

The Economic Feasibility of Sugar Beet Biofuel Production in North Dakota

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Abstract

This study examines the financial feasibility of producing ethanol biofuel from sugar beets in the state of 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 North Dakota to determine economic feasibility and risks of production. Study results indicate that ethanol and co-product sales could respectively account for about 74% and 21% of total sale revenues. Feedstock costs, which include sugar beets and beet molasses, account for 81% of all total expenses. Results also show that one of the most important factors that affect investment success is the price of ethanol. At an ethanol price of \$1.71 per gallon, and assuming other factors remain unchanged, the estimated net present value (NPV) of the plant is \$30 million which is well above zero. However, if the ethanol price falls below the breakeven price of \$1.50 per gallon, NPV turns negative. Other factors such as changes in prices of co-products and inputs have a relatively minor affect on investment viability.

Introduction

U.S. ethanol demand has been steadily increasing 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 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 percent 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 account for about 55 percent 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 percent lower GHG emissions than the equivalent petroleum-based gasoline.

The reduction in GHG emissions will allow its ethanol to qualify as either an “advanced” or “cellulosic” biofuel per the federally mandated renewable fuels standard.

The model developed in this study is also based on a 20 MGY ethanol plant in North Dakota and uses 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.
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 North Dakota. Results from this study will contribute to growing literature on the feasibility of producing ethanol from alternative feedstocks in the U.S.

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. They based their work on an annual Monte Carlo simulation financial model. The model was simulated for 10 years for a 40 MGY (million gallons per year) ethanol plant. They found that existing sugar mills could be retrofitted to produce ethanol and could almost always generate positive annual returns. An 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 close 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, 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 sugar. Hence, the relationship between sugar and ethanol prices is non-existent; it is not possible to use the U.S. sugar price data to study the impact of sugar prices on prices of ethanol. 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. 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. Our study yields similar results: the sugar-based ethanol plant can tolerate increases in sugar beet and beet molasses prices to a certain level without having a critical impact on the profits, assuming that the price of ethanol is above the breakeven level at \$1.71 per gallon.

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 sliced before further processing. Sliced pieces are pressed and extracted to produce sugar juice. 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. 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.

In this study, the sugar-beet-based ethanol plant is assumed to produce 20 million gallons of ethanol per year. 70% of ethanol production will come from sugar beets and 30% from beet molasses. The plant will require about 1,511 tons of sugar beets and 220 tons of beet molasses per day for 333 days annually. Sugar beet growers will be contracted to supply all the required sugar beets. Beet molasses will be purchased through the contract. Total investment costs which include engineering and construction costs, and development and start-up costs for the plant are \$43 million and financed with 50% equity and 50% debt at 8% interest over 10 years (Table 2). Technical conversion data originate from a BBI study (Heartland Renewable Energy, 2008) and localized with price information and sugarbeet production cost data from 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 etc. 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, investing 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 percent in this study. The model produces a ten year operating financial forecast.

Stochastic Data Description

Variables used in the model can be deterministic and stochastic. The 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. Ethanol and co-product prices capture the plant's revenue risk, while other input prices capture the plant's production cost risk. Annual ethanol price data (from 1990 to 2008) used in simulation were collected from the Official Nebraska Government website. They 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. Sugar beet prices were allowed to vary from \$30 per ton to \$75 per ton and beet molasses prices were assumed to vary from \$100 per ton to \$250 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 1 and 2¹. Distributions for prices of ethanol, natural gas and electricity were determined using the fitting algorithms in @Risk (Palisade Corporation, 2009). Due to data limitations, prices for co-products, sugar beets and beet molasses were modeled as a triangular distribution as described in Table 1. The financial model was transformed into a Monte Carlo simulation model using @Risk simulation package. Simulation results are shown in Figure 2, 3 and 4. The simulated model is iterated 1000 times, each time with a different price level.

