

## **Final Report**

### **Xcel Renewable Development Fund Project (RD-56)**

## **Generating Electricity with Biomass Fuels at Ethanol Plants**

### **Chapter/Task 15 – Spreadsheet Architecture**

**This chapter describes development of the architecture of the spreadsheet used to conduct the economic analysis of Chapter/Task 16. It was primarily prepared by project participants at the University of Minnesota.**

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## **RD56: Generating Electricity With Biomass Fuels at Ethanol Plants Report for Task 15, “Spreadsheet Architecture”**

### **Overall Analysis Needs of the Project**

This project required a means of evaluating the economic feasibility of using biomass fuels with appropriate technologies to produce process heat and power at fuel ethanol plants. In addition to a conventional plant using natural gas and purchased electricity, we evaluated nine configurations of fuel and equipment for all levels of analysis. In addition we investigated two other biomass options that utilized syrup supplemented by natural gas. To make economic comparisons of the numerous technology-fuel choices and keep track of our operating assumptions, electronic workbooks consisting of numerous spreadsheets were developed. Aspen Plus modeling was conducted to determine the likely methods of combustion as well as the necessary capacities of equipment and operating expenses to utilize biomass at different levels of intensity. A key consideration was that of determining if a biomass system could comply with prevailing standards of emissions and sustain associated expenses.

In order to compare the economics of plants using by-products such as DDGS, syrup, and corn stover as fuels versus conventional, natural gas powered plants, spreadsheets of unique annual operating statements or proformas were designed and organized into workbooks. Starting from spreadsheets designed to analyze the profitability of dry-grind plants using natural gas, a template was prepared to capture the unique elements of systems using biomass fuels. This approach allowed fair comparisons in terms of returns on investment of combinations of technologies and biomass fuels to power the plants and reflect various options including the use of biomass at the following levels of intensity:

- 1) provide process heat for the plant’s use
- 2) provide process heat and electricity for the plant’s use
- 3) provide process heat and electricity for plant use and electricity to sell to grid

Another requirement for the spreadsheets’ design was to have the ability to change various cost categories to represent the various biomass fuels and technologies to utilize them. Using a workbook, a menu page was created to establish key assumptions at baseline conditions and then allow one or more of these to be changed in an effort to understand the sensitivity of the system. The assumptions of the menu page are thus available to be applied by the individual spreadsheets represent specific technology bundles.

### **Details on Individual Spreadsheets for Specific Technology Bundles**

#### **Capital Costs**

Depending upon the fuel and combustion system chosen, ASPEN Plus Software was used to determine equipment specifications in order to determine appropriate capital costs. With biomass fuels there are likely to be additional capital costs for the following:

- 1) feed mechanisms for the biomass
- 2) the combustion unit, itself
- 3) emissions control equipment

#### 4) ash handling costs

### **Fuel and Electricity Costs**

In ethanol plant economics one key factor of success is the cost of biomass fuel, itself. We analyzed the total cost of using various biomass fuels. In some cases that included the need to purchase the biomass from others, while in the cases of syrup and DDGS, the biomass fuel was produced concurrently with ethanol production at the plant. In cases using DDGS or syrup as fuel, the plant has less DDGS to sell. An ethanol plant combusting syrup also reduces the amount of natural gas needed to dry the DDGS under conventional processing. A plant using cornstover must purchase this material from local farmers and be competitive versus farmers' valuation of the cornstover as a nutrient source and useful groundcover. As discussed in the economics paper, the corn stover price presumes that densified material is delivered to the plant.

When electricity is produced at the ethanol plant such as the case of combined heat and power (CHP) and CHP plus sales to the grid, no purchases of electricity are made. When electric power is produced beyond the requirements of the plant, they become a revenue source for the plant.

### **Operating Costs Associated with Combustion Technology Used**

Details of operating expense are contained on the individual spreadsheets representing specific technology bundles. Among these expenses are the following:

- 1) maintenance and repairs (based on published sources and capital costs)
- 2) labor (based on published sources)
- 3) management (assumed at 1/3 of labor expenses)
- 4) ground limestone and quicklime (based on Aspen Plus modeling for sulfur capture)
- 5) anhydrous ammonia (based on Aspen Plus)
- 6) ash derived from biomass was determined to have a value as a fertilizer consisting of (0-18-28) analysis of N-P-K. This revenue source was assumed to have a value of \$200 per ton, based on the experience of Corn Plus, Winnebago, MN.

### **Spreadsheet for Dry-Grind Plant Using Natural Gas**

On the following page one can see the spreadsheet used to calculate profits for a conventional dry-grind ethanol plants under a variety of operating conditions. Cells that are masked in yellow and pink in **Column C** can be changed in order to model the conditions for various ethanol plants and various situations. For example, it is possible to see the impact of different ethanol prices, DDGS prices, CO2 prices on annual revenues for the plant. The spreadsheet allows one to calculate **Gross Margin** between the products sold and the cost of corn purchased for processing.

Similar detail is allowed with respect to **Operating Expenses**, where natural gas is the major expense item. It is possible to specify the price of natural gas as well as the BTU's of heat needed by the plant as well as the kilowatt-ours and the cost per kWh purchased.

