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# The Economic Feasibility of Sugarbeet Biofuel Production in Central North Dakota



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## **Abstract**

This study examines the financial feasibility of producing ethanol biofuel from sugar beets in central North Dakota. Under the Energy Independence and Security Act (EISA) of 2007, biofuel from sugar beets uniquely qualifies as an “advanced biofuel”. EISA mandates production of 15 billion gallons of advanced biofuels annually by 2022. A stochastic simulation financial model was calibrated with irrigated sugar beet data from central North Dakota to determine economic feasibility and risks of production for a 10MGY (million gallon per year) and 20MGY ethanol plant. Study results indicate that feedstock costs, which include sugar beets and beet molasses, account for more than 70% of total production expenses. The estimated breakeven ethanol price for the 20MGY plant is \$1.52 per gallon and \$1.71 per gallon for the 10MGY plant. Breakeven prices for feedstocks are also estimated and show that the 20MGY plant can tolerate greater ethanol and feedstock price risk than the 10MGY plant. Our results also show that one of the most important factors that affect investment success is the price of ethanol. At an ethanol price of \$1.84 per gallon, and assuming other factors remain unchanged, the estimated net present value (NPV) of the 20MGY plant is \$41.54 million. By comparison, the estimated NPV of the 10MGY plant is only \$8.30 million. Other factors such as changes in prices of co-products and utilities have a relatively minor effect on investment viability.

# **The Economic Feasibility of Sugar Beet Biofuel Production in Central North Dakota**

## **Introduction**

U.S. ethanol demand has steadily increased following passage of Renewable Fuel Standard (RFS) and the Energy Independence and Security Act of 2007 (EISA). Most domestic ethanol production utilizes corn grain as the feedstock. As production continues to rise, industry demand for corn has increased substantially resulting in higher corn prices. Rising corn prices are encouraging current and potential ethanol producers to seek alternative feedstocks, especially cellulosic sources. EISA defines three classes of biofuels: conventional, advanced, and cellulosic. These classes are differentiated based on potential reduction of greenhouse gas (GHG) emissions of 20, 50, and 60% respectively. Existing biofuel producers are striving to develop new conventional and cellulosic biofuels that qualify under EISA.

At present, several firms have pilot scale cellulosic ethanol production facilities under construction and testing. However, the transition from pilot scale to full commercialization of cellulosic ethanol will be long and difficult due to financial constraints being imposed on the biofuel industry (Gustafson, 2008).

Advanced biofuels have received scant attention, primarily because feedstock supplies are narrow. Two crops that uniquely qualify as “advanced biofuels” under the EISA are sugar beets and sugarcane. Advanced biofuel production of 15 billion gallons per year will be required by 2022, creating a niche market opportunity.

In 2008, North Dakota and Minnesota accounted for about 55% of total sugar beet production in the nation. In order to minimize transportation costs and GHG emissions, it would be most cost effective to locate sugar-beet-based fuel ethanol plants in North Dakota or Minnesota where sugar beet production is highly concentrated. In addition to expansion of existing sugar beet acreage, beet molasses produced from existing sugar refineries is a surplus commodity in the region and can also be used to produce ethanol. Beet molasses has a higher concentration of sugar than sugar beets and hence can result in higher rates of ethanol production and plant efficiency.

Highlands Enviro Fuels LLC (HEF) is developing a 20 million gallon per year (MGY) ethanol plant in Highlands County, Florida, which will process non-food sweet sorghum and sugar cane as its primary feedstocks. The company has completed a life-cycle analysis of greenhouse gas (GHG) emissions and demonstrated that the planned sugar-based ethanol process will result in 80% lower GHG emissions than the equivalent petroleum-based gasoline. This reduction in GHG emissions will allow its ethanol to qualify as a “cellulosic” biofuel.

The model developed in this study is based on 10MGY and 20MGY ethanol plants in central North Dakota which use non-food sugar beets and beet molasses as primary feedstocks. Ethanol produced from this plant is expected to have GHG emissions that are lower than the “advanced” biofuel standard because a co-product of production is spray dried in a patented process and used to generate 75% of the plant’s thermal energy needs.

### *Rationale and Objective*

Production of advanced biofuels using sugar beets as a feedstock in North Dakota would have the following comparative advantages:

1. Low transportation, storage and processing costs of sugar beets in the region due to close proximity to the resource, cool climate, and already existing processing infrastructure, technology know-how and human capital.
2. Because of their high sugar content, sugar beets can double the ethanol production per acre as compared to corn which reduces land area requirements.
3. Unlike corn, sugar beets produce higher sugar in soils with minimal nitrogen, a key contributor to GHG.
4. The region has great potential to expand irrigated sugar beet production, minimizing land competition with existing food crops.
5. The process of sugar-to-ethanol conversion is simpler than that of corn-to-ethanol conversion and hence requires less capital and energy resulting in lower production costs and greenhouse gas emissions.
6. Current sugar producers and processors in the region can diversify their assets by producing both sugar-beet-based ethanol and beet sugar.

The goal of this study is to investigate the economic feasibility of sugar-beet-based fuel ethanol production in central North Dakota. Results from this study will contribute to growing literature on the feasibility of producing ethanol from alternative feedstocks in the U.S.

### **Economic Impact of Sugar Beet Production in Central North Dakota**

Currently, U.S. sugar beets are processed into food sugar. If sugar-beet-based ethanol was to be produced, more sugar beets would have to be planted in North Dakota to meet the demand for both ethanol and sugar production. By growing additional sugar beets for ethanol production, farmers can generate positive economic impacts to the region's economy through expenditures for production inputs and net returns from production. Table 1 shows the economic impacts of irrigated and non-irrigated sugar beet production in central North Dakota based on the ten year average data of crop enterprise analysis. As can be seen in the table, the economic impact of farm net returns is about \$539.13 per acre for irrigated sugar beets and \$201.39 per acre for non-irrigated sugar beets. Economic impact from the farm total expenditures is about \$804.87 per acre for irrigated sugar beets and \$592.83 per acre for non-irrigated sugar beets.

This study examines the economic feasibility of 10MGY and 20MGY fuel ethanol plants. To produce 10MGY (20MGY) of fuel ethanol from sugar beets, one would need 377,358 (754,717) tons of sugar beets per year. In order to produce 754,717 of sugar beets for a 20MGY ethanol plant, 23,585 acres of farm land for irrigated sugar beets or 39,911 acres of farm land for non-irrigated sugar beets would be required, assuming that one acre of farm land yields 32 tons of irrigated sugar beets and 19 tons of non-irrigated sugar beets. If we assume that the average net return in Table 1 holds true for all growers of irrigated (or non-irrigated) sugar beets in central North Dakota, then additional gross farm income of \$12.72 million (or \$8.04 million)<sup>1</sup> can be generated by the growers as a result of 20 MGY sugar-beet-based ethanol production. Similarly, as a result of 20MGY of sugar-beet ethanol production, the direct economic impact

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<sup>1</sup> The opportunity costs of replacing alternative crops are not included.



from the expenditures of irrigated (or non-irrigated) sugar-beet production inputs would be about \$18.98 million (or \$23.66 million).