Results

Financial results from Table 3 shows that on average the plant is expected to generate about \$31.3 million of revenue per year from ethanol sales and about \$9 million of revenue per year from co-product sales. Production costs which include feedstock, chemical, labor, utility, administrative and operating costs etc. which average \$34.1 million per year. Other expenses include interest, income tax, depreciation and amortization costs total \$2.4 million per year. Net income for the 20 MGY ethanol plant averages \$5.7 million per year. Average return on investment is 27% per year. Results from Table 3 are also reported in dollars per gallon. In order to determine the attractiveness of equity investment in North Dakota sugar-beet-based ethanol production, net present value (NPV) of the project is estimated. Assuming the price of ethanol is \$1.71 per gallon, the NPV is found to be \$30 million which suggests that sugar-beet-

¹ The data and assumptions were obtained from the Heartland Renewable Energy and local industry sources.

based ethanol production is profitable and hence may attract potential equity investors. However, fluctuations in ethanol prices can have a substantial impact on the profitability of ethanol production. The breakeven price for sugar-beet-based ethanol is found to be about \$1.5 per gallon.

Sensitivity and Risk Analysis

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 and output price changes on investment risk. Figure 2 shows the distribution of ethanol price and its impact on the distribution of net present values. The figure is simulated based on three cases: base ethanol price scenario, 20% increase in ethanol price scenario and 50% increase in ethanol price scenario. The distribution of base ethanol price is fitted based on the annual historic ethanol price of Omaha (1990 to 2008). The base case scenario (Figure 2a) indicates that distributions of ethanol price and NPV have mean values of \$1.48 per gallon and \$-5.2 million respectively. The figure suggests that with about 34.5% probability NPV can become positive. Figure 2 (b) and (c) suggest 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. Using base case values in Figure 2 (a), ethanol prices are plotted against NPV and depicted in Figure 3 (a). Again the breakeven price for ethanol is shown to be \$1.5 per gallon. As a whole, Figure 3 shows that ethanol price is the most significant variable in affecting the profitability of the investment. A small amount of increase/decrease in ethanol price will have a large positive/negative impact on the NPV. Comparatively, Figure 3 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.

Of all total expenses, feedstock costs account for as much as about 81%. Figure 4 illustrates the impact of fluctuations in feedstock and other input prices on the NPV. As expected, the figure indicates that variations in sugar beet prices will have a relatively large impact on the profit level, since sugar beets are assumed to account for about 70% of ethanol production. In the figure, breakeven prices for sugar beets and beet molasses are shown to be \$50.5 per ton and \$180 per ton respectively. This suggests that the plant has some leeway in allowing feedstock prices to fluctuate without having a critical impact on the profits. As can be seen in the figure, variations in utility expenses such as electricity and natural gas expenses have

little impact on the NPV. Overall, analyses in this study show that the price of ethanol will be one of the greatest determining factors for the future feasibility of a sugar beet-based ethanol plant in North Dakota.

Summary and Conclusions

At present no fuel ethanol has been 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 North Dakota. Due to its close proximity to the sugar beet supply market, cool climate, and already existing processing infrastructure, North Dakota has the potential to produce sugar-beet-based fuel ethanol. Results in this study indicate that ethanol and co-product sales could respectively account for about 74% and 21% of all total sale revenue. On the cost side, feedstock costs which include sugar beets and beet molasses costs could account for as much as 81% of all total expenses.

One of the most important factors that affect the profitability of the investment is the price of ethanol. At the price of \$1.71 per gallon and assuming other factors remain unchanged, the estimated net present value (NPV) of the plant is well above zero. At that price level, sugar-beet-based ethanol production could become attractive to equity investors. But, if the ethanol price falls below \$1.50 per gallon, the NPV can turn negative and the investment in sugar-beet-based ethanol production could become unattractive. Other factors such as changes in prices of co-products have a relatively minor affect 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. However, the breakeven prices for these feedstocks are found to be higher than their assumed base prices. This implies that the ethanol plant can tolerate the feedstock price increase to a certain level without having a critical impact on profits. 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 the price of ethanol will be mostly responsible for determining the future feasibility of a sugar-beet-based ethanol plant in 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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Table 1 Data and Distribution for Stochastic Variables

Variable	Mean	Standard Deviation	Distribution
Prices for			
Beet Molasses (\$/ton)	156.67	33.25	Triangular
Whole Beets (\$/ton)	49.00	9.51	Triangular
Ethanol (\$/gal)	1.48	0.49	Inverse Gauss
Electricity (\$/kWh)	0.04	0.01	Exponential
Natural Gas (\$/Million BTU)	6.13	2.04	Normal
Co-products			
Yeast (\$/ton)	516.67	92.04	Triangular
Fertilizer (\$/ton)	99.80	37.44	Triangular
Beet Pulp (\$/ton)	87.73	15.19	Triangular