As far as results, this spreadsheet shows the ethanol plant profits for the established levels of **corn cost, ethanol price, DDGS price, natural gas cost**, and the lesser factors. The number of bushels of corn ground in a year and the number of denatured gallons are summarized. A high degree of volatility in plant returns can occur because of the volatility of the four key factors.

Profits can change drastically based on changes in any of the four, but especially ethanol price, corn price, and natural gas price.

At the right of row 10 is the calculated rate of return on invested capital of 13.05%, which is the annual income divided by the capital cost. ( $\$14,686,250 / \$112,500,000$ ).

Although representing the comparison case of the typical conventional ethanol plant buying natural gas and electricity, categories of additional revenue sources and credits as well as expense items have been established that apply only to the biomass cases.

1 Base Case; Natural Gas & Electricity

2 Purchased NG & Elect.

	Cost/Denat. Gal. Ethanol	Ranges for Column C
3 Nameplate Ethanol Prod. (Denat. Gal.)	50,000,000	
4 Investment per Nameplate Gallon	\$2.25	
5 Factor of Nameplate Capacity	1.20	(80%- 150%)
6 Debt-Equity Assumptions		
7 Factor of Equity	0.40	
8 Factor of Debt	0.60	
9 Interest Rate Charged on Debt	0.08	
10 Rate of Return Req'd. by Investors on Equity	0.12	
11		
12 Conversion Efficiency Assumptions		
13 Anhydrous Ethanol Extracted (Gal. per Bu.)	2.750	2.5-2.9 gal/bu
14 DDGS per Bushel (lb. per Bu.)	18.152	15-19 lb./bu
15 CO2 extracted per Bushel (lb. per Bu.)	18	15-19lb./bu

17 Establishment of Gross Margin

	Price per Unit		
18 Ethanol Price (denatured price) \$/gal.	\$2.30	\$ .80 to \$2.50	
19 DDGS Price \$/T	\$145.00	\$55-\$130	
20 CO2 Price (\$ per Ton liq. CO2)	\$8.00	\$2- \$12 / liq.Ton	
21 Electricity Price Sold @		KWH per gallon	0
22 Ash Sold @ \$ per Ton		Tons	0
23 Federal Small Producer Credit	\$0.10		
24 RFS Ethanol Tradable Credit	\$0.07		
25 Federal Renewable Electric Credit			
26 Prem for Low-Carbon Imprint for Ethanol			
27 Revenue per Unit			
29 Corn Price Paid by Processor (\$ per bu.)	\$5.00	\$1.60---\$3.25	
30 Gross Margin			

32 Operating Expenses Per Bushel

	Price per Unit		
33 Natural Gas Price (\$ 1,000,000 Btu)	\$10.00	(\$3-\$15/Dtherm)	
34 LP (Propane) Price (\$ per gallon)	\$1.50	\$ .80- \$2.00/gal.	
35 Factor of Time Operating on Propane	0.02	0-.12	
36 Stover Price @	0.00	Stover Tons	
37 Syrup Price @	0.00	Syrup Tons	
38 DDGS Used @ \$ per Ton	0.00	DDGS Tons	0
39 BTU's of Heat fr Fuel Req./ Denat. Gal.	34,000	28,500-55,000	
40 Combined Heating Cost			
41 Electricity Price (\$ per kWh)	\$0.06	\$.025-\$.090/kWh	
42 Kilowatt Hours Required per Denat.Gal.	0.75	.70 -1.25 kWh/denat. gal.	
43 Electrical Cost			
44 Total BTU's of Fuel and Electricity	41,500		
45 Total Energy Cost			

47

	Cost/Denat. Gal. Ethanol		
48 Enzymes	\$0.0400		
49 Yeasts	\$0.0040		
50 Other Proc.Chemicals & Antibiotics	\$0.0200		
51 Boiler & Cooling Tower Chemicals	\$0.0050		
52 Water	\$0.0030	\$.005-.010	
53 Denaturant Price per Gal.	\$3.0000	Denat/100 gal An	2
54 Ammonia Price per Ton for NOX Control @		Tons Required	
55 Limestone Price per Ton for Sulfur Capture @		Tons Required	
56 Quicklime Price per Ton for Scrubber			
57 Total Chemical Cost			

59 Depreciation based on C49 asset life

59 Depreciation based on C49 asset life	15	Years	
60 Maintenance & Repairs	\$0.0400		
61 Interest Expense			
62 Labor	\$0.0500	\$.04--\$.06	
63 Management & Quality Control	\$0.0167	\$.010-\$.022	
64 Real Estate Taxes	\$0.0020		
65 Licenses, Fees& Insurance, Waste Mgmt.	\$0.0140	0030-.0050	
66 Other Expenses	\$0.0040	\$.01-\$.03	
67 Total of Other Processing Costs			
68 Total Processing Costs			
69 Net Margin Achieved Per Unit			
70 Investor Req'd. Return on Equity	12.00%		
71 Increment of Success/Failure to Meet Required Return			