Increased revenues to sugar beet growers are additional impact of sugar-beet-based ethanol production. For every one million dollars of revenue generated by beet growers, the state's economic activity would grow by \$2.7 million<sup>2</sup>. In addition, one million dollars of sugar beet sales would result in \$0.55 million of additional household income and create 28 new jobs in the state<sup>3</sup>. With additional farm income of \$12.72 million from irrigated sugar beet production, a total of 356 new jobs would be created.

**Table 1 Economic Impact of Sugar Beet Production in Central North Dakota**

	<b>Irrigated</b>	<b>Non-irrigated</b>
Yield per Acre (in ton)	32.00*	18.91
Value per ton (\$)	42.00	42.00
Return per Acre (\$)	1,344.00	794.22
Variable Costs per Acre (\$)		
Seed	56.54	57.75
Fertilizer	57.22	42.91
Crop Chemicals	114.33	106.57
Crop Insurance	26.88	19.92
Irrigation Energy	25.61	0.00
Fuel and Oil	59.28	40.52
Repairs	93.35	57.94
Land Rent	50.00**	50.00**
Hauling and Trucking	73.98	0.00
Stock/Quota Lease	0.00	24.82
Machinery Leases	31.73	0.23
Others	62.81	58.26
Fixed Costs per Acre (\$)		
Machinery and Building Depreciation	75.15	53.78
Hired Labor	47.16	30.69
Farm Insurance	7.34	4.02
Interest	21.27	16.19
Utilities	4.43	4.14
Others	-2.21	25.09
Total Production Costs per Acre (\$)	804.87	592.83
Net Return per Acre (\$)	539.13	201.39

Note: Both irrigated and non-irrigated cost data are the 10-year average data. Irrigated cost data are based on the Minnesota's data, as no irrigated sugar beets are produced in North Dakota.

\*Based on the yield trial data in Carrington, central North Dakota.

\*\*Based on the average land rent value of central North Dakota.

Source: FINBIN Farm Financial Database

<sup>2</sup> Based on the output multiplier of 2.698 in North Dakota (Cryan, 2004), assuming that there are no opportunity costs of growing additional sugar beets for ethanol production.

<sup>3</sup> Based on the North Dakota's household earning and employment multipliers of 0.5463 and 27.96 respectively (Cryan, 2004).

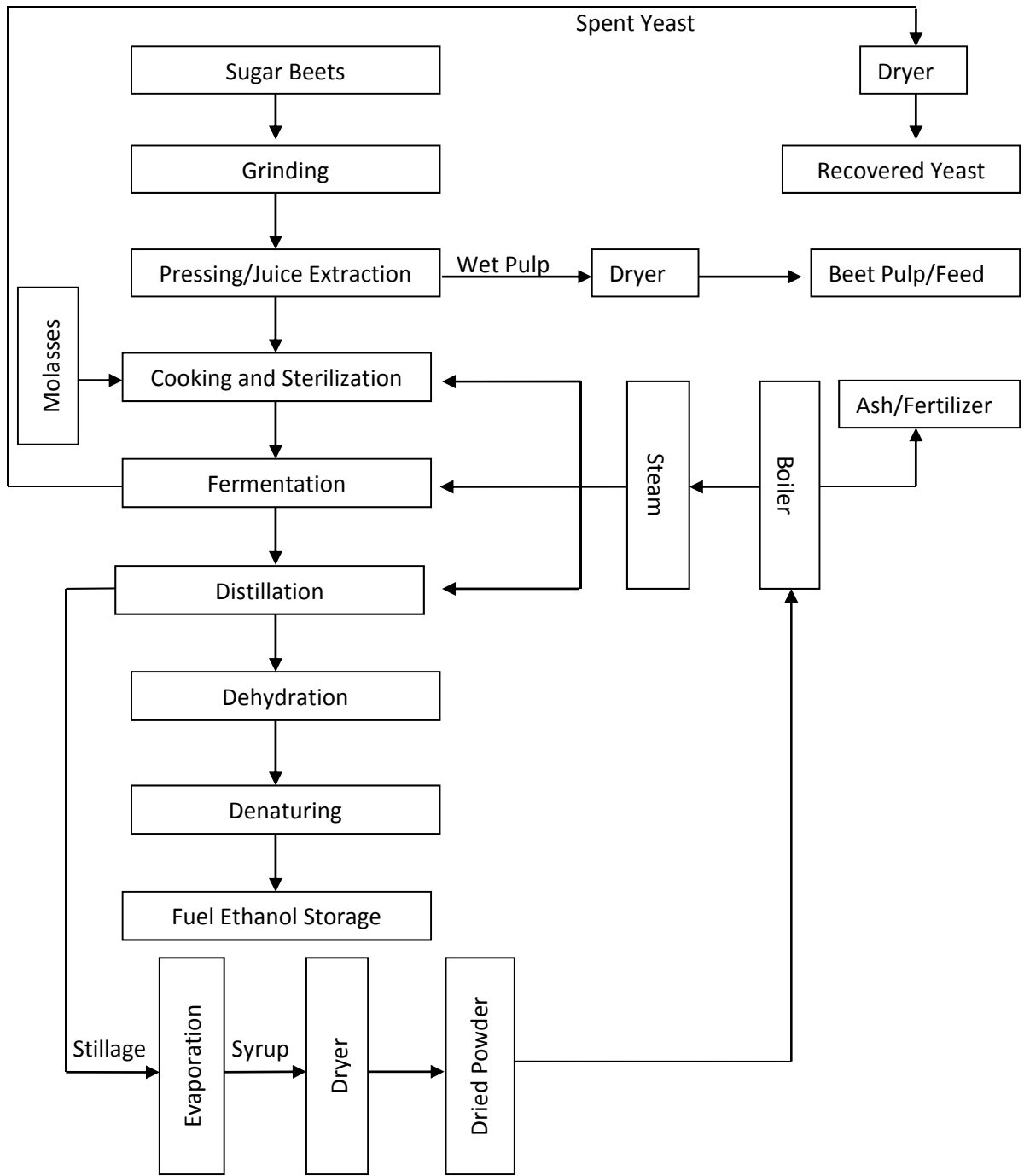
## Background and Literature

Many studies have examined the economic feasibility of corn-based ethanol production. However, only a few have assessed the feasibility of producing sugar-based ethanol. Outlaw et al. (2007) analyzed the feasibility of integrating ethanol production into the existing sugar mill that uses sugarcane juice as the feedstock for ethanol production. The authors developed an annual Monte Carlo simulation financial model which analyzed a 40 MGY (million gallons per year) ethanol plant for 10 years. They found that existing sugar mills could be retrofitted to produce ethanol and usually generated positive annual returns. Overall net present value (NPV) was found to be positive in their study.

