

Evaluation of the Potential for the Production of Lignocellulosic Based Ethanol at Existing Corn Ethanol Facilities

**Final Subcontract Report
2 March 2000—30 March 2002**

Delta T Corporation
Williamsburg, VA



NREL

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

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NREL Technical Monitor: A. Aden

Prepared under Subcontract No. ZCL-0-30008-01



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TABLE OF CONTENTS

Goals	1
Scope	1
Objectives	2
Gasification of Biomass to Synthesis Gas to Ethanol.....	2
Conversion of DDG to Sugars to Ethanol.....	5
Dilute Acid Hydrolysis of Biomass to Sugars to Ethanol.....	5
Near Term Commercialization Study	6
Incremental Block Blow Diagram.....	6
Incremental Utility Requirements.....	6
Capital Equipment Modifications and Additions to the Existing Facility	6
Additional Infrastructure Requirements	7
Production Capacity Before and After the Installation of the Process.....	7
Feedstock Description	7
Facility Description	8
Process Addition Description.....	9
Required Modifications, Production Parameters, and Availability of Capital- Equipment and Infrastructure That Will Be Shared	10
Additional Equipment.....	11
Minimum Feedstock Supply Quantities and Expected Quality Mix.....	11
Ethanol Production Rate In Gal/Day and Solid By-Product Rate.....	12
Environmental Emission Characteristics, In Terms of Quantity Emitted Per Ton of Feedstock Processed.	12
Area Requirements and Preferred Shape	12
Utility and Chemical Requirements (Water, Steam, Fuel, Power, Chemicals).....	13
Capital and Operating Costs	15
Incremental Financial Pro Forma.....	15
Sensitivity Analysis	16
Recommendations for Further Work.....	17
Appendix.....	18

GOALS

The goals of this study were:

- To provide the opportunity to explore the business potential provided by converting biomass to products such as ethanol.
- To take advantage of the grain-processing infrastructure by investigating the co-location of additional biomass conversion facilities at an existing plant site.

SCOPE

Delta-T's task was to perform process assessments for three biomass conversion processes. The feasibility studies were used to evaluate the potential alternatives for plant integration of biomass feedstock with an existing corn to ethanol facility. Delta T has recommended a preferred technology, DDG Conversion using Dilute Acid hydrolysis, based upon its near-term commercial viability.

The three processes considered were:

- Gasification of Biomass to Synthesis Gas to Ethanol
- DDG Conversion
- Dilute Acid Hydrolysis

Gasification was to be reviewed and considered primarily as a stand-alone alternative approach to ethanol production and not necessarily for specific co-location and integration into an existing ethanol facility.

OBJECTIVES

The technical objectives of the study were designed to evaluate the business opportunity for lignocellulosic biomass conversion for the specific processing site. The overall result of this study is as follows:

GASIFICATION OF BIOMASS TO SYNTHESIS GAS TO ETHANOL

To date, production of fuel grade alcohol has been focused on converting feedstock from renewable sources such as corn and other grown starch containing materials or cellulose containing materials through biological processing. This approach, almost without exception, relies on “bugs” and materials that are susceptible to infection which result in either significantly reduced yields or greatly increased production costs for the alcohol product desired. An alternative approach to alcohol production is to consider a method of chemical processing to produce alcohol. Commercially in much of the world, carbonaceous materials are processed through partial oxidation (gasification) to generate a synthesis (“syngas”) gas consisting of carbon monoxide (CO) and hydrogen (H₂). This syngas is then processed through catalytic steps to produce a chemical basic material. Two bulk chemicals that come to mind that are produced in this fashion are ammonia and methanol. Sasol has, on a commercial basis for over 35 years now, used the approach of converting coal through gasification to a syngas from which gasoline and a wide variety of chemical basic and intermediate compounds are produced.

Since residual materials such as corn stover, rice straw and hull, etc. contain carbonaceous materials, they can, in principle, be processed in a complete (burning) or partial oxidation (gasification) system. Gasification offers the advantage over complete combustion of producing a syngas that has the potential of being converted to ethanol as well as heat that could be used for process steam. In addition, chemical synthesis of ethanol offers the following advantages over conventional biological approaches for ethanol production:

- High temperature processing eliminating conditions that support infections in typical biological processing.
- Elimination of the need for yeast and “bugs” for obtaining yield and conversion efficiencies.
- Elimination of large quantities and volume of tankage and piping & pumping required in a typical biomass unit, minimizing plant foot print requirements.

On the other hand, drawbacks of this approach are:

- Catalysis of syngas to chemical constituents is generally accomplished at high pressure, requiring special design considerations in plant & equipment design and significant compression requirements.
- Until recently, no catalyst had been identified that offers the potential for longevity and reasonable yield for alcohol production.

Accordingly, the effort associated with this evaluation was focused at identifying if any work exists that might lead to a near-term implementation of a gasification/syngas conversion approach for the production of alcohol. The following summarizes the results of this assessment.

A limited literature search was conducted to identify what work might have already been sponsored by DOE/NREL in the application of gasification to ethanol production. Under this category, some bench scale work had been performed in processing syngas in a liquid type fermentation approach. From Delta-T's review, the work performed resulted in an approach that rendered alcohol production susceptible to infection and large residence time (tankage) requirements similar to that in an acid hydrolysis process. In addition, work performed to-date had been at the bench scale level only. Significant research and development would be required to assess commercialization potential. As the criteria for assessing technologies is the potential for near term commercialization, this approach was deemed not consistent with this criteria for the purposes of this evaluation.

Additional investigation identified an ethanol production approach using catalytic conversion of syngas. The use of catalyst for chemical manufacturing represents an approach used commercially throughout the world today. Particularly, chemical synthesis of methanol using this approach is widely practiced. With respect to use of gasification for producing syngas from which chemicals are synthesized, Sasol represents a prime example where this has been practiced for over 35 years now. While an integrated gasification-to-ethanol system has not been demonstrated, individual steps of the process are commercially available. The following describes one such process.

The process entails using biomass feed stock such as corn stover, wood chips, or other carbonaceous material, prepared and introduced into a partial oxidation unit. High purity oxygen is fed with the feed material to generate both heat and the basic syngas. The syngas is cleaned; adjustment made to obtain the appropriate H₂/CO ratio, compressed, and fed through the catalytic conversion step. Dehydration of the Ecalene™ product is accomplished using molecular sieve technology and forwarded to storage. Heat recovery is

obtained from the gasification process and downstream processing to provide process steam. A block diagram (attachment 5a) is attached summarizing this process approach.

Ecalene™ has the following advertised composition:

<u>Component</u>	<u>Weight %</u>	<u>Mole %</u>
Methanol	0.3	0.4
Ethanol	75.0	81.9
Propanol	9.0	8.1
Butanol	7.0	4.8
Pentanol	5.0	2.8
Hexanol & higher	3.7	2.0
Total	100.0	100.0

Although the ASTM D 4806 requires a minimum of 92.1-volume% ethanol, Ecalene™ has been categorized by EPA as an acceptable gasoline additive. Bench scale testing has been performed to confirm effectiveness of the catalyst. A firm, Power Energy Technologies has obtained a patent for the Ecalene™ production catalyst. A 700-gallon per day demonstration skid unit has been constructed.

Based on published information, a conceptual capital and operating cost assessment was performed for a commercial size Ecalene™ production plant (attachments 5b, 5c, 5d). The general economic approach used was similar to that in NREL report “Corn Stover To Ethanol Process Design” dated 21May98. Cost estimates for sub-system within the Ecalene™ production facility were based on the referenced NREL report, information obtained from selected, available information on the web, and independent supplier contact. A 15 million gallon per year undenatured alcohol product capacity was selected. Based on this approach, the total annual cost using the Ecalene™ process approach with gasification is \$ 1.28/gal. Total installed equipment cost for this facility is approximately \$28.4 million and total capital investment, using the criteria from the referenced report above, of \$48.2 million.

The estimate prepared compares to the \$ 1.30/gal for the 58 million gallon per year capacity in the referenced NREL study. Assuming a capital scale factor of 0.6, the Ecalene™ process approach at the 58 million gallon per year capacity would result in a \$1.08/gal on an annual basis.

Based on the above, Delta-T believes this approach warrants further investigation. For instance, potential integration of this technology approach into an existing corn-to-ethanol plant could be considered to replace the

steam generation equipment while producing ethanol. The unit would use corn stover as a feedstock and the product could be blended with corn plant alcohol directly. This effort would require a very specific detailed engineering study and was assessed to be beyond the scope of this effort.

In summary, the approach of gasification and catalytic conversion to an alcohol product for fuel grade material offers potential for renewable materials as a feedstock and should be investigated further.

CONVERSION OF DDG TO SUGARS TO ETHANOL

Delta-T has looked at the inclusion of the Brelsford 2 stage dilute acid hydrolysis process at CVEC for the conversion of DDG to sugars to ethanol. This appeared to be a cost effective method of increasing the yield at an existing ethanol facility. Using the Brelsford process, a yield increase of up to 18.75% in ethanol production has been forecasted by Brelsford Engineering. The byproduct stream of Wet Distillers Grain would be reduced from 35,000 lbs/hr to 18,000 lbs/hr but the protein content has been assumed to remain the same. Therefore the revenue from this co-product is assumed to be unchanged and is not included in the analysis. The reduced cellulose content in the Wet Distillers Grain may in fact make it more marketable.

DILUTE ACID HYDROLYSIS OF BIOMASS TO SUGARS TO ETHANOL

Both the NREL dilute acid hydrolysis process and an alternative dilute acid hydrolysis process had previously been considered earlier in the study. Further consideration of these approaches was not pursued because:

- Preliminary economic assessment did not indicate adequate commercial viability.
- Economic viability depended on conceptual, non-demonstrated processing steps for by-product recovery and basic process performance.

NEAR TERM COMMERCIALIZATION STUDY

From a near term commercialization stand point, the conversion of DDG via dilute acid hydrolysis to sugars to ethanol appeared to be the most promising process and was therefore chosen by Delta-T as the preferred process for further study. This decision was made as technical and reaction model data was available from bench scale testing performed on DDGS for the Brelsford 2 stage process. Delta-T has investigated this process further and has proceeded with the study of the installation of a Brelsford two-stage dilute acid hydrolysis process at the Chippewa Valley conversion facility.

As part of this study the following information was produced:

INCREMENTAL BLOCK BLOW DIAGRAM

See attachment 1a, b, and c.

INCREMENTAL UTILITY REQUIREMENTS

Steam to Brelsford Process 8.5 MMBTU/Hr.

Electric Power

New Chiller/Cooling Tower	423KW
Brelsford Process	420 KW
Lime Addition	15KW
Seed fermentation	31KW
Total Electric Power	889 KW

CAPITAL EQUIPMENT MODIFICATIONS AND ADDITIONS TO THE EXISTING FACILITY

See attachment 2a, Based Case Equipment Estimate.