73 Ethanol Plant Profits for Shareholders and Principal Reduction

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50MM Gal	1/10/2008	Plant Totals
	Plant Cost	\$ 112,500,000
	Initial Debt	\$ 67,500,000
	Payback of Addl Invest.	(Not Applicable)
	Rate of Return	13.05%
Annual Production		
Bushels Ground	Denat. Gallons	Tons of DDGS Sold
21,398,601	60,000,000	194,214

Revenue/Bu. Ground	Revenue/Gal. Denatured Sold	Plant Totals
\$6.4490	\$2.3000	\$ 138,000,000
\$1.3160	\$0.4693	\$ 28,160,987
\$0.0720	\$0.0257	\$ 1,540,699
		\$ 1,500,000
		\$ 4,119,231
		\$ -
\$8.0996	\$2.8887	\$ 173,320,917.48
\$5.0000	\$1.7832	\$ 106,993,006.99
\$3.0996	\$1.1055	\$ 66,327,910.49

Cost /Bushel Ground	Cost /Gal. Denatured Sold	Plant Totals
\$0.9343	\$0.3332	\$ 19,992,000
\$0.0312	\$0.0017	\$ 668,122
		\$ 20,660,122
\$0.9655	\$0.3443	\$ 20,660,122
\$0.1262	\$0.0450	\$ 2,700,000
\$1.0917	\$0.3893	\$ 23,360,122

\$0.1122	\$0.0400	\$ 2,400,000
\$0.0112	\$0.0040	\$ 240,000
\$0.0561	\$0.0200	\$ 1,200,000
\$0.0140	\$0.0050	\$ 300,000
\$0.0084	\$0.0030	\$ 180,000
\$0.1618	\$0.0577	\$ 3,461,538
\$0.3636	\$0.1297	\$ 7,781,538
\$0.3505	\$0.1250	\$ 7,500,000
\$0.1122	\$0.0400	\$ 2,400,000
\$0.2524	\$0.0900	\$ 5,400,000
\$0.1402	\$0.0500	\$ 3,000,000
\$0.0467	\$0.0167	\$ 1,000,000
\$0.0056	\$0.0020	\$ 120,000
\$0.0393	\$0.0140	\$ 840,000
\$0.0112	\$0.0040	\$ 240,000
\$0.9580 #	\$0.3417	\$ 20,500,000
\$2.4133	\$0.8607	\$ 51,641,661
\$0.6863	\$0.2448	\$ 14,686,250
\$0.2524	\$0.0900	\$ 5,400,000
\$0.4340	\$0.1548	\$ 9,286,250
\$14,686,250	\$14,686,250	\$ 14,686,250

Spreadsheets for Technology Bundles Using Biomass

Individual spreadsheets for ethanol plants using biomass to provide process heat and electricity are shown on pages 6,7, and 8. They represent biomass usage for process heat with corn stover,

CHP with syrup and corn stover, and CHP + grid sales for DDGS, respectively. The individual spreadsheets of the biomass cases are similar to the spreadsheet for the conventional plant shown on the previous page, but more details are represented. For example, many have revenues for sale of electricity, federal credits for renewable electricity, sales of ash, and premiums for the sale of ethanol having a lower carbon footprint. The specific lines for these revenue sources are the following:

- 1) electricity sold---**line 21** has price and kWh of electricity sold per gallon of ethanol
- 2) ash sold—**line 22** has the price per ton of ash assumed as well as the amount of ash per per year.
- 3) CHP and CHP + grid cases (2 and 3)---**line 25** has the federal renewable electric credit
- 4) DDGS price for in the case of syrup + stover cases---**line 19** assumes that a 10% higher price is received per ton of DDG than traditional DDGS.

With respect to expenses, the biomass technology bundles have the following lines populated with data applied to calculate their economics:

- 1) **Line 36** contains the price and amount of corn stover required.
- 2) **Line 42** contains the amount of electricity required per gallon of ethanol produced.
- 3) **Line 54** contains the price and tons of anhydrous ammonia required.
- 4) **Line 55** contains the price and tons of limestone required.
- 5) **Line 56** contains the price and tons of quicklime required

### **Menu Page**

The menu page contains both assumptions applied to all the individual spreadsheets as well as the results of the analysis in both graphical and numerical forms.

The menu page in each workbook (with an example for a 50 million gallon per year plant shown on page 9) offers the opportunity to feed assumptions to all spreadsheets in the workbook for ethanol plants of that particular size. The menu page offers current assumptions in active cells that are shaded either pink or yellow to the individual spreadsheets. A blue line is drawn across the top of each bar of the histogram to designate the rates of return on investment at baseline conditions so that the effects of subsequent changes to one or more variables can be seen, graphically.