USDA (2006) assessed the feasibility of ethanol production from sugar in the U.S. The USDA study made use of a variety of published data to estimate the cost of producing ethanol from sugarcane, molasses and sugar beet. The study found that it is economically feasible to make ethanol from molasses and that producing ethanol from sugar beets and sugarcane can become profitable only with spot market prices for ethanol rose to \$4 per gallon. Yoder et al. (2009) investigated the potential development of an ethanol industry in Washington State utilizing sugar beets as a feedstock. Their model was based on a 20 MGY plant utilizing not only sugar beets but beet pulp in a hydrolysis process to produce ethanol. Results from their study did not offer positive prospects for the development of a sugar-beet ethanol industry in Washington State primarily due to the high costs of sugar beet production and high costs of transportation to a sugar beet processing plant. They pointed out that Washington State simply does not have a comparative advantage in producing fuel ethanol using sugar beets.

Factors that may have significant economic impact on the feasibility of utilizing sugar beets to produce ethanol include ethanol and gasoline prices, the price of inputs such as sugar beets and beet molasses, and corn and sugar prices. Studies (Coltrain 2001; Herbst et al 2003) show that ethanol price is the most important factor when considering the profitability of an investment in ethanol production. Higher ethanol prices are directly correlated with higher profits. Zhang et al (2009) indicate that ethanol demand is a derived demand from gasoline production, the price of gasoline would have a direct influence on the price of ethanol. Serra et al (2008) show that in the U.S., ethanol, corn and oil prices tend to move together over the long run and a positive/negative shock in oil and corn prices causes a positive/negative change in ethanol prices. Because U.S. ethanol producers have negligible market power in the gasoline/oil sector, they are price takers in the biofuel market. Currently in the U.S., all sugar beets are used to produce food sugar. Hence, the relationship between sugar and ethanol prices is non-existent. However, in Brazil, sugar and ethanol prices tend to move together because a large number of plants are dual plants producing both sugar and ethanol and they can easily switch between the production of sugar and ethanol based on relative prices (Elobeid and Tokgoz, 2008). An increase in corn prices in the U.S. and sugar prices in Brazil will have negative impacts on the world's supply of ethanol, assuming that the price of ethanol is fixed. Nevertheless, Coltrain (2001) argues that only extremely high input grain prices can cause substantial losses in ethanol production when the price of ethanol is \$1.77 per gallon.

**Figure 1 Sugar-beet/Molasses Ethanol Production Process Flow Diagram**



### Technology Overview and Methodology

Sugar beet/molasses ethanol production technology utilizing spray-dried yeast is illustrated in Figure 1. Sugar-based ethanol production processes involve simple sugar molecules rather than a large amount of solid starch. Consequently the production processes require fewer operations than starch- or cellulose-based ethanol production processes (Heartland Renewable Energy,

2008). As shown in Figure 1, sugar beets are first ground before further processing. Ground pieces are pressed and extracted to produce sugar juice. The actual grinding process for preparing energy beets for biofuel is less refined compared with sugar production in which beets are sliced. Simple grinding can tolerate small rocks less than 1" in diameter which enables production in a wider variety of soil types and geographic locations. Once the juice is extracted, it is separated from solid beet pulp which is processed into animal feed. Before the final product of fuel ethanol is produced, sugar bearing juice moves through various stages of cooking, sterilization, fermentation, distillation, dehydration, and denaturing – similar to corn ethanol production. During the fermentation process yeast is added to convert sugar to ethanol. The spent yeast is then recovered through centrifugation and a spray drying processes. The recovered yeast can be sold as a co-product or used for plant thermal needs. After the distillation process, the left over solid known as stillage is converted into a syrup through the evaporation process. The syrup is then dried to a powder which is used to generate steam to meet 75% of the plant's thermal energy needs. The plant's remaining thermal energy requirements are assumed to be generated from natural gas. Ash generated by the boiler during the energy production process can be sold as a fertilizer. Electricity to operate the plant is purchased.

This study uses 10MGY and 20MGY ethanol plant models to examine the economic feasibility of producing ethanol from sugar-beet-based feedstocks in central North Dakota. At present all sugar beets grown in North Dakota are used to produce sugar for consumption and the majority of sugar beet production is concentrated in eastern part of the state. In order to allow development of sugar beet production in new geographic regions for ethanol production, the model in this study assumes that 30% sugar beet feedstock (324 tons per day for the 10MGY plant and 648 tons per day for the 20MGY plant) and 70% molasses (220 tons and 514 tons per day for each respective plant type) will be used initially. Over time as sugar beet acres increase, the model assumes a gradual increase in the use of sugar beets from 30% to 70% and a gradual decrease in the use of beet molasses from 70% to 30%. Both sugar beet growers and beet molasses suppliers will be contracted to supply all the required feedstocks. Total investment costs are shown in Table 3 and 4 for both 20MGY and 10MGY plants. Engineering and construction costs, and development and start-up costs for the 20MGY and 10MGY plants respectively account for about \$42.5 million and \$33.4 million, and financed with 50% equity and 50% debt at 8.5% interest over 10 years.

Technical conversion data originate from a BBI study (Heartland Renewable Energy, 2008) and localized with price information and sugar beet production cost data from central North Dakota. The model can be categorized into four sections. The first section describes production assumptions which include the conversion of sugar beets and beet molasses to ethanol, the annual requirement for feedstocks and their respective prices, the annual co-product yields and prices, and the annual requirements for electricity and natural gas. The second section constructs an income statement with annual ethanol and co-product sale revenues, production costs, and administrative and operating expenses. The cash flow financial statement is established in the third section with variables including annual net earnings, working capital balances, investment activities, financing activities and net cash balance. In the final section, the balance sheet with annual asset values, liabilities and equities is developed. The net present value (NPV) is used to conduct sensitivity and risk analysis and to determine breakeven prices for ethanol, sugar beet and beet molasses. The NPV is calculated using the following formulation:

$$NPV = -Initial\ Equity\ Investment + \sum_{n=1}^{10} \frac{NCF_n}{(1+i)^n}$$

NCF represents net cash flows. The relationship between NCF and net income (NI) can be expressed as follows:

$$NCF = \widetilde{NI} + Depreciation/Amortization - Noncash\ Revenues - Capital\ Expenses$$

$$\widetilde{NI} = \tilde{P}_O \times Q_O - \tilde{P}_I \times Q_I - Other\ Costs$$

where  $\tilde{P}_O$  represents stochastic output prices which include ethanol and co-product prices.  $\tilde{P}_I$  is defined as stochastic input prices which include prices of sugar beets, molasses, electricity, natural gas, yeast and enzymes etc. Other costs include administrative and operating expenses, and interest, depreciation and amortization expenses. The discount rate,  $i$ , is assumed to be 8.5% in this study. The model produces a ten year operating financial forecast.