For the purposes of this study, it was assumed the existing dryer system could adequately handle the co product from the Brelsford process. The new co product of WDG is expected to have less fiber content and may be too dusty for processing in a direct fired dryer. This concern can only be addressed by testing and assessment of the existing dryer, which is beyond the scope of this study.

ADDITIONAL INFRASTRUCTURE REQUIREMENTS

The addition of the Brelsford process would require additional steam at higher pressures than presently produced at the CVEC facility. An additional boiler and piping to the Brelsford process have been included in the capital estimate for the base case.

The new process will require additional chilled water capacity to cool the stream to fermentation from the Brelsford process. Costs have been included for an additional chiller, cooling tower cell, and pumps.

PRODUCTION CAPACITY BEFORE AND AFTER THE INSTALLATION OF THE PROCESS

Ethanol Production

Before proposed modifications	19.2 MMgal/yr
After proposed modifications	22.8 MMgal/yr

DDGS Before proposed modifications	114 Million #/yr.
DDGS After proposed modifications	60 Million #/yr.

(Note the total protein content of the DDGS produced before and after the modifications is assumed to be constant. Accordingly, the total value of the DDG was assumed to be unchanged from current plant revenues for this co product.)

FEEDSTOCK DESCRIPTION

Wet Distillers Grain was the assumed feedstock for the addition of dilute acid hydrolysis process at this facility. This consists of the combination of the syrup and the wet distillers grain that normally is delivered to the dryer at this facility. The Brelsford process is expected to produce a Wet Distillers Grain co-product of lesser flow than the existing stream but it has been assumed for the purposes of this study that the total protein content will remain the same. A further assumption is that the revenue generated from the DDGS is based upon protein content. Therefore, the revenue generated from DDGS is considered to be unaffected and the cost of the feedstock is assumed to be zero.

FEEDSTOCK COMPOSITION (WET CAKE AND SYRUP) LB/HR FLOW 35% DRY BASIS

Alpha Cellulose	Hemi Cellulose	Dextrin	Soluble Sugars	Protein	Fat	Ash	Lignin	Total Solids
1187	2653	1130	1243	3562	1613	869	154	12411

FACILITY DESCRIPTION

Chippewa Valley Ethanol Company, Benson, MN site specifications.

FACILITY PRODUCTION CAPACITY

Anhydrous Ethanol-Production MMgal/yr.	19.2
Anhydrous Ethanol-gallons/Dry Bushel Corn	2.7
DDGS-lbs/Bushel corn	16.3
Design fermentable sugar to fermentation MM#/yr.	213

INFRASTRUCTURE DESCRIPTION (UTILITIES, WATER, WASTE DISPOSAL, ROADS, RAIL)

Power

CVEC has 3 460V-1500KW transformers, 2 are fully loaded and 1 is currently loaded to 400KW. Substation capacity is 3700KW.

Water

CVEC is permitted for 75 million gallons per year. The year 2000 usage was 63.5 million gallons.

Waste Disposal

CVEC has 2 40000-gallon wastewater tanks that are permitted for only 12 days of use per year. Cooling tower and boiler blow down is permitted to go to an existing fire protection pond and overflow goes to a ditch leading to the Chippewa River. During overflow months, the flow is sampled and tested by the state. There are no other process sewer or wastewater connections. CVEC is a “zero effluent” plant therefore any process additions must minimize water emissions.

Roads

CVEC is located just to the West of Benson, MN. It is at the intersection of route. 9 and route 20.

Rail

CVEC has a rail spur for product load out to the north of the facility. This spur is off the Burlington Northern Railroad.

PROCESS ADDITION DESCRIPTION

(See Brelsford Engineering, Inc. Distillers Grains Cellulose Hydrolysis to Fermentable Sugars for Production of Fuel Ethanol and Hi-Protein Feedstuff- Preliminary Engineering and Economics feasibility Study for a more detailed description)

Distillers Wet Grains and Syrup (DWGS) are extracted from the existing process by redirection of the flow from the existing centrifuges. An additional series of screw conveyors would direct this feedstock to a mix tank. In this mix tank the WDGS is mixed with back set from the existing process to yield an acceptable dilution ratio for pumping, estimated at 18% solids. This mixture is then pumped through a heat exchanger to a reaction temperature and pressure of 35 psia. and 275 deg. F via indirect steam heat. Sulfuric acid is added to the process stream to a concentration of 1.5%. The slurry is then pumped through a series of plug flow reactor tubes with a residence time of approximately 10 minutes. The hemi cellulose (HC) fraction and a part of the resistant cellulose fraction of the holocellulose are converted to their respective sugars.

At the end of first stage of the process, the cellulose hydrolyzate sugars in solution and unhydrolyzed cellulose-protein-fat residue are continuously flashed to lower pressures in two stages. The first slurry hydrolyzate flash tank is to stop degrading of the sugars in the hydrolyzate, and to recover process heat and remove water/furfural/methanol vapor. At the second flash, the vapor pressure is dropped to atmospheric pressure. In addition, the second flash tank provides partial clarification and thickening of the unhydrolyzed cellulose-protein-fat residue. The thickened slurry is separated into a liquid hydrolyzate stream and a dewatered residue wet cake by means of a rotary vacuum filter. (An alternate process improvement might be to utilize the existing or new centrifuges.) The hydrolyzate stream, consisting of the converted sugars, is sent on to the lime addition module for acid neutralization. The thickened wet cake from the first stage is sent to the second stage of the Brelsford process.

In the second stage of the Brelsford process the unhydrolyzed cellulose feedstock from the 1st stage and unhydrolyzed alpha-cellulose residue recycle from the 2nd stage are put through a reaction process similar to the first stage. In the 2nd stage of the process, the reaction temperature and pressure are raised to 356 deg. F and 160 psia. The reaction time is 13 minutes at an acid

concentration of 1%. The resultant slurry from this second stage is separated into a high protein wet cake stream and a dilute acid and alpha cellulose hydrolyzate solution. The wet cake stream is sent back to the existing dryer system at the CVEC facility for processing and storage as high protein DDGS. The hydrolyzate solution from the second stage is recycled to the 1st stage of the Brelsford process for recovery of the hydrolyzate. Additional benefits of this recycle are reuse of acid, recovery of process heat, and the use of liquid for front end dilution of the Brelsford process feedstock (the existing WDG process stream).

The hydrolyzate from the 1st stage of the Brelsford process is sent on to the new lime addition module for acid neutralization. This process module is taken from the NREL study section A200 Lime addition.

After the acid neutralization and cooling down of the hydrolyzate sugar solution from the Brelsford process, the process stream is combined with the flow from the existing Saccharification Tank (now at a reduce liquid flow due to the reduction in backset sent to the slurry mix tank). The combined stream is sent to the existing Fermentation tanks for conversion of the sugars to ethanol.

The existing yeast fermentation at CVEC uses the *Saccharomyces Cerevisiae* yeast. This yeast is unable to convert the Hemi cellulose hydrolyzate, which is the majority of the conversion from the Brelsford process, into ethanol. Delta- T has therefore included a module to convert the existing fermentation process to NREL's *Zymomonas mobilis* bacterium for ethanol production. An alternative for further investigation might be the use of the Purdue University's laboratory of Renewable Resources Engineering (LORRE) *saccharomyces* yeast strain 1400 (LNH-ST). This genetically engineered yeast is capable of fermenting the sugars produced from the Brelsford dilute acid process. Delta-T is not aware of any commercial use of either of these organisms. The conversion to untried fermentation at CVEC may be unacceptable. In addition, questions arise in the use of genetically altered organisms for the production of animal feedstock- the DDGS.

REQUIRED MODIFICATIONS, PRODUCTION PARAMETERS, AND AVAILABILITY OF CAPITAL-EQUIPMENT AND INFRASTRUCTURE THAT WILL BE SHARED

The Proposed Brelsford process will be integrated into the existing CVEC production facility via a new building addition on the north side of the main process building. The two stage process would be located near the existing wet cake load out at the facility in order to minimize process runs for WDG to

and from the process. Screw conveyors would tie into the existing routing of the WDG to the existing dryer and would also feed the new WDG co product from the Brelsford process. Process lines would be added from the existing pipe racks for backset, steam, condensate return, acid, and the new mash flow to the existing fermentation process. In order to support the Brelsford process steam and cool down requirements, additional boiler chiller, and cooling tower capacity has been included in the capital and operating cost estimate.

ADDITIONAL EQUIPMENT

The addition of the Brelsford 2 stage dilute acid hydrolysis of WDG at CVEC would require the following equipment:

THE BRELSFORD 2 STAGE PROCESS

Each stage of the Brelsford process will consist of a mix tank with agitator, progressive cavity pump, heat exchanger, Double Tube Heat Exchanger reactor, flash vessel, slurry pump, flash cyclone, and an auto-vac filter.

LIME ADDITION TO THE RESULTING HYDROLYSATE FOR ACID NEUTRALIZATION

The resulting Hydrolysate will be at 1½ % sulfuric acid concentration and therefore will need to be neutralized with lime addition. The equipment for this module was extracted from the NREL study ((NREL TP-580-26157) and adjusted for process flow. The equipment required for this module consists of Lime Unloading Blower, Lime Storage Bin, Lime solids feeder, Overliming Tank and agitator, pump, Reacidification tank and agitator, pump, and a Hydroclone and Rotary Drum filter. Gypsum produced by this process would be discharged into a dumpster to be sent to land fill.

SEED FERMENTATION MODULE

The sugars produced by the Brelsford process result in approximately 10% hexoses and 90% pentoses sugars. The existing saccharomyces cerevisiae yeast fermentation cannot convert the pentose sugars to ethanol. Additional equipment has been included to convert fermentation to zymomonas mobilis continuous fermentation. The process equipment design, sizes, and costs are scaled from the NREL study.

MINIMUM FEEDSTOCK SUPPLY QUANTITIES AND EXPECTED QUALITY MIX

The overall feedstock to the Brelsford process will consist of the existing Wet Distillers Grain and syrup at a flow rate of 35,500 pounds per hour. Based upon information from CVEC, the composition of this stream is 35% solids and will, on a dry basis, consist of 50% carbohydrates, 29% protein, 13% fat, 7% ash, and 1% lignin.

ETHANOL PRODUCTION RATE IN GAL/DAY AND SOLID BY-PRODUCT RATE

Based upon estimates from Brelsford Engineering, the increased ethanol production from this modification would be an additional 3.6 million gallons per year (9,912 gallons/day).

The solid co product, a high protein wet distillers grain, production rate would be 18,030 #/hr total on a wet basis. On a dry basis of 6310 #/hr., the DDGS has a protein content of 56.5%. This is a reduction in DDGS total dry mass flow but an unchanged production rate on a protein content basis.

ENVIRONMENTAL EMISSION CHARACTERISTICS, IN TERMS OF QUANTITY EMITTED PER TON OF FEEDSTOCK PROCESSED.