1 Fluidized Bed Combustion; Indirect Steam Drier; Level

2 Corn Stover

3 Nameplate Ethanol Prod. (Denat. Gal.)	50,000,000	
4 Investment per Nameplate Gallon	\$ 3.04	
5 Factor of Nameplate Capacity	1.06	(80%- 150%)
6 Debt-Equity Assumptions		
7 Factor of Equity	0.40	
8 Factor of Debt	0.60	
9 Interest Rate Charged on Debt	0.08	
10 Rate of Return Req'd. by Investors on Equity	0.12	
11 Conversion Efficiency Assumptions		
13 Anhydrous Ethanol Extracted (Gal. per Bu.)	2.750	2.5-2.9 gal/bu
14 DDGS per Bushel (lb. per Bu.)	18.152	15-19 lb./bu
15 CO2 extracted per Bushel (lb. per Bu.)	18	15-19lb./bu

17 Establishment of Gross Margin

18 Ethanol Price (denatured price) \$/gal.	\$2.30	\$ .80 to \$2.50
19 DDGS Price \$/T	\$145.00	\$55-\$130
20 CO2 Price (\$ per Ton liq. CO2)	\$8.00	\$2-\$12 / liq.Ton
21 Electricity Price Sold @	\$0.10	KWH per gallon
22 Ash sold @ per Ton	\$200.00	Tons
23 Federal Small Producer Credit	\$0.10	
24 RFS Ethanol Tradable Credit	\$0.07	
25 Federal Renewable Electric Credit		
26 Prem for Low-Carbon Imprint for Ethanol	\$0.18	
27 Revenue per Unit		
28		
29 Corn Price Paid by Processor (\$ per bu.)	\$5.00	\$1.60--\$7.00
30 Gross Margin		

32 Operating Expenses Per Bushel

33 Natural Gas Price (\$ 1,000,000 Btu)	\$10.00	(\$3-\$15/Dtherm)
34 LP (Propane) Price (\$ per gallon)	\$1.50	\$.80- \$2.00/gal.
35 Factor of Time Operating on Propane	0.00	0-.12
36 Stover Price @ \$ per Ton	\$ 80.00	Stover Tons
37 Syrup Used @ \$ per Ton	0.00	Syrup Tons
38 DDGS Used @ \$ per Ton	0.00	DDGS Tons
39 BTU's of Heat fr Fuel Required	37,000	28,500-55,000
40 Combined Heating Cost		
41 Electricity Price (\$ per kWh)	\$0.06	\$.025-\$.090/kWh
42 Kilowatt Hours Purchased per Denat.Gal.	0.943	.70 -1.25 kWh/denat. gal.
43 Electrical Cost		
44 Total BTU's of Fuel and Electricity	46,430	
45 Total Energy Cost		

47

48 Enzymes	\$0.0400	
49 Yeasts	\$0.0040	
50 Other Proc.Chemicals & Antibiotics	\$0.0200	
51 Boiler & Cooling Tower Chemicals	\$0.0050	
52 Water	\$0.0030	\$.005-.010
53 Denaturant Price per Gal.	\$3.0000	Denat/100 gal Anhyd.
54 Ammonia Price per Ton for NOx Control @	\$ 700.00	Tons Required
55 Limestone Price per Ton for Sulfur Capture @	\$ 25.00	Tons Required
56 Quicklime Price per Ton for Scrubber	\$ 77.13	Tons Required
57 Total Chemical Cost		
59 Depreciation based on C49 asset life	15	Years
60 Maintenance & Repairs	\$0.0611	per \$ Plant Cost
61 Interest Expense		
62 Labor	\$0.0601	per \$ Plant Cost
63 Management & Quality Control	\$0.0200	\$.010-\$.022
64 Real Estate Taxes	\$0.0023	per \$ Plant Cost
65 Licenses, Fees& Insurance, Waste Mgmt.	\$0.0158	.0030-.0050
66 Miscellaneous Expenses	\$0.0045	\$.01-\$.03
67 Total of Other Processing Costs		
68 Total Processing Costs		
69 Net Margin Achieved Per Unit		

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50MM Gal	1/10/2008	Plant Totals
	Plant Cost	\$ 151,819,000
	Initial Debt	\$ 91,091,400
	Payback of Addl Inves	4.8
	Rate of Return	15.04%
Annual Production		
Bushels Ground	Denat. Gallons	Tons of DDGS Sold
18,902,098	53,000,000	171,555.44

Revenue/Bu. Ground	Revenue/Gal. Denatured Sold	Plant Totals
\$6.4490	\$2.3000	\$ 121,900,000
\$1.3160	\$0.4693	\$ 24,875,539
\$0.0720	\$0.0257	\$ 1,360,951
\$ -	\$ -	\$ -
\$ 0.0902	\$ 0.0322	\$ 1,705,752
\$0.0794	\$0.0283	\$ 1,500,000
\$0.1925	\$0.0687	\$ 3,638,654
\$0.4950	\$0.1765	\$ 9,356,538
\$8.6941	\$3.1007	\$ 164,337,434
\$5.0000	\$1.7832	\$ 94,510,490
\$3.6941	\$1.3175	\$ 69,826,945

Cost /Bushel Ground	Cost /Gal. Denatured Sold	Plant Totals
\$0.0000	\$0.0000	\$ -
\$ 0.5785	\$ 0.2063	\$ 10,934,706
\$0.5785	\$0.2063	\$ 10,934,706
\$0.1586	\$0.0566	\$ -
\$0.7371	\$0.2629	\$ 13,933,446