### Stochastic Data Description

Stochastic variables used in the model are annual prices for ethanol, co-products (which include feed, yeast, and fertilizer), sugar beet, beet molasses, electricity and natural gas. Remaining variables are deterministic. Ethanol and co-product prices represent the plant's revenue risk, while other input prices capture the plant's production cost risk. Annual ethanol price data (from 2001 to 2008) used in simulation were collected from the Official Nebraska Government website<sup>4</sup> and are used as proxies for North Dakota ethanol prices. Annual North Dakota natural gas and electricity prices were gathered from the Energy Information Administration website<sup>5</sup>. Annual North Dakota sugar beet prices (also from 2001 to 2008) were obtained from the Economic Research Service, USDA website<sup>6</sup>. Beet molasses prices were assumed to vary from \$100 per ton to \$200 per ton during the simulation. Similar assumptions were made for co-product prices. Data, distribution and assumptions used in the model are summarized in Table 2, 3 and 4<sup>7</sup>. Distributions of ethanol, natural gas and electricity prices were determined using the fitting algorithms in @Risk (Palisade Corporation, 2009). Due to data limitations, prices for co-products and beet molasses were modeled as a triangular distribution as described in Table 2. The financial model was transformed into a Monte Carlo simulation model using @Risk simulation package. Simulation results are shown in Figure 2, 3, 4 and 5. The simulated model was iterated 1000 times, each time with a different price level.

<sup>4</sup> <http://www.neo.ne.gov/statshtml/66.html>

<sup>5</sup> [http://www.eia.doe.gov/cneaf/electricity/page/at\\_a\\_glance/sales\\_tabs.html](http://www.eia.doe.gov/cneaf/electricity/page/at_a_glance/sales_tabs.html)

<sup>6</sup> <http://www.ers.usda.gov/briefing/sugar/data.htm>

<sup>7</sup> The data and assumptions were obtained from the Heartland Renewable Energy and local industry sources.

**Table 2 Data and Distribution for Stochastic Variables**

<b>Variable</b>	<b>Minimum</b>	<b>Mean</b>	<b>Maximum</b>	<b>Std. Dev.</b>	<b>CV</b>	<b>Distribution*</b>
Prices for						
Beet Molasses (\$/ton)	101.03	140.00	199.16	21.62	0.15	Triangular
Whole Beets (\$/ton)	31.00	45.87	60.02	3.35	0.07	Logistic
Ethanol (\$/gal)	0.75	1.89	7.84	0.68	0.36	Log Logistic
Electricity (\$/kWh)	0.03	0.04	0.09	0.01	0.25	Exponential
Natural Gas (\$/Million BTU)	0.00	6.23	16.48	2.10	0.34	Logistic
Co-products						
Yeast (\$/ton)	308.92	500.00	694.07	81.70	0.16	Triangular
Fertilizer (\$/ton)	41.16	93.13	158.15	24.99	0.27	Triangular
Beet Pulp (\$/ton)	60.77	84.39	118.74	12.88	0.15	Triangular

CV stands for coefficient of variation. \*Distributions are the same for both 10MGY and 20MGY plants.

**Table 3 Assumptions Used in the 20MGY Plant Model**

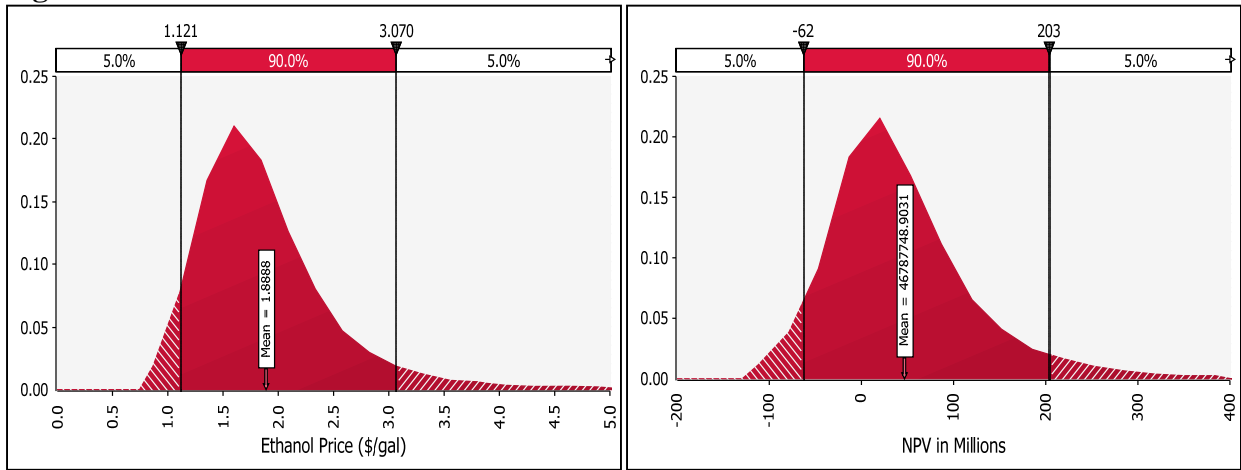
	<b>20 MGY Plant</b>
Conversion Rate for Whole Beets (gal/ton)	26.50
Conversion Rate for Beet Molasses (gal/ton)	77.89
Average Sugar Beets Requirement (tons/yr)	431,266.85
Average Beet Molasses Requirement (tons/yr)	97,818.05
Electricity Requirement (Million kWh/yr)	12.00
Thermal Energy Requirement	
Stillage Powder (Million BTU/yr)	450,000.00
Natural Gas (Million BTU/yr)	150,000.00
Local Ethanol Transportation Cost (\$/gal)	\$ 0.02
Base Prices for	
Beet Molasses (\$/ton)	\$ 120.00
Whole Beets (\$/ton)	\$ 42.00
Ethanol (\$/gal)	\$ 1.84
Electricity (\$/kWh)	\$ 0.06
Natural Gas (\$/Million BTU)	\$ 7.35
Co-products	
Yeast (\$/ton)	\$ 500.00
Fertilizer (\$/ton)	\$ 79.40
Beet Pulp (\$/ton)	\$ 73.18
Engineering and Construction Cost	\$ 32,665,280.00
Development and Start-up Cost	\$ 9,828,860.00
Total Capital Cost	\$ 42,494,140.00
Equity Capital 50%	\$ 21,247,070.00