The environmental emissions from this process would consist mainly of the gypsum produced in the overliming process, which is required to neutralize the hydrolysate to fermentation. The expected flow rate is 35 MM#/yr. of gypsum. A disposal cost from past NREL studies has been assumed.

In addition, a vapor stream of 15500 #/hr with concentrations of furfural would be generated. No additional equipment has been included for handling this process stream. Further study is required for the handling of this item.

AREA REQUIREMENTS AND PREFERRED SHAPE

The area requirements for this process will consist of three main units.

THE BRELSFORD 2 STAGE ACID HYDROLYSIS

Given the size of the reactors from Brelsford Engineering, a 150'x 25' addition has been assumed. In order to facilitate access to the Wet Distillers Grain for infeed and discharge from this module, it has been located on the North side of the Main process building near the existing centrifuges and the dryer building.

OVER LIME ADDITION MODULE

The Lime Addition Module was sized from the NREL study dated July 1999 (NREL TP-580-26157). Using scaled down equipment from the NREL study, an area of 50' x 50' is shown on the plot plan to the south of the existing CVEC main process building.

ZYMONAS MOBILIS SEED FERMENTATION MODULE

The Seed fermentation Module for this study was sized from the referenced NREL study. Based upon the tank sizes for three stages of seed fermentation for 2 trains, a module area of 25' x 25' has been included in the CVEC layout. This area is shown as being located on the south side of the Main Process Building, next to the existing fermentation tanks.

UTILITY AND CHEMICAL REQUIREMENTS (WATER, STEAM, FUEL, POWER, CHEMICALS)

WATER REQUIREMENTS

Water for the Brelsford process is considered negligible. Make up to dilute the wet cake and syrup feedstock will come from the use of backset from the existing thin stillage surge tank. This liquid will be added back into the existing process in the form of the hydrolyzate from the Brelsford process. This hydrolyzate would be added back into the existing feed to the fermentation tanks. As a result of the use of the backset, there will be an increase in solid percentage content in the feed to cook tubes and saccharification tanks. This increase is assumed to be acceptable.

Water for Lime Addition Process is assumed to be negligible.

Water for the addition of the Seed Fermentation is based upon the information in the NREL study, is assumed to be negligible.

STEAM REQUIREMENTS

Steam energy for the Brelsford process is required to achieve the high reaction temperatures in the two-stage process. A total input of 6762 #/hr of low-pressure steam (40 psia) and 7650 #/hr of high-pressure (150 psia) steam is required for the two stage process. The Brelsford process is based upon direct steam injection, but the addition of this water to the existing CVEC process would be unacceptable. Therefore additional work with Brelsford would be required to convert the process to indirect steam heating. Costs for indirect steam heat exchangers have been included in the estimate. In addition the reuse of flash steam heat from each stage will greatly reduce the steam needs for this process. The full load for steam and the high-pressure steam requirements could not be met with the existing CVEC boiler system. Therefore costs have been included for an additional boiler in capital cost estimate.

FUEL REQUIREMENTS

Fuel requirements for the process modifications have been included as the operating costs for steam.

POWER REQUIREMENTS

Power for the Brelsford process has been scaled from the Brelsford Preliminary Engineering and Economics Feasibility Study based upon the total flow to the process and the number of stages. The Brelsford study quotes 138 KW for one stage at a flow of 7800 #/hr dry basis. The power requirement for these two modules was therefore estimated at 420 KW.

Power for the Lime Addition module was developed from the NREL study and adjusted for process flow. The resulting demand is 15 KW.

Power for the Seed Fermentation module is estimated at 31 KW based upon estimates from the NREL study.

Power requirements for the additional chiller, cooling tower, and pumps are based upon Richardson and are estimated at 423 KW.

CHEMICAL REQUIREMENTS

Chemical requirements for the Brelsford process will consist of the addition of Sulfuric Acid. Based upon information from Brelsford Engineering, the two stage process will require the addition of 1037 #/ hour of acid.

Chemical requirements for the Lime addition module were estimated from the NREL study. The lime addition requirements were based upon the acid flow to the lime addition module from the Brelsford process. Lime requirements were estimated at 1155 #/hr. Pricing for the lime was based upon a cost from the Brelsford study at \$60.00 per ton.

Incremental Chemical Requirements for the Seed Fermentation module were assumed to be negligible.

SPECIAL TRANSPORTATION REQUIREMENTS (TRUCK, WATER, RAIL LINE)

Other than as mentioned above, it is assumed there will be no additional transportation requirements. The existing truck receiving and rail service is assumed to be adequate for the modifications proposed to the CEVC facility.

SPECIAL STORAGE REQUIREMENTS FOR FEEDSTOCK, BY-PRODUCTS, AND CHEMICALS.

Storage for Feedstock

There will be no additional storage requirements for the feedstock.

Storage for Co Product WDG and DDGS

There will be no additional storage requirements for the feedstock for the Brelsford process. The existing wet cake pad, dryers and DDGS storage facility are assumed to be adequate for the co product. One concern is the fact that the new co product will have less fiber content and therefore will be a more powdery product. This may cause problems with the existing dryer system and material handling procedures. For the purposes of this study, these concerns have not been addressed and are held for further study. A proforma case has been run with the cost of a replacement dryer included.

Storage for Chemicals

Chemical Storage for the Brelsford process will consist of an additional Acid storage tank and delivery system. CVEC has an existing acid tank, but from

a logistics standpoint, an additional tank has been included in the capital equipment estimate.

Chemical Storage for the Lime addition module will consist of additional receiving and storage for lime. No specific site in the layout has been shown for this receiving equipment or storage. The sizing for the lime storage and the costs are based upon the NREL study.

Chemical storage for the Seed fermentation module is assumed to be adequate.

CAPITAL AND OPERATING COSTS

Delta T has developed capital and operating costs for the recommended process based on process considerations. These are included in the proforma economics.

For the purposes of the study, the cost of the incremental feedstock, the Wet Distillers Grain and syrup from the existing facility was assumed to be zero.

INCREMENTAL FINANCIAL PRO FORMA

Delta T has prepared three incremental financial evaluations for the installation of the recommended process at the CVEC facility. The assumptions and the rationale used in the Pro Forma are as listed below:

BASE CASE (ATTACHMENT 2A, 2B)

Assumptions

The Brelsford process capital equipment cost is as supplied by Brelsford Engineering. An adjustment was made to the reactor cost to adjust from 304-carbon steel to Hastelloy C-2000 by increasing cost by 50%. This is the same adjustment factor as used in the referenced NREL cost estimate.

FEEDSTOCK COSTS:

This process is expected to increase the yield of ethanol per bushel of corn. The base case assumes the facility could increase throughput accordingly.

Case 2 looks at decreasing the corn feedstock to maintain the hydraulic flow to fermentation. It was assumed that the typical facility would be running at capacity and the net result of this process improvement would be a decrease in corn feedstock.

ETHANOL PRODUCTION VALUE

Ethanol production was estimated to increase by 3.6 million gallons per year for an increase in revenue of \$3,960,000.

BYPRODUCTS PRODUCTION VALUE:

The Brelsford process will result in a net decrease in the production of WDG but the protein content is assumed to remain constant. For the purposes of this study, the value of the WDG is based upon the protein and is therefore considered to be unchanged.

PAYBACK PERIOD

A division of the capital cost for this case divided by the expected net increased revenue yields a payback period of 3.42 years.

SENSITIVITY ANALYSIS

CASE 2- REDUCED INFEEED TO THE EXISTING PROCESS (ATTACHMENT 3A, 3B)

Delta T has identified that the existing process could not handle the new flow to the distillation and evaporation modules. Therefore the corn feedstock was adjusted in this case by 15%. The feedstock costs and variable costs of the existing CVEC operation were adjusted by 15%. In addition the operating costs and production increases for the Brelsford process addition were adjusted by 15%. The capital costs for this case were considered identical to the base case above.

Payback period

Unfortunately, the decrease in DDGS production resulted in a net decrease in the revenue generated, resulting in a negative payback.

CASE 3-EQUIPMENT COST ESTIMATE WITH NEW DRYER AND CENTRIFUGES (ATTACHMENT 4A, 4B)

The Brelsford process uses a low cost vacuum filter process for solid liquid separation. In this case costs were included for the addition of new centrifuges for the process. In addition, costs for a new dryer have been included in this case.

Payback Period

The addition of capital equipment in this case resulted in a further reduction in revenue generated, resulting in a negative payback.

RECOMMENDATIONS FOR FURTHER WORK

The Brelsford Process

In summarization of the Brelsford process, the increased hydraulic load of the returned liquid to fermentation causes a bottleneck in the distillation process of an existing facility. The facility would have to be derated, resulting in a negative affect on the revenue generation. In addition the following items would require additional investigation:

The Brelsford process design is based upon 304 ss 1' diameter reactors. The material may have to be adjusted to Hastelloy C-2000 as was used in the NREL study for the reactor M-202. A 50% increase in the cost of the Brelsford reactor could be expected with this adjustment. Further study of the materials of composition for this process is recommended.

The steam usage in the Brelsford process is based upon unproven assumptions for the reuse of high-pressure steam between the stages. The best-case cost would be the reuse of the flash steam in the Brelsford process. The worst-case cost would be the cost of no flash recovery of steam. The handling of furfural and other gases generated in the process requires further study. Delta-T looked at condensing the stream and sending it back to the process or disposing of it. CVEC is a zero effluent facility and no method of disposing of the stream is available. In addition, Delta-T looked at venting the stream with the dryer stack gas. This also appeared unacceptable from an emissions standpoint. The resolution of the disposal of this stream is outside the scope of this investigation.