\$0.1122	\$0.0400	\$ 2,120,000
\$0.0112	\$0.0040	\$ 212,000
\$0.0561	\$0.0200	\$ 1,060,000
\$0.0140	\$0.0050	\$ 265,000
\$0.0084	\$0.0030	\$ 159,000
\$0.1618	\$0.0577	\$ 3,057,692
\$0.0041	\$0.0015	\$ 77,910
\$0.0066	\$0.0002	\$ 11,130
\$0.0003	\$0.0001	\$ 6,377
\$0.3687	\$0.1315	\$ 6,969,109
\$0.5355	\$0.1910	\$ 10,121,267
\$ 0.1713	\$ 0.0611	\$ 3,238,805
\$0.3855	\$0.1375	\$ 7,287,312
\$ 0.1684	\$ 0.0601	\$ 3,184,000
\$ 0.0561	\$ 0.0200	\$ 1,061,333
\$ 0.0063	\$ 0.0023	\$ 120,000
\$ 0.0444	\$ 0.0158	\$ 840,000
\$ 0.0127	\$ 0.0045	\$ 240,000
\$1.3804	\$0.4923	\$ 26,092,717
\$2.4862	\$0.8867	\$ 46,995,272
\$1.2079	\$0.4308	\$ 22,831,673

1 Fluidized Bed Combustion; Indirect Steam Drier; Level

2 Copyright: Douglas Tiffany

2 Stover and Syrup

	Cost/Denat. Gal. Ethanol	Ranges for Column C
3 Nameplate Ethanol Prod. (Denat. Gal.)	50,000,000	
4 Investment per Nameplate Gallon	\$ 3.15	
5 Factor of Nameplate Capacity	1.06	(80%- 150%)
6 Debt-Equity Assumptions		
7 Factor of Equity	0.40	
8 Factor of Debt	0.60	
9 Interest Rate Charged on Debt	0.08	
10 Rate of Return Req'd. by Investors on Equity	0.12	
11		
12 Conversion Efficiency Assumptions	18.152	0.589614573
13 Anhydrous Ethanol Extracted (Gal. per Bu.)	2.750	2.5-2.9 gal/bu
14 DDGS per Bushel (lb. per Bu.)	10.70268374	15-19 lb./bu
15 CO2 extracted per Bushel (lb. per Bu.)	18	15-19lb./bu

50MM Gal	1/10/2008	Plant Totals
	Plant Cost	\$ 157,535,000

Initial Debt	\$ 94,521,000
Payback of Addl Inv	3.6
Rate of Return	17.17%

Annual Production		
Bushels Ground	Denat. Gallons	Tons of Sold DDG
18,902,098	53,000,000	101,151.59

	Price per Unit	
17 Establishment of Gross Margin		
18 Ethanol Price (denatured price) \$/gal.	\$2.30	\$.80 to \$2.50
19 DDGS Price \$/T	\$159.50	\$55-\$130
20 CO2 Price (\$ per Ton liq. CO2)	\$8.00	\$2- \$12 / liq. Ton
21 Electricity Price Sold @	\$0.10	KWH per gallon
22 Ash sold @ per Ton	\$200.00	Tons
23 Federal Small Producer Credit	\$0.10	
24 RFS Ethanol Tradable Credit	\$0.07	
25 Federal Renewable Electric Credit		
26 Prem for Low-Carbon Imprint for Ethanol	\$0.20	
27 Revenue per Unit		
29 Corn Price Paid by Processor (\$ per bu.)	\$5.00	\$1.60--\$3.25
31 Gross Margin		

Revenue/Bu. Ground	Revenue/Gal. Denatured Sold	Plant Totals
\$6.4490	\$2.3000	\$ 121,900,000
\$0.8535	\$0.3044	\$ 16,133,678
\$0.0720	\$0.0257	\$ 1,360,951
\$ 0.3828	\$ 0.1365	\$ 7,235,723
\$ 0.1565	\$ 0.0558	\$ 2,958,460
\$0.0794	\$0.0283	\$ 1,500,000
\$0.1925	\$0.0687	\$ 3,638,654
\$0.5500	\$0.1962	\$ 10,396,154
\$8.7357	\$3.1155	\$ 165,123,620
\$5.0000	\$1.7832	\$ 94,510,490
\$3.7357	\$1.3323	\$ 70,613,131

	Price per Unit	
32 Operating Expenses Per Bushel		
33 Natural Gas Price (\$ 1,000,000 Btu)	\$10.00	(\$3-\$15/Dtherm)
34 LP (Propane) Price (\$ per gallon)	\$1.50	\$.80- \$2.00/gal.
35 Factor of Time Operating on Propane	0.00	0-.12
36 Stover Price @ \$ per Ton	\$ 80.00	Stover Tons
37 Syrup Used @ \$ per Ton		Syrup Tons
38 DDGS Used @ \$ per Ton	0.00	DDGS Tons
39 BTU's of Heat fr Fuel Required	37,000	28,500-55,000
40 Combined Heating Cost		
41 Electricity Price (\$ per kWh)	\$0.06	\$.025-\$ .090/kWh
42 Kilowatt Hours Purchased per Denat.Gal.	0.956	.70 -1.25 kWh/denat. gal.
43 Electrical Cost		
44 Total BTU's of Fuel and Electricity	46,560	
45 Total Energy Cost		