Table 2 Assumptions Used in the Financial Model

	20 MGY Plant
Conversion Rate for Whole Beets (gal/ton)	26.50
Conversion Rate for Beet Molasses (gal/ton)	77.89
Sugar Beets Requirement (tons/yr)	503,144.65
Beet Molasses Requirement (tons/yr)	73,363.53
Electricity Requirement (Million kWh/yr)	1.10
Thermal Energy Requirement	
Stillage Powder (Million BTU/yr)	450,000.00
Natural Gas (Million BTU/yr)	150,000.00
Base Prices for	
Beet Molasses (\$/ton)	\$ 120.00
Whole Beets (\$/ton)	\$ 42.00
Ethanol (\$/gal)	\$ 1.71
Electricity (\$/kWh)	\$ 0.05
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	\$ 9,955,000.00
Total Capital Cost	\$ 42,620,280.00
Borrowed Capital 50%	\$ 21,310,140.00
Equity Capital 50%	\$ 21,310,140.00

Table 3 Results from the Model

	\$/Year	\$/Gallon	% of Total Revenue	% of Total Cost
Sale Revenue				
Ethanol	31,330,225	1.64	74.21%	
Yeast	6,324,883	0.33	14.93%	
Fertilizer	951,529	0.05	2.26%	
Feed	1,740,056	0.09	4.07%	
Producer Tax Credit	1,818,182	0.10	4.52%	
Total Sale Revenue	42,164,875	2.21	100.00%	
Production Costs				
Feedstock Costs	27,627,970	1.45		81.01%
Other Input Costs	4,256,393	0.22		12.29%
Administrative and Operating Costs	2,222,588	0.12		6.70%
Total Production Costs	34,106,951	1.79		100.00%
Interest, Income Tax, Depreciation and Amortization	2,390,895	0.13		
Net Profit	5,667,029	0.30		