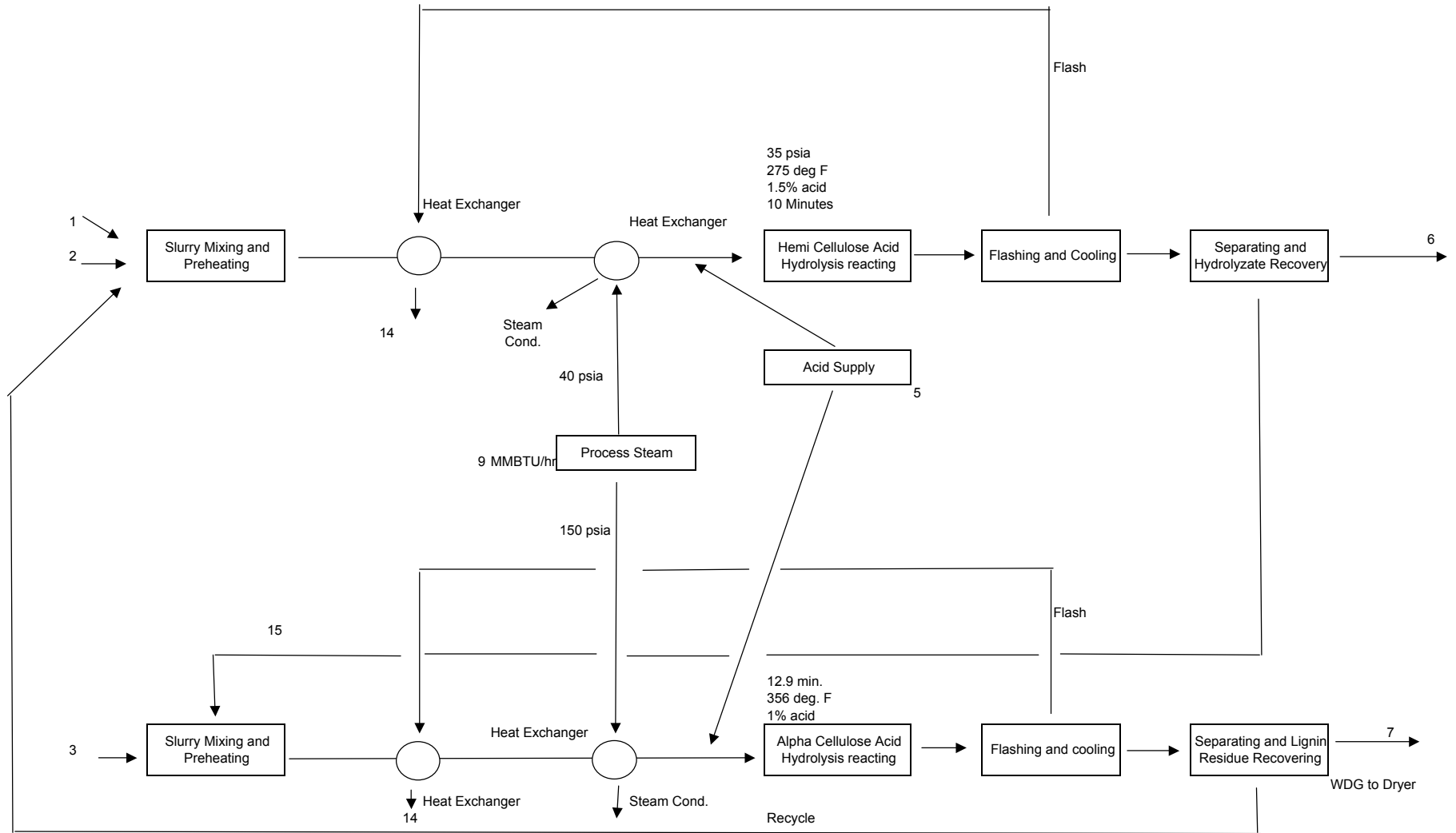
The assumption has been made that the existing fermentation can be switched over to Z-mobilis with the addition of seed fermentation. This conversion may be unacceptable to the existing operation. Further study is required to identify the best method to convert the sugars produced from the Brelsford process.

Gasification of Biomass

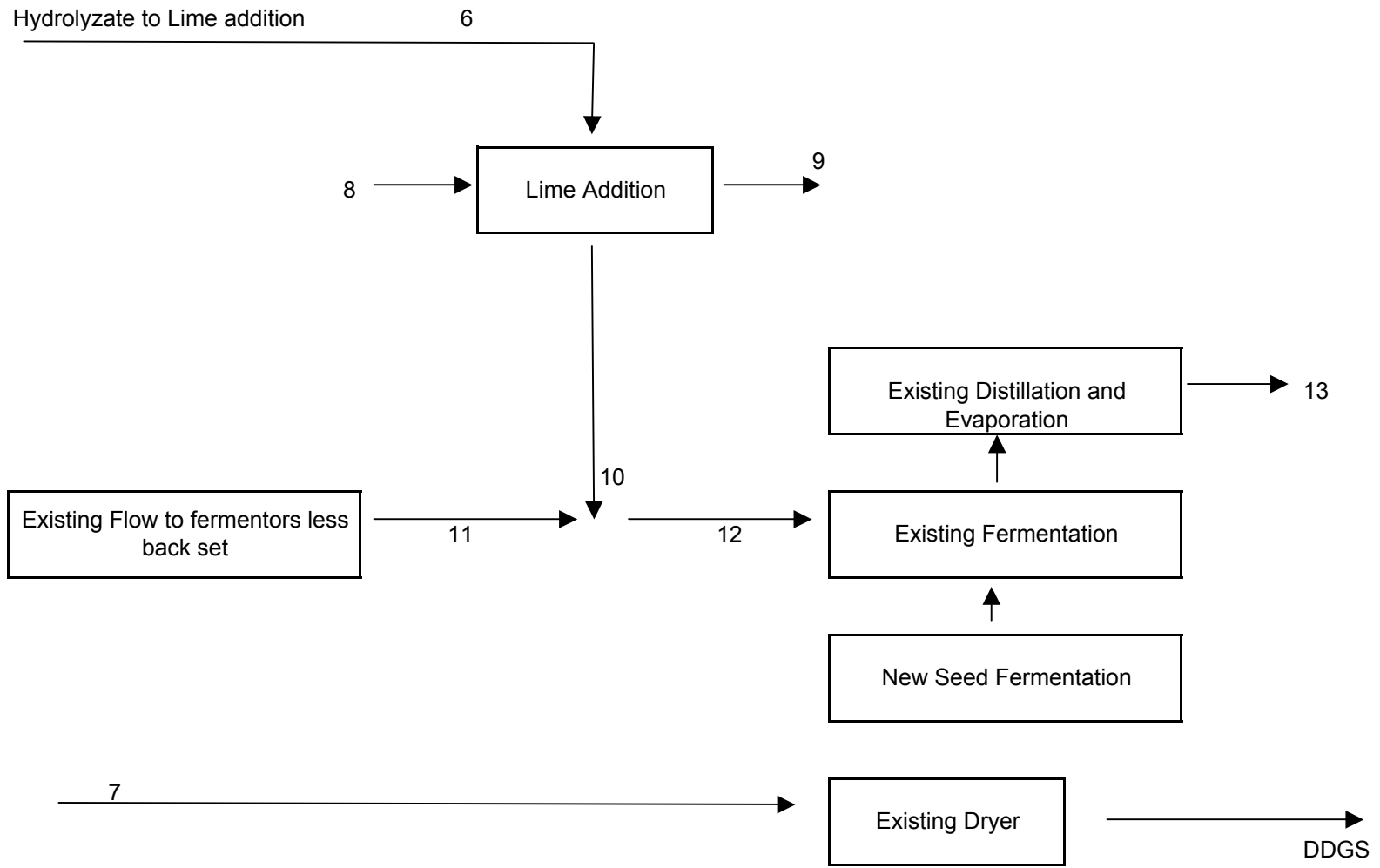
The Web based search of gasification and catalytic conversion to an alcohol product for fuel grade material as a standalone or add on to a facility offers potential for renewable materials as a feedstock and should be investigated further. The preliminary economics of this study are favorable and it is recommended that a more detail study now be considered for this approach.

APPENDIX

Attachment 1a
Incremental Process Block Flow Diagram
Brelsford Process Addition, CVEC, Benson, MN.



Attachment 1b
Incremental Process Block Flow Diagram
Brelsford Process Addition, CVEC, Benson, MN.



Attachment 1c
Block Flow Diagram Stream Legend
Incremental Stream Flows

Stream	Description	Total Flow	Liquid	Dry matter/ Vapors	Flow #/hr.						
					HCH	ACH	Carbo.	Protein	Fat	Ash	Lignin
1	Feedstock-WDG and Syrup	35500	23075	12425			6213	3566	1615	870	162
2	Backset Make Up to 1st Stage	7574	7574	682							
3	Backset Make Up to 2nd Stage	20700	20700	1863							
5	Sulfuric Acid	1037	1037								
	Total input	64811	52386	14970							
14	Flash Cond to WDG (see comment box)	15482	12767	5260							
6	Hydrolyzate From Brelsford Process	31300	27900	3400	2500	900					
7	WDG from Brelsford Process	18029	11719	6310				3562			
	Outputs from Brelsford Process	49329	39619	9710							
8	Lime Addition	1155	0	1155							
9	Gypsum to Landfill	3936	787	3149							
10	Net Flow to fermentation	46548	38831	7716							
11	Existing Flow to Fermen. Less Back Set	122644									
12	New Flow to fermentation with Brelsford Process	169192									
	Derating of Plant for Hydraulic Flow Limit	85%									
13	Additional Ethanol Production	2682	18.00%								

