.
Well pump	60	1
Miscellaneous small motors	300	1

TABLE 2 - BIOMASS TO ETHANOL FACILITY ESTIMATED DEVELOPMENT COSTS

100 SITE AND IMPROVEMENTS			$2,792,100
110 LAND		$120,000	
130 SURVEYING , SOIL BORING, SITE ENGINEERING		$79,000	
131 Topographical survey	$9,500		
132 Other surveying and locating costs	$9,000		
133 Soil borings and geotech report	$9,000		
134 Soil testing services during constr.	$6,500		
135 Site engineering and bid documents	$45,000		
140 SITE WORK		$1,955,000	
Excavation, fill, roads, fire water mains, sewer lines, septic system, etc.	$830,000		
Excavation for Wastewater Treatment			
Anaerobic Reactor 100,000 yd.	$750,000		
Aerobic Reactor 50,000 yd.	$375,000		
145 TOWNSHIP ROAD IMPROVEMENTS		$65,000	
150 WELL, 250 GPM, 1400 FT. DEEP		$154,600	
151 WATER STORAGE TANK		$118,000	
152 DOMESTIC WATER SUPPLY CONNECTION		$20,000	
154 NATURAL GAS CONNECTION CHARGES		$2,500	
160 RAIL SPUR, SIDINGS, SWITCHES, ETC.		$245,000	
170 SITE SECURITY FENCES, GATES, ETC.		$23,000	
190 OTHER SITE IMPROVEMENT COSTS		$10,000	
200 BUILDINGS, CONCRETE, AND STRUCTURES			$7,198,050
210 CONCRETE			
Office Building 36' x 100' x 12'	90 yd.	$36,000	
Mechanical Building 70' x 120' x 20'	315 yd.	$97,650	
Process Building 116' x 240' x 50'	1,300 yd.	$422,500	
Lignin Building 60' x 100' x 30'	325 yd.	$123,500	
Milling Shed 120' x 140' x 30'	440 yd.	$110,000	
Bale Shed 260' x 500' x 24'	2,600 yd.	$650,000	
Distillation Building 24' x 45' x 58'	135 yd.	$58,050	
Outdoor Pipe Racks	20 yd.	$8,500	
Miscellaneous Concrete and Structures	140 yd.	$59,500	
Cooling tower sump, Outdoor tanks, etc.			
220 BUILDINGS (INCL. MAS., CPNPTRY, DOORS, ETC.)			
Office and Lab Building 36' x 100' x 12'	3,600 s.f.	$162,000	
Mechanical Building 70' x 120' x 20'	8,400 s.f.	$176,400	
Process Building 116' x 240' x 50'	27,840 s.f.	$543,400	
Lignin Building 60' x 100' x 30'	6,000 s.f.	$138,000	
Milling Shed 120' x 140' x 30'	16,800 s.f.	$235,200	
Bale Shed 260' x 500' x 24'	130,000 s.f.	$1,170,000	
Distillation Building 24' x 45' x 58'	1080 s.f.	$64,800	
250 STRUCTURAL STEEL AND MILLWRIGHT		$1,400,000	
270 WASTEWATER TREATMENT BASINS			
271 Concrete Anaerobic Reactor	3,100 yd.	$1,085,000	
272 Anaerobic Basin membrane roof	42,025 s.f.	$84,050	
275 Concrete Aerobic Reactor	1250 yd.	$437,500	
276 Concrete Sedimentation Tanks (2)	180 yd.	$63,000	
290 TRUCK SCALE		$73,000	

TABLE 2 - BIOMASS TO ETHANOL FACILITY ESTIM. DEVELOPMENT COSTS (CONT.)

300 MECHANICAL				$2,732,000
310 PIPING AND VALVES			$585,000	
311 Pre-fabricated pipe		$230,000		
312 Small pipe and fittings		$85,000		
315 Manual valves		$98,000		
316 Control valves		$92,000		
317 XV valves		$35,000		
318 Safety valves and discs		$45,000		
320 HVAC, PLUMBING, AND UNDERGROUND PIPING			$182,000	
330 PROCESS AND MECHANICAL PIPING CONTRACT			$1,050,000	
335 WASTEWATER MILLWRIGHT AND MECHANICAL			$425,000	
340 PIPE AND VESSEL INSULATION CONTRACT			$215,000	
370 FIRE SPRINKLER SYSTEM, PUMP, ETC.			$275,000	
400 PROCESS, MECHANICAL, AND INVENTORY EQUIPMENT				$14,781,000
100 GRASS HANDLING AND MILLING			$3,076,000	
200 PREHYDROLYSIS			$3,878,000	
300 BATCH SSCF (SIMULTANEOUS SACH. AND CO-FERMENTATION)			$1,641,000	
400 CELLULASE PRODUCTION			$426,000	
600 DISTILLATION, DEHYDRATION, CENTRIFUGATION			$3,070,500	
700 TANK FARM			$285,500	
800 WASTE TREATMENT			$912,000	
900 MECHANICAL EQUIPMENT AND CIP			$1,492,000	
500 ELECTRICAL	CONNECTED H.P.:	9,548	$235/h.p.	$2,243,780
Mains, panels, MCC's, VFD's, transformers				
Materials, conduit, wire, disconnects, etc.				
Lighting, receptacles, communications wiring				
Instrumentation and control system wiring				
Labor and equipment costs				
Fire alarms, emergency lighting				
Heat tracing				
Miscellaneous electrical				
600 INSTRUMENTATION				$536,000
601 FIELD INSTRUMENTATION AND SENSORS			$245,000	
602 CONTROLLERS, CONTROL SYSTEMS, CONFIGURATION			$280,000	
603 LOCAL INDICATORS AND GAUGES			$11,000	
800 OTHER CONSTRUCTION COSTS				$2,885,009
810 GENERAL CONSTRUCTION EXPENSE AND LABOR			$305,000	
820 PAINTING			$90,000	
830 MATERIALS TESTING, ETC.			$35,000	
840 FREIGHT			$145,000	
860 BUILDER'S RISK INSURANCE			$30,000	
870 RENTALS, SUPPLIES, UTILITIES, ETC.			$220,000	
880 SALES TAX			$1,441,830	
890 CONTRACTOR'S EXCISE TAX			$618,179	

TABLE 2 - BIOMASS TO ETHANOL FACILITY ESTIM. DEVELOPMENT COSTS (CONT.)

900	**OTHER PROJECT EQUIPMENT, COSTS**		**$7,328,221**
920	MAINTENANCE EQUIPMENT Welders Benches Parts shelves Tools, etc.	$70,000	
925	RADIO EQUIPMENT	$12,000	
930	SPARE PARTS	$275,000	
940	LAB EQUIPMENT	$235,000	
945	SAFETY EQUIPMENT	$19,000	
950	OFFICE EQUIPMENT AND FURNISHINGS Phone system Desks, chairs Computers Copy machine, fax machine Other	$135,000	
960	CONSTRUCTION MANAGEMENT (3%)	$995,038	
970	ENGINEERING FEES (10%) Process engineering, mechanical engineering architectural, structural, electrical engineering	$3,316,794	
975	PERMITTING	$42,000	
980	START-UP AND EMPLOYEE TRAINING	$300,000	
990	CONTINGENCIES (5%)	$1,928,389	
	TOTAL		**$40,496,160**

Operating Cost Estimate

The fuel ethanol facility operating costs for the first year of operation, including utility costs, have also been estimated, with an accuracy of ±30%. Fixed costs have been estimated at $1.013 million, and the variable costs have been estimated at $7,622,793 for a total of $8,635,793 for the first year. Over $3.3 million of the operating costs would be for the switchgrass feedstocks. Please refer to TABLE 3 - BIOMASS TO ETHANOL FACILITY ESTIMATED OPERATING COSTS on Page 23 for a detailed breakdown of all of the contributing costs.

The actual operating costs will very likely be less than reflected by the estimates. This is because the facility will, due to its size, be able to negotiate better prices for the utilities needed. Since the outcome of such future negotiations is uncertain, current prices had to be used for this estimate, resulting in a high estimate. The following section discusses each utility, their service connections, and potential for savings, if any.

TABLE 3 - BIOMASS TO ETHANOL FACILITY ESTIMATED OPERATING COSTS

(330 operating days per year)

VARIABLE COSTS		QUAN./HR.	QUAN./DAY	UNITS	PRICE	COST/DAY	COST/YR.
FEEDSTOCK					Per task 2:		
14 to 18 percent moisture mixed grass					$28.93/BDT, or		
hay in 1000 to 1200 lb. bales		16.96	407.00	ton	$24.88	$10,126	$3,341,580
(14% moisture basis)					per 14%ton		
BOILER FUEL							
Steam required (lbs./hr.):	41,000						
Boiler efficiency:	82.0%						
Total fuel required		48.00	1,152.0	MMBtu			
Methane from anaerobic digester		41.45	994.8	MMBtu	$0.00	$0	
Natural gas required (interruptible):		6.35	152.4	MMBtu	$2.20	$335	
Natural gas surcharge, first 5 yrs.						$103	
Liquid Propane for interruptions		0.20	4.8	MMBtu	$5.68	$27	
TOTAL BOILER FUEL COSTS						$465	$153,450
ELECTRICITY							
Connected horsepower:	9,548						
Utilization	67.0%						
KW per utilized h.p.	0.53						
Total Energy required / hr.:	3,390						
Energy Charge 1st 100 KWH/KW/Mo.		642	15,411	KWH	$0.0550	$848	
Energy Charge Balance		2,748	65,961	KWH	$0.0345	$2,276	
Demand Charge:	4,238			KW	$10.000	$1,541	
Facilities Charge						$1	
TOTAL ELECTRICITY COST						$4,666	$1,539,780
WATER	gpm						
Total plant (well) water required	180	10,800	259,200	gal.	$0.0000	$0	$0
Domestic water	0.25	15	360	gal.	$0.0049	$2	$582
SEWER OR OUTFALL							
Sanitary to on-site septic system		15	360	gal.			
Cooling tower blowdown	21	1,260	30,240	gal.			
RO reject	48	2,880	69,120	gal.			
Treated process wastewater	50	3,000	72,000	gal.			
TOTAL	119	7,155	171,720	gal.	$0.000	$0	$0
CHEMICALS							
DENATURANT (at 5% level in fuel)			1,595	gal.	$0.65	$1,037	$342,104
SULFURIC ACID (98% H2SO4)		684	16,408	pounds	$0.06	$984	$324,882
HYDRATED LIME (Ca(OH)2)		509	12,221	pounds	$0.04	$489	$161,315
WATER, BOILER, TOWER TREATMENT CHEMICALS						$160	$52,800
MISCELLANEOUS CHEMICALS, INGREDIENTS, NUTRIENTS						$300	$99,000
MAINTENANCE, SUPPLIES, SERVICES							
REPAIRS, UPKEEP						$1,018	$335,800
MISCELLANEOUS SUPPLIES, SERVICES						$553	$182,500
OPERATION LABOR		QUAN.					
OPERATION PAYROLL		36				$2,727	$900,000
OTHER PAYROLL COSTS		21.0%				$573	$189,000
SUBTOTAL:						$23,099	$7,622,793

FIXED COSTS EXCLUDING DEPRECIATION AND DEBT SERVICING	QUAN.	COST/DAY	COST/YR.
ADMINISTRATIVE PAYROLL	5	$606	$200,000
OTHER PAYROLL COSTS	21.0%	$127	$42,000
MISCELLANEOUS FIXED COSTS		$1,115	$368,000
INSURANCE		$494	$163,000
PROPERTY TAXES		$727	$240,000
SUBTOTAL:		$3,070	$1,013,000

Facility Utilities

Domestic Water Supply

To avoid being classified as a public water system, it makes more economic sense to use the available domestic water from WEB Water Development. This water already meets all applicable standards. By using WEB water, the facility would not need to perform routine testing for bacteriological and chemical quality standards for the relatively small projected domestic water usage.

The maximum distance from the proposed plant site to the nearest large line size water connection is less than five miles to the south. However, the domestic water usage of this facility will be minimal, and it is felt that a 2" plastic pipe connection can be made at a point less than a mile away. The installed cost for domestic water service is $3-4 per foot, the cost of the water is $2.40 per thousand gallons, and there would also be a monthly service fee of $25.[9]

The estimated connection charge should be about $20,000; this is reflected in Table 2 (Page 19) under Site and Improvements. The cost of the water itself is minimal, and is shown in Table 3 (Page 23) as a variable operating cost. On Table 3, the monthly charge has been calculated into the water charge, and is shown as a total of $0.0049 per gallon of water.