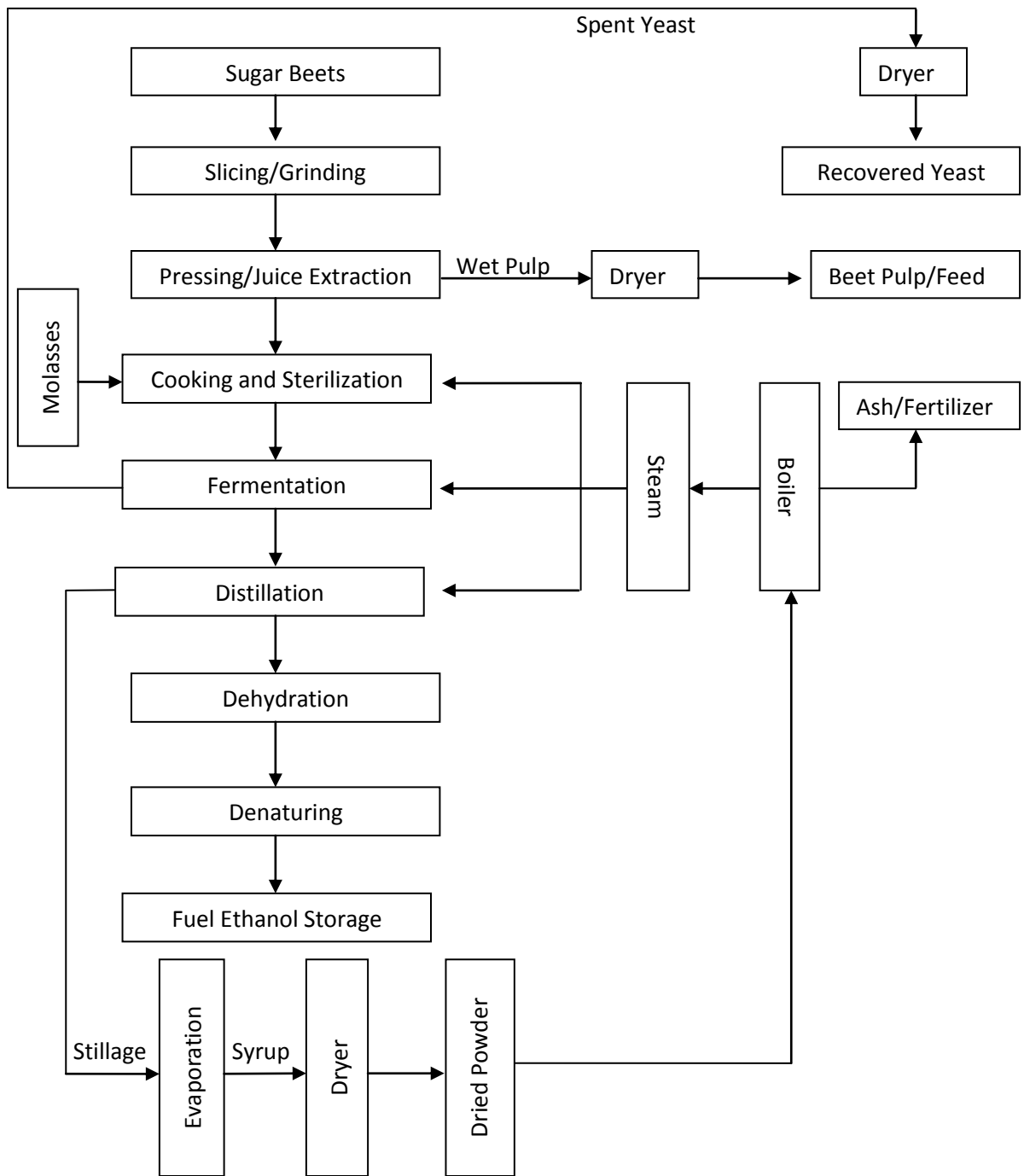
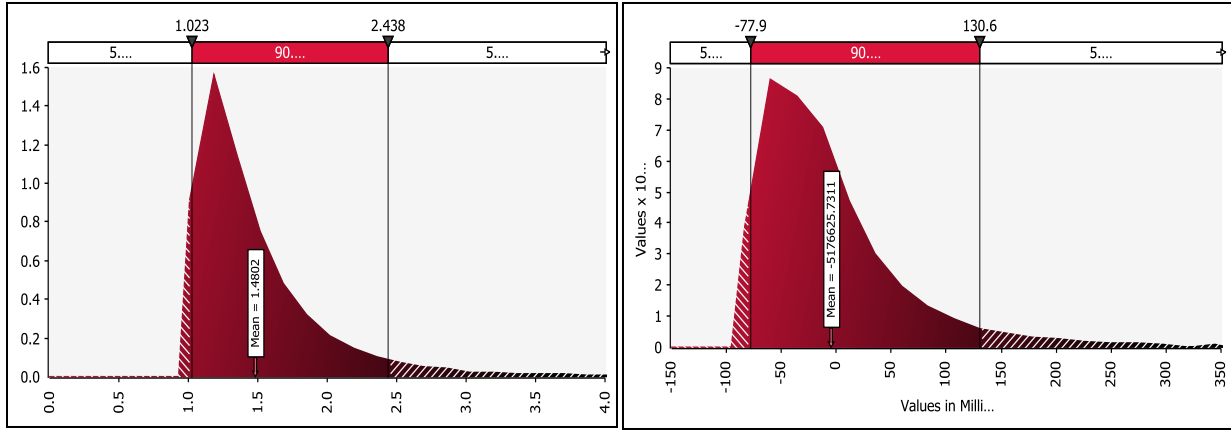
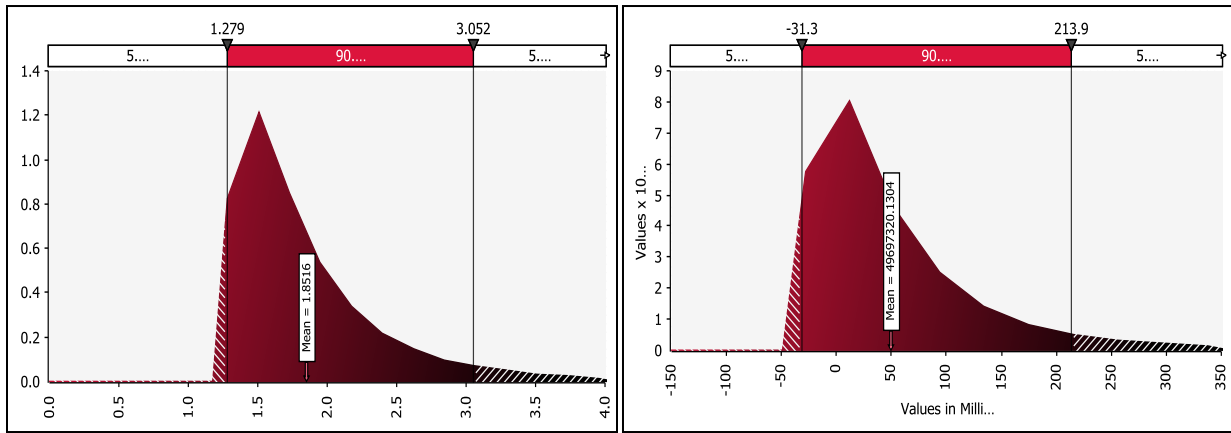