**Attachment 2a
Base Case Equipment Estimate
Capital Equipment Additions for Brelsford Process**

Quantity	Equip. Number	Equipment Description	Source	Size Ratio Current/ Base	Original Cost	Base Year	Scaling Exponent	Scaled Cost in Base Year	Install Factor	Installed Cost In Base Year	Installed Cost in 1999
Infrastructure Requirements											
1		Boiler	Richardso	0.40	\$ 195,000	1994	0.40	\$ 135,163	1.5	\$ 202,745	\$ 235,037
1		Chiller	Richardso	1.00	\$ 92,649	1994	1.00	\$ 92,649	1.50	\$ 138,974	\$ 161,108
1		Cooling Tower	Richardso	1.00	\$ 18,084	1994	1.00	\$ 18,084	2.80	\$ 50,635	\$ 58,700
1		Chiller Pump	Richardso	1.00	\$ 4,800	1994	1.00	\$ 4,800	2.80	\$ 13,440	\$ 15,581
1		Condens. Pump	Richardso	1.00	\$ 4,800	1994	1.00	\$ 4,800	2.80	\$ 13,440	\$ 15,581
Total Plant Modifications											\$ 486,007
Brelsford Stage 1											
1	CF-1	Wet Grains Feed conveyor	Brelsford	1.38	\$ 4,080	1999	0.51	\$ 4,804	1.2	\$ 5,765	\$ 5,765
		Slurry Mix Tank	Delta-T	1.00	\$ 21,136	1995	1.00	\$ 21,136	1.2	\$ 25,363	\$ 29,168
1	M-1	Conveyor	Brelsford	1.38	\$ 8,300	1999	0.51	\$ 9,773	1.2	\$ 11,728	\$ 11,728
1	D-1	Disintegrator	Brelsford	1.38	\$ 18,900	1999	0.79	\$ 24,343	1.3	\$ 31,647	\$ 31,647
1	P-1	Progressive cavity Pump	Brelsford	1.38	\$ 8,800	1999	0.79	\$ 11,335	2.8	\$ 31,737	\$ 31,737
1	HH-1	Hydro Heater	Brelsford	1.38	\$ 4,850	1999	0.79	\$ 6,247	2.8	\$ 17,491	\$ 17,491
1	HX-1	Heat Exchanger	Atlas	1.00							\$ 18,100
1	HX-2	Heat Exchanger	Atlas	1.00							\$ 17,050
2	PFR-1	Double Tube reactor	Brelsford	1.38	\$ 331,000	1999	0.79	\$ 426,333	1.5	\$ 639,500	\$ 639,500
1	T-1	Flash vessel	Brelsford	1.38	\$ 11,000	1999	0.71	\$ 13,810	1.4	\$ 19,333	\$ 19,333
1	P-1	Slurry Pump	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
1	Cy-1	Flash Cyclone	Brelsford	1.38	\$ 11,000	1999	0.79	\$ 14,168	1.4	\$ 19,835	\$ 19,835
1	S-1	Screen	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	2.8	\$ 19,835	\$ 19,835
1	RF-1	Rotary Filter	Brelsford	1.38	\$ 54,800	1999	0.79	\$ 70,583	2.8	\$ 197,633	\$ 197,633
1	T-2	Surge Tank	Brelsford	1.38	\$ 13,600	1999	0.79	\$ 17,517	1.4	\$ 24,524	\$ 24,524
1		Conveyors to second stage	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	1.2	\$ 8,501	\$ 8,501
1		Pump to Lime Addition	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
Total Brelsford Stage 1											\$ 1,109,879
Brelsford Stage 2											
1	T-201	Acid Storage Tank	NREL	0.24	\$ 42,500	1997	0.51	\$ 20,389	1.2	\$ 24,467	\$ 25,957
1	P-201	Acid Storage Tank Pump	NREL	0.24	\$ 8,000	1997	0.79	\$ 2,564	2.8	\$ 7,180	\$ 7,617
1	A-201	Acid Mixer	NREL	0.23	\$ 1,900	1997	0.48	\$ 935	1.0	\$ 935	\$ 992
1	P-1	Progressive cavity Pump	Brelsford	1.38	\$ 8,800	1999	0.79	\$ 11,335	2.8	\$ 31,737	\$ 31,737
1	HH-1	Hydro Heater	Brelsford	1.38	\$ 4,850	1999	0.79	\$ 6,247	2.8	\$ 17,491	\$ 17,491
1	HX-1	Heat Exchanger	Atlas	1.00							\$ 18,100
1	HX-2	Heat Exchanger	Atlas	1.00							\$ 17,050
1	PFR-1	Double Tube reactor	Brelsford	1.38	\$ 165,500	1999	0.79	\$ 213,167	1.5	\$ 319,750	\$ 319,750
1	T-1	Flash vessel	Brelsford	1.38	\$ 11,000	1999	0.71	\$ 13,810	1.4	\$ 19,333	\$ 19,333
1	P-1	Slurry Pump	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
1	Cy-1	Flash Cyclone	Brelsford	1.38	\$ 11,000	1999	0.79	\$ 14,168	1.4	\$ 19,835	\$ 19,835
1	S-1	Screen	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	2.8	\$ 19,835	\$ 19,835
1	RF-1	Rotary Filter	Brelsford	1.38	\$ 54,800	1999	0.79	\$ 70,583	2.8	\$ 197,633	\$ 197,633
1	T-2	Surge Tank	Brelsford	1.38	\$ 13,600	1999	0.79	\$ 17,517	1.4	\$ 24,524	\$ 24,524
1		Conveyors to dryer	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	1.2	\$ 8,501	\$ 8,501
1		Slurry Pump to 1st Stage	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
Total Brelsford Stage 2											\$ 746,388
Lime Addition Module											
1	T-301	Lime Storage Bin	NREL	1.00	\$ 69,200	1997	0.46	\$ 69,200	1.3	\$ 89,960	\$ 95,439
1	S-301	Lime Dust Baghouse	NREL	1.00	\$ 32,200	1997	1.00	\$ 32,200	1.5	\$ 48,300	\$ 51,198
1	C-301	Lime Solids Feeder	NREL	0.15	\$ 3,900	1997	1.00	\$ 3,900	1.3	\$ 5,070	\$ 5,374
1	T-300	Overliming Tank	NREL	0.15	\$ 71,000	1997	0.71	\$ 18,188	1.4	\$ 25,463	\$ 26,991
1	A-300	Overliming Tank Agitator	NREL	0.15	\$ 19,800	1997	0.51	\$ 7,444	1.3	\$ 9,677	\$ 10,258
1	P-300	Overlimed Hydrolyzate Pump	NREL	0.15	\$ 10,700	1997	0.79	\$ 2,351	2.8	\$ 6,583	\$ 6,978
1	S-302	Rotary Drum Filter and Hydroclone	NREL	0.15	\$ 165,000	1998	0.39	\$ 78,089	1.4	\$ 109,324	\$ 112,604
1	P-302	Overlimed Hydrolyzate Liquor Pump	NREL	0.15	\$ 10,800	1997	0.79	\$ 2,373	2.8	\$ 6,644	\$ 6,844
1	T-303	Reacidification Tank	NREL	0.15	\$ 147,800	1997	0.51	\$ 55,566	1.2	\$ 66,679	\$ 68,680
1	A-303	Reacidification Tank Agitator	NREL	0.15	\$ 65,200	1997	0.51	\$ 24,512	1.2	\$ 29,415	\$ 30,297
1	P-302	Fermentation Feed Pump	NREL	0.19	\$ 61,368	1998	0.70	\$ 19,122	2.8	\$ 53,541	\$ 55,147
1	A-304	In-line Acid Mixer	NREL	0.15	\$ 2,600	1997	0.48	\$ 1,035	1.0	\$ 1,035	\$ 1,098
1	B-300	Lime unloading Blower	NREL	0.15	\$ 47,600	1998	0.50	\$ 18,242	1.4	\$ 25,539	\$ 26,305
1	P-303	Reacidification Liquor Pump	NREL	0.15	\$ 10,800	1997	0.79	\$ 2,373	2.8	\$ 6,644	\$ 6,844
1		Heat Exchanger	Atlas	1.00							\$ 18,100
Total Lime Addition Module											\$ 522,155
Seed Fermentation											
2	A-304	Seed Vessel Agitator	NREL	0.91	\$ 11,700	1997	0.51	\$ 22,295	1.2	\$ 26,754	\$ 28,360
2	A-305	Seed Vessel Agitator	NREL	0.91	\$ 10,340	1996	0.51	\$ 19,704	1.2	\$ 23,644	\$ 25,772
2	F-301	1st SSCF Seed Fermentor	NREL	1.00	\$ 14,700	1997	0.91	\$ 29,400	2.8	\$ 82,320	\$ 87,259
2	F-302	2nd SSCF Seed Fermentor	NREL	1.00	\$ 32,600	1997	0.93	\$ 65,200	2.8	\$ 182,560	\$ 193,514
2	F-303	3rd SSCF Seed Fermentor	NREL	1.00	\$ 81,100	1997	0.93	\$ 162,200	2.8	\$ 454,160	\$ 481,410
2	F-304	4th SSCF Seed Fermentor	NREL	0.91	\$ 39,500	1997	0.93	\$ 72,331	1.2	\$ 86,798	\$ 92,005
1	H-301	SSCF Seed Hydrolyzate Cooler	NREL	0.91	\$ 15,539	1998	0.78	\$ 14,414	2.1	\$ 30,270	\$ 31,178
1	H-302	SSCF Hydrolyzate Cooler	NREL	0.98	\$ 25,409	1998	0.78	\$ 75,201	2.1	\$ 157,922	\$ 162,660
1	H-304	Seed Fermentor Coils	NREL	0.92	\$ 3,300	1997	0.83	\$ 3,066	1.2	\$ 3,679	\$ 3,899
2	P-302	Seed Transfer Pump	NREL	0.91	\$ 54,088	1998	0.70	\$ 101,228	1.4	\$ 141,720	\$ 145,971
Total Seed Fermentation Module											\$ 1,252,028
Eng./Const.Mgt.											\$ 1,975,899
Total Incremental Capital Equipment Cost											\$ 6,092,356

Notes

- Brelsford Module Costs based upon estimates from Bresford Engineering "Distiller grains Cellulose Hydrolysis to Fermentable sugars for Production of Fuel Ethanol and Protein Feedstuff" Preliminary Engineering and Economics Feasibility Study.
- Lime Addition Module Costs based upon July 1999 NREL/TP-580-26157 Study Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis current and Futuristic Scenarios. Costs were adjusted for sulfuric acid flow rates.
- Seed fermentation Module Costs based upon July 1999 NREL/TP-580-26157.

Attachment 2b
Base Case Proforma Economics

	Units	Unit Price \$	Quantity/yr	\$/Yr.
Revenue				
Increased Ethanol	gallons	1.10	\$ 3,600,000	\$ 3,960,000
 Operating Cost				
Feedstock			na	
Sulfuric Acid	Tons	96.88	4542	\$ 440,035
Lime	Tons	60.00	5059.33	\$ 303,560
Gypsum Removal	\$/#	0.01	34479975	\$ 344,800
Steam	MM BTU	5.31	74460	\$ 395,383
Electric Power	\$/KWh	0.04	7787640	\$ 280,355
Shift operators	1/shift	28000.00	4	\$ 112,000
Maint.Cost-5% Capital				\$ 304,618
Total Incremental Operating Cost				\$ 2,180,750
Net Increased Revenue				\$ 1,779,250
Capital Cost				\$ 6,092,356
Capital payback period				3.42

Notes

1. Increased ethanol based upon estimate from Brelsford Engineering of and additional 3.6 million gallons/yr of increased production. Unit price based upon Fiscal year 2000
2. Feedstock cost changes assumed to be zero.
3. Sulfuric Acid cost based upon CVEC unit cost for FY 2000. Sulfuric Acid use based upon estimates from Brelsford Engineering.
4. Lime addition costs and requirements based upon NREL TP-580-26157 study adjusted for Brelsford study flows.
5. Gypsum removal costs and requirements based upon NREL TP-580-26157 study adjusted for Brelsford study flows.
6. Steam costs based upon CVEC unit costs for FY 2000. Steam use based upon estimates from Brelsford Engineering.
7. Electric Power costs based upon CVEC unit costs for FY 2000

Attachment 3a
Reduced Infeed Equipment Estimate
Capital Equipment Additions for Brelsford Process