Process Water Supply

A well will be developed for process water supply, drawing water from the Dakota Aquifer. By far most of the Dakota wells are located in the James Basin region of Day County with very few found on the Coteau des Prairies because the wells on the highlands have to be pumped with a required water lift of 500 feet in places.[10] The well is depth is estimated at 1400 feet, and will be sized to pump 250 gallons per minute. The bore hole would be 14 - 3/4" in diameter, the casing would be 10 inches in diameter, and the 60 HP pump would deliver water through a four inch drawpipe. The pump setting will be at an estimated 600 feet; the well development costs include the drilling of a five inch test well to measure the drawdown and recovery rates.[11]

The total developed well cost estimate is given in Table 2 under Site and Improvements. Since in this case the facility would own the well outright, there would be no additional charges or fees for the water itself; consequently, it appears as no charge on Table 3, under variable operating costs.

Natural Gas Supply

Even though biogas is expected to supply the majority of the boiler fuel requirements for this facility, it is necessary to have enough fuel available to cover for potential periods of time where the boiler demand is high but there is no biogas available. Therefore, the gas supply line was sized to deliver 50 million BTU per hour. Northwestern Public Service Company proposes to install a three inch steel pipe, which would deliver natural gas to the facility at about 400 psig. The current interruptible gas cost is about $2.20 per million BTU, and was used for the variable operating cost estimate in Table 3.

The proposed facility is located about 4.2 miles north of the nearest natural gas source, which is a four inch high pressure steel line servicing the towns of Bristol and Webster to the east. The utility company has indicated that there would be no charge to install the gas service to the facility, which they would classify as a large commercial and industrial user, other than the charge for the metering equipment at the point of use (this appears as a $2,500 natural gas connection charge on Table 2, under Site and Improvements). Instead, the utility would recover their investment by imposing a natural gas surcharge which would be in effect for the first five years of plant operation.

The actual natural gas consumption is estimated to average only 6.35 million BTU per hour, due to the contribution of biogas generated by the anaerobic digesters. A Gas Expansion Feasibility Analysis done for this usage rate (502,920 therms per year) would result in a surcharge of $0.06783 per therm.[12] This surcharge has been broken out in Table 3 as a daily cost. It should be noted, however, that this value is only applicable to a gas use rate of 6.35 million BTU per hour. Increasing the usage rates would significantly reduce the amount of the surcharge; at an annual usage rate of 1,106,758 therms, the surcharge will drop to zero.

Decreased usage rates would result in significant surcharge increases. As an example, gas used at a rate of 243,936 therms per year would result in a surcharge of $0.19983 per therm. Even so, it is still more financially attractive for the biomass-to-ethanol facility to maximize the use of the biogas. Regarding the quoted price for natural gas, the utility company has indicated that for a large user such as this plant, a significantly lower price can usually be negotiated.

Propane Backup Fuel Supply

It does not appear to be economical to subscribe to a firm natural gas supply. Therefore, interruptible gas pricing was used, and provisions were made for a propane backup fuel supply system. For the purposes of this study, it was estimated that natural gas service would be interrupted for ten days per year. The propane system is sized at 50 million BTU per hour, which is large enough to sustain the plant operation on its own. Two 12,000 gallon storage tanks would be able to hold the contents of 10,000 gallon propane delivery trucks; there would need to be at least one delivery per day if the plant was running entirely on propane.

The option of receiving propane by rail was investigated. The facility would then need to have much larger storage tanks, as it would be required to receive the entire 30,000 to 31,000 gallon quantity. Due to the very small price savings over truck delivered propane, this option is no longer being considered. Propane is used very extensively throughout the region, and there would be no problem getting the needed propane supply on a daily basis. Three propane pipeline terminals are located nearby, in Benson, MN, Woolsey, SD, and Carrington, ND; all of these terminals are within 170 miles of the proposed plant site.[13] It should also be mentioned that the option of using propane entirely over natural gas was investigated, but it quickly became obvious that it was not economically favorable.

Electrical Supply

The most likely electrical supplier would be Lake Region Electric Association of Webster, SD, an REA which is associated with East River Electric Power Cooperative (EREPC). Lake Region has a 7,200V, three phase buried line running along the township road between Site D and Site E, and they also have a substation less than one mile away. EREPC also has a 69KV line about one-half mile away, but it is a single phase line. Western Area Power has a 115KV hydroelectric transmission line about two miles away, and it is also single phase.[14]

Lake Region will provide electrical service to the new facility at no charge as long as the distance is no more than 600 feet. As is the case with the natural gas utility recovering their investment through the sale of natural gas, the electric utility would recover their investment through the sale of electricity. The quoted costs for electricity and the demand charge on Table 3 (Page 23) are self explanatory; the facility charge has been broken down into a cost per day from the anticipated billing of $25 per month.

The actual electrical costs are likely to be much lower. With the coming deregulation of the industry, it will be possible to negotiate for the cost of electrical power. Even without deregulation, plants such as this large commercial facility, which have loads over 2000 KW, have long been able to negotiate both the electrical rate and the demand charges with the utility. Significantly lower rates than those presented should be able to be obtained, thereby reducing the plant operating costs. One method of lowering costs, that might be considered in the future, is to install an electric generator at the plant site to lower the electrical demand.

Identification of Selected Site

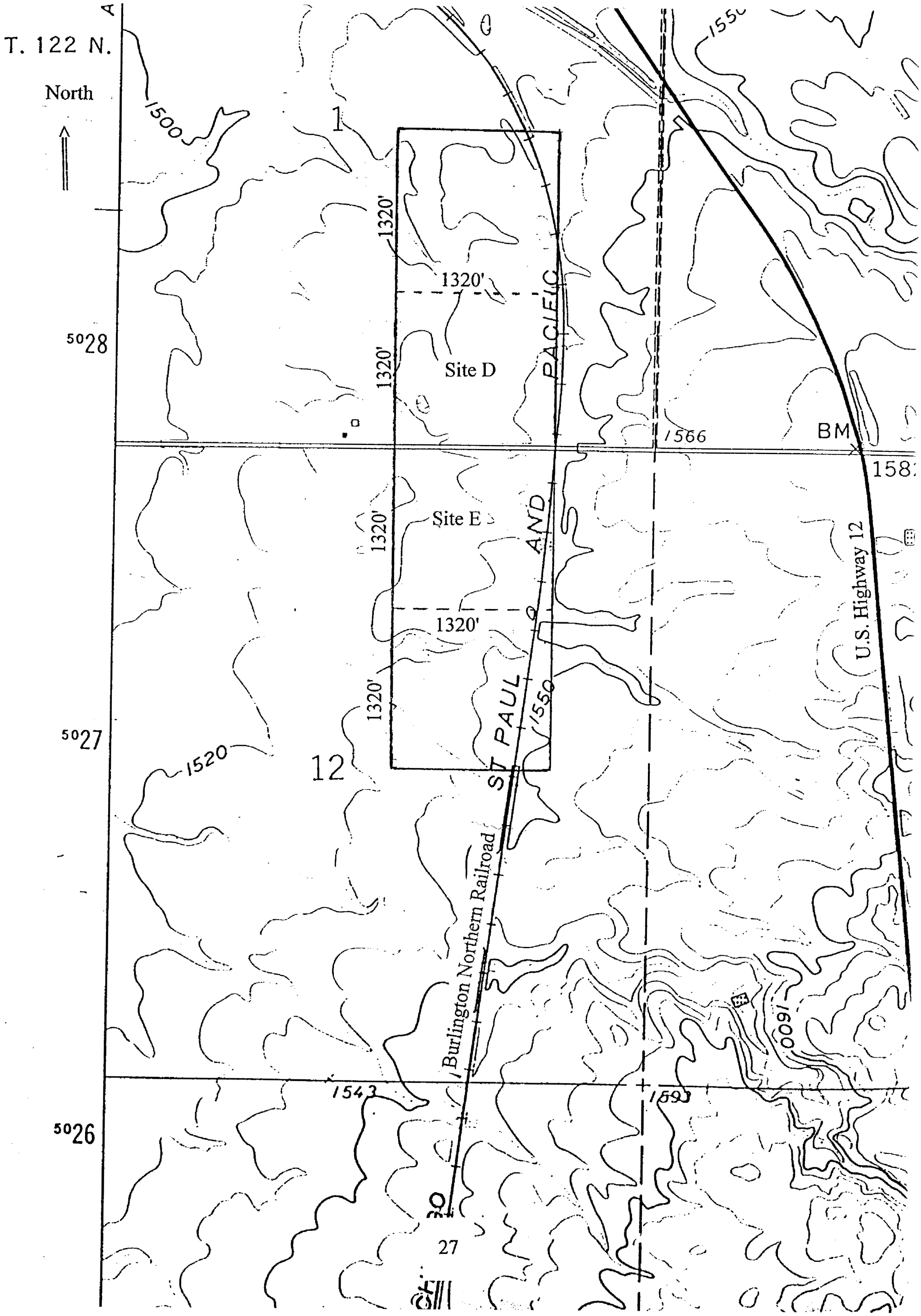
Site Description

In Task 3 of this study, Site DE was identified as the best location within the study area for the proposed biomass-to-ethanol processing plant. This site is in Sections 1 & 12 of Andover Township, Day County, South Dakota. It is roughly 35 miles east of Aberdeen, South Dakota. The land is at an elevation of about 1,545 feet, drains into Mud Creek via minor branch streams, and is about two miles east and one-half mile south of the town of Andover. Burlington Northern Railroad runs next to the site, and U.S. Highway 12 is about one-half mile to the east.

Map 1, on Page 27, is enlarged from a topographical map.[15] It shows the scale of the 40 to 80 acre sites D and E. Note that the Chicago Milwaukee St. Paul and Pacific Railroad identified on this older map (1958, photorevised 1979) is now Burlington Northern Railroad. Since the exact size and shape of the actual plant site is not known at this time, each 40-acre site is represented here with a 1320' square.

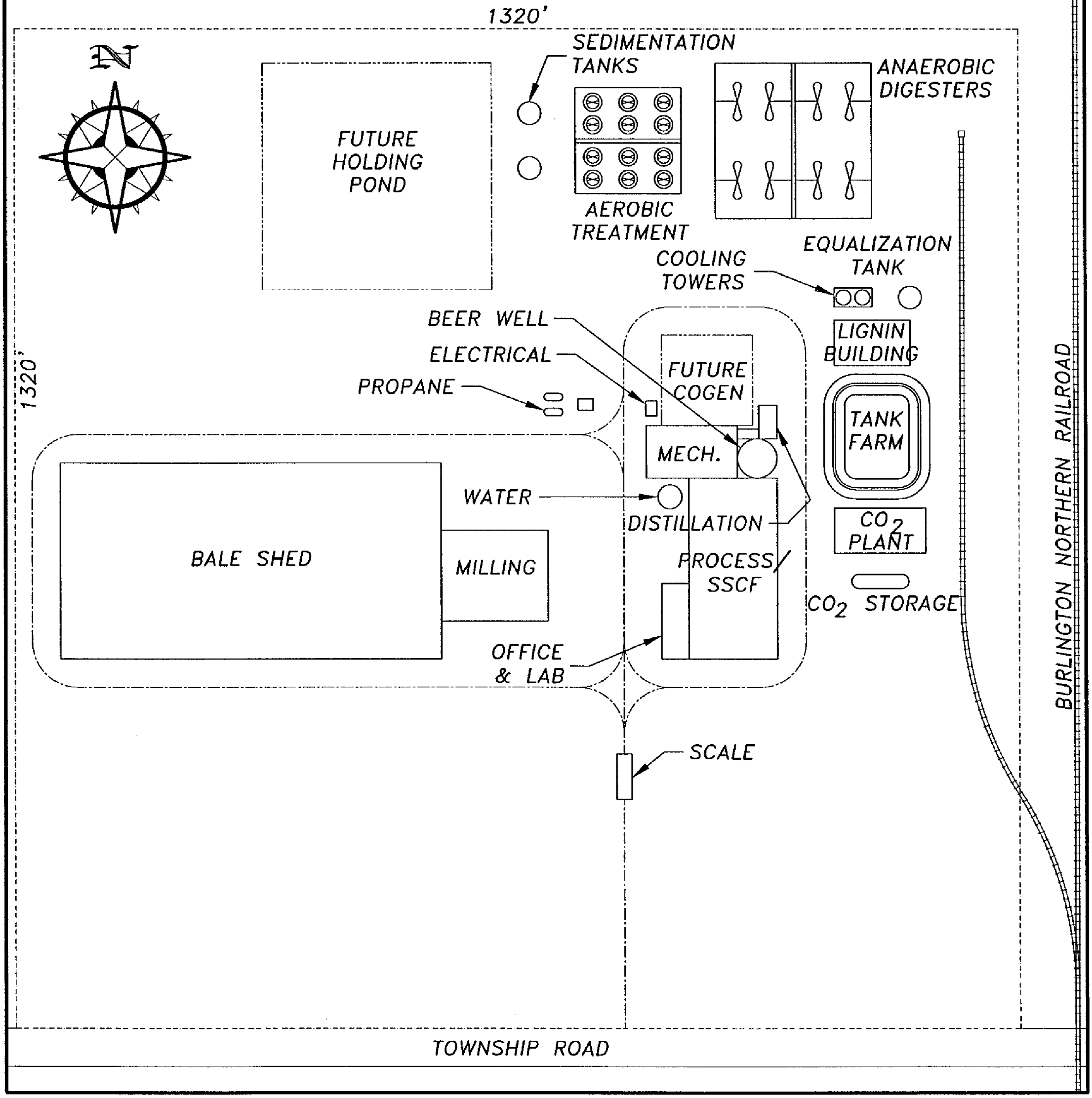
Site Layout

Map 2 is an example of a process plant site layout, for which Site D is shown on Page 28. This layout will be modified depending upon the actual plot size and shape, for which side of the township road it is, and for layout improvements. For most of the buildings and features shown, the layout example is at a scale of 200' per inch for a 10 million gallon per year biomass-to-ethanol plant.