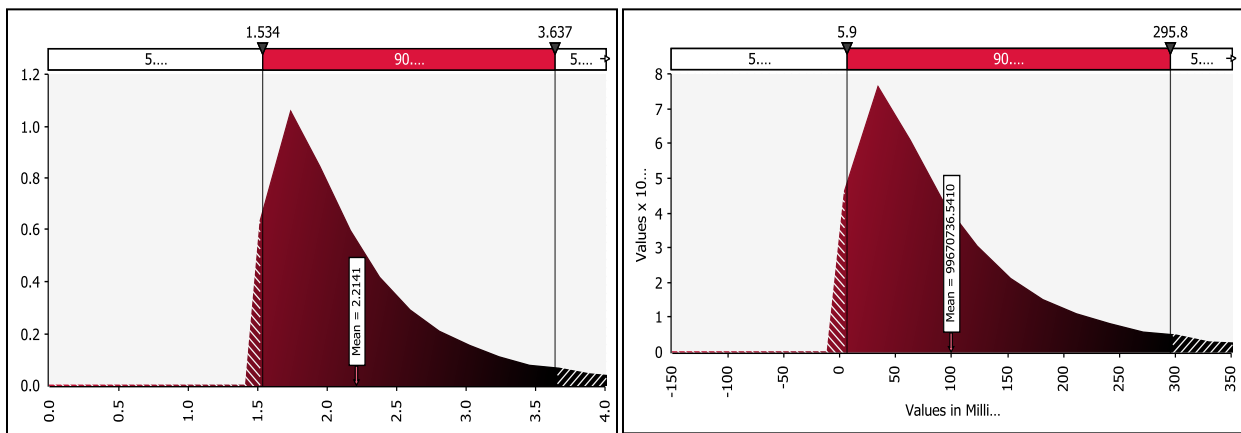
Figure 1 Sugar-beet/Molasses Ethanol Production Process Flow Diagram



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

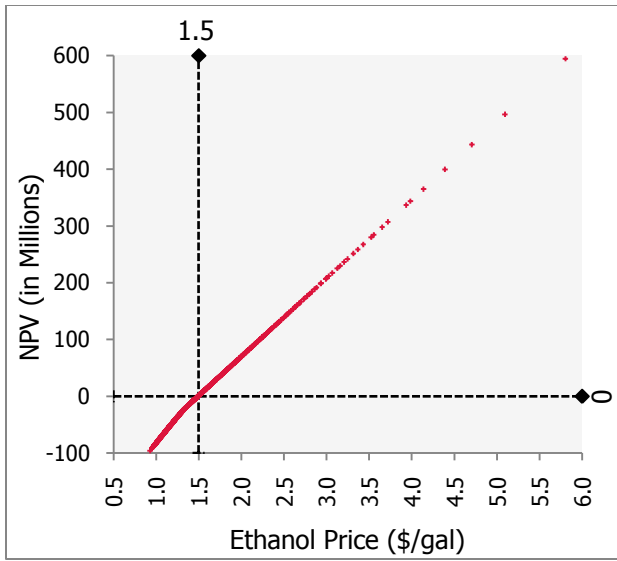


(b) 25% Increase in Ethanol Price: Distribution of Ethanol Price (\$/gal) and Net Present Value (in millions)