Equip. Number	Equipment Description	Source	Size Ratio		Base Year	Scaling Exponent	Scaled Cost in Base Year	Install Factor	Installed Cost In Base Year	Installed Cost in 1999
			Current/ Base	Original Cost						
Infrastructure Requirements										
1	Boiler	Richardson	0.40	\$ 195,000	1994	0.40	\$ 135,163	1.5	\$ 202,745	\$ 235,037
1	Chiller	Richardson	1.00	\$ 92,649	1994	1.00	\$ 92,649	1.50	\$ 138,974	\$ 161,108
1	Cooling Tower	Richardson	1.00	\$ 18,084	1994	1.00	\$ 18,084	2.80	\$ 50,635	\$ 58,700
1	Chiller Pump	Richardson	1.00	\$ 4,800	1994	1.00	\$ 4,800	2.80	\$ 13,440	\$ 15,581
1	Condens. Pump	Richardson	1.00	\$ 4,800	1994	1.00	\$ 4,800	2.80	\$ 13,440	\$ 15,581
Total Plant Modifications										\$ 486,007
Brelsford Stage 1										
1	CF-1 Wet Grains Feed conveyor	Brelsford	1.38	\$ 4,080	1999	0.51	\$ 4,804	1.2	\$ 5,765	\$ 5,765
	Slurry Mix Tank	Delta-T	1.00	\$ 21,136	1995	1.00	\$ 21,136	1.2	\$ 25,363	\$ 29,168
1	M-1 Conveyor	Brelsford	1.38	\$ 8,300	1999	0.51	\$ 9,773	1.2	\$ 11,728	\$ 11,728
1	D-1 Disintegrator	Brelsford	1.38	\$ 18,900	1999	0.79	\$ 24,343	1.3	\$ 31,647	\$ 31,647
1	P-1 Progressive cavity Pump	Brelsford	1.38	\$ 8,800	1999	0.79	\$ 11,335	2.8	\$ 31,737	\$ 31,737
1	HH-1 Hydro Heater	Brelsford	1.38	\$ 4,850	1999	0.79	\$ 6,247	2.8	\$ 17,491	\$ 17,491
1	HX-1 Heat Exchanger	Atlas	1.00							\$ 18,100
1	HX-2 Heat Exchanger	Atlas	1.00							\$ 17,050
2	PFR-1 Double Tube reactor	Brelsford	1.38	\$ 331,000	1999	0.79	\$ 426,333	1.5	\$ 639,500	\$ 639,500
1	T-1 Flash vessel	Brelsford	1.38	\$ 11,000	1999	0.71	\$ 13,810	1.4	\$ 19,333	\$ 19,333
1	P-1 Slurry Pump	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
1	Cy-1 Flash Cyclone	Brelsford	1.38	\$ 11,000	1999	0.79	\$ 14,168	1.4	\$ 19,835	\$ 19,835
1	S-1 Screen	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	2.8	\$ 19,835	\$ 19,835
1	RF-1 Rotary Filter	Brelsford	1.38	\$ 54,800	1999	0.79	\$ 70,583	2.8	\$ 197,633	\$ 197,633
1	T-2 Surge Tank	Brelsford	1.38	\$ 13,600	1999	0.79	\$ 17,517	1.4	\$ 24,524	\$ 24,524
1	Conveyors to second stage	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	1.2	\$ 8,501	\$ 8,501
1	Pump to Lime Addition	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
Total Brelsford Stage 1										\$ 1,109,879
Brelsford Stage 2										
1	T-201 Acid Storage Tank	NREL	0.24	\$ 42,500	1997	0.51	\$ 20,389	1.2	\$ 24,467	\$ 25,957
1	P-201 Acid Storage Tank Pump	NREL	0.24	\$ 8,000	1997	0.79	\$ 2,564	2.8	\$ 7,180	\$ 7,617
1	A-201 Acid Mixer	NREL	0.23	\$ 1,900	1997	0.48	\$ 935	1.0	\$ 935	\$ 992
1	P-1 Progressive cavity Pump	Brelsford	1.38	\$ 8,800	1999	0.79	\$ 11,335	2.8	\$ 31,737	\$ 31,737
1	HH-1 Hydro Heater	Brelsford	1.38	\$ 4,850	1999	0.79	\$ 6,247	2.8	\$ 17,491	\$ 17,491
1	HX-1 Heat Exchanger	Atlas	1.00							\$ 18,100
1	HX-2 Heat Exchanger	Atlas	1.00							\$ 17,050
1	PFR-1 Double Tube reactor	Brelsford	1.38	\$ 165,500	1999	0.79	\$ 213,167	1.5	\$ 319,750	\$ 319,750
1	T-1 Flash vessel	Brelsford	1.38	\$ 11,000	1999	0.71	\$ 13,810	1.4	\$ 19,333	\$ 19,333
1	P-1 Slurry Pump	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
1	Cy-1 Flash Cyclone	Brelsford	1.38	\$ 11,000	1999	0.79	\$ 14,168	1.4	\$ 19,835	\$ 19,835
1	S-1 Screen	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	2.8	\$ 19,835	\$ 19,835
1	RF-1 Rotary Filter	Brelsford	1.38	\$ 54,800	1999	0.79	\$ 70,583	2.8	\$ 197,633	\$ 197,633
1	T-2 Surge Tank	Brelsford	1.38	\$ 13,600	1999	0.79	\$ 17,517	1.4	\$ 24,524	\$ 24,524
1	Conveyors to dryer	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	1.2	\$ 8,501	\$ 8,501
1	Slurry Pump to 1st Stage	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
Total Brelsford Stage 2										\$ 746,388
Lime Addition Module										
1	T-301 Lime Storage Bin	NREL	1.00	\$ 69,200	1997	0.46	\$ 69,200	1.3	\$ 89,960	\$ 95,439
1	S-301 Lime Dust Baghouse	NREL	1.00	\$ 32,200	1997	1.00	\$ 32,200	1.5	\$ 48,300	\$ 51,198
1	C-301 Lime Solids Feeder	NREL	0.15	\$ 3,900	1997	1.00	\$ 3,900	1.3	\$ 5,070	\$ 5,374
1	T-300 Overliming Tank	NREL	0.15	\$ 71,000	1997	0.71	\$ 18,188	1.4	\$ 25,463	\$ 26,991
1	A-300 Overliming Tank Agitator	NREL	0.15	\$ 19,800	1997	0.51	\$ 7,444	1.3	\$ 9,677	\$ 10,258
1	P-300 Overlimed Hydrolyzate Pump	NREL	0.15	\$ 10,700	1997	0.79	\$ 2,351	2.8	\$ 6,583	\$ 6,978
1	S-302 Rotary Drum Filter and Hydroclone	NREL	0.15	\$ 165,000	1998	0.39	\$ 78,089	1.4	\$ 109,324	\$ 112,604
1	P-302 Overlimed Hydrolyzate Liquor Pump	NREL	0.15	\$ 10,800	1997	0.79	\$ 2,373	2.8	\$ 6,644	\$ 6,844
1	T-303 Reacidification Tank	NREL	0.15	\$ 147,800	1997	0.51	\$ 55,566	1.2	\$ 66,679	\$ 68,680
1	A-303 Reacidification Tank Agitator	NREL	0.15	\$ 65,200	1997	0.51	\$ 19,512	1.2	\$ 29,415	\$ 30,297
1	P-302 Fermentation Feed Pump	NREL	0.19	\$ 61,368	1998	0.70	\$ 19,122	2.8	\$ 53,541	\$ 55,147
1	A-304 In-line Acid Mixer	NREL	0.15	\$ 2,600	1997	0.48	\$ 1,035	1.0	\$ 1,035	\$ 1,098
1	B-300 Lime unloading Blower	NREL	0.15	\$ 47,600	1998	0.50	\$ 18,242	1.4	\$ 25,539	\$ 26,305
1	P-303 Reacidification Liquor Pump	NREL	0.15	\$ 10,800	1997	0.79	\$ 2,373	2.8	\$ 6,644	\$ 6,844
1	Heat Exchanger	Atlas	1.00							\$ 18,100
Total Lime Addition Module										\$ 522,155
Seed Fermentation										
2	A-304 Seed Vessel Agitator	NREL	0.91	\$ 11,700	1997	0.51	\$ 22,295	1.2	\$ 26,754	\$ 28,360
2	A-305 Seed Vessel Agitator	NREL	0.91	\$ 10,340	1996	0.51	\$ 19,704	1.2	\$ 23,644	\$ 25,772
2	F-301 1st SSCF Seed Fermentor	NREL	1.00	\$ 14,700	1997	0.91	\$ 29,400	2.8	\$ 82,320	\$ 87,259
2	F-302 2nd SSCF Seed Fermentor	NREL	1.00	\$ 32,600	1997	0.93	\$ 65,200	2.8	\$ 182,560	\$ 193,514
2	F-303 3rd SSCF Seed Fermentor	NREL	1.00	\$ 81,100	1997	0.93	\$ 162,200	2.8	\$ 454,160	\$ 481,410
2	F-304 4th SSCF Seed Fermentor	NREL	0.91	\$ 39,500	1997	0.93	\$ 72,331	1.2	\$ 86,798	\$ 92,005
1	H-301 SSCF Seed Hydrolyzate Cooler	NREL	0.91	\$ 15,539	1998	0.78	\$ 14,414	2.1	\$ 30,270	\$ 31,178
3	H-302 SSCF Hydrolyzate Cooler	NREL	0.98	\$ 25,409	1998	0.78	\$ 75,201	2.1	\$ 157,922	\$ 162,660
1	H-304 Seed Fermentor Coils	NREL	0.92	\$ 3,300	1997	0.83	\$ 3,066	1.2	\$ 3,679	\$ 3,899
2	P-302 Seed Transfer Pump	NREL	0.91	\$ 54,088	1998	0.70	\$ 101,228	1.4	\$ 141,720	\$ 145,971
Total Seed Fermentation Module										\$ 1,252,028
Eng./Const.Mgt.										197,589
Total Incremental Capital Equipment										\$ 6,092,356

Notes

- Brelsford Module Costs based upon estimates from Brelsford Engineering "Distiller grains Cellulose Hydrolysis to Fermentable sugars for Production of Fuel Ethanol and Hi-Protein Feedstuff" Preliminary Engineering and Economics Feasibility Study.
- Lime Addition Module Costs based upon July 1999 NREL/TP-580-26157 Study Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis current and Futuristic Scenarios. Costs were adjusted for sulfuric acid flowrates.
- Seed fermentation Module Costs based upon July 1999 NREL/TP-580-26157.

**Attachment 3b
Reduced Infeed Proforma Economics**

	Units	Unit Price \$	Quantity/yr	Infeed Reduction	\$/Yr.
Revenue					
Increased Ethanol	gallons	1.10	180,000	85%	\$ 198,000
Reduction in DDGS Value	Tons	67.24	-8559.75	85%	\$ (575,558)
			Revenue Reduction		(377558)
Operating Cost					
Existing Operation Reduction					
Corn Feedstock reduction	bushels	1.67	-1051273.05		\$ (1,755,626)
Reduction in Variable Cost	\$/bushel	0.27	-1051273.05		\$ (283,591)
Brelsford Process Addition					
Sulfuric Acid	Tons	96.88	4542	85%	\$ 374,030
Lime	Tons	60.00	5059.33	85%	\$ 258,026
Gypsum Removal	\$/#	0.01	34479975	85%	\$ 293,080
Steam	MM BTU	5.31	74460	85%	\$ 336,075
Electric Power	\$/KWh	0.04	7787640	85%	\$ 238,302
Shift operators	1/shift	28000.00	4		\$ 112,000
Maint.Cost-5% Capital					\$ 304,618
			Total Incremental Operating Cost		\$ (123,087)
			Net Increased Revenue		\$ (254,470)
			Capital Cost		\$ 6,092,356

Capital payback period yrs. negative payback

Notes

1. Reduced Infeed Rate is Based upon holding total flow to existing fermentation at 144000 #/hr. This results in a reduction in feedstock and chemical costs of 15%. Power and Steam requirements are held constant for the existing facility.
2. Brelsford process, lime addition, and seed fermentation operating costs have been adjusted to 85% of base case to adjust for reduction in infeed of facility.