T. 122 N.
North
1500
1
1320'
1320'
PACIFIC
5028
1320'
Site D
1566
BM
1582
Site E
AND
1320'
U.S. Highway 12
1320'
1550
1320'
ST PAUL
5027
1520
12
Burlington Northern Railroad
1600
1543
1593
5026

BIOMASS TO ETHANOL
40 ACRE PLANT SITE (1320' X 1320')
(SITE D SHOWN)
ANDOVER, SD

SCALE: 1"=200'-0"



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Appendix F

Financial Evaluation of the Preferred Site (Task 5)

Prepared by: Vogelbusch U.S.A., Inc.

American Coalition for Ethanol - PO Box 85102 - Sioux Falls, SD 57104

SCREENING STUDY FOR UTILIZING FEEDSTOCKS GROWN ON CRP LANDS IN A BIOMASS TO ETHANOL PRODUCTION FACILITY

..............Task 5 - Financial Evaluation of the Preferred Site................

Subcontract No. ACG-6-16644-01
Prime Contract DE-AC36-83CH10093

Prepared by
American Coalition for Ethanol
&
Vogelbusch U.S.A., Inc

for
United States Department of Energy's
National Renewable Energy Laboratory BioFuels Program

April 22, 1998

Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

TASK 5 - FINANCIAL EVALUATION OF THE PREFERRED SITE

Prepared by Vogelbusch U.S.A., Inc.
Houston, Texas
January 1998

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Preface

A financial analysis was prepared for the construction and long-term operation of a nominal 10,000,000 gallon per year, biomass-to-ethanol facility in northeast South Dakota. This site was selected in Task 3 as the most preferred location within the study area. The evaluation incorporates site specific capital and operating costs, as well as feedstock cost and market value of the ethanol and other byproducts determined in Task 4.

A "Base Case", based on capital costs, operating costs, feedstock costs, and final products market value provided in Task 4, as well as a "Best Case Scenario", incorporating a more favorable feedstock cost and a state producers incentive, is provided. Each analysis consist of the following:

Sources and Application of Funds (Year 1)

Sources and Application of Funds (Year 2)

Balance Sheet (Years 1 through 12)

Income Statement (Years 1 through 12)

Cash Flow Statement (Years 1 through 12)

Pricing Sensitivity Matrix - Average Annual Pre-tax Income (Years 3 through 12)

Pricing Sensitivity Matrix - Average Annual Cash Flow (Years 3 through 12)

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Screening Study for Utilizing Feedstocks Grown on CRP Lands in a Biomass-to-Ethanol Production Facility

TASK 5 - FINANCIAL EVALUATION OF THE PREFERRED SITE

Plant Design Capacity

The projections presented are for a facility that will produce 10,000,000 gallons per year of 200 proof ethanol from switchgrass. Feedstock consumption and product yields were taken from Task 4.

The annual design production capacity of the plant is as follows:

fuel grade ethanol	10,526,316 gallons
carbon dioxide	31,812 tons
lignin fuel	31,416 tons

Grass consumption is estimated at 134,310 tons annually, based on an incoming moisture content of 14%.

Annual production and consumption rates are based on 330 operating days annually, allowing 35 days per year for scheduled and unscheduled maintenance and cleaning.

Project Cost and Financing

It was estimated in Task 4 that the total installed plant cost will equal $40,496,160. Working capital and other reserves will bring the total project cost to approximately $44,500,000.

Total project financing is assumed at $31,500,000 with equity participation making up the remaining necessary capital. This represents a 2.4 to 1 debt-to-equity ratio.

The following details the total project costs and the anticipated funding sources:

Capital Improvements	$40,496,160
Working Capital & Reserves	$4,003,840
Total	**$44,500,000**
Project Financing (Term Loan)	$31,500,000
Equity	$13,000,000
Total	**$44,500,000**

Construction Period

The facility is to be constructed over a 12 month period. After construction is complete, the plant will be started in month 13, when it is expected to achieve an overall production rate of 30% of rated capacity. It is assumed that production in month 14 will be 70% of rated capacity with full rated capacity anticipated for month 15.

Draw Down Schedule

The projections are based on a construction draw down schedule that ties progress payments to construction progress. It is anticipated that construction funds will be drawn, as follows:

Month 1	30%	$12,148,848
Month 2	5%	$2,024,808
Month 3	5%	$2,024,808
Month 4	5%	$2,024,808
Month 5	5%	$2,024,808
Month 6	5%	$2,024,808
Month 7	5%	$2,024,808
Month 8	5%	$2,024,808
Month 9	5%	$2,024,808
Month 10	5%	$2,024,808
Month 11	5%	$2,024,808
Month 12	5%	$2,024,808
Month 13	5%	$2,024,808
Month 14	10%	$4,049,616
TOTAL	**100%**	**$40,496,160**

Financing Terms

It is assumed that the project will be financed with a $31,500,000 loan bearing a fixed interest rate of 10% over a 15 year term and structured so that interest only is paid on the note balance during years 1 and 2. In year 3, full amortization begins with a total annual debt service of $4,141,424, including both principal and interest.

Detail of debt service is shown on the following page.

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

DEBT SERVICE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Total Plant Debt Balance	24,310,880	31,500,000	30,508,576	29,418,010	28,218,387	26,898,801	25,447,258	23,850,559	22,094,191	20,162,186	18,036,981	15,699,255
Interest Payment		3,053,451	3,150,000	3,050,858	2,941,801	2,821,839	2,689,880	2,544,726	2,385,056	2,209,419	2,016,219	1,803,698
Principal Payment			991,424	1,090,566	1,199,623	1,319,585	1,451,544	1,596,698	1,756,368	1,932,005	2,125,205	2,337,726

Beginning Debt	31,500,000
Interest Rate	10.00%
Payments	15
Annual Debt Service Payment	4,141,424

Depreciation and Amortization

The projections anticipate that the term loan will be fully amortized over a 15 year period.

Interest paid during construction on the draw down of the available credit line is capitalized and added to the cost of the plant. Total plant cost of $40,496,160 is being depreciated using straight line depreciation over the estimated life of the facility of 15 years.

The project will incur fees to the lenders. It is anticipated that these fees will equal 2% of the financing amount or $630,000. The anticipated bank fees are capitalized and amortized on a straight line basis over a 15 year period beginning in year 1.

Expenses incurred prior to startup of the plant have been capitalized as organizational expenses. These expenses are estimated at $1,204,797 and will be amortized on a straight line basis beginning in year 2.

Details of depreciation and amortization calculations is provided on the following page.

DEPRECIATION CALCULATIONS

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

DEPRECIATION CALCULATIONS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Plant Cost	35,401,688	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112
Annual depreciation-percentage		6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%
Annual depreciation-dollars	**0**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**	**2,765,074**
Cumulative depreciation	0	2,765,074	5,530,148	8,295,222	11,060,296	13,825,370	16,590,444	19,355,518	22,120,592	24,885,666	27,650,740	30,415,814
Net plant value	35,401,688	38,711,038	35,945,964	33,180,890	30,415,816	27,650,742	24,885,668	22,120,594	19,355,520	16,590,446	13,825,372	11,060,298
Loan Fees	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000
Annual amortization-percentage	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%	6.67%
Annual amortization-dollars	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**	**42,000**
Cumulative amortization	42,000	84,000	126,000	168,000	210,000	252,000	294,000	336,000	378,000	420,000	462,000	504,000
Net loan fees	588,000	546,000	504,000	462,000	420,000	378,000	336,000	294,000	252,000	210,000	168,000	126,000
Start up expenses	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797
Annual amortization-percentage		20.00%	20.00%	20.00%	20.00%	20.00%						
Annual amortization-dollars	**0**	**240,959**	**240,959**	**240,959**	**240,959**	**240,961**						
Cumulative amortization	0	240,959	481,918	722,877	963,836	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797
Net start up expenses	1,204,797	963,838	722,879	481,920	240,961							

Accounts Receivable and Inventories

Accounts receivable are estimated to climb as sales escalate until they stabilize at 30 days sales. Normal industry terms are net 30. There has been no provision for uncollectible accounts. Accounts receivable will equal an investment of $1,062,555.

Inventories are projected to rise as the plant comes on stream, with raw materials equaling five days of production, work in progress anticipated to equal two days of production, and finished goods estimated at three days or $185,524.

All inventory and accounts receivable values have been inflated at a rate of 2% per year, starting in year 3.

Accounts Payable

Accounts payable are estimated to be paid on a net 30 basis, except for items which, contractually, are to be paid on different terms and payroll, which is projected on a cash basis. In order to be conservative in projecting cash flow, no provision for accounts payable are shown in the projections.

Product Sales and Raw Material Costs

The pro forma financial statements reflect the following estimates provided in Task 4 for products and raw material:

Grass (14% moisture)	$25.00/ton
Fuel Ethanol	$1.15/gallon
Carbon Dioxide	$9.00/ton
Lignin Fuel (dry basis)	$11.43/ton

Sensitivity tables generated by various grass costs and selling prices for fuel ethanol are provided. One table shows the average annual after tax income and another the average annual cash flow for full operating years, with debt service. The prices for carbon dioxide and the lignin fuel are assumed to be constant since the price for each will most probably be set by long term contracts and will not vary to the extent a commodity, like fuel ethanol, will.

Operating Costs

Variable operating costs are based on the following estimates provided in Task 4, all of which are per anhydrous ethanol gallon produced:

chemicals	$0.09801
water	$0.00006
electricity	$0.15398
boiler fuel	$0.01535
maintenance	$0.05183
sewer	$0.00000

All costs have been inflated at a rate of 2% per year, starting in year 3.

Plant Labor, Plant Management, and Administrative Costs

Salaries and wages required to operate and maintain the facility are included in the plant operating expenses. In Task 4 it was determined that the plant will employ 36 persons when it achieves full production. Total annual compensation, including 21% for benefits, was estimated to be $1,089,000 in year 2 and is adjusted annually by increasing this cost by 2% per year.

It was also determined in Task 4 that the organization will also require a staff of five to perform administrative duties. Total annual compensation, including 21% for benefits, is anticipated to be $242,000 in year 2 and is adjusted annually by increasing this cost by 2% per year.

Provisions for relocation of three key employees are included in Operations and Administrative Salaries and Benefits. A one time payment for moving expenses of $15,000 per key employee, for a total of $45,000, is provided.