Cost /Bushel Ground	Cost /Gal. Denatured Sold	Plant Totals
\$0.0000	\$0.0000	\$ -
\$ 0.3270	\$ 0.1166	\$ 6,181,750
\$0.3270	\$0.1166	6,181,750
\$0.1608	\$0.0574	\$ 3,040,080
\$0.4879	\$0.1740	\$ 9,221,830

	Cost/Denat. Gal. Ethanol	
47		
48 Enzymes	\$0.0400	
49 Yeasts	\$0.0040	
50 Other Proc.Chemicals & Antibiotics	\$0.0200	
51 Boiler & Cooling Tower Chemicals	\$0.0050	
52 Water	\$0.0030	\$.005-.010
53 Denaturant Price per Gal.	\$3.0000	Denat/100 gal A
54 Ammonia Price per Ton for NOx Control @	\$ 700.00	Tons Required
55 Limestone Price per Ton for Sulfur Capture @	\$ 25.00	Tons Required
56 Quicklime Price per Ton for Scrubber	\$ 77.13	
57 Total Chemical Cost		
59 Depreciation based on C49 asset life	15	Years
60 Maintenance & Repairs	\$0.0634	per \$ Plant Cost
61 Interest Expense		
62 Labor	\$0.0635	per \$ Plant Cost
63 Management & Quality Control	\$0.0212	\$.010-\$ .022
64 Real Estate Taxes	\$0.0023	per \$ Plant Cost
65 Licenses, Fees & Insurance	\$0.0158	.0030-.0050
66 Miscellaneous Expenses	\$0.0045	\$.01-\$ .03
67 Total of Other Processing Costs		
68 Total Processing Costs		
69 Net Margin Achieved Per Unit		
70 Investor Req'd. Return on Equity	12.00%	

\$0.1122	\$0.0400	\$ 2,120,000
\$0.0112	\$0.0040	\$ 212,000
\$0.0561	\$0.0200	\$ 1,060,000
\$0.0140	\$0.0050	\$ 265,000
\$0.0084	\$0.0030	\$ 159,000
\$0.1618	\$0.0577	\$ 3,057,692
\$0.0085	\$0.0030	\$ 160,272
\$0.0080	\$0.0029	\$ 152,084
\$0.0023	\$0.0008	\$ 44,067
\$0.3825	\$0.1364	\$ 7,230,115
\$0.5556	\$0.1982	\$ 10,502,333
\$ 0.1778	\$ 0.0634	\$ 3,360,747
\$0.4000	\$0.1427	\$ 7,561,680
\$ 0.1782	\$ 0.0635	\$ 3,368,000
\$ 0.0594	\$ 0.0212	\$ 1,122,667
\$0.0063	\$0.0023	\$ 120,000
\$0.0444	\$0.0158	\$ 840,000
\$0.0127	\$0.0045	\$ 240,000
\$1.4345	\$0.5116	\$ 27,115,427
\$2.3049	\$0.8220	\$ 43,567,373
\$1.4308	\$0.5103	\$ 27,045,758
\$0.4000	\$0.1427	\$ 7,561,680