**Table 4 Assumptions Used in the 10MGY Plant Model\***

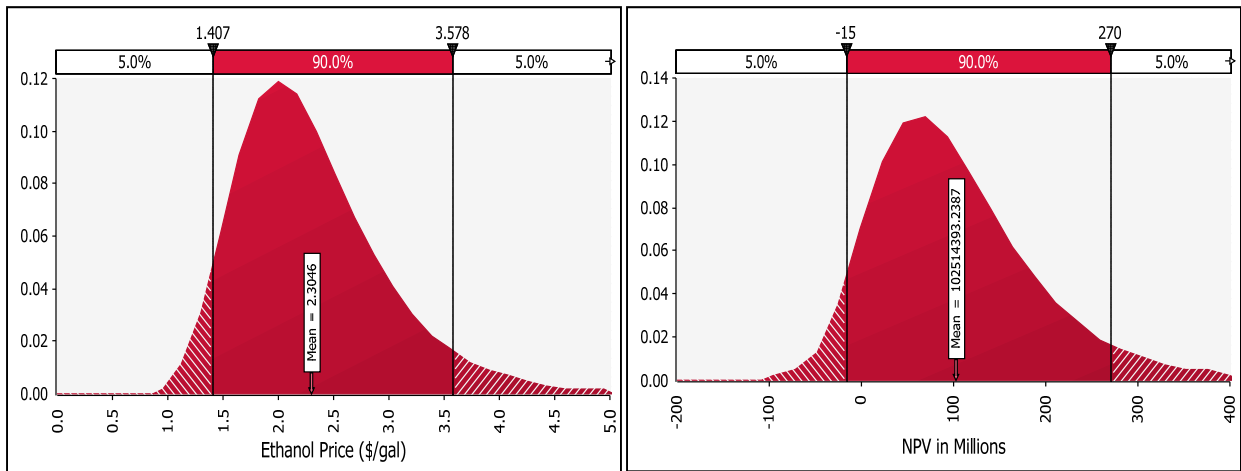
	<b>10 MGY Plant</b>
Average Sugar Beets Requirement (tons/yr)	215,633.42
Average Beet Molasses Requirement (tons/yr)	47,686.30
Electricity Requirement (Million kWh/yr)	6.00
Thermal Energy Requirement	
Stillage Powder (Million BTU/yr)	225,000.00
Natural Gas (Million BTU/yr)	75,000.00
Engineering and Construction Cost	\$ 26,834,553.00
Development and Start-up Cost	\$ 6,566,652.00
Total Capital Cost	\$ 33,401,205.00
Equity Capital 50%	\$ 16,700,603.00

\*The rest of the assumptions are the same as the assumptions in the 20MGY plant.

**Figure 2 Distributions of Ethanol Price and Net Present Value for the 20MGY Plant**



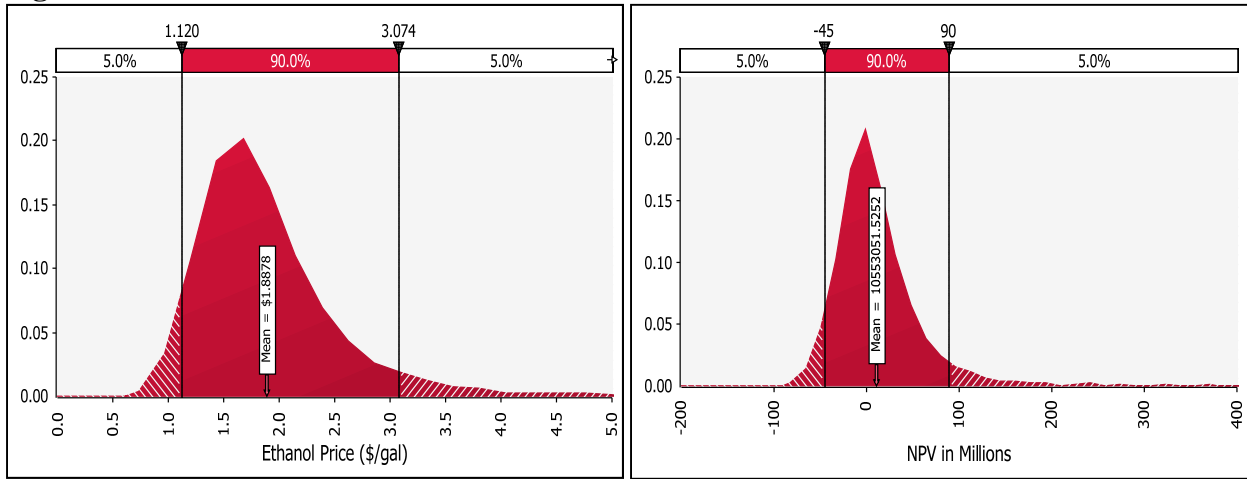
(a) Base case: Distribution of Ethanol Price (\$/gal) and Net Present Value (in millions)



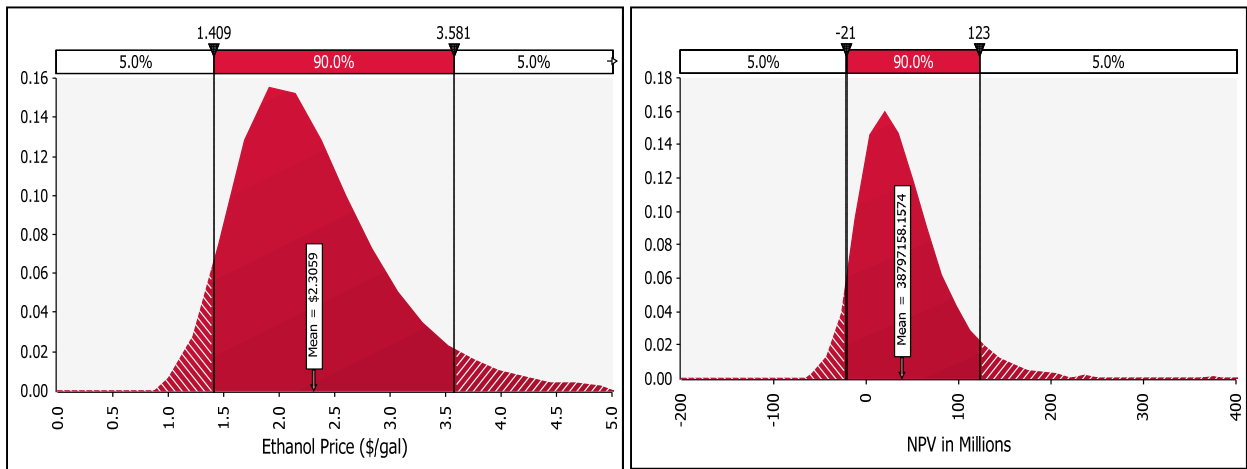
(b) 25% Increase in Ethanol Price: Distribution of Ethanol Price (\$/gal) and Net Present Value (in millions)