Details of both plant and administrative personnel is provided on the next four pages in the following spreadsheets:

Salaries, Wages, and Benefits by Job Classification

Salaries, Wages, and Benefits by Job Classification - Year 1 Details

Salaries, Wages, and Benefits by Job Classification - Year 2 Details

Personnel Detail

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

PLANT SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Operations												
Management												
Plant Manager	56,464	84,696	87,237	89,854	92,550	95,327	98,187	101,133	104,167	107,292	110,511	113,826
Production Manager	25,210	60,504	62,319	64,189	66,115	68,098	70,141	72,245	74,412	76,644	78,943	81,311
Professional												
Lab Manager	16,251	65,004	66,954	68,963	71,032	73,163	75,358	77,619	79,948	82,346	84,816	87,360
Supervisory												
Shift Supervisor	35,694	144,561	148,898	153,365	157,966	162,705	167,586	172,614	177,792	183,126	188,620	194,279
Maintenance Supervisor	8,112	32,854	33,839	34,854	35,900	36,977	38,086	39,229	40,406	41,618	42,867	44,153
Administrative Supervisor	4,958	29,748	30,640	31,559	32,506	33,481	34,485	35,520	36,586	37,684	38,815	39,979
Direct Labor												
Operators	71,386	433,670	446,680	460,080	473,882	488,098	502,741	517,823	533,358	549,359	565,840	582,815
Indirect Labor												
Maintenance Technicians	18,026	109,508	112,793	116,177	119,662	123,252	126,950	130,759	134,682	138,722	142,884	147,171
Laboratory Technicians	7,932	48,187	49,633	51,122	52,656	54,236	55,863	57,539	59,265	61,043	62,874	64,760
Shipping/Receiving Clerk	1,622	19,626	20,215	20,821	21,446	22,089	22,752	23,435	24,138	24,862	25,608	26,376
Administrative	2,929	35,148	36,202	37,288	38,407	39,559	40,746	41,968	43,227	44,524	45,860	47,236
Yard	2,929	35,441	36,504	37,599	38,727	39,889	41,086	42,319	43,589	44,897	46,244	47,631
TOTAL	251,513	1,098,946	1,131,914	1,165,871	1,200,849	1,236,874	1,273,981	1,312,203	1,351,570	1,392,117	1,433,882	1,476,897

ADMINISTRATIVE SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Administration												
Management												
General Manager	91,812	91,812	94,566	97,403	100,325	103,335	106,435	109,628	112,917	116,305	119,794	123,388
Marketing Manager	0	54,456	56,090	57,773	59,506	61,291	63,130	65,024	66,975	68,984	71,054	73,186
Professional												
Plant Engineer	40,336	60,504	62,319	64,189	66,115	68,098	70,141	72,245	74,412	76,644	78,943	81,311
Other												
Secretary	20,136	20,136	20,740	21,362	22,003	22,663	23,343	24,043	24,764	25,507	26,272	27,060
Receptionist	0	15,096	15,549	16,015	16,495	16,990	17,500	18,025	18,566	19,123	19,697	20,288
TOTAL	152,284	242,004	249,264	256,742	264,444	272,377	280,549	288,965	297,634	306,563	315,760	325,233

SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION
YEAR 1 DETAILS

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

PLANT SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION - YEAR 1 DETAILS

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Total
Operations													
Management													
Plant Manager					7,058	7,058	7,058	7,058	7,058	7,058	7,058	7,058	56,464
Production Manager								5,042	5,042	5,042	5,042	5,042	25,210
Professional													
Lab Manager										5,417	5,417	5,417	16,251
Supervisory													
Shift Supervisor										11,898	11,898	11,898	35,694
Maintenance Supervisor										2,704	2,704	2,704	8,112
Administrative Supervisor											2,479	2,479	4,958
Direct Labor													
Operators											35,693	35,693	71,386
Indirect Labor													
Maintenance Technicians											9,013	9,013	18,026
Laboratory Technicians											3,966	3,966	7,932
Shipping/Receiving Clerk												1,622	1,622
Administrative												2,929	2,929
Yard												2,929	2,929
TOTAL	0	0	0	0	7,058	7,058	7,058	12,100	12,100	32,119	83,270	90,750	251,513

ADMINISTRATIVE SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION - YEAR 1 DETAILS

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Total
Administration													
Management													
General Manager	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	91,812
Marketing Manager													0
Professional													
Plant Engineer					5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	40,336
Other													
Secretary	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	20,136
Receptionist													0
TOTAL	9,329	9,329	9,329	9,329	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	152,284

SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION
YEAR 2 DETAILS

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

PLANT SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION - YEAR 2 DETAILS

	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24	Total
Operations													
Management													
Plant Manager	7,058	7,058	7,058	7,058	7,058	7,058	7,058	7,058	7,058	7,058	7,058	7,058	84,696
Production Manager	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	60,504
Professional													
Lab Manager	5,417	5,417	5,417	5,417	5,417	5,417	5,417	5,417	5,417	5,417	5,417	5,417	65,004
Supervisory													
Shift Supervisor	13,683	11,898	11,898	11,898	11,898	11,898	11,898	11,898	11,898	11,898	11,898	11,898	144,561
Maintenance Supervisor	3,110	2,704	2,704	2,704	2,704	2,704	2,704	2,704	2,704	2,704	2,704	2,704	32,854
Administrative Supervisor	2,479	2,479	2,479	2,479	2,479	2,479	2,479	2,479	2,479	2,479	2,479	2,479	29,748
Direct Labor													
Operators	41,047	35,693	35,693	35,693	35,693	35,693	35,693	35,693	35,693	35,693	35,693	35,693	433,670
Indirect Labor													
Maintenance Technicians	10,365	9,013	9,013	9,013	9,013	9,013	9,013	9,013	9,013	9,013	9,013	9,013	109,508
Laboratory Technicians	4,561	3,966	3,966	3,966	3,966	3,966	3,966	3,966	3,966	3,966	3,966	3,966	48,187
Shipping/Receiving Clerk	1,784	1,622	1,622	1,622	1,622	1,622	1,622	1,622	1,622	1,622	1,622	1,622	19,626
Administrative	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	35,148
Yard	3,222	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	2,929	35,441
TOTAL	100,696	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	1,098,946

ADMINISTRATIVE SALARIES, WAGES, AND BENEFITS BY JOB CLASSIFICATION - YEAR 2 DETAILS

	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24	Total
Administration													
Management													
General Manager	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	7,651	91,812
Marketing Manager	4,538	4,538	4,538	4,538	4,538	4,538	4,538	4,538	4,538	4,538	4,538	4,538	54,456
Professional													
Plant Engineer	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	5,042	60,504
Other													
Secretary	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	1,678	20,136
Receptionist	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,258	1,258	15,096
TOTAL	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	242,004

PERSONNEL DETAIL

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

PLANT PERSONNEL	Rate	Hourly/ Salaried	Annual Hours	Annual Comp.	Number	Base Comp.	21% Benefits	Annual Total
Operations								
Management								
Plant Manager	70,000	S		70,000	1	70,000	14,700	84,700
Production Manager	50,000	S		50,000	1	50,000	10,500	60,500
Professional								
Lab Manager	50,000	S		50,000	1	50,000	15,000	65,000
Supervisory								
Shift Supervisor	12.00	H	2,288	27,456	4	109,824	32,947	142,771
Maintenance Supervisor	12.00	H	2,080	24,960	1	24,960	7,488	32,448
Administrative Supervisor	11.00	H	2,080	22,880	1	22,880	6,864	29,744
Direct Labor								
Operators	9.00	H	2,288	20,592	16	329,472	98,842	428,314
Indirect Labor								
Maintenance Technicians	10.00	H	2,080	20,800	4	83,200	24,960	108,160
Laboratory Technicians	8.00	H	2,288	18,304	2	36,608	10,982	47,590
Shipping/Receiving Clerk	7.20	H	2,080	14,976	1	14,976	4,493	19,469
Administrative	6.50	H	2,080	13,520	2	27,040	8,112	35,152
Yard	6.50	H	2,080	13,520	2	27,040	8,112	35,152
			Total Employment:		**36**	**Total Compensation:**		**$1,089,000**

ADMINISTRATIVE PERSONNEL	Rate	Hourly/ Salaried	Annual Hours	Annual Comp.	Number	Base Comp.	21% Benefits	Annual Total
Administration								
Management								
General Manager	75,880	S		75,880	1	75,880	15,935	91,815
Marketing Manager	45,000	S		45,000	1	45,000	9,450	54,450
Professional								
Plant Engineer	50,000	S		50,000	1	50,000	10,500	60,500
Other								
Secretary	8.00	H	2,080	16,640	1	16,640	3,494	20,134
Receptionist	6.00	H	2,080	12,480	1	12,480	2,621	15,101
			Total Employment:		**5**	**Total Compensation:**		**$242,000**

Additional Fixed Costs

The following additional fixed annual costs are incorporated into the financial analysis:

taxes and Insurance	$403,000
miscellaneous fixed costs	$368,000

Federal Income Taxes

It is anticipated that the SD Biomass to Ethanol Facility will be set up as a limited partnership and, as such, there are no taxes charged directly to the partnership. The financial projections do, however, show a deduction for corporate income taxes at the 35% rate. It will be necessary to distribute to the partners an amount equal to the tax effect of the "pass through" earnings. Therefore, a deduction prior to the net income for income tax is shown.

Pro Forma - Base Case

The Base Case Financial Statements are made up of the following:

- Sources and Application of Funds (Year 1)
- Sources and Application of Funds (Year 2)
- Balance Sheet (Years 1 through 12)
- Income Statement (Years 1 through 12)
- Cash Flow Statement (Years 1 through 12)
- Pricing Sensitivity Matrix - Average Annual Pre-tax Income (Years 3 through 12)
- Pricing Sensitivity Matrix - Average Annual Cash Flow (Years 3 through 12)

Although the Base Case shows a steadily improving annual cash flow in the first 10 years of full operation, the average in net increase (or decrease) in cash for years 3 through 12 is only $319,195. The range is -$67,694 in Year 3 to $727,060 in year 12.

The Base Case Income Statement only shows a profit in the last year displayed in the projections (Year 12). The average annual after-tax income is -$976,856 over the first ten years of full operation, representing a -2.20% annual return on investment. Cumulative earnings reach a low at the end of Year 11 of -$12,693,924.

SOURCES AND APPLICATION OF FUNDS
YEAR 1

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

SOURCES AND APPLICATION OF FUNDS (YEAR 1)	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Total
CASH INFLOW													
PRODUCTION UNITS													
Fuel Ethanol (gal)													0
Carbon Dioxide (tons)													0
Lignin Fuel (tons)													0
INVENTORY-FINISHED PRODUCTS													
Fuel Ethanol (gal)													
Carbon Dioxide (tons)													
Lignin Fuel (tons)													
SALES UNITS													
Fuel Ethanol (gal)													0
Carbon Dioxide (tons)													0
Lignin Fuel (tons)													0
SALES DOLLARS													
Fuel Ethanol													0
Carbon Dioxide													0
Lignin Fuel													0
Total Sales	0	0	0	0	0	0	0	0	0	0	0	0	0
ACCOUNTS RECEIVABLE	0	0	0	0	0	0	0	0	0	0	0	0	0
STATE PRODUCERS INCENTIVE	0	0	0	0	0	0	0	0	0	0	0	0	0
INCOMING CASH													
COLLECTIONS												0	0
EQUITY	13,000,000												13,000,000
SUBORDINATED DEBT													0
OTHER FINANCING													0
PROJECT FINANCING	0	1,975,814	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,440,824	24,310,880
Total incoming cash	13,000,000	1,975,814	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,440,824	37,310,880
DISBURSEMENTS													
Construction draws	12,148,848	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	34,421,736
Loan commitment fees	630,000												630,000
Grass												64,395	64,395
Chemicals													0
Process water													0
Electricity													0
Boiler Fuel													0
Maintenance													0
Plant salaries and benefits	0	0	0	0	7,058	7,058	7,058	12,100	12,100	32,119	98,270	90,750	266,513
Taxes and insurance	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	403,000
Administrative salaries and benefits	24,329	9,329	9,329	9,329	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	167,284
Consulting													0
Miscellaneous	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	368,000
Interest expense		0	16,465	34,089	51,860	69,879	88,049	106,370	124,886	143,556	162,548	182,250	979,952
Total disbursements	12,867,427	2,098,387	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,440,824	37,300,880
Beginning cash	0	132,573	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	0
Total receipts	13,000,000	1,975,814	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,440,824	37,310,880
Total disbursements	12,867,427	2,098,387	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,440,824	37,300,880
Ending cash	132,573	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Note balance	0	1,975,814	4,090,666	6,223,142	8,385,489	10,565,855	12,764,391	14,986,290	17,226,705	19,505,809	21,870,056	24,310,880	
Interest rate	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	
Interest expense	0	16,465	34,089	51,860	69,879	88,049	106,370	124,886	143,556	162,548	182,250	202,591	