**Attachment 4a
Equipment Cost Estimate with New Dryer and Centrifuges
Capital Equipment Additions for Brelsford Process**

Quantity	Equip. Number	Equipment Description	Source	Size Ratio Current/Base	Original Cost	Base Year	Scaling Exponent	Scaled Cost in Base Year	Install Factor	Installed Cost in Base Year	Installed Cost in 1999
Infrastructure Requirements											
1		Boiler	Richardson	0.40	\$ 195,000	1994	0.40	\$ 135,163	1.5	\$ 202,745	\$ 235,037
1		Chiller	Richardson	1.00	\$ 92,649	1994	1.00	\$ 92,649	1.50	\$ 138,974	\$ 161,108
1		Cooling Tower	Richardson	1.00	\$ 18,084	1994	1.00	\$ 18,084	2.80	\$ 50,635	\$ 58,700
1		Chiller Pump	Richardson	1.00	\$ 4,800	1994	1.00	\$ 4,800	2.80	\$ 13,440	\$ 15,581
1		Condens. Pump	Richardson	1.00	\$ 4,800	1994	1.00	\$ 4,800	2.80	\$ 13,440	\$ 15,581
Total Plant Modifications											\$ 486,007
Brelsford Stage 1											
1	CF-1	Wet Grains Feed conveyor	Brelsford	1.38	\$ 4,080	1999	0.51	\$ 4,804	1.2	\$ 5,765	\$ 5,765
		Slurry Mix Tank	Delta-T	1.00	\$ 21,136	1995	1.00	\$ 21,136	1.2	\$ 25,363	\$ 29,168
1	M-1	Conveyor	Brelsford	1.38	\$ 8,300	1999	0.51	\$ 9,773	1.2	\$ 11,728	\$ 11,728
1	D-1	Disintegrator	Brelsford	1.38	\$ 18,900	1999	0.79	\$ 24,343	1.3	\$ 31,647	\$ 31,647
1	P-1	Progressive cavity Pump	Brelsford	1.38	\$ 8,800	1999	0.79	\$ 11,335	2.8	\$ 31,737	\$ 31,737
1	HH-1	Hydro Heater	Brelsford	1.38	\$ 4,850	1999	0.79	\$ 6,247	2.8	\$ 17,491	\$ 17,491
1	HX-1	Heat Exchanger	Atlas	1.00							\$ 18,100
1	HX-2	Heat Exchanger	Atlas	1.00							\$ 17,050
2	PFR-1	Double Tube reactor	Brelsford	1.38	\$ 496,500	1999	0.79	\$ 639,500	1.5	\$ 959,249	\$ 959,249
1	T-1	Flash vessel	Brelsford	1.38	\$ 11,000	1999	0.71	\$ 13,810	1.4	\$ 19,333	\$ 19,333
1	P-1	Slurry Pump	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
1	Cy-1	Flash Cyclone	Brelsford	1.38	\$ 11,000	1999	0.79	\$ 14,168	1.4	\$ 19,835	\$ 19,835
		Centrifuge	Delta-T	1.00	\$ 530,000	1995	1.00	\$ 530,000	1.2	\$ 636,000	\$ 715,824
1	S-1	Screen	Brelsford	1.38		1999	0.79	\$ -	2.8	\$ -	\$ -
1	RF-1	Rotary Filter	Brelsford	1.38		1999	0.79	\$ -	2.8	\$ -	\$ -
1	T-2	Surge Tank	Brelsford	1.38	\$ 13,600	1999	0.79	\$ 17,517	1.4	\$ 24,524	\$ 24,524
1		Conveyors to second stage	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	1.2	\$ 8,501	\$ 8,501
1		Pump to Lime Addition	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
Total Brelsford Stage 1											\$ 1,927,984
Brelsford Stage 2											
1	T-201	Acid Storage Tank	NREL	0.24	\$ 42,500	1997	0.51	\$ 20,389	1.2	\$ 24,467	\$ 25,957
1	P-201	Acid Storage Tank Pump	NREL	0.24	\$ 8,000	1997	0.79	\$ 2,564	2.8	\$ 7,180	\$ 7,617
1	A-201	Acid Mixer	NREL	0.23	\$ 1,900	1997	0.48	\$ 935	1.0	\$ 935	\$ 992
1	P-1	Progressive cavity Pump	Brelsford	1.38	\$ 8,800	1999	0.79	\$ 11,335	2.8	\$ 31,737	\$ 31,737
1	HH-1	Hydro Heater	Brelsford	1.38	\$ 4,850	1999	0.79	\$ 6,247	2.8	\$ 17,491	\$ 17,491
1	HX-1	Heat Exchanger	Atlas	1.00							\$ 18,100
1	HX-2	Heat Exchanger	Atlas	1.00							\$ 17,050
1	PFR-1	Double Tube reactor	Brelsford	1.38	\$ 165,500	1999	0.79	\$ 213,167	1.5	\$ 319,750	\$ 319,750
1	T-1	Flash vessel	Brelsford	1.38	\$ 11,000	1999	0.71	\$ 13,810	1.4	\$ 19,333	\$ 19,333
1	P-1	Slurry Pump	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
1	Cy-1	Flash Cyclone	Brelsford	1.38	\$ 11,000	1999	0.79	\$ 14,168	1.4	\$ 19,835	\$ 19,835
		Centrifuge	Delta-T	1.00	\$ 530,000	1995	1.00	\$ 530,000	1.2	\$ 636,000	\$ 715,824
1	S-1	Screen	Brelsford	1.38		1999	0.79	\$ -	2.8	\$ -	\$ -
1	RF-1	Rotary Filter	Brelsford	1.38		1999	0.79	\$ -	2.8	\$ -	\$ -
1	T-2	Surge Tank	Brelsford	1.38	\$ 13,600	1999	0.79	\$ 17,517	1.4	\$ 24,524	\$ 24,524
1		Conveyors to dryer	Brelsford	1.38	\$ 5,500	1999	0.79	\$ 7,084	1.2	\$ 8,501	\$ 8,501
1		Slurry Pump to 1st Stage	Brelsford	1.38	\$ 2,500	1999	0.79	\$ 3,220	2.8	\$ 9,016	\$ 9,016
Total Brelsford Stage 2											\$ 1,244,743
Lime Addition Module											
1	T-301	Lime Storage Bin	NREL	1.00	\$ 69,200	1997	0.46	\$ 69,200	1.3	\$ 89,960	\$ 95,439
1	S-301	Lime Dust Baghouse	NREL	1.00	\$ 32,200	1997	1.00	\$ 32,200	1.5	\$ 48,300	\$ 51,198
1	C-301	Lime Solids Feeder	NREL	0.15	\$ 3,900	1997	1.00	\$ 3,900	1.3	\$ 5,070	\$ 5,374
1	T-300	Overliming Tank	NREL	0.15	\$ 71,000	1997	0.71	\$ 18,188	1.4	\$ 25,463	\$ 26,991
1	A-300	Overliming Tank Agitator	NREL	0.15	\$ 19,800	1997	0.51	\$ 7,444	1.3	\$ 9,677	\$ 10,258
1	P-300	Overlimed Hydrolyzate Pump	NREL	0.15	\$ 10,700	1997	0.79	\$ 2,351	2.8	\$ 6,583	\$ 6,978
1	S-302	Rotary Drum Filter and Hydroclone	NREL	0.15	\$ 165,000	1998	0.39	\$ 78,089	1.4	\$ 109,324	\$ 112,604
1	P-302	Overlimed Hydrolyzate Liquor Pump	NREL	0.15	\$ 10,800	1997	0.79	\$ 2,373	2.8	\$ 6,644	\$ 6,844
1	T-303	Reacidification Tank	NREL	0.15	\$ 147,800	1997	0.51	\$ 55,566	1.2	\$ 66,679	\$ 68,680
1	A-303	Reacidification Tank Agitator	NREL	0.15	\$ 65,200	1997	0.51	\$ 24,512	1.2	\$ 29,415	\$ 30,297
1	P-302	Fermentation Feed Pump	NREL	0.19	\$ 61,368	1998	0.70	\$ 19,122	2.8	\$ 53,541	\$ 55,147
1	A-304	In-line Acid Mixer	NREL	0.15	\$ 2,600	1997	0.48	\$ 1,035	1.0	\$ 1,035	\$ 1,098
1	B-304	Lime unloading Blower	NREL	0.15	\$ 47,600	1998	0.50	\$ 18,242	1.4	\$ 25,539	\$ 26,305
1	P-303	Reacidification Liquor Pump	NREL	0.15	\$ 10,800	1997	0.79	\$ 2,373	2.8	\$ 6,644	\$ 6,844
1		Heat Exchanger	Atlas	1.00							\$ 18,100
Total Lime Addition Module											\$ 522,155
Seed Fermentation											
2	A-304	Seed Vessel Agitator	NREL	0.91	\$ 11,700	1997	0.51	\$ 22,295	1.2	\$ 26,754	\$ 28,360
2	A-305	Seed Vessel Agitator	NREL	0.91	\$ 10,340	1996	0.51	\$ 19,704	1.2	\$ 23,644	\$ 25,772
2	F-301	1st SSCF Seed Fermentor	NREL	1.00	\$ 14,700	1997	0.91	\$ 29,400	2.8	\$ 82,320	\$ 87,259
2	F-302	2nd SSCF Seed Fermentor	NREL	1.00	\$ 32,600	1997	0.93	\$ 65,200	2.8	\$ 182,560	\$ 193,514
2	F-303	3rd SSCF Seed Fermentor	NREL	1.00	\$ 81,100	1997	0.93	\$ 162,200	2.8	\$ 454,160	\$ 481,410
2	F-304	4th SSCF Seed Fermentor	NREL	0.91	\$ 39,500	1997	0.93	\$ 72,331	1.2	\$ 86,798	\$ 92,005
1	H-301	SSCF Seed Hydrolyzate Cooler	NREL	0.91	\$ 15,539	1998	0.78	\$ 14,414	2.1	\$ 30,270	\$ 31,178
3	H-302	SSCF Hydrolyzate Cooler	NREL	0.98	\$ 25,409	1998	0.78	\$ 75,201	2.1	\$ 157,922	\$ 162,660
1	H-304	Seed Fermentor Coils	NREL	0.92	\$ 3,900	1997	0.83	\$ 3,066	1.2	\$ 3,679	\$ 3,899
2	P-302	Seed Transfer Pump	NREL	0.91	\$ 54,088	1998	0.70	\$ 101,228	1.4	\$ 141,720	\$ 145,971
Total Seed Fermentation Module											\$ 1,252,028
Replacement Dryer											
		Dryer	Delta T	1.00	\$ 1,015,529	1,995	0.80	\$ 1,015,529	1.20	\$ 1,218,635	\$ 1,371,584
											Eng./Const.Mgt. \$ 3,266,161
Total Incremental Capital Equipment											\$ 10,070,662

Notes

1. Additional costs to base case equipment estimate have been added for inclusion of new centrifuges on each Brelsford module. In addition costs have been included for replacement of the dryer for a unit that might better handle the Brelsford process low fiber DDGS.