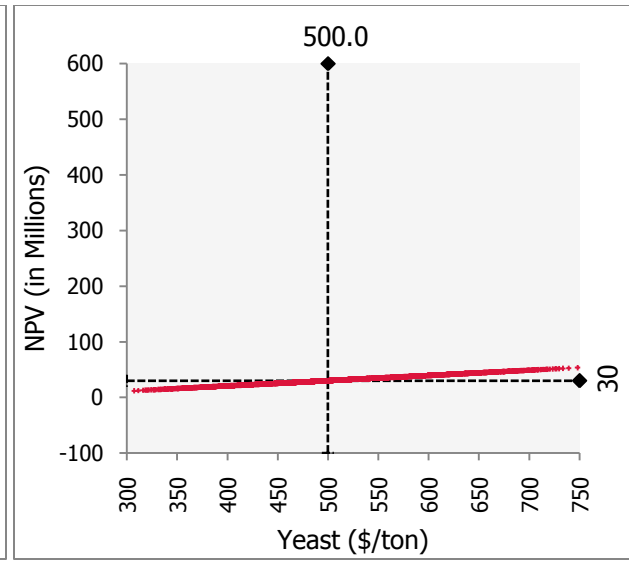


(c) 50% Increase in Ethanol Price: Distribution of Ethanol Price (\$/gal) and Net Present Value (in millions)

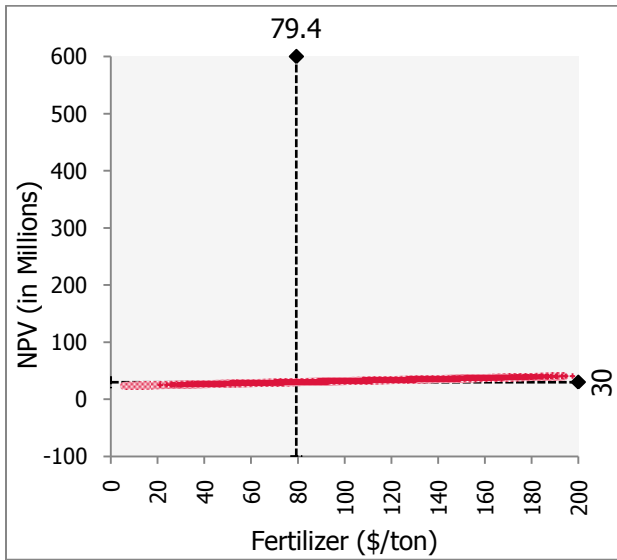
Figure 2 Distributions of Ethanol Price and Net Present Value



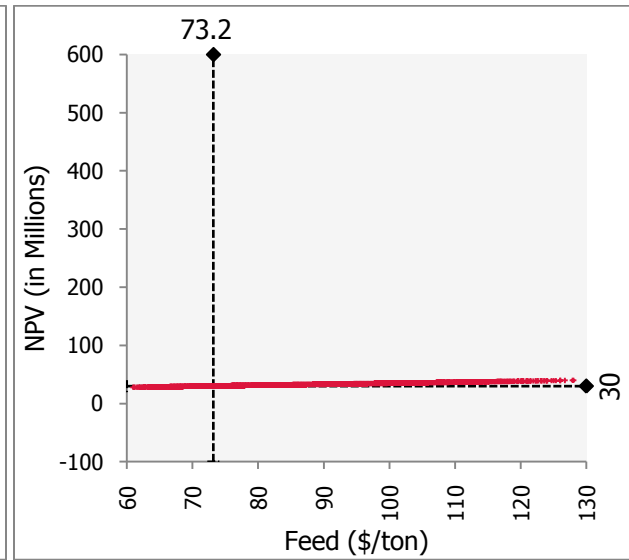
(a)



(b)

