Integrating Ethanol Production into a U.S. Sugarcane Mill: A Risk Based Feasibility Analysis

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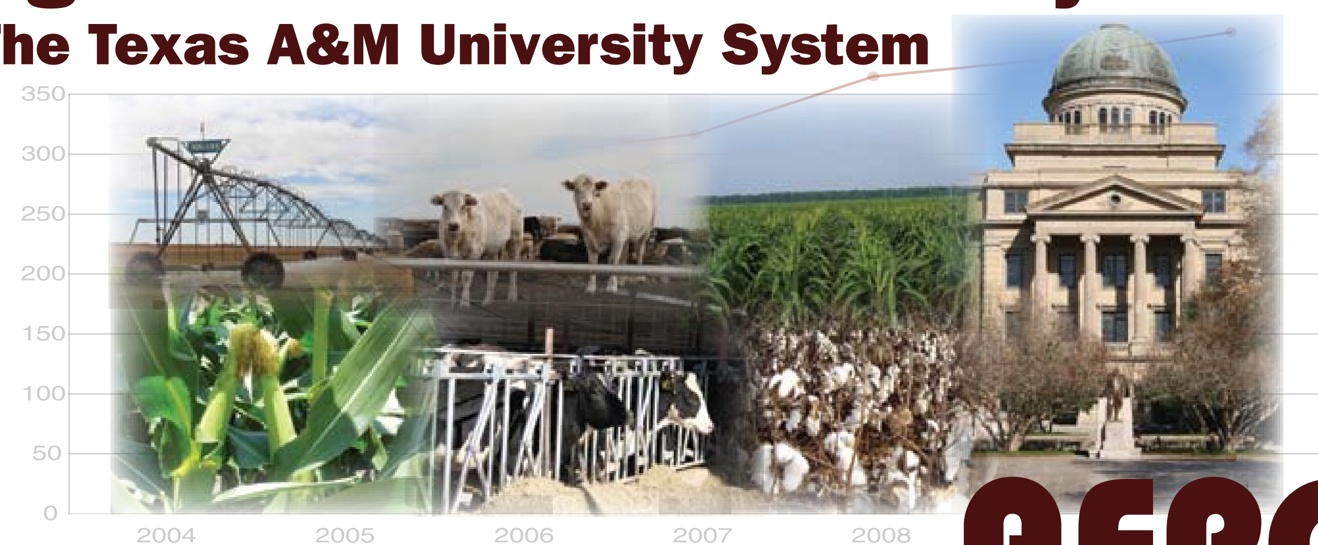

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Higher petroleum demand along with limited production alternatives worldwide has led to significant increases in gasoline and diesel prices over the past 2 years. The increase in worldwide demand, largely attributed to economic growth in China and India, is not expected to decline in the near future. Given the expectation of higher motor fuel prices, many countries, including the United States, are turning to renewable fuels such as ethanol and biodiesel. In addition to the demand for these products to extend existing petroleum supplies, ethanol has been used in the U.S. as an oxygenate in motor fuels in some areas, which creates a unique set of market conditions for the fuel.

Annual ethanol production in the United States has increased from 1.77 billion gallons in 2001 to 4.9 billion gallons in 2006. Presently there are 86 plants under construction with a combined capacity of 6.3 billion gallons per year (Renewable Fuels Association, 2007). Thus far this decade, the average ethanol price has gone from slightly over $1.00 per gallon to a high of nearly $4.00 per gallon in during the summer of 2006. As the price of ethanol rose, interest in production by U.S. investors has surpassed expectations. Presently prospective ethanol plants that have contracted corn supplies and arranged financing for a new ethanol plant are being told there is an 18-24 month delivery time for new plants.

Corn is the primary feedstock used in U.S. ethanol plants which use a fermentation-distillation process. These corn-fueled plants are primarily located in the Midwest where corn is in surplus. Earlier studies by Outlaw, et al. (2003), Herbst (2003), and Gill (2004) showed that ethanol production in a corn deficit region such as Texas was not feasible with then prevailing ethanol prices. However, higher ethanol prices have made it economically feasible to produce ethanol from corn in Texas (Richardson et al., 2006).

Brazil is the world leader of ethanol production from sugarcane. In 2005 Brazil had around 13.5 million acres of sugarcane and there are plans to increase its sugarcane area by 5 to 8 million acres in the next 4-5 years (Burnquist, W., 2006). On average, 55% of Brazilian sugarcane is turned into alcohol and the rest into sugar. However, depending on the demand and prices, sugar mill/distilleries have the flexibility to change this ratio up to 70/30 or vice versa (Cortellazzi, 2006).