SOURCES AND APPLICATION OF FUNDS
YEAR 2

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

SOURCES AND APPLICATION OF FUNDS (YEAR 2)	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24	Total
CASH INFLOW													
PRODUCTION UNITS													
Fuel Ethanol (gal)	263,158	614,035	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	9,649,123
Carbon Dioxide (tons)	795	1,856	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	29,161
Lignin Fuel (tons)	785	1,833	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	28,798
INVENTORY-FINISHED PRODUCTS													
Fuel Ethanol (gal)	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	
Carbon Dioxide (tons)	300	300	300	300	300	300	300	300	300	300	300	300	
Lignin Fuel (tons)	300	300	300	300	300	300	300	300	300	300	300	300	
SALES UNITS													
Fuel Ethanol (gal)	163,158	614,035	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	9,549,123
Carbon Dioxide (tons)	495	1,856	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	28,861
Lignin Fuel (tons)	485	1,833	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	28,498
SALES DOLLARS													
Fuel Ethanol	187,632	706,140	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	10,981,492
Carbon Dioxide	4,458	16,701	23,859	23,859	23,859	23,859	23,859	23,859	23,859	23,859	23,859	23,859	259,749
Lignin Fuel	5,548	20,947	29,924	29,924	29,924	29,924	29,924	29,924	29,924	29,924	29,924	29,924	325,735
Total Sales	**197,638**	**743,788**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**11,566,976**
ACCOUNTS RECEIVABLE	197,638	743,788	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555
STATE PRODUCERS INCENTIVE	0	0	0	0	0	0	0	0	0	0	0	0	0
INCOMING CASH													
COLLECTIONS	0	743,788	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	11,369,338
EQUITY													0
SUBORDINATED DEBT													0
OTHER FINANCING													0
PROJECT FINANCING	2,854,051	4,297,797	33,833	0	0	0	0	0	0	3,439			7,189,120
Total incoming cash	**2,854,051**	**5,041,585**	**1,096,388**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,065,994**	**1,062,555**	**1,062,555**	**18,558,458**
DISBURSEMENTS													0
Construction draws	2,024,808	4,049,616											6,074,424
Loan commitment fees													0
Grass	83,944	335,776	391,738	279,813	279,813	279,813	279,813	279,813	279,813	279,813	279,813	279,813	3,329,775
Chemicals	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	980,100
Process water	49	49	49	49	49	49	49	49	49	49	49	49	588
Electricity	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	1,539,780
Boiler Fuel	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	153,456
Maintenance	13,639	31,825	45,465	45,465	45,465	45,465	45,465	45,465	45,465	45,465	45,465	45,465	500,114
Plant salaries and benefits	100,696	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	1,098,946
Taxes and insurance	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	403,000
Administrative salaries and benefits	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	242,004
Inventories	121,129												121,129
Miscellaneous	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	368,000
Interest expense	202,591	226,374	262,189	262,471	262,471	262,471	262,471	262,471	262,471	262,471	262,500	262,500	3,053,451
Total disbursements	**2,854,051**	**5,041,585**	**1,097,386**	**985,743**	**985,743**	**985,743**	**985,743**	**985,743**	**985,743**	**985,743**	**985,772**	**985,772**	**17,864,767**
Beginning cash	10,000	10,000	10,000	9,002	85,814	162,626	239,438	316,250	393,062	469,874	550,125	626,908	10,000
Total receipts	2,854,051	5,041,585	1,096,388	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,065,994	1,062,555	1,062,555	18,558,458
Total disbursements	2,854,051	5,041,585	1,097,386	985,743	985,743	985,743	985,743	985,743	985,743	985,743	985,772	985,772	17,864,767
Ending cash	**10,000**	**10,000**	**9,002**	**85,814**	**162,626**	**239,438**	**316,250**	**393,062**	**469,874**	**550,125**	**626,908**	**703,691**	**703,691**
Note balance	**27,164,931**	**31,462,728**	**31,496,561**	**31,496,561**	**31,496,561**	**31,496,561**	**31,496,561**	**31,496,561**	**31,496,561**	**31,500,000**	**31,500,000**	**31,500,000**	
Interest rate	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	
Interest expense	226,374	262,189	262,471	262,471	262,471	262,471	262,471	262,471	262,471	262,500	262,500	262,500	

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

BALANCE SHEET	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Assets												
Current Assets												
Cash	10,000	393,220	325,526	339,305	436,188	617,837	885,948	1,242,250	1,688,506	2,226,515	2,858,115	3,585,174
Accounts receivable	0	1,062,555	1,083,806	1,105,482	1,127,592	1,150,144	1,173,147	1,196,610	1,220,542	1,244,953	1,269,852	1,295,249
State Producers Incentive	0	0	0	0	0	0	0	0	0	0	0	0
Inventory	64,395	185,524	189,235	193,019	196,880	200,817	204,834	208,931	213,109	217,371	221,719	226,153
Prepaid expenses												
Reserve for Capital Expenses		0	0	0	0	0	0	0	0	0	0	0
Total Current Assets	**74,395**	**1,641,299**	**1,598,567**	**1,637,807**	**1,760,660**	**1,968,798**	**2,263,928**	**2,647,790**	**3,122,157**	**3,688,839**	**4,349,685**	**5,106,576**
Property, Plant & Equipment												
Plant equipment	35,401,688	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112
Construction in progress												
Accumulated depreciation	0	2,765,074	5,530,148	8,295,222	11,060,296	13,825,370	16,590,444	19,355,518	22,120,592	24,885,666	27,650,740	30,415,814
Net Plant Value	**35,401,688**	**38,711,038**	**35,945,964**	**33,180,890**	**30,415,816**	**27,650,742**	**24,885,668**	**22,120,594**	**19,355,520**	**16,590,446**	**13,825,372**	**11,060,298**
Other Assets												
Organizational costs	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797
Accumulated amortization	0	240,959	481,918	722,877	963,836	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797
Loan acquisition costs	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000
Accumulated amortization	42,000	84,000	126,000	168,000	210,000	252,000	294,000	336,000	378,000	420,000	462,000	504,000
Total Other Assets	**1,792,797**	**1,509,838**	**1,226,879**	**943,920**	**660,961**	**378,000**	**336,000**	**294,000**	**252,000**	**210,000**	**168,000**	**126,000**
Total Assets	**37,268,880**	**41,862,175**	**38,771,410**	**35,762,617**	**32,837,437**	**29,997,540**	**27,485,596**	**25,062,384**	**22,729,677**	**20,489,285**	**18,343,057**	**16,292,874**
Liabilities and Partners' Equity												
Current Liabilities												
Income Taxes Payable												
Current portion of long-term debt		991,424	1,090,566	1,199,623	1,319,585	1,451,544	1,596,698	1,756,368	1,932,005	2,125,205	2,337,726	2,571,498
Total Current Liabilities	**0**	**991,424**	**1,090,566**	**1,199,623**	**1,319,585**	**1,451,544**	**1,596,698**	**1,756,368**	**1,932,005**	**2,125,205**	**2,337,726**	**2,571,498**
Long-Term Liabilities												
Project financing	24,310,880	31,500,000	30,508,576	29,418,010	28,218,387	26,898,801	25,447,258	23,850,559	22,094,191	20,162,186	18,036,981	15,699,255
Subordinated Debt												
Other loan												
Less current portion		(991,424)	(1,090,566)	(1,199,623)	(1,319,585)	(1,451,544)	(1,596,698)	(1,756,368)	(1,932,005)	(2,125,205)	(2,337,726)	(2,571,498)
Total Long-Term Liabilities	**24,310,880**	**30,508,576**	**29,418,010**	**28,218,387**	**26,898,801**	**25,447,258**	**23,850,559**	**22,094,191**	**20,162,186**	**18,036,981**	**15,699,255**	**13,127,757**
Partners' Equity												
Equity	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000
Accumulated earnings	(42,000)	(2,637,825)	(4,737,166)	(6,655,393)	(8,380,950)	(9,901,261)	(10,961,662)	(11,788,175)	(12,364,514)	(12,672,901)	(12,693,924)	(12,406,381)
Total Partners' Equity	**12,958,000**	**10,362,175**	**8,262,834**	**6,344,607**	**4,619,050**	**3,098,739**	**2,038,338**	**1,211,825**	**635,486**	**327,099**	**306,076**	**593,619**
Total Liabilities and Equity	**37,268,880**	**41,862,175**	**38,771,410**	**35,762,617**	**32,837,437**	**29,997,540**	**27,485,596**	**25,062,384**	**22,729,677**	**20,489,285**	**18,343,057**	**16,292,874**

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

INCOME STATEMENT	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Sales												
Fuel Ethanol	0	10,981,492	12,105,263	12,347,368	12,594,315	12,846,201	13,103,125	13,365,188	13,632,492	13,905,142	14,183,245	14,466,910
Carbon Dioxide	0	259,749	286,311	292,037	297,878	303,836	309,913	316,111	322,433	328,882	335,460	342,169
Lignin Fuel	0	325,735	359,086	366,268	373,593	381,065	388,686	396,460	404,389	412,477	420,727	429,142
Total Sales	**0**	**11,566,976**	**12,750,660**	**13,005,673**	**13,265,786**	**13,531,102**	**13,801,724**	**14,077,759**	**14,359,314**	**14,646,501**	**14,939,432**	**15,238,221**
State Producers Incentive	0	0	0	0	0	0	0	0	0	0	0	0
Total Income	**0**	**11,566,976**	**12,750,660**	**13,005,673**	**13,265,786**	**13,531,102**	**13,801,724**	**14,077,759**	**14,359,314**	**14,646,501**	**14,939,432**	**15,238,221**
Cost of sales												
Grass	0	3,329,775	3,357,755	3,424,911	3,493,409	3,563,277	3,634,543	3,707,234	3,781,379	3,857,007	3,934,147	4,012,830
Chemicals	0	980,100	980,101	999,703	1,019,697	1,040,091	1,060,893	1,082,111	1,103,753	1,125,828	1,148,345	1,171,312
Process water	0	588	582	594	606	618	630	643	656	669	682	696
Electricity	0	1,539,780	1,539,780	1,570,576	1,601,988	1,634,028	1,666,709	1,700,043	1,734,044	1,768,725	1,804,100	1,840,182
Boiler Fuel	0	153,456	153,450	156,519	159,649	162,842	166,099	169,421	172,809	176,265	179,790	183,386
Maintenance	0	500,114	518,300	528,666	539,239	550,024	561,024	572,244	583,689	595,363	607,270	619,415
Plant salaries and benefits	0	544,500	1,089,000	1,110,780	1,132,996	1,155,656	1,178,769	1,202,344	1,226,391	1,250,919	1,275,937	1,301,456
Depreciation	0	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074
Total Cost of Sales	**0**	**9,813,387**	**10,404,042**	**10,556,823**	**10,712,658**	**10,871,610**	**11,033,741**	**11,199,114**	**11,367,795**	**11,539,850**	**11,715,345**	**11,894,351**
Gross Margin	**0**	**1,753,589**	**2,346,617**	**2,448,850**	**2,553,128**	**2,659,492**	**2,767,983**	**2,878,645**	**2,991,519**	**3,106,651**	**3,224,087**	**3,343,870**
General & Administrative Costs												
Taxes and insurance		403,000	403,000	411,060	419,281	427,667	436,220	444,944	453,843	462,920	472,178	481,622
Administrative salaries and benefits		242,004	242,000	246,840	251,777	256,813	261,949	267,188	272,532	277,983	283,543	289,214
Consulting expenses		0	0	0	0	0	0	0	0	0	0	0
Interest expense		3,053,451	3,150,000	3,050,858	2,941,801	2,821,839	2,689,880	2,544,726	2,385,056	2,209,419	2,016,219	1,803,698
Amortization-Loan Fees	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000
Amortization-Start-up Expenses	0	240,959	240,959	240,959	240,959	240,961	0	0	0	0	0	0
Miscellaneous		368,000	368,000	375,360	382,867	390,524	398,334	406,301	414,427	422,716	431,170	439,793
Total Gen. & Admin. Expenses	**42,000**	**4,349,414**	**4,445,959**	**4,367,077**	**4,278,685**	**4,179,804**	**3,828,383**	**3,705,159**	**3,567,858**	**3,415,038**	**3,245,110**	**3,056,327**
Pre-Tax Income	**(42,000)**	**(2,595,825)**	**(2,099,342)**	**(1,918,227)**	**(1,725,557)**	**(1,520,312)**	**(1,060,400)**	**(826,514)**	**(576,339)**	**(308,387)**	**(21,023)**	**287,543**
Income taxes-35%												
Net Income	**(42,000)**	**(2,595,825)**	**(2,099,342)**	**(1,918,227)**	**(1,725,557)**	**(1,520,312)**	**(1,060,400)**	**(826,514)**	**(576,339)**	**(308,387)**	**(21,023)**	**287,543**

Cumulative pre-tax earnings	(42,000)	(2,637,825)	(4,737,166)	(6,655,393)	(8,380,950)	(9,901,261)	(10,961,662)	(11,788,175)	(12,364,514)	(12,672,901)	(12,693,924)	(12,406,381)
Cumulative earnings	(42,000)	(2,637,825)	(4,737,166)	(6,655,393)	(8,380,950)	(9,901,261)	(10,961,662)	(11,788,175)	(12,364,514)	(12,672,901)	(12,693,924)	(12,406,381)