**Figure 3 Distributions of Ethanol Price and Net Present Value for the 10MGY Plant**

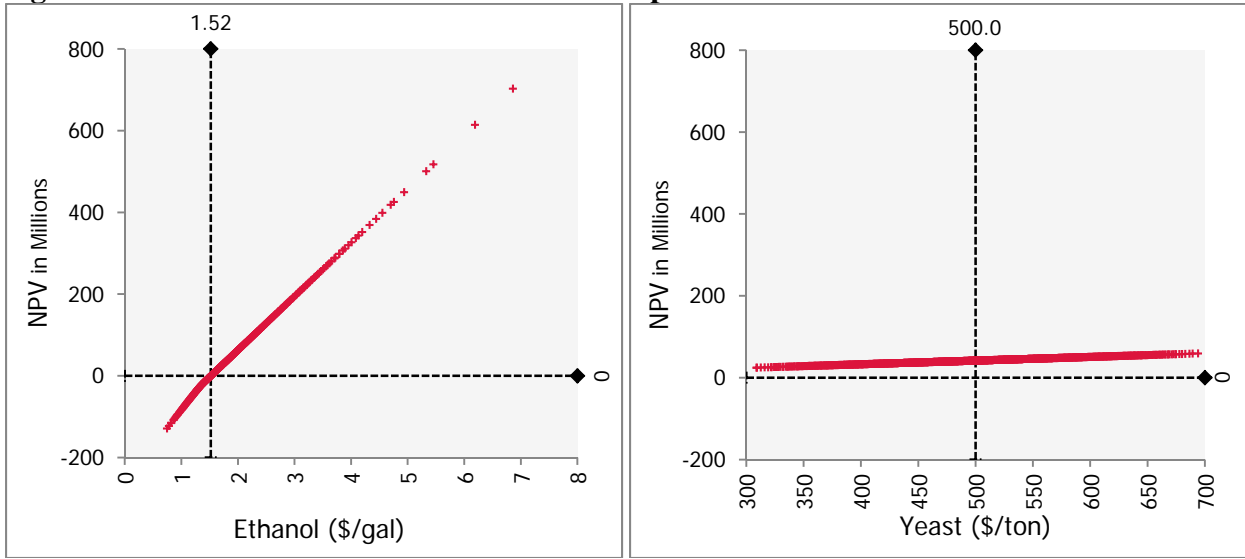


(a) Base case: Distribution of Ethanol Price (\$/gal) and Net Present Value (in millions)



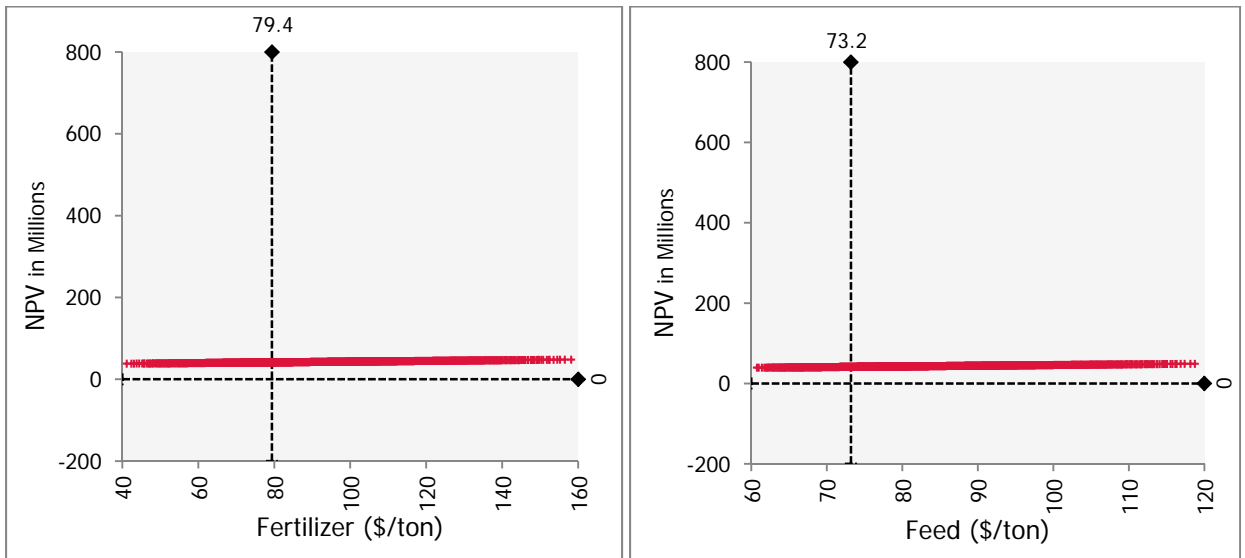
(b) 25% Increase in Ethanol Price: Distribution of Ethanol Price (\$/gal) and Net Present Value (in millions)