Annual ethanol production in Brazil has increased from 3 billion gallons in 2001 to 4.5 billion gallons in 2005 (CEPEA, 2006). Most of the ethanol is produced in the South Center region of Brazil where 80 percent of its sugar mill/ethanol distilleries are located. Currently, there are around 330 operating mills producing ethanol, with another 89 planned (UNICA, 2006). Recent increases in ethanol production is facilitated by the introduction of flex fuel cars –cars that run on ethanol, gasoline or any mix of both (Martines-Filho, et al., 2006). Since their introduction in 2003, sales of flex fuel cars have gone up exponentially from about 5% of new vehicle sales to over 76% in 2005.

Ethanol production in the U.S. and Brazil is very different. First, the U.S. uses mainly corn as feedstock for producing ethanol while Brazil uses only sugarcane. Both industries are very cost efficient in ethanol production, however, the Brazilian industry is more mature. Brazil started producing ethanol on a commercial scale in 1975 with the government supported program Pro-alcohol, which established the infrastructure for ethanol production, distribution, and marketing (UNICA, 2006). With over 30,000 gas stations offering both gasoline and ethanol, and consumers who are accustomed to having ethanol as an alternative fuel, the industry is well established. Moreover, domestic car manufacturers have over 30 years of experience in supplying ethanol-fueled cars and nowadays supplying flex-fuel cars as well. In the last 4-5 years the U.S. has started developing the market and infrastructure for an ethanol industry. There are around 1,000 U.S. gas stations that offer E85, a mixture of 85% ethanol and 15% gasoline (NEVC, 2006). Moreover, with the phasing out of the MTBE, ethanol seems to be a viable alternative.

The U.S. has not explored the production of ethanol from sugarcane juice and/or molasses. Using the Brazilian experience as an example, there are many advantages in looking at sugarcane-based ethanol. A sugar mill/ethanol plant is energy independent as it burns its bagasse (the crushed stalks of sugarcane after extracting the juice) in the mill's boiler to produce energy for the plant, and has enough left to sell to the electrical grid (Dirceu, 2006; Lacerda, 2006; Fingerut, 2005a and b). Ethanol production from sugarcane is more efficient on a per acres basis, producing about 870 gallons/acre compared to only 400 gallons/acre from corn. For these reasons sugarcane ethanol is almost seven times more energy efficient; its net energy, expressed as Energy Returned on Energy Invested (ERoEI), is 9:1 while corn ethanol has an ERoEI of 1.3:1 (Maciel, 2006). In addition, sugarcane is a semi-perennial culture (3-5 years cycle) that needs fewer nutrients than corn.

The U.S. grew 922,600 acres of sugarcane in Texas, Louisiana, Hawaii, and Florida in the 2005-06 season down from 1.02 million acres in the 2000/01 season (Table 1). Recent reduction in sugarcane acreage was due to hurricane damage in Louisiana and Florida. At current fuel prices, it may be profitable for at least a few of the more than two dozen U.S. sugarcane mills to add some sugarcane acreage and diversify their revenue stream by adding an ethanol plant. Gallager, et al. (2006) recently compared the competitiveness of U.S. corn-based ethanol with sugar-ethanol processing in Brazil showing no specific trends, only cyclical periods of advantages for both industries. Moreover, a recent USDA/LSU study showed the lack of economic feasibility to convert raw and refine sugar into ethanol (Shapouri, et al., 2006). The results of this study are complicated by the assumption that the U.S. sugar support program values sugarcane grown for ethanol production. The present study will show the economic viability of the Brazilian method of producing sugar and ethanol using juice and/or molasses in the United States.

Objective

The objective of this paper is to analyze the feasibility of integrating an ethanol production facility into an existing sugarcane mill in the United States. The analysis will assess the feasibility of adding ethanol plants to sugarcane mills in Texas, Louisiana, and Florida.

Brazilian Process

Before the Pro-alcohol program was established most of the ethanol produced from cane was mainly from molasses. Currently, Brazilian ethanol is produced from a combination of sugarcane juice and molasses (Fingerut, 2005a). The variation in the proportion of sugar and alcohol produced by a mill is based on the need of the market which gives the advantage of flexibility to the sugar mill, i.e. milling capacity could be fully maintained, but the proportion of sugar and ethanol could be regulated, depending on market requirements.