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

CASH FLOW STATEMENT	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Cash Flow From Operations												
Net income	(42,000)	(2,595,825)	(2,099,342)	(1,918,227)	(1,725,557)	(1,520,312)	(1,060,400)	(826,514)	(576,339)	(308,387)	(21,023)	287,543
Adjustments to Reconcile Net Income												
to Net Cash Provided by Operations												
Depreciation	0	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074
Amortization	42,000	282,959	282,959	282,959	282,959	282,961	42,000	42,000	42,000	42,000	42,000	42,000
Net (Increase)Decrease in Operating Assets:												
Accounts receivable	0	(1,062,555)	(21,251)	(21,676)	(22,110)	(22,552)	(23,003)	(23,463)	(23,932)	(24,411)	(24,899)	(25,397)
State Producers Incentive	0	0	0	0	0	0	0	0	0	0	0	0
Inventories	(64,395)	(121,129)	(3,710)	(3,785)	(3,860)	(3,938)	(4,016)	(4,097)	(4,179)	(4,262)	(4,347)	(4,434)
Prepaid items												
Net Increase (Decrease) in Operating Liabilities:												
Accounts payable												
Other current liabilities			0	0	0	0	0	0	0	0	0	0
Net Cash From Operations	**(64,395)**	**(731,476)**	**923,730**	**1,104,346**	**1,296,506**	**1,501,234**	**1,719,655**	**1,953,001**	**2,202,624**	**2,470,014**	**2,756,805**	**3,064,785**
Cash Flows From Investing Activities												
(Increase) Decrease in Property and Equipment	(35,401,688)	(6,074,424)	0	0	0	0	0	0	0	0	0	0
(Increase) Decrease in Organization Costs	(1,204,797)	0	0	0	0	0	0	0	0	0	0	0
(Increase) Decrease in Loan Fees	(630,000)	0	0	0	0	0	0	0	0	0	0	0
(Increase) Decrease in Equipment Reserve												
Cash Flows From Financing Operations												
Increase (Decrease) in Equity	13,000,000											
Increase (Decrease) in Long Term Financing	24,310,880	7,189,120	(991,424)	(1,090,566)	(1,199,623)	(1,319,585)	(1,451,544)	(1,596,698)	(1,756,368)	(1,932,005)	(2,125,205)	(2,337,726)
Net Increase (Decrease) in Cash	**10,000**	**383,220**	**(67,694)**	**13,779**	**96,883**	**181,649**	**268,111**	**356,302**	**446,256**	**538,009**	**631,600**	**727,060**
Cash Balance - Beginning of Period	**0**	**10,000**	**393,220**	**325,526**	**339,305**	**436,188**	**617,837**	**885,948**	**1,242,250**	**1,688,506**	**2,226,515**	**2,858,115**
Cash Balance - End of Period	**10,000**	**393,220**	**325,526**	**339,305**	**436,188**	**617,837**	**885,948**	**1,242,250**	**1,688,506**	**2,226,515**	**2,858,115**	**3,585,174**

Ethanol ($/gallon)

		0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
G	**32.00**	($4,548,606)	($4,022,291)	($3,495,975)	($2,969,659)	($2,443,343)	**($1,917,028)**	($1,390,712)	($864,396)	($338,080)	$188,236	$714,551
r	**31.00**	($4,414,296)	($3,887,980)	($3,361,665)	($2,835,349)	($2,309,033)	**($1,782,717)**	($1,256,402)	($730,086)	($203,770)	$322,546	$848,862
a	**30.00**	($4,279,986)	($3,753,670)	($3,227,354)	($2,701,039)	($2,174,723)	**($1,648,407)**	($1,122,091)	($595,776)	($69,460)	$456,856	$983,172
s	**29.00**	($4,145,676)	($3,619,360)	($3,093,044)	($2,566,728)	($2,040,413)	**($1,514,097)**	($987,781)	($461,465)	$64,851	$591,166	$1,117,482
s	**28.00**	($4,011,366)	($3,485,050)	($2,958,734)	($2,432,418)	($1,906,102)	**($1,379,787)**	($853,471)	($327,155)	$199,161	$725,477	$1,251,792
	27.00	($3,877,055)	($3,350,740)	($2,824,424)	($2,298,108)	($1,771,792)	**($1,245,476)**	($719,161)	($192,845)	$333,471	$859,787	$1,386,103
$	**26.00**	($3,742,745)	($3,216,429)	($2,690,114)	($2,163,798)	($1,637,482)	**($1,111,166)**	($584,850)	($58,535)	$467,781	$994,097	$1,520,413
	25.00	**($3,608,435)**	**($3,082,119)**	**($2,555,803)**	**($2,029,488)**	**($1,503,172)**	**($976,856)**	**($450,540)**	**$75,776**	**$602,091**	**$1,128,407**	**$1,654,723**
p	**24.00**	($3,474,125)	($2,947,809)	($2,421,493)	($1,895,177)	($1,368,862)	**($842,546)**	($316,230)	$210,086	$736,402	$1,262,717	$1,789,033
e	**23.00**	($3,339,815)	($2,813,499)	($2,287,183)	($1,760,867)	($1,234,551)	**($708,236)**	($181,920)	$344,396	$870,712	$1,397,028	$1,923,343
r	**22.00**	($3,205,504)	($2,679,189)	($2,152,873)	($1,626,557)	($1,100,241)	**($573,925)**	($47,610)	$478,706	$1,005,022	$1,531,338	$2,057,654
	21.00	($3,071,194)	($2,544,878)	($2,018,563)	($1,492,247)	($965,931)	**($439,615)**	$86,701	$613,016	$1,139,332	$1,665,648	$2,191,964
t	**20.00**	($2,936,884)	($2,410,568)	($1,884,252)	($1,357,936)	($831,621)	**($305,305)**	$221,011	$747,327	$1,273,642	$1,799,958	$2,326,274
o	**19.00**	($2,802,574)	($2,276,258)	($1,749,942)	($1,223,626)	($697,310)	**($170,995)**	$355,321	$881,637	$1,407,953	$1,934,268	$2,460,584
n	**18.00**	($2,668,263)	($2,141,948)	($1,615,632)	($1,089,316)	($563,000)	**($36,684)**	$489,631	$1,015,947	$1,542,263	$2,068,579	$2,594,894

Note: Matrix assumes that the selling price of lignin fuel and carbon dioxide remains constant

PRICING SENSITIVITY MATRIX

AVERAGE ANNUAL CASH FLOW (YEARS 3 THROUGH 12)

NREL - South Dakota Biomass to Ethanol Facility **BASE CASE**

Ethanol ($/gallon)

Grass $ per ton	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
32.00	($3,252,555)	($2,726,240)	($2,199,924)	($1,673,608)	($1,147,292)	($620,977)	($94,661)	$431,655	$957,971	$1,484,287	$2,010,602
31.00	($3,118,245)	($2,591,929)	($2,065,614)	($1,539,298)	($1,012,982)	($486,666)	$39,649	$565,965	$1,092,281	$1,618,597	$2,144,913
30.00	($2,983,935)	($2,457,619)	($1,931,303)	($1,404,988)	($878,672)	($352,356)	$173,960	$700,275	$1,226,591	$1,752,907	$2,279,223
29.00	($2,849,625)	($2,323,309)	($1,796,993)	($1,270,677)	($744,362)	($218,046)	$308,270	$834,586	$1,360,902	$1,887,217	$2,413,533
28.00	($2,715,315)	($2,188,999)	($1,662,683)	($1,136,367)	($610,051)	($83,736)	$442,580	$968,896	$1,495,212	$2,021,528	$2,547,843
27.00	($2,581,004)	($2,054,689)	($1,528,373)	($1,002,057)	($475,741)	$50,575	$576,890	$1,103,206	$1,629,522	$2,155,838	$2,682,154
26.00	($2,446,694)	($1,920,378)	($1,394,063)	($867,747)	($341,431)	$184,885	$711,201	$1,237,516	$1,763,832	$2,290,148	$2,816,464
25.00	($2,312,384)	($1,786,068)	($1,259,752)	($733,437)	($207,121)	$319,195	$845,511	$1,371,827	$1,898,142	$2,424,458	$2,950,774
24.00	($2,178,074)	($1,651,758)	($1,125,442)	($599,126)	($72,811)	$453,505	$979,821	$1,506,137	$2,032,453	$2,558,768	$3,085,084
23.00	($2,043,764)	($1,517,448)	($991,132)	($464,816)	$61,500	$587,815	$1,114,131	$1,640,447	$2,166,763	$2,693,079	$3,219,394
22.00	($1,909,453)	($1,383,138)	($856,822)	($330,506)	$195,810	$722,126	$1,248,441	$1,774,757	$2,301,073	$2,827,389	$3,353,705
21.00	($1,775,143)	($1,248,827)	($722,512)	($196,196)	$330,120	$856,436	$1,382,752	$1,909,067	$2,435,383	$2,961,699	$3,488,015
20.00	($1,640,833)	($1,114,517)	($588,201)	($61,885)	$464,430	$990,746	$1,517,062	$2,043,378	$2,569,693	$3,096,009	$3,622,325
19.00	($1,506,523)	($980,207)	($453,891)	$72,425	$598,741	$1,125,056	$1,651,372	$2,177,688	$2,704,004	$3,230,319	$3,756,635
18.00	($1,372,212)	($845,897)	($319,581)	$206,735	$733,051	$1,259,367	$1,785,682	$2,311,998	$2,838,314	$3,364,630	$3,890,945

Note: Matrix assumes that the selling price of lignin fuel and carbon dioxide remains constant

Pro Forma - Best Case Scenario

The Best Case Scenario incorporates the same assumptions as the Base Case with the following two exceptions:

> A $0.20 per anhydrous gallon, state sponsored producer incentive is included. This incentive caps at a maximum of $1,000,000 per year and $10,000,000 per facility. It is assumed that paperwork for the incentive would be submitted to the state on a monthly basis and that payment would be received within 30 days of submittal.
>
> The cost of the feedstock grass was lowered to $22/ton, based on 14% moisture content.

The Best Case Scenario Financial Statements are made up of the following:

- Sources and Application of Funds (Year 1)
- Sources and Application of Funds (Year 2)
- Balance Sheet (Years 1 through 12)
- Income Statement (Years 1 through 12)
- Cash Flow Statement (Years 1 through 12)
- Pricing Sensitivity Matrix - Average Annual Pre-tax Income (Years 3 through 12)
- Pricing Sensitivity Matrix - Average Annual Cash Flow (Years 3 through 12)

The state producers incentive and lower grass cost assumptions included in the Best Case Scenario have a significant effect on the cash flow projections. The average in net increase (or decrease) in cash for years 3 through 12 is $1,696,839 and ranges from $1,355,391 in Year 3 to $2,039,193 in year 11. Income drops significantly after the state producers incentive is phased out after Year 11.

However, the Best Case Scenario Income Statement shows losses in the first four years of full operation. The average annual after-tax income is $364,344 in Years 3 through 12, representing an average 0.82% return on investment. Cumulative earnings reach a low at the end of Year 6 of -$2,841,164 but do reach break-even in Year 10.