1 Fluidized Bed Combustion; Indirect Steam Drier; Level

2 DDGS

	Cost/Denat. Gal. Ethanol	Ranges for Column C
3 Nameplate Ethanol Prod. (Denat. Gal.)	50,000,000	
4 Investment per Nameplate Gallon	\$ 3.50	\$1.00- \$2.00
5 Factor of Nameplate Capacity	1.06	(80%- 150%)
6 Debt-Equity Assumptions		
7 Factor of Equity	0.40	
8 Factor of Debt	0.60	
9 Interest Rate Charged on Debt	0.08	
10 Rate of Return Req'd. by Investors on Equity	0.12	
11		
12 Conversion Efficiency Assumptions		
13 Anhydrous Ethanol Extracted (Gal. per Bu.)	2.750	2.5-2.9 gal/bu
14 DDGS per Bushel (lb. per Bu.)	18.152	15-19 lb./bu
15 CO2 extracted per Bushel (lb. per Bu.)	18	15-19lb./bu
16		
17 Establishment of Gross Margin	Price per Unit	
18 Ethanol Price (denatured price) \$/gal.	\$2.30	\$ .80 to \$2.50
19 DDGS Price \$/T	\$145.00	\$55-\$130
20 CO2 Price (\$ per Ton liq. CO2)	\$8.00	\$2- \$12 / liq. Ton
21 Electricity Price Sold @	\$0.10	KWH per gallon
22 Ash sold @ per Ton	\$200.00	Tons
23 Federal Small Producer Credit	\$0.10	
24 RFS Ethanol Tradable Credit	\$0.07	
25 Federal Renewable Electric Credit	\$0.020	
26 Prem for Low-Carbon Imprint for Ethanol	\$0.20	
27 Revenue per Unit		
29 Corn Price Paid by Processor (\$ per bu.)	\$5.00	\$1.60---\$3.25
30 Gross Margin		
31		
32 Operating Expenses Per Bushel	Price per Unit	
33 Natural Gas Price (\$ 1,000,000 Btu)	\$10.00	(\$3-\$15/Dtherm)
34 LP (Propane) Price (\$ per gallon)	\$1.50	\$.80- \$2.00/gal.
35 Factor of Time Operating on Propane	0.00	0-.12
36 Stover Purchased @ \$ per Ton	\$ 80.00	Stover Tons
37 Syrup Used @ \$ per Ton	0.00	Syrup Tons
38 DDGS Used @ \$ per Ton	0.00	DDGS Tons
39 BTU's of Heat fr Fuel Required	37,000	28,500-55,000
40 Combined Heating Cost		
41 Electricity Price (\$ per kWh)	\$0.06	\$.025-\$.090/kWh
42 Kilowatt Hours Purchased per Denat.Gal.	0.925	.70 -1.25 kWh/denat. gal.
43 Electrical Cost		
44 Total BTU's of Fuel and Electricity	46,250	
45 Total Energy Cost		
46		
47	Cost/Denat. Gal. Ethanol	
48 Enzymes	\$0.0400	
49 Yeasts	\$0.0040	
50 Other Proc.Chemicals & Antibiotics	\$0.0200	
51 Boiler & Cooling Tower Chemicals	\$0.0050	
52 Water	\$0.0030	\$.005-.010
53 Denaturant Price per Gal.	\$3.0000	Denat/100 gal A
54 Ammonia Price per Ton for NOx Control @	\$ 700.00	Tons Required
55 Limestone Price per Ton for Sulfur Capture @	\$ 25.00	Tons Required
56 Quicklime Price per Ton for Scrubber	\$ 77.13	Tons Required
57 Total Chemical Cost		
58		
59 Depreciation based on C49 asset life	15	Years
60 Maintenance & Repairs	\$0.0705	per \$ Plant Cost
61 Interest Expense		
62 Labor	\$0.0635	per \$ Plant Cost
63 Management & Quality Control	\$0.0212	\$.010-\$0.022
64 Real Estate Taxes	\$0.0023	per \$ Plant Cost
65 Licenses, Fees & Insurance	\$0.0158	.0030-.0050
66 Miscellaneous Expenses	\$0.0045	\$.01-.03
67 Total of Other Processing Costs		
68 Total Processing Costs		
69 Net Margin Achieved Per Unit		

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50MM Gal	1/10/2008	Plant Totals
	Plant Cost	\$ 175,240,000
	Initial Debt	\$ 105,144,000
	Payback of Addl Inv	7.5
	Rate of Return	13.14%
Annual Production		
Bushels Ground	Denat. Gallons	Tons of DDGS Sold
18,902,098	53,000,000	0.00
Revenue/Bu. Ground	Revenue/Gal. Denatured Sold	Plant Totals
\$6.4490	\$2.3000	\$ 121,900,000
\$0.0000	\$0.0000	\$ -
\$0.0720	\$0.0257	\$ 1,360,951
\$ 0.6707	\$ 0.2392	\$ 12,678,110
\$ 0.1821	\$ 0.0649	\$ 3,442,000
\$0.0794	\$0.0283	\$ 1,500,000
\$0.1925	\$0.0687	\$ 3,638,654
\$0.1341	\$0.0478	\$ 2,535,622
\$0.5500	\$0.1962	\$ 10,396,154
\$8.3298	\$2.9708	\$ 157,451,490
\$5.0000	\$1.7832	\$ 94,510,490
\$3.3298	\$1.1876	\$ 62,941,001
Cost /Bushel Ground	Cost /Gal. Denatured Sold	Plant Totals
\$0.0000	\$0.0000	\$ -
\$ -	\$ -	\$ -
\$0.0000	\$0.0000	\$ -
\$0.1556	\$0.0555	\$ 2,941,500
\$0.1556	\$0.0555	\$ 2,941,500
\$0.1122	\$0.0400	\$ 2,120,000
\$0.0112	\$0.0040	\$ 212,000
\$0.0561	\$0.0200	\$ 1,060,000
\$0.0140	\$0.0050	\$ 265,000
\$0.0084	\$0.0030	\$ 159,000
\$0.1618	\$0.0577	\$ 3,057,692
\$0.0119	\$0.0042	\$ 224,700
\$0.0119	\$0.0042	\$ 225,125
\$0.0066	\$0.0024	\$ 125,336
\$0.3941	\$0.1405	\$ 7,448,854
\$0.6181	\$0.2204	\$ 11,682,667
\$ 0.1978	\$ 0.0705	\$ 3,738,453
\$0.4450	\$0.1587	\$ 8,411,520
\$ 0.1782	\$ 0.0635	\$ 3,368,000
\$ 0.0594	\$ 0.0212	\$ 1,122,667
\$ 0.0063	\$ 0.0023	\$ 120,000
\$0.0444	\$0.0158	\$ 840,000
\$0.0127	\$0.0045	\$ 240,000
\$1.5619	\$0.5570	\$ 29,523,306
\$2.1116	\$0.7531	\$ 39,913,660
\$1.2182	\$0.4345	\$ 23,027,341