Edemilson Lacerda (2006), Industrial Manager of Usina Costa Pinto, one of Brazil's largest sugar mill/ethanol plants and part of the Cosan Group, the second largest ethanol producer group in Brazil, stated that there are two types of ethanol plants in Brazil. One is an autonomous ethanol distillery, which produces only ethanol from sugarcane. The other is a sugar/ethanol plant, basically attached to a sugar mill. Among the sugar/ethanol plants there are two kinds where the main difference among them is how they separate the juice from the grinders. One of these uses the juice extracted from the first grinder for sugar production while the juice from subsequent grinders (usually five more) plus the molasses from sugar production is used to produce ethanol. Usually these plants produce more ethanol than sugar. The other kind of sugar/ethanol plant uses the juice from all six grinders and then decides how much of each product, sugar and ethanol, to produce given the relative levels of different types of sugar (sucrose, glucose, and fructose) present.

In general, a sugar mill that produces mainly sugar, yields about 240 lbs. of sugar and 1.7 to 2.4 gallons of ethanol from molasses per ton of sugarcane (Fingerut, 2005b). An autonomous distillery produces on average 20.4 gallons of ethanol per ton of sugarcane. A sugar/ethanol plant that produces 50/50 yields 134 lbs. of sugar and 10.1 gallons of ethanol per ton of sugarcane. Lacerda (2006) explained that mills in Brazil have the flexibility of changing the proportion of sugar/ethanol by balancing the Total Recoverable Sugars (ATR, abbreviation in Portuguese). Once the juice is extracted from the cane, the levels of sucrose, glucose and fructose are measured to estimate the potential ethanol, by multiplying the ATR by a stoichiometric factor (Fernandes, 2003).

Lacerda (2006) and Fingerut (2005a) describe in general the process of producing sugar and ethanol simultaneously:

1. Extract the juice from cane either using only the juice from first grinder for sugar and the rest for ethanol along with the molasses, or extract all of the

juice from grinders and then decide the amount of sugar and ethanol to be produced.

2. In sugar production there is no need to extract all of the sugar from the juice, usually two extractions or massecuites (strike A and B) is enough to extract most of the sugar. When ethanol is being produced, the sugar mill can send "richer" (higher sugar content) molasses along with the juice on to the ethanol production process.
3. Low pressure vapors from the evaporators can be efficiently used in the heat treatment of the juice sent to the distilleries and also in the distillation of the fermented mashes.
4. The necessity for evaporation of juice sent to the distillery is minimized since it can be mixed with molasses, in order to reach the right sugar concentration for the fermentation (18-24^{o} Brix).
5. Sugar and ethanol are produced in a very efficient way since the two processes take advantage of common steam and electricity generation, water, waste disposal, laboratories, maintenance workshops, management, safety, and commercialization.

The ATRs are also used in computing the price paid per ton of sugarcane (Burnquist, H., 2006). The Association of Sugarcane, Sugar and Ethanol Producers (CONSECANA) uses the ATRs along with domestic, international and industrial prices of anhydrous and hydrated ethanol, and domestic and external prices of white, very high polarity (VHP) and crystal sugar to calculate the prices paid to sugarcane produces. The price of sugarcane is a weighted average of the prices for all products produced from sugarcane sold in the domestic, international or industrial markets multiplied times the ATR. All sugarcane producing states in Brazil have their own weights on the prices established by their respective CONSECANA.

A byproduct of sugarcane-based ethanol is vinasse, a residue that comes from alcohol fermentation and distillation (Elias Neto and Nakahodo, 1995). The vinasse, also know as stillage, can be obtained from the juice of several agricultural products like grapes, oranges, sugar beet, and sugarcane. (Penatti, et al., 2005). The vinasse in Brazilian ethanol production comes from fermentation of sugarcane juice mixed with molasses. Vinasse could be used as fertilizer due to its high organic matter and potassium content, medium to low values of nitrogen, and calcium, and low values of phosporus and magnesium. Some disadvantages of vinasse are that it has a bad odor, and since it is a liquid, it could pollute water sources.

On average, the production of one gallon of ethanol will yield 13 gallons of vinasse (Panatti, et al., 2005; Campos, 2006). This value could range from 10 to 15 gallons, depending on sugarcane quality and the industrial process. In Brazil, most of the sugarcane comes from fields owned by the mill, so the vinasse is used as fertilizer and is applied back to the sugarcane fields (Burquist, W., 2006; Cortellazzi, 2006). However, in the U.S. applying vinasse to farmland could cause problems due environmental regulations. Vinasse handling in the U.S. could be addressed in a couple of ways, either by burning it in a boiler specifically built for that purpose, or using an anaerobic digester to reduce the organic matter and possibly applying it to farmland (Campos, 2006).