SOURCES AND APPLICATION OF FUNDS
YEAR 1

NREL - South Dakota Biomass to Ethanol Facility **BEST CASE**

SOURCES AND APPLICATION OF FUNDS (YEAR 1)	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12	Total
CASH INFLOW													
PRODUCTION UNITS													
Fuel Ethanol (gal)													0
Carbon Dioxide (tons)													0
Lignin Fuel (tons)													0
INVENTORY-FINISHED PRODUCTS													
Fuel Ethanol (gal)													
Carbon Dioxide (tons)													
Lignin Fuel (tons)													
SALES UNITS													
Fuel Ethanol (gal)													0
Carbon Dioxide (tons)													0
Lignin Fuel (tons)													0
SALES DOLLARS													
Fuel Ethanol													0
Carbon Dioxide													0
Lignin Fuel													0
Total Sales	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ACCOUNTS RECEIVABLE	0	0	0	0	0	0	0	0	0	0	0	0	0
STATE PRODUCERS INCENTIVE	0	0	0	0	0	0	0	0	0	0	0	0	0
INCOMING CASH													
COLLECTIONS												0	0
EQUITY	13,000,000												13,000,000
SUBORDINATED DEBT													0
OTHER FINANCING													0
PROJECT FINANCING	0	1,975,814	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,433,097	24,303,153
Total incoming cash	**13,000,000**	**1,975,814**	**2,114,852**	**2,132,476**	**2,162,347**	**2,180,366**	**2,198,536**	**2,221,899**	**2,240,415**	**2,279,104**	**2,364,247**	**2,433,097**	**37,303,153**
DISBURSEMENTS													
Construction draws	12,148,848	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	2,024,808	34,421,736
Loan commitment fees	630,000												630,000
Grass												56,668	56,668
Chemicals													0
Process water													0
Electricity													0
Boiler Fuel													0
Maintenance													0
Plant salaries and benefits	0	0	0	0	7,058	7,058	7,058	12,100	12,100	32,119	98,270	90,750	266,513
Taxes and insurance	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	403,000
Administrative salaries and benefits	24,329	9,329	9,329	9,329	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	167,284
Consulting													0
Miscellaneous	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	368,000
Interest expense		0	16,465	34,089	51,860	69,879	88,049	106,370	124,886	143,556	162,548	182,250	979,952
Total disbursements	**12,867,427**	**2,098,387**	**2,114,852**	**2,132,476**	**2,162,347**	**2,180,366**	**2,198,536**	**2,221,899**	**2,240,415**	**2,279,104**	**2,364,247**	**2,433,097**	**37,293,153**
Beginning cash	0	132,573	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	0
Total receipts	13,000,000	1,975,814	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,433,097	37,303,153
Total disbursements	12,867,427	2,098,387	2,114,852	2,132,476	2,162,347	2,180,366	2,198,536	2,221,899	2,240,415	2,279,104	2,364,247	2,433,097	37,293,153
Ending cash	**132,573**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**
Note balance	**0**	**1,975,814**	**4,090,666**	**6,223,142**	**8,385,489**	**10,565,855**	**12,764,391**	**14,986,290**	**17,226,705**	**19,505,809**	**21,870,056**	**24,303,153**	
Interest rate	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	
Interest expense	0	16,465	34,089	51,860	69,879	88,049	106,370	124,886	143,556	162,548	182,250	202,526	

SOURCES AND APPLICATION OF FUNDS
YEAR 2

NREL - South Dakota Biomass to Ethanol Facility **BEST CASE**

SOURCES AND APPLICATION OF FUNDS (YEAR 2)	Month 13	Month 14	Month 15	Month 16	Month 17	Month 18	Month 19	Month 20	Month 21	Month 22	Month 23	Month 24	Total
CASH INFLOW													
PRODUCTION UNITS													
Fuel Ethanol (gal)	263,158	614,035	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	9,649,123
Carbon Dioxide (tons)	795	1,856	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	29,161
Lignin Fuel (tons)	785	1,833	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	28,798
INVENTORY-FINISHED PRODUCTS													
Fuel Ethanol (gal)	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	
Carbon Dioxide (tons)	300	300	300	300	300	300	300	300	300	300	300	300	
Lignin Fuel (tons)	300	300	300	300	300	300	300	300	300	300	300	300	
SALES UNITS													
Fuel Ethanol (gal)	163,158	614,035	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	877,193	9,549,123
Carbon Dioxide (tons)	495	1,856	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	2,651	28,861
Lignin Fuel (tons)	485	1,833	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	2,618	28,498
SALES DOLLARS													
Fuel Ethanol	187,632	706,140	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	1,008,772	10,981,492
Carbon Dioxide	4,458	16,701	23,859	23,859	23,859	23,859	23,859	23,859	23,859	23,859	23,859	23,859	259,749
Lignin Fuel	5,548	20,947	29,924	29,924	29,924	29,924	29,924	29,924	29,924	29,924	29,924	29,924	325,735
Total Sales	**197,638**	**743,788**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**11,566,976**
ACCOUNTS RECEIVABLE	197,638	743,788	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555
STATE PRODUCERS INCENTIVE	50,000	116,667	166,667	166,667	166,667	166,667	166,667	0	0	0	0	0	1,000,000
INCOMING CASH													
COLLECTIONS	0	743,788	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	11,369,338
EQUITY													0
SUBORDINATED DEBT													0
OTHER FINANCING													0
PROJECT FINANCING	2,843,913	4,351,524	0	0	0	0	0	0	0	1,410			7,196,847
Total incoming cash	**2,843,913**	**5,095,312**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,062,555**	**1,063,965**	**1,062,555**	**1,062,555**	**18,566,185**
DISBURSEMENTS													0
Construction draws	2,024,808	4,049,616											6,074,424
Loan commitment fees													0
Grass	73,871	295,482	344,729	246,235	246,235	246,235	246,235	246,235	246,235	246,235	246,235	246,235	2,930,197
Chemicals	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	81,675	980,100
Process water	49	49	49	49	49	49	49	49	49	49	49	49	588
Electricity	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	128,315	1,539,780
Boiler Fuel	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	12,788	153,456
Maintenance	13,639	31,825	45,465	45,465	45,465	45,465	45,465	45,465	45,465	45,465	45,465	45,465	500,114
Plant salaries and benefits	100,696	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	90,750	1,098,946
Taxes and insurance	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	33,583	403,000
Administrative salaries and benefits	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	20,167	242,004
Inventories	121,129												121,129
Miscellaneous	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	30,667	368,000
Interest expense	202,526	226,226	262,488	262,488	262,488	262,488	262,488	262,488	262,488	262,488	262,500	262,500	3,053,656
Total disbursements	**2,843,913**	**5,001,143**	**1,050,676**	**952,182**	**952,182**	**952,182**	**952,182**	**952,182**	**952,182**	**952,182**	**952,194**	**952,194**	**17,465,394**
Beginning cash	10,000	10,000	104,169	116,048	226,421	336,794	447,167	557,540	667,913	778,286	890,069	1,000,430	10,000
Total receipts	2,843,913	5,095,312	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,062,555	1,063,965	1,062,555	1,062,555	18,566,185
Total disbursements	2,843,913	5,001,143	1,050,676	952,182	952,182	952,182	952,182	952,182	952,182	952,182	952,194	952,194	17,465,394
Ending cash	**10,000**	**104,169**	**116,048**	**226,421**	**336,794**	**447,167**	**557,540**	**667,913**	**778,286**	**890,069**	**1,000,430**	**1,110,791**	**1,110,791**
Note balance	**27,147,066**	**31,498,590**	**31,498,590**	**31,498,590**	**31,498,590**	**31,498,590**	**31,498,590**	**31,498,590**	**31,498,590**	**31,500,000**	**31,500,000**	**31,500,000**	
Interest rate	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	
Interest expense	226,226	262,488	262,488	262,488	262,488	262,488	262,488	262,488	262,488	262,500	262,500	262,500	

NREL - South Dakota Biomass to Ethanol Facility **BEST CASE**

BALANCE SHEET	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Assets												
Current Assets												
Cash	10,000	800,321	2,135,712	3,560,639	5,076,892	6,686,299	8,390,723	10,192,065	12,092,262	14,093,292	16,132,485	17,768,707
Accounts receivable	0	1,062,555	1,083,806	1,105,482	1,127,592	1,150,144	1,173,147	1,196,610	1,220,542	1,244,953	1,269,852	1,295,249
State Producers Incentive	0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	0
Inventory	56,668	177,797	181,353	184,980	188,679	192,453	196,302	200,228	204,233	208,317	212,484	216,733
Prepaid expenses												
Reserve for Capital Expenses		0	0	0	0	0	0	0	0	0	0	0
Total Current Assets	**66,668**	**3,040,673**	**4,400,871**	**5,851,101**	**7,393,164**	**9,028,896**	**10,760,172**	**12,588,903**	**14,517,037**	**16,546,562**	**18,614,820**	**19,280,689**
Property, Plant & Equipment												
Plant equipment	35,401,688	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112	41,476,112
Construction in progress												
Accumulated depreciation	0	2,765,074	5,530,148	8,295,222	11,060,296	13,825,370	16,590,444	19,355,518	22,120,592	24,885,666	27,650,740	30,415,814
Net Plant Value	**35,401,688**	**38,711,038**	**35,945,964**	**33,180,890**	**30,415,816**	**27,650,742**	**24,885,668**	**22,120,594**	**19,355,520**	**16,590,446**	**13,825,372**	**11,060,298**
Other Assets												
Organizational costs	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797
Accumulated amortization	0	240,959	481,918	722,877	963,836	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797	1,204,797
Loan acquisition costs	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000
Accumulated amortization	42,000	84,000	126,000	168,000	210,000	252,000	294,000	336,000	378,000	420,000	462,000	504,000
Total Other Assets	**1,792,797**	**1,509,838**	**1,226,879**	**943,920**	**660,961**	**378,000**	**336,000**	**294,000**	**252,000**	**210,000**	**168,000**	**126,000**
Total Assets	**37,261,153**	**43,261,549**	**41,573,714**	**39,975,911**	**38,469,941**	**37,057,638**	**35,981,840**	**35,003,497**	**34,124,557**	**33,347,008**	**32,608,192**	**30,466,987**
Liabilities and Partners' Equity												
Current Liabilities												
Income Taxes Payable										64,688	572,565	841,744
Current portion of long-term debt		991,424	1,090,566	1,199,623	1,319,585	1,451,544	1,596,698	1,756,368	1,932,005	2,125,205	2,337,726	2,571,498
Total Current Liabilities	**0**	**991,424**	**1,090,566**	**1,199,623**	**1,319,585**	**1,451,544**	**1,596,698**	**1,756,368**	**1,932,005**	**2,189,893**	**2,910,290**	**3,413,243**
Long-Term Liabilities												
Project financing	24,303,153	31,500,000	30,508,576	29,418,010	28,218,387	26,898,801	25,447,258	23,850,559	22,094,191	20,162,186	18,036,981	15,699,255
Subordinated Debt												
Other loan												
Less current portion		(991,424)	(1,090,566)	(1,199,623)	(1,319,585)	(1,451,544)	(1,596,698)	(1,756,368)	(1,932,005)	(2,125,205)	(2,337,726)	(2,571,498)
Total Long-Term Liabilities	**24,303,153**	**30,508,576**	**29,418,010**	**28,218,387**	**26,898,801**	**25,447,258**	**23,850,559**	**22,094,191**	**20,162,186**	**18,036,981**	**15,699,255**	**13,127,757**
Partners' Equity												
Equity	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000	13,000,000
Accumulated earnings	(42,000)	(1,238,451)	(1,934,862)	(2,442,099)	(2,748,446)	(2,841,164)	(2,465,418)	(1,847,062)	(969,634)	120,134	998,647	925,987
Total Partners' Equity	**12,958,000**	**11,761,549**	**11,065,138**	**10,557,901**	**10,251,554**	**10,158,836**	**10,534,582**	**11,152,938**	**12,030,366**	**13,120,134**	**13,998,647**	**13,925,987**
Total Liabilities and Equity	**37,261,153**	**43,261,549**	**41,573,714**	**39,975,911**	**38,469,941**	**37,057,638**	**35,981,840**	**35,003,497**	**34,124,557**	**33,347,008**	**32,608,192**	**30,466,987**