**Figure 4 Net Present Value vs. Ethanol and Co-product Prices for the 20MGY Plant**



**(a)**

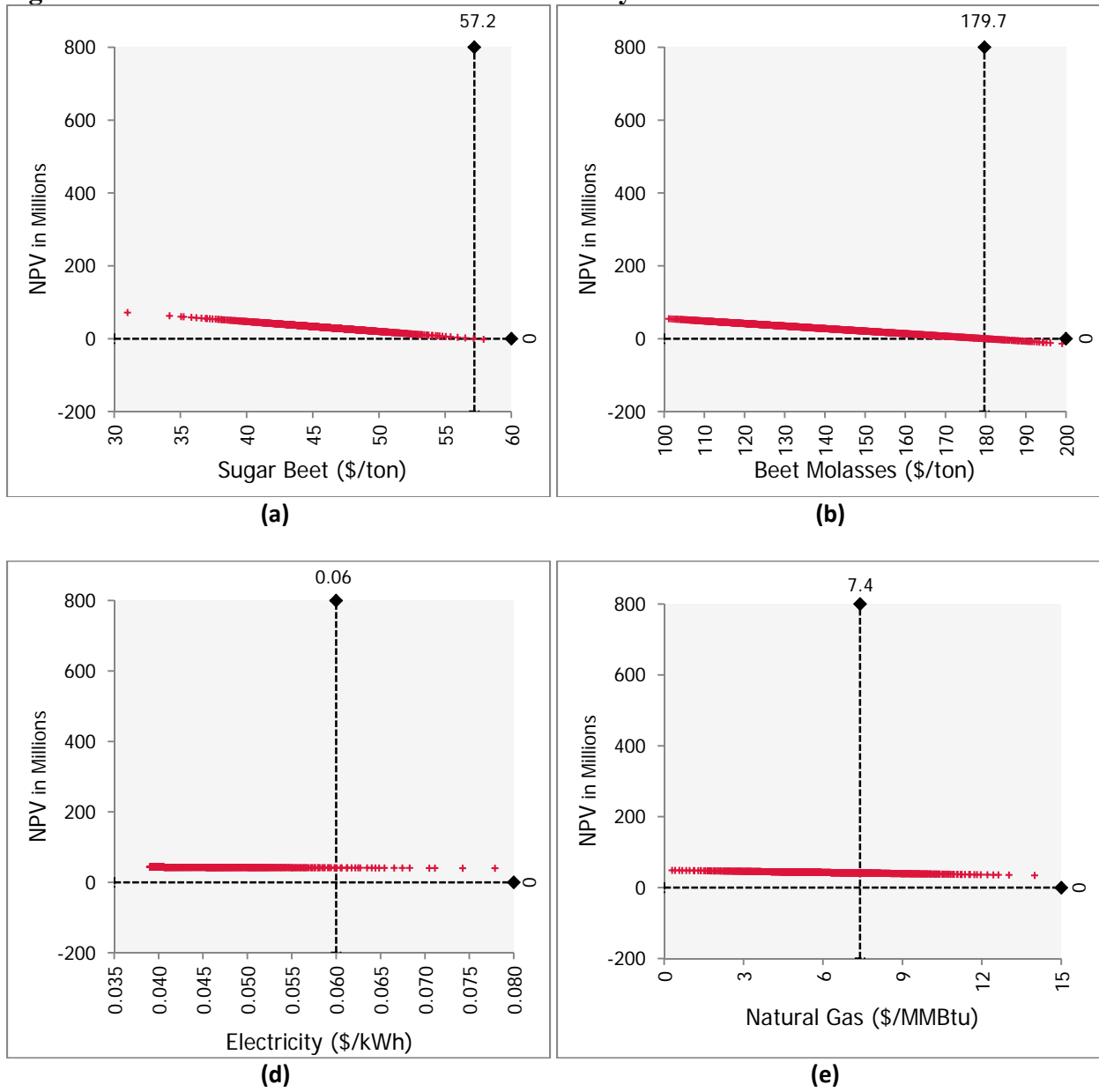
**(b)**



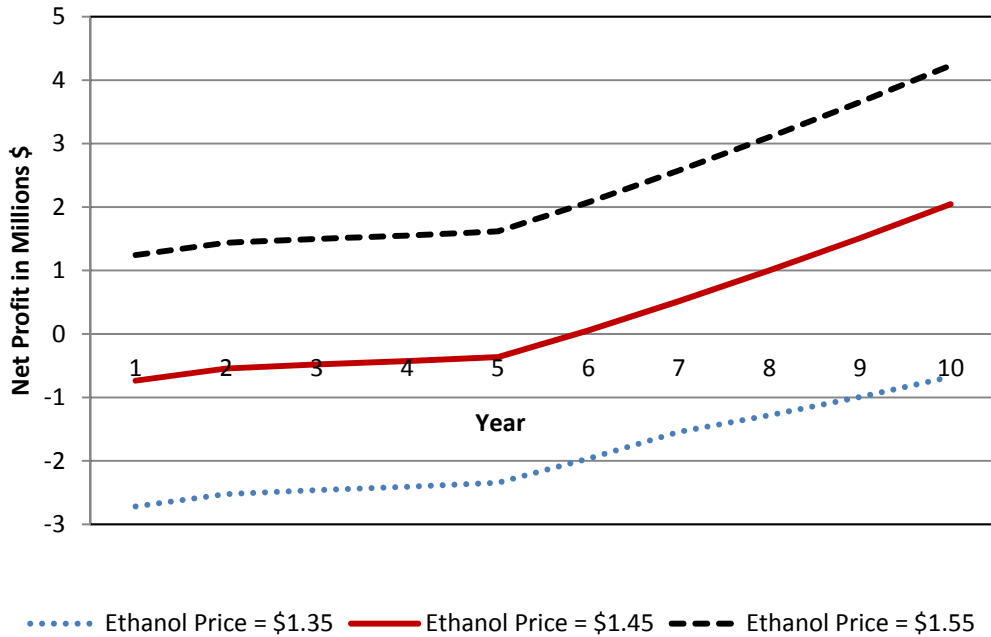
**(d)**

**(e)**

**Figure 5 Net Present Value vs. Feedstock and Utility Prices for the 20MGY Plant**



**Figure 6 Impact of Changes in Ethanol Prices on Net Profit for 20MGY Plant**



**Results**

Financial results for both plant sizes are reported in Table 5 and 6<sup>8</sup>. The 20MGY model results in Table 5 show that on average the plant is expected to generate about \$33.7 million of revenue per year from ethanol sales and about \$9 million of revenue per year from co-product sales. Production costs include feedstock, chemical, labor, utility, administrative and operating costs etc. which average \$34.7 million per year. Other expenses include interest, income tax, depreciation and amortization costs total about \$2.6 million per year. Net profit for the plant averages \$7.3 million per year. Results are also reported in dollars per gallon. Similarly, results for the 10MGY model shown in Table 6 can be interpreted in the same manner. The table indicates that on average the 10MGY ethanol plant generates about \$1.86 million per year of net profit which is much less than that of 20MGY plant. Feedstock costs account for 80% of total production expenses for the 20MGY plant and 75% for the 10MGY plant. To determine the profitability of equity investment in sugar-beet-based ethanol production in central North Dakota, the NPV is estimated for the project. Assuming the price of ethanol is \$1.84 per gallon, the NPV is found to be about \$41.54 million for the 20MGY ethanol plant (see Table 7) which suggests that investment in sugar-beet-based ethanol production is profitable. The estimated NPV for the 10MGY plant is about \$8.3 million which also implies profitable investment under this model. However, fluctuations in ethanol prices can have a substantial impact on the profitability of ethanol production.

<sup>8</sup> The ethanol base price of \$1.84 per gallon is used for these results.

**Table 5 The 20MGY Plant Model Results\***

	<b>\$/Year</b>	<b>\$/Gallon</b>	<b>% of Total Revenue</b>	<b>% of Total Cost</b>
<b>Sale Revenue</b>				
Ethanol	33,742,325	1.77	75.69%	
Yeast	6,324,883	0.33	14.19%	
Fertilizer	951,529	0.05	2.13%	
Feed	1,740,056	0.09	3.90%	
Producer Tax Credit	1,818,182	0.10	4.08%	
Total Sale Revenue	44,576,975	2.34	100.00%	
<b>Production Costs</b>				
Feedstock Costs	27,551,310	1.45		79.50%
Other Input Costs	4,901,701	0.26		14.14%
Administrative and Operating Costs	2,203,285	0.12		6.36%
Total Production Costs	34,656,296	1.82		100.00%
Interest, Income Tax, Depreciation and Amortization	2,592,312	0.14		
<b>Net Profit</b>	<b>7,328,367</b>	<b>0.38</b>		

**Table 6 The 10MGY Plant Model Results\***

	<b>\$/Year</b>	<b>\$/Gallon</b>	<b>% of Total Revenue</b>	<b>% of Total Cost</b>
<b>Sale Revenue</b>				
Ethanol	16,871,162	1.77	75.53%	
Yeast	3,162,442	0.33	14.16%	
Fertilizer	641,904	0.07	2.87%	
Feed	752,469	0.08	3.37%	
Producer Tax Credit	909,091	0.10	4.07%	
Total Sale Revenue	22,337,068	2.35	100.00%	
<b>Production Costs</b>				
Feedstock Costs	13,642,267	1.43		74.62%
Other Input Costs	2,708,948	0.28		14.82%
Administrative and Operating Costs	1,930,559	0.20		10.56%
Total Production Costs	18,281,774	1.92		100.00%
Interest, Income Tax, Depreciation and Amortization	2,197,171	0.23		
<b>Net Profit</b>	<b>1,858,123</b>	<b>0.20</b>		

\*Results are based on the 11-year average.

**Sensitivity and Risk Analysis**

The following analyses examine the impact of changes in one variable (for example, an ethanol price) on the NPVs of 10MGY and 20MGY ethanol plants while assuming other variables remain constant.