Economic Feasibility Studies

Many feasibility studies have been conducted for ethanol production from corn and/or sorghum in the United States. These economic studies were either developed using deterministic prices for ethanol, distillers dry grain solubles (DDGS), corn, and natural gas (Bryan and Bryan International, 2001) or using Monte Carlo simulation models to incorporate risk for prices and production into their analysis (Outlaw, et al., 2003; Lau, 2005; Richardson, et al., 2006a). However, only two known studies have been done on the economic feasibility or cost of production of sugarcane-based ethanol for the U.S., Bryan and Bryan International, 2003, and Shapouri, et al., 2006.

Monte Carlo financial statement models are useful for economic feasibility analyses because they estimate probability distributions for key output variables (KOVs) of interest to business managers and investors. Business managers need to know the probability distributions for annual net cash income and annual ending year cash flows to understand the risks for a new business. Of primary interest is, "What is the chance that the business will have a negative annual cash flow and What is the chance of two such years in a row?" Also of interest is the question, "Will the investment generate a rate of return that is greater than the opportunity cost of capital?" This last question is answered by estimating and analyzing the investment's net present value (NPV) probability distribution.

Reutlinger (1971) proposed using Monte Carlo financial statement models to estimate the probability distribution for an investment's NPV. Because the NPV represents the present value of annual net returns and the change in net worth over the planning horizon, it is a good variable for summarizing the overall economic viability of a proposed business. The probability of economic success as defined by Richardson and Mapp (1976) as the chance that NPV is greater than zero. Their logic was that if NPV is greater than zero, the investment generated a return exceeding the investor's discount rate or opportunity cost of capital, so the investment is a success.

Sugar Mill/Ethanol Simulation Model

It is assumed that the existing sugar mill grinds 10,000 tons of cane per day for about 180 days needing around 40,000 acres of sugarcane. The sugar mill owns all the harvesting and hauling equipment and charges the service to the producers. The proposed ethanol plant will produce 35 million gallons of ethanol per year and will be a $92 million addition to an existing sugarcane mill. In order to sustain this amount of production the sugarcane acreage will be doubled to 80,000 acres and the grinding capacity of the sugar mill will be increased to 15,000 tons of cane per day. The new plant will be built adjacent to the existing sugar mill so no additional land will be required. The cost of the proposed plant includes storage tanks, additional harvesting and hauling equipment, vinasse handling, as well as changes in the sugar mill to be able to grind and process more cane such as a bigger and/or additional boiler, vacuum pans, mud filters, and water cooling systems.

The simulation model to analyze the sugar mill/ethanol plant is an annual Monte Carlo financial statement model. Similar simulation models have been used by Richardson and Mapp (1976), Cochran, et al. (1990), and Outlaw, et al. (2003) to analyze proposed businesses. The model consists of a production section which annually calculates conversion of sugarcane into sugar and ethanol using stochastic values for cane yield and sugar content. The second section of the model calculates the variables for the income statement, i.e. annual receipts, production costs, fixed costs, and interest expenses. The third section calculates the cash flow financial statement variables including annual interest earnings, principal payments, income taxes, investor dividends, and ending cash reserves. The final section of the model calculates the balance sheet with an annual updating of asset values, liabilities, and net worth. The model is recursive in that positive ending cash reserves for the current year are beginning cash reserves for the next year. If ending cash reserves are negative the firm obtains a one year loan to cover the deficit and repays the principal plus interest the next year. The final segment of the financial model calculates the NPV as:

$$\text{NPV} = -\text{Beginning Net Worth} + \sum \text{Dividends}_t / (1+i)^t + \text{Ending Net Worth} / (1+i)^{10}$$

This formula for NPV quantifies the real change of net worth from retained earnings and changes in net worth, as well as the value of the earnings extracted from the firm, in current purchasing power.

The stochastic variables in the model are variables which management can not control:

- yield of sugarcane (tons/acre),
- sugar content of sugarcane (lbs sugar/ton),
- price of sugarcane ($/ton)
- price of unleaded gasoline ($/gallon),
- price of electricity ($/KWH),
- price of raw sugar ($/ton),
- price of molasses ($/ton), and
- price of ethanol ($/gallon)

Parameter estimation for the multivariate distribution to simulate these random variables was done in two parts. The sugarcane yield and quality of cane data were least plentiful with only five years of data. These two variables were simulated as a multivariate empirical (MVE) using a Parzen Kernel density to expand the distribution, as suggested by (Richardson, et al., 2006b). Sixteen years of historical price data for the remaining stochastic variables were used to estimate the multivariate empirical distribution following the procedure outlined by Richardson, et al. (2000). The stochastic variables were detrended to remove systematic error and the residuals were used to parameterize the multivariate empirical probability function. The parameters for both multivariate distributions were estimated using Simetar©, a Microsoft Excel Add-In (Richardson, et al., 2006c).