Attachment 4b

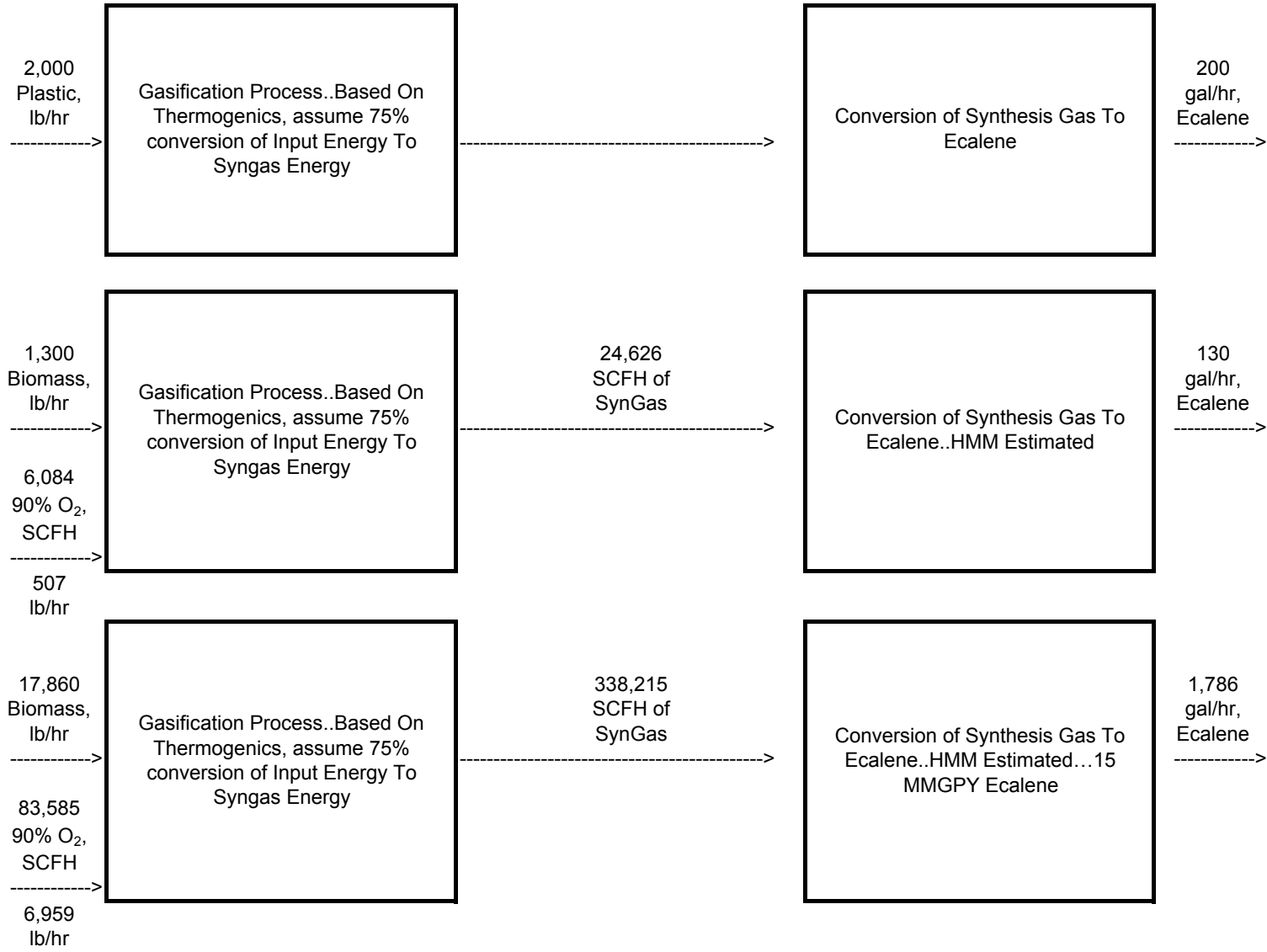
Equipment Cost with New Dryer and Centrifuges Proforma Economics

	Units	Unit Price \$	Quantity/yr	Infeed Reduction	\$/Yr.
Revenue					
Increased Ethanol	gallons	1.10	180,000	85%	\$ 198,000
Reduction in DDGS Value	Tons	67.24	-8559.75	85%	\$ (575,558)
			Revenue Reduction		(377558)
Operating Cost					
Existing Operation Derating					
Corn Feedstock reduction	bushels	1.67	-1051273.05		\$ (1,755,626)
Reduction in Variable Cost	\$/bushel	0.27	-1051273.05		\$ (283,591)
Brelsford Process Addition					
Sulfuric Acid	Tons	96.88	4542	85%	\$ 374,030
Lime	Tons	60.00	5059.33	85%	\$ 258,026
Gypsum Removal	\$/#	0.01	34479975	85%	\$ 293,080
Steam	MM BTU	5.31	74460	85%	\$ 336,075
Electric Power	\$/KWh	0.04	7787640	85%	\$ 238,302
Shift operators	1/shift	28000.00	4		\$ 112,000
Maint.Cost-5% Capital					\$ 503,533
			Total Incremental Operating Cost		\$ 75,828
				Net Increased Revenue	\$ (453,385)
				Capital Cost	\$ 10,070,662
				Capital payback period yrs. negative payback	

Notes

1. Additional costs to base case equipment estimate have been added for inclusion of new centrifuges on each Brelsford module. In addition costs have been included for replacement of the dryer for a unit that might better handle the Brelsford process low fiber DDGS.

**Attachment 5a
Conceptual Feed Alternatives..Ecalene Production**



Attachment 5b

Conceptual Capital Cost Estimate..15 MMGPY Ecalene Production

Capital Cost	Base Capacity	Capacity Units	Base Cost, Current USD	Base Cost Source	Current Capacity	Capacity Units	Cost, Current USD	Source
Feed Handling & Processing	70	DSTPH	5,200,000	NREL 21May98 Report	9	DSTPH	1,511,670	Delta-T Conceptual Estimate
Oxygen Plant				Vendor Budget Price	83,585	SCFH	3,000,000	Vendor Budget Price
SynGas Generation & Clean-up	300	DSTPD	5,000,000	Delta-T	182	DSTPD	3,706,690	Delta-T Conceptual Estimate
Ecalene Production	1	USGAL/YR	1.00	Vendor Budget Price	15,002,400	1.00	15,002,400	Delta-T Conceptual Estimate
Ecalene Dehydration & Processing	3,630	USGPH	2,800,000	Delta-T	1,786	USGPH	1,829,550	Delta-T Conceptual Estimate
Ecalene Storage & Loading	7,250	USGPH	2,300,000	NREL 21May98 Report	1,786	USGPH	992,330	Delta-T Conceptual Estimate
Utilities	7,250	USGPH	5,000,000	NREL 21May98 Report	1,786	USGPH	1,078,620	Delta-T Conceptual Estimate
Waste Water Treatment	1,225	USGPM	9,000,000	NREL 21May98 Report	48	USGPM	1,280,850	Delta-T Conceptual Estimate
Total Installed Equipment Cost							28,402,110	
Added Cost To Get To Total Project Investment				73% of sum of Area Capital			19,798,520	NREL 21May98 Report
Total Capital Cost							48,200,630	

Attachment 5c

Conceptual Operating Cost Estimate..15 MMGPY Ecalene Production

Operating hours/yr: 8400
Interest Rate: 10.0%
Time Period, Yrs: 8
Capital Factor: 0.1874
Annual UDA ETOH: 15,000,000

Variable Annual Operating Cost	Annual Quantity	Capacity	Unit Cost	Cost, Current	Source
Feedstock	75,012	DST	15.00	1,125,180	Unit Cost NREL 21May98 Report
Solids Disposal	3,380	DST	30.00	101,400	Unit Cost NREL 21May98 Report
Electrical Power Consumption	58	10 ⁶ KWH	45,000.00	2,608,200	Unit Cost NREL 21May98 Report
Denaturant	-	USGAL	1.00	-	Not required for product
Chemicals & Catalyst				2,606,483	Delta-T Estimate
Make-up Water	94	10 ⁶ USGAL	1,065.00	100,110	Unit Cost NREL 21May98 Report
Total Annual Variable Operating Cost				6,541,373	
Fixed Annual Operating Cost					
Operating Labor	10	EA	37,120.00	371,200	Unit Cost NREL 21May98 Report
Operating Foreman	2	EA	42,532.56	85,065	Unit Cost NREL 21May98 Report
Supervision	1	EA	52,200.00	52,200	Unit Cost NREL 21May98 Report
Direct Overhead	1	EA	45% of L&M	228,809.30	Unit Cost NREL 21May98 Report
Maintenance Material & Labor	1	EA	4% of Fixed	1,928,025	Unit Cost NREL 21May98 Report
Plant Overhead	1	EA	65% of L&M	125,322	Unit Cost NREL 21May98 Report
Insurance & Taxes	1	EA	1.5% of Fixed	723,009	Unit Cost NREL 21May98 Report
Total Annual Fixed Operating Cost				3,513,631	
Total Annual Operating Cost				10,055,004	
Total Annualized Capital Cost				9,034,920	
Total Annual Cost				19,089,923	
Annual Cost/Undenatured Gal ETOH				1.273	

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE July 2002	3. REPORT TYPE AND DATES COVERED Final Subcontract Report 2 March 2000—30 March 2002	
4. TITLE AND SUBTITLE Evaluation of the Potential for the Production of Lignocellulosic Based Ethanol at Existing Corn Ethanol Facilities			5. FUNDING NUMBERS BFP2.A420	
6. AUTHOR(S) Delta T Corporation				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Delta T Corporation Williamsburg, Virginia			8. PERFORMING ORGANIZATION REPORT NUMBER ZCL-0-30008-01	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3393			10. SPONSORING/MONITORING AGENCY REPORT NUMBER NREL/SR-510-32381	
11. SUPPLEMENTARY NOTES NREL Technical Monitor: Andy Aden				
12a. DISTRIBUTION/AVAILABILITY STATEMENT National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Subcontract report on opportunities to explore the business potential provided by converting biomass to products such as ethanol.				
14. SUBJECT TERMS Delta T; biomass conversion; feasibility; distillers dry grains; dilute acid hydrolysis			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	