**Assumptions Common Across All Processes**

6/2/2008

**INSTALLED COSTS**

**Debt-Equity Assumptions**

	Active Val.	Base Val.
Factor of Equity	40%	40%
Factor of Debt	60%	60%
Interest Rate Charged on Debt	8%	8%
Investor Required Return on Equity	12%	12%
Depreciation based on asset life (years)	15	15

**Output Market Prices**

Ethanol Price (denatured price) \$/gal.	\$2.30	\$2.30
DDGS Price \$/T	\$145.00	\$145.00
Electricity Price (Plant is Seller) (\$ per kWh)	\$0.06	\$0.06
Value of Ash (\$ per Ton)	\$200.00	\$200.00
CO2 Price (\$ per Ton liq. CO2)	\$8.00	\$8.00
Max. Premium for Low-Carbon (\$0.00 per gallon)	\$0.20	\$0.20

**Government Subsidies**

Federal Small Producer Credit (\$/gal.)	\$0.10	\$0.10
RFS Ethanol Tradable Credit (\$/gal.)	\$0.07	\$0.07
Fed. Renew Elect Cred Closed-Loop (\$/kWh)	\$ 0.020	\$0.020

**Feedstock Delivered Prices Paid by Processor**

Corn Price (\$ per bu.)	\$5.00	\$5.00
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**Energy Prices**

Natural Gas Price (\$ per 1,000,000 Btu)	\$10.00	\$10.00
Stover Purchased @ (\$ per dry Ton)	\$80.00	\$80.00
Electricity Price (Plant is Buyer) (\$ per kWh)	\$0.06	\$0.06
LP (Propane) Price (\$ per gallon)	\$1.10	\$1.10

**Operating Costs/Input Prices**

Denaturant Price / gal	\$3.00	\$3.00
Denat/100 gal Anhyd.	2	2

**Feedstock-to-Ethanol Conversion Yields**

Ethanol Yield (anhydrous gal per bushel)	2.75	2.75
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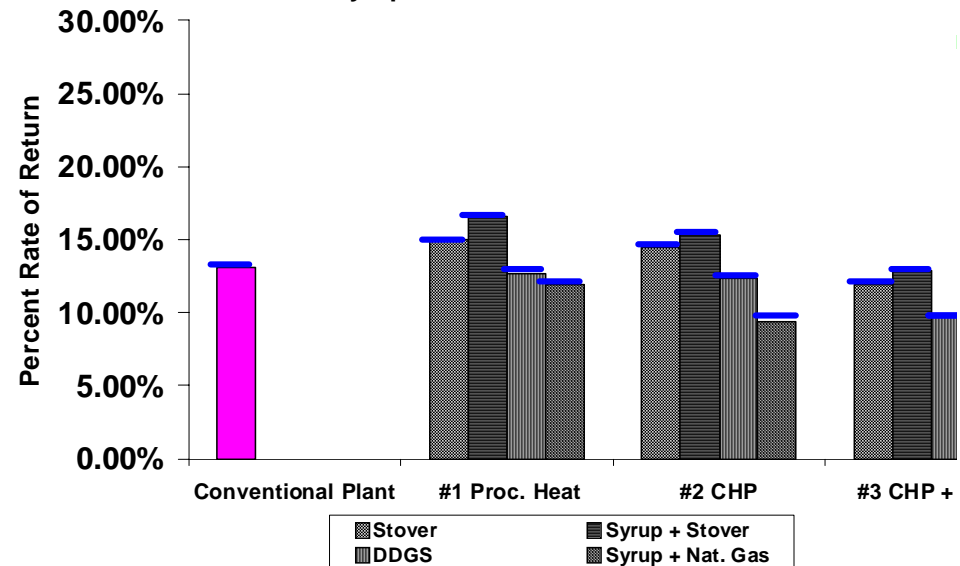
**50MM Gal**

Author: Douglas G. Tiffany, University of Minnesota

6/2/2008

	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	
	13.05%	15.04%	14.49%	11.92%	Stover
		16.55%	15.37%	12.84%	Syrup + Stover
		12.71%	12.38%	9.73%	DDGS
		11.93%	9.41%		Syrup + Nat. Gas

**Rates of Return on Investment for 50 MM Gal. Dry-Grind Plants: Conventional Plants versus those Using Stover or Stover + Syrup or DDGS or Syrup + Natural Gas at Various Intensities**



**Years to Payback Additional Investment**

	Conventional Plant	#1 Proc. Heat	#2 CHP	#3 CHP + Grid	50MM Gal
	Not Applicable	4.8	5.8	9.7	Stover
		3.2	4.7	8.0	Syrup + Stover
		8.7	9.3	26.5	DDGS
		14.6	-279.5		Syrup + Nat. Gas