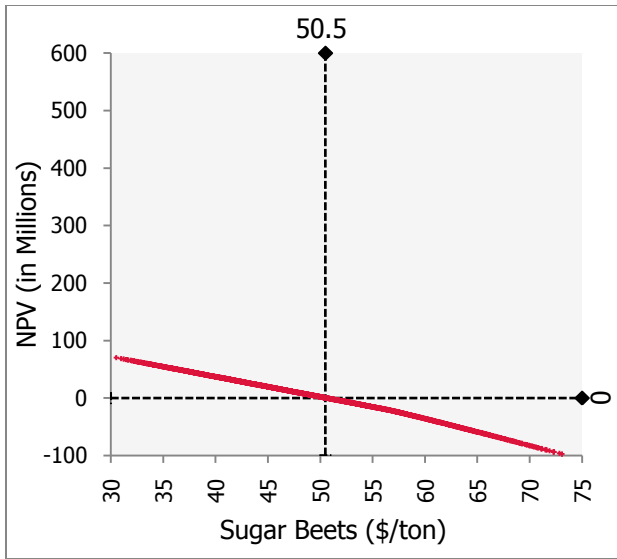


(d)

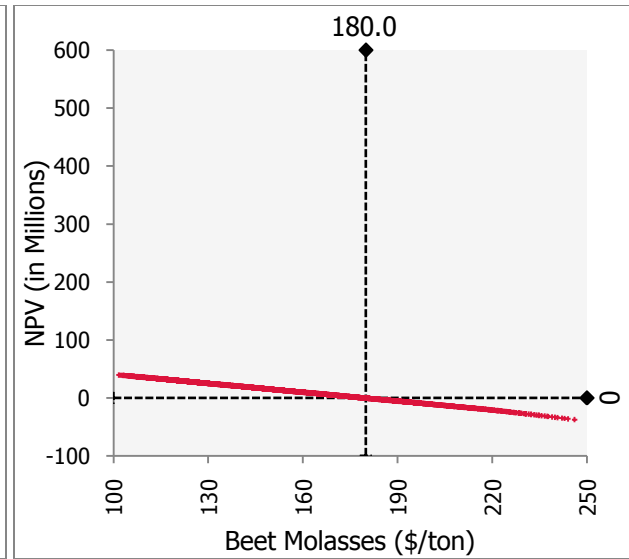


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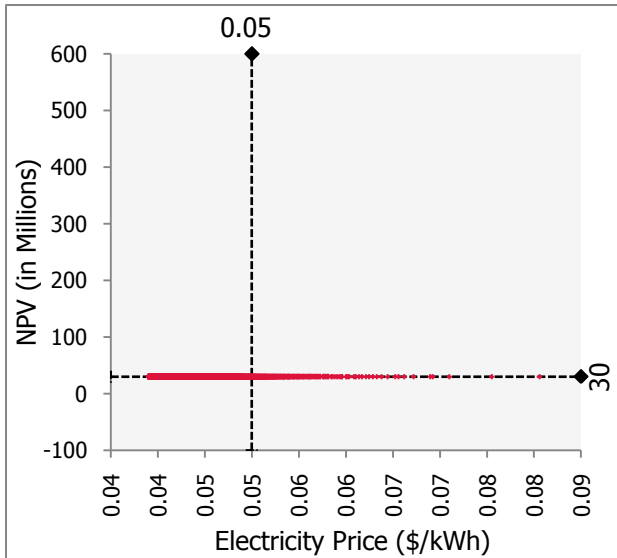
Figure 3 Net Present Value vs. Ethanol and Co-product Prices



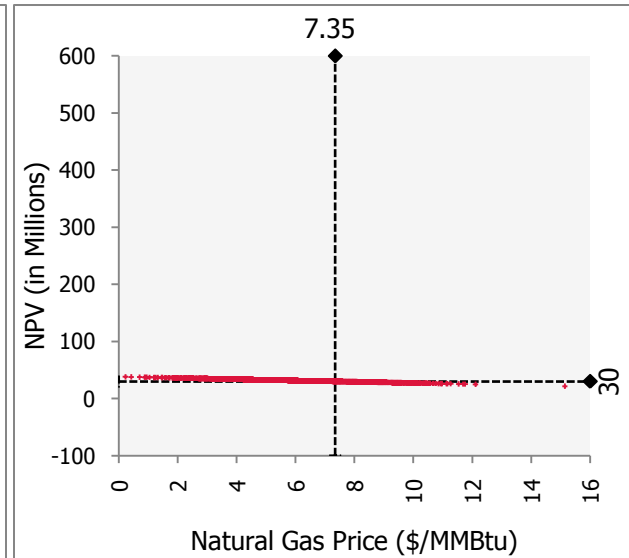
(a)



(b)



(d)



(e)

Figure 4 Net Present Value vs. Feedstock and Utility Prices