*Sensitivity of NPV to Output Prices*

The NPVs for both ethanol plant sizes under varying ethanol prices are reported in Table 7. The table shows that breakeven prices for the 10MGY and 20MGY plants are \$1.71 per gallon and \$1.52 per gallon respectively. This suggests that sugar-beet-based ethanol producers can afford to bear more ethanol price risks by producing 20MGY rather than 10MGY. Figure 2 shows the distribution of ethanol price and its impact on the distribution of NPVs for the 20MGY plant. The figure is simulated based on two cases: base ethanol price scenario and 25% increase in ethanol price scenario. The distribution of base ethanol price is fitted based on the annual historic ethanol prices. The base case scenario (Figure 2a) indicates that distributions of ethanol price and NPV have mean values of \$1.89 per gallon and \$46.8 million respectively. The figure suggests that there is a 30% probability the NPV for the 20MGY plant can become negative. Similarly, Figure 3 shows the distribution of ethanol prices and its impact on the distribution of NPVs for the 10MGY plant. The figure implies that there is a 47% probability the NPV for the 10MGY plant can become negative. Both Figure 2 and 3 show that as the mean price of ethanol increases, the risk of generating negative NPV declines. Conversely, if the mean ethanol price decreases, the risk of generating negative NPV increases. Overall, we can conclude that the 20MGY plant has a higher chance of generating a positive NPV than the 10MGY plant.

**Table 7 Net Present Value under Various Ethanol Price Scenarios**

Ethanol Price (\$/gal)	Net Present Value (million \$)	
	10MGY	20MGY
1.52	-12.77	0.00
1.61	-6.84	11.26
1.71	0.00	24.42
1.84 (Base)	8.30	41.54
1.91	12.91	50.75
2.01	19.49	63.92

Using base case values, ethanol prices are plotted against the NPVs and depicted in Figure 4 (a) for the 20MGY plant. Again the breakeven price for ethanol is shown to be \$1.52 per gallon for the 20MGY plant. As a whole, Figure 4 shows that ethanol price is the most significant variable in affecting the profitability of the investment. A small change in ethanol price will have a large impact on the NPV (This point is illustrated with net profit in Figure 6). Comparatively, Figure 4 suggests that the sale of co-products such as yeast, fertilizer and feed have negligible impact on revenue generation. This especially holds true for fertilizer and feed. Similar results (not shown here) can be reported and interpreted for the 10MGY plant.

*Sensitivity of NPV to Input Prices*

Producers of ethanol face potential risks not only from ethanol price changes but from variations in feedstock and other input prices. Analyses were conducted to examine the impact of input price changes on investment risk. Figure 5 illustrates the impact of fluctuations in feedstock and other input prices on the NPVs for the 20MGY model. As expected, the figure indicates that variations in sugar beet and beet molasses prices will have a relatively large impact on profit level since feedstock costs account for more than 70% of total production expenses. In the figure (also see Table 8 and 9), breakeven prices for sugar beets and beet molasses (about \$57 per ton and \$180 per ton respectively) for the 20MGY plant are shown to be much higher than their assumed base prices. This suggests that the 20MGY plant has some leeway in allowing feedstock prices to fluctuate from their base level without having a critical impact on the profits. However, for the 10MGY plant, little leeway is allowed for the feedstock price changes as can be seen in Table 8 and 9. Variations in utility expenses such as electricity and natural gas expenses are found to have little impact on the NPVs (see Figure 5). Because of the economies of scale involved in a large production, ethanol producers would find it more desirable to produce 20 MGY of ethanol rather than 10 MGY. By doing so they would be able to generate more cash revenues from ethanol sales and hedge against future ethanol and feedstock price risks.

**Table 8 Net Present Value under Various Sugar Beet Price Scenarios**

Sugar Beet Price (\$/ton)	Net Present Value (million \$)	
	10MGY	20MGY
27.00	28.75	82.44
34.00	19.21	63.35
42.00 (Base)	8.30	41.54
48.09	0.00	24.94
57.23	-12.46	0.00
60.00	-16.45	-7.54

**Table 9 Net Present Value under Various Beet Molasses Price Scenarios**

Beet Molasses Price (\$/ton)	Net Present Value (million \$)	
	10MGY	20MGY
90.00	18.39	62.39
120.00 (Base)	8.30	41.54
144.67	0.00	24.38
160.00	-5.16	13.72
179.74	-11.80	0.00
200.00	-19.29	-14.09

### *Sensitivity of NPV to Transportation Cost*

Another important factor that will affect the profitability of sugar-beet ethanol investment is transportation cost. This study assumes that ethanol is transported via truck to local and regional markets. The base cost of transport is assumed to be \$0.02 per gallon. Because the transport cost is directly linked to the price of ethanol, a slight variation in the cost will have a high impact on the profitability of investment. Table 10 reports the sensitivity of changes in transport cost on the NPV. Assuming that other variables remain unchanged, the table shows that a \$0.12 increase in transport cost will result in a negative NPV for the 10MGY plant. As expected, the 20MGY plant can endure a larger increase in transport cost from its base level without having a tremendously great impact on the NPV.

**Table 10 Net Present Value under Various Transportation Cost Scenarios**

Transport Cost (\$/gal)	Net Present Value (million \$)	
	10MGY	20MGY
0.02 (Base)	8.30	41.54
0.06	5.48	35.90
0.10	2.66	30.26
0.14	-0.16	24.62
0.18	-2.97	18.99
0.20	-4.38	16.17

### **Summary and Conclusions**

At present no fuel ethanol has been commercially produced from sugar beets in the U.S. The purpose of this paper is to assess the feasibility of producing ethanol from sugar beets in central North Dakota. Due to its close proximity to the sugar beet supply market, cool climate, and already existing infrastructure, North Dakota has the potential to produce sugar-beet-based fuel ethanol. Results in this study indicate that ethanol sales account for more than 70% of sale revenues. Similarly, on the cost side, feedstock costs account for more than 70% total production expenses.

One of the most important factors that affect the profitability of the investment is the price of ethanol. At the base price of \$1.84 per gallon and assuming other factors remain unchanged, the estimated net present value (NPV) for the 20MGY plant is about \$41.54 million which is well above zero. At that price level, sugar-beet-based ethanol production could become attractive to investors. The estimated NPV for the 10MGY plant is about \$8.3 million. The breakeven ethanol prices for the 10MGY and 20MGY plants are respectively found to be \$1.71 per gallon and \$1.52 per gallon. This indicates that the 20MGY plant can endure more ethanol price risks than the 10MGY plant. Other factors such as changes in prices of co-products have a relatively minor effect on the profitability of investment. Variations in feedstock prices such as increase/decrease in sugar beet and beet molasses prices can have a negative/positive impact on the investment profitability. The breakeven prices for these feedstocks are found to be much higher than their assumed base prices for the 20MGY plant. This suggests that the 20MGY plant can tolerate more feedstock price fluctuations than the 10MGY plant. Fluctuations in utility



prices such as electricity and natural gas prices are found to have little impact on the profitability of investment.

Overall, this study shows that from the producer standpoint it would be more worthwhile to construct the 20MGY ethanol plant than the 10MGY plant, because the 20MGY plant can withstand larger ethanol and feedstock price swings than the 10MGY plant. The price of ethanol will be one of the most important factors for determining the future feasibility of a sugar-beet-based ethanol plant in central North Dakota. Because the price of ethanol closely follows the price of crude oil, future investment decisions on a sugar-beet-based ethanol plant will likely depend on future crude oil prices.

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