NREL - South Dakota Biomass to Ethanol Facility **BEST CASE**

INCOME STATEMENT	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Sales												
Fuel Ethanol	0	10,981,492	12,105,263	12,347,368	12,594,315	12,846,201	13,103,125	13,365,188	13,632,492	13,905,142	14,183,245	14,466,910
Carbon Dioxide	0	259,749	286,311	292,037	297,878	303,836	309,913	316,111	322,433	328,882	335,460	342,169
Lignin Fuel	0	325,735	359,086	366,268	373,593	381,065	388,686	396,460	404,389	412,477	420,727	429,142
Total Sales	**0**	**11,566,976**	**12,750,660**	**13,005,673**	**13,265,786**	**13,531,102**	**13,801,724**	**14,077,759**	**14,359,314**	**14,646,501**	**14,939,432**	**15,238,221**
State Producers Incentive	0	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	0
Total Income	**0**	**12,566,976**	**13,750,660**	**14,005,673**	**14,265,786**	**14,531,102**	**14,801,724**	**15,077,759**	**15,359,314**	**15,646,501**	**15,939,432**	**15,238,221**
Cost of sales												
Grass	0	2,930,197	2,954,825	3,013,921	3,074,199	3,135,683	3,198,397	3,262,365	3,327,612	3,394,164	3,462,047	3,531,288
Chemicals	0	980,100	980,101	999,703	1,019,697	1,040,091	1,060,893	1,082,111	1,103,753	1,125,828	1,148,345	1,171,312
Process water	0	588	582	594	606	618	630	643	656	669	682	696
Electricity	0	1,539,780	1,539,780	1,570,576	1,601,988	1,634,028	1,666,709	1,700,043	1,734,044	1,768,725	1,804,100	1,840,182
Boiler Fuel	0	153,456	153,450	156,519	159,649	162,842	166,099	169,421	172,809	176,265	179,790	183,386
Maintenance	0	500,114	518,300	528,666	539,239	550,024	561,024	572,244	583,689	595,363	607,270	619,415
Plant salaries and benefits	0	544,500	1,089,000	1,110,780	1,132,996	1,155,656	1,178,769	1,202,344	1,226,391	1,250,919	1,275,937	1,301,456
Depreciation	0	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074
Total Cost of Sales	**0**	**9,413,809**	**10,001,112**	**10,145,833**	**10,293,448**	**10,444,016**	**10,597,595**	**10,754,245**	**10,914,028**	**11,077,007**	**11,243,245**	**11,412,809**
Gross Margin	**0**	**3,153,168**	**3,749,548**	**3,859,840**	**3,972,338**	**4,087,086**	**4,204,129**	**4,323,514**	**4,445,286**	**4,569,494**	**4,696,187**	**3,825,412**
General & Administrative Costs												
Taxes and insurance		403,000	403,000	411,060	419,281	427,667	436,220	444,944	453,843	462,920	472,178	481,622
Administrative salaries and benefits		242,004	242,000	246,840	251,777	256,813	261,949	267,188	272,532	277,983	283,543	289,214
Consulting expenses		0	0	0	0	0	0	0	0	0	0	0
Interest expense		3,053,656	3,150,000	3,050,858	2,941,801	2,821,839	2,689,880	2,544,726	2,385,056	2,209,419	2,016,219	1,803,698
Amortization-Loan Fees	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000
Amortization-Start-up Expenses	0	240,959	240,959	240,959	240,959	240,961	0	0	0	0	0	0
Miscellaneous		368,000	368,000	375,360	382,867	390,524	398,334	406,301	414,427	422,716	431,170	439,793
Total Gen. & Admin. Expenses	**42,000**	**4,349,619**	**4,445,959**	**4,367,077**	**4,278,685**	**4,179,804**	**3,828,383**	**3,705,159**	**3,567,858**	**3,415,038**	**3,245,110**	**3,056,327**
Pre-Tax Income	**(42,000)**	**(1,196,451)**	**(696,411)**	**(507,237)**	**(306,347)**	**(92,718)**	**375,746**	**618,355**	**877,428**	**1,154,456**	**1,451,077**	**769,085**
Income taxes-35%										**64,688**	**572,565**	**841,744**
Net Income	**(42,000)**	**(1,196,451)**	**(696,411)**	**(507,237)**	**(306,347)**	**(92,718)**	**375,746**	**618,355**	**877,428**	**1,089,768**	**878,513**	**(72,659)**

Cumulative pre-tax earnings	(42,000)	(1,238,451)	(1,934,862)	(2,442,099)	(2,748,446)	(2,841,164)	(2,465,418)	(1,847,062)	(969,634)	184,821	1,635,899	2,404,984
Cumulative earnings	(42,000)	(1,238,451)	(1,934,862)	(2,442,099)	(2,748,446)	(2,841,164)	(2,465,418)	(1,847,062)	(969,634)	120,134	998,647	925,987

CASH FLOW STATEMENT

NREL - South Dakota Biomass to Ethanol Facility **BEST CASE**

CASH FLOW STATEMENT	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12
Cash Flow From Operations												
Net income	(42,000)	(1,196,451)	(696,411)	(507,237)	(306,347)	(92,718)	375,746	618,355	877,428	1,089,768	878,513	(72,659)
Adjustments to Reconcile Net Income												
to Net Cash Provided by Operations												
Depreciation	0	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074	2,765,074
Amortization	42,000	282,959	282,959	282,959	282,959	282,961	42,000	42,000	42,000	42,000	42,000	42,000
Net (Increase)Decrease in Operating Assets:												
Accounts receivable	0	(1,062,555)	(21,251)	(21,676)	(22,110)	(22,552)	(23,003)	(23,463)	(23,932)	(24,411)	(24,899)	(25,397)
State Producers Incentive	0	(1,000,000)	0	0	0	0	0	0	0	0	0	1,000,000
Inventories	(56,668)	(121,129)	(3,556)	(3,627)	(3,700)	(3,774)	(3,849)	(3,926)	(4,005)	(4,085)	(4,166)	(4,250)
Prepaid items												
Net Increase (Decrease) in Operating Liabilities:												
Accounts payable												
Other current liabilities			0	0	0	0	0	0	0	64,688	507,877	269,180
Net Cash From Operations	**(56,668)**	**(332,103)**	**2,326,815**	**2,515,493**	**2,715,877**	**2,928,992**	**3,155,968**	**3,398,040**	**3,656,565**	**3,933,034**	**4,164,398**	**3,973,948**
Cash Flows From Investing Activities												
(Increase) Decrease in Property and Equipment	(35,401,688)	(6,074,424)	0	0	0	0	0	0	0	0	0	0
(Increase) Decrease in Organization Costs	(1,204,797)	0	0	0	0	0	0	0	0	0	0	0
(Increase) Decrease in Loan Fees	(630,000)	0	0	0	0	0	0	0	0	0	0	0
(Increase) Decrease in Equipment Reserve												
Cash Flows From Financing Operations												
Increase (Decrease) in Equity	13,000,000											
Increase (Decrease) in Long Term Financing	24,303,153	7,196,847	(991,424)	(1,090,566)	(1,199,623)	(1,319,585)	(1,451,544)	(1,596,698)	(1,756,368)	(1,932,005)	(2,125,205)	(2,337,726)
Net Increase (Decrease) in Cash	**10,000**	**790,321**	**1,335,391**	**1,424,927**	**1,516,254**	**1,609,407**	**1,704,424**	**1,801,342**	**1,900,197**	**2,001,030**	**2,039,193**	**1,636,222**
Cash Balance - Beginning of Period	**0**	**10,000**	**800,321**	**2,135,712**	**3,560,639**	**5,076,892**	**6,686,299**	**8,390,723**	**10,192,065**	**12,092,262**	**14,093,292**	**16,132,485**
Cash Balance - End of Period	**10,000**	**800,321**	**2,135,712**	**3,560,639**	**5,076,892**	**6,686,299**	**8,390,723**	**10,192,065**	**12,092,262**	**14,093,292**	**16,132,485**	**17,768,707**

PRICING SENSITIVITY MATRIX
AVERAGE ANNUAL PRE-TAX INCOME (YEARS 3 THROUGH 12)

NREL - South Dakota Biomass to Ethanol Facility **BEST CASE**

Ethanol ($/gallon)

Grass $ per ton		0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
G	**29.00**	($3,207,406)	($2,681,091)	($2,154,775)	($1,628,459)	($1,102,143)	($575,828)	($49,512)	$476,804	$1,003,120	$1,529,436	$2,055,751
r	**28.00**	($3,073,096)	($2,546,780)	($2,020,465)	($1,494,149)	($967,833)	($441,517)	$84,798	$611,114	$1,137,430	$1,663,746	$2,190,062
a	**27.00**	($2,938,786)	($2,412,470)	($1,886,154)	($1,359,839)	($833,523)	($307,207)	$219,109	$745,424	$1,271,740	$1,798,056	$2,324,372
s	**26.00**	($2,804,476)	($2,278,160)	($1,751,844)	($1,225,528)	($699,213)	($172,897)	$353,419	$879,735	$1,406,051	$1,932,366	$2,458,682
s	**25.00**	($2,670,166)	($2,143,850)	($1,617,534)	($1,091,218)	($564,902)	($38,587)	$487,729	$1,014,045	$1,540,361	$2,066,677	$2,592,992
	24.00	($2,535,855)	($2,009,540)	($1,483,224)	($956,908)	($430,592)	$95,724	$622,039	$1,148,355	$1,674,671	$2,200,987	$2,727,303
$	**23.00**	($2,401,545)	($1,875,229)	($1,348,914)	($822,598)	($296,282)	$230,034	$756,350	$1,282,665	$1,808,981	$2,335,297	$2,861,613
	22.00	($2,267,235)	($1,740,919)	($1,214,603)	($688,288)	($161,972)	$364,344	$890,660	$1,416,976	$1,943,291	$2,469,607	$2,995,923
p	**21.00**	($2,132,925)	($1,606,609)	($1,080,293)	($553,977)	($27,662)	$498,654	$1,024,970	$1,551,286	$2,077,602	$2,603,917	$3,130,233
e	**20.00**	($1,998,615)	($1,472,299)	($945,983)	($419,667)	$106,649	$632,964	$1,159,280	$1,685,596	$2,211,912	$2,738,228	$3,264,543
r	**19.00**	($1,864,304)	($1,337,989)	($811,673)	($285,357)	$240,959	$767,275	$1,293,590	$1,819,906	$2,346,222	$2,872,538	$3,398,854
	18.00	($1,729,994)	($1,203,678)	($677,363)	($151,047)	$375,269	$901,585	$1,427,901	$1,954,216	$2,480,532	$3,006,848	$3,533,164
t	**17.00**	($1,595,684)	($1,069,368)	($543,052)	($16,736)	$509,579	$1,035,895	$1,562,211	$2,088,527	$2,614,842	$3,141,158	$3,667,474
o	**16.00**	($1,461,374)	($935,058)	($408,742)	$117,574	$643,890	$1,170,205	$1,696,521	$2,222,837	$2,749,153	$3,275,468	$3,801,784
n	**15.00**	($1,327,063)	($800,748)	($274,432)	$251,884	$778,200	$1,304,516	$1,830,831	$2,357,147	$2,883,463	$3,409,779	$3,936,094

Note: Matrix assumes that the selling price of lignin fuel and carbon dioxide remains constant

PRICING SENSITIVITY MATRIX
AVERAGE ANNUAL CASH FLOW (YEARS 3 THROUGH 12)

NREL - South Dakota Biomass to Ethanol Facility **BEST CASE**

Ethanol ($/gallon)

		0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
G	**29.00**	($1,874,911)	($1,348,596)	($822,280)	($295,964)	$230,352	$756,667	$1,282,983	$1,809,299	$2,335,615	$2,861,931	$3,388,246
r	**28.00**	($1,740,601)	($1,214,285)	($687,970)	($161,654)	$364,662	$890,978	$1,417,293	$1,943,609	$2,469,925	$2,996,241	$3,522,557
a	**27.00**	($1,606,291)	($1,079,975)	($553,659)	($27,344)	$498,972	$1,025,288	$1,551,604	$2,077,919	$2,604,235	$3,130,551	$3,656,867
s	**26.00**	($1,471,981)	($945,665)	($419,349)	$106,967	$633,282	$1,159,598	$1,685,914	$2,212,230	$2,738,546	$3,264,861	$3,791,177
s	**25.00**	($1,337,671)	($811,355)	($285,039)	$241,277	$767,593	$1,293,908	$1,820,224	$2,346,540	$2,872,856	$3,399,172	$3,925,487
	24.00	($1,203,360)	($677,045)	($150,729)	$375,587	$901,903	$1,428,219	$1,954,534	$2,480,850	$3,007,166	$3,533,482	$4,059,798
$	**23.00**	($1,069,050)	($542,734)	($16,419)	$509,897	$1,036,213	$1,562,529	$2,088,845	$2,615,160	$3,141,476	$3,667,792	$4,194,108
	22.00	($934,740)	($408,424)	$117,892	$644,207	$1,170,523	$1,696,839	$2,223,155	$2,749,471	$3,275,786	$3,802,102	$4,328,418
p	**21.00**	($800,430)	($274,114)	$252,202	$778,518	$1,304,833	$1,831,149	$2,357,465	$2,883,781	$3,410,097	$3,936,412	$4,462,728
e	**20.00**	($666,120)	($139,804)	$386,512	$912,828	$1,439,144	$1,965,459	$2,491,775	$3,018,091	$3,544,407	$4,070,723	$4,597,038
r	**19.00**	($531,809)	($5,494)	$520,822	$1,047,138	$1,573,454	$2,099,770	$2,626,085	$3,152,401	$3,678,717	$4,205,033	$4,731,349
	18.00	($397,499)	$128,817	$655,132	$1,181,448	$1,707,764	$2,234,080	$2,760,396	$3,286,711	$3,813,027	$4,339,343	$4,865,659
t	**17.00**	($263,189)	$263,127	$789,443	$1,315,759	$1,842,074	$2,368,390	$2,894,706	$3,421,022	$3,947,337	$4,473,653	$4,999,969
o	**16.00**	($128,879)	$397,437	$923,753	$1,450,069	$1,976,385	$2,502,700	$3,029,016	$3,555,332	$4,081,648	$4,607,963	$5,134,279
n	**15.00**	$5,432	$531,747	$1,058,063	$1,584,379	$2,110,695	$2,637,011	$3,163,326	$3,689,642	$4,215,958	$4,742,274	$5,268,589

Note: Matrix assumes that the selling price of lignin fuel and carbon dioxide remains constant

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Feasibility study for a cellulosic ethanol plant using grasses grown on Conservation Reserve Program lands in three counties of South Dakota, with several subcomponent appendices.

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