The deterministic component of the MVE price distribution came from linear trend forecasts and existing forecast models. Projected annual average prices for sugar came from the January 2006 FAPRI Baseline (FAPRI, 2006). Projected annual prices for gasoline came from Bryant, et al (2006). Ethanol prices were assumed to be $2.00 per gallon over the planning horizon. The projected prices and yields were treated as the assumed means for the 10 year planning horizon in the MVE distributions.

Two types of validation tests were performed on the simulated random variables to insure that they statistically reproduced the historical correlation, variability, and their assumed mean levels. Student-t tests of the correlation coefficients implicit in the simulated yields and prices were not statistically different from their respective historical counterparts at the 99% level. Student-t tests were used to test if the simulated yields and prices statistically reproduced their assumed means. At the 95% confidence level, the means for all simulated variables were not statistically different from their assumed means. Chi-square tests were performed to validate that the standard deviations for the stochastic variables equaled their historical values. None of the random variables failed the Chi-square test at the 95% confidence level.

The model was programmed in Microsoft® Excel because it offers easy to use programming capabilities and Add-Ins are available to simulate random variables. The risk analysis Add-In selected for developing the model is Simetar© because it provides tools for parameter estimation, simulation of multivariate distributions and ranking risky alternatives (Richardson, et al., 2006c).

The completed Monte Carlo model was simulated for 10 years. The random variables were simulated using the Latin Hypercube method and the Mersenne Twister Random Number Procedure. The Mersenne Twister has shown to not degenerate for large problems. The model's 10 year planning horizon starts in 2007 and was replicated for 500 iterations (or trials). With a Latin Hypercube sampling procedure 500 iterations is more an adequate sample size to insure that all regions of the MVE distributions are sampled.

Information for the sugar mill and ethanol plant consists of fixed and marginal costs for operating the plant and input/output coefficients for production (Table 1). Managers of an existing sugar mill provided costs and input/output coefficients necessary to simulate an existing sugar mill. Cost of plant and ethanol production coefficients for the sugar mill/ethanol plant were provided by Rodrigo Campos (2006), Export Manager – Alcohol of Dedini, the world's biggest manufacturers of sugar mill and ethanol plants, and Ivan Chavez (2006), CEO of Chaves Consultoria, a sugar and ethanol consultant firm, both located in Piracicaba, Brazil. Sugar and ethanol conversion factors were obtained from Fernandes (2003). The remaining input/output coefficients came from recent ethanol feasibility studies by Bryan and Bryan International (2003).

The sugar mill financial statement simulation model was extended to analyze the economic benefits of two alternative business plans for the sugar mill. The two scenarios are:

- Operate the sugar mill with no change in the scope of the operations for a base scenario, and
- Operate a sugar mill/ethanol plant that makes sugar from sugarcane and makes ethanol from sugarcane juice and molasses.

The two plant scenarios will be ranked by comparing the probability distributions for net present value (NPV), annual net cash income, and annual cash flows. Empirical NPV probability distributions for the two business plans are estimated from the stochastic simulation model. The NPV values calculated for each of the 500 iterations (random realizations of the stochastic variables) represent the individual points on the NPV distributions. The NPV distributions will be ranked using stochastic efficiency with respect to a function (SERF) from Hardaker, et al (2004). SERF is a risk ranking procedure which calculates certainty equivalents (CE) at risk aversion levels ranging from risk neutral to extremely risk averse and then ranks the risky alternatives (plant management scenarios) based on the alternative which has the largest CE at each risk aversion level. A power utility function with relative risk aversion coefficients ranging from 0 to 4 are used for the present study. Thus the ranking will be based on wealth/risk preferences for decision makers who range from risk neutral to extremely risk averse.

Results

The information used to describe and analyze the economic viability of a sugar mill with an ethanol plant is summarized in table 2. Projected mean values for the stochastic variables affecting the business are summarized in Table 3. Projections available from the FAPRI January 2006 baseline and Bryant (2006) were used as much as possible. As noted in the footnote for Table 3, the annual projected means for other variables were projected using linear trend or the historical means.

The estimated total cost of production per gallon of ethanol in the U.S. is $1.87 (Table 4). This cost includes a $0.91/gallon for the cost of sugarcane, $0.64/gallon for administrative, processing and other costs, $0.11/gallon for capital cost, and $0.21/gallon for depreciation. The cost of production in Brazil is $1.22 per gallon of ethanol excluding capital cost and depreciation (Chaves, 2006). Chaves (2006) stated that the cost of production in 2005 was $0.89 per gallon with the exchange rate of R$3.00/$US. However, due to the depreciation of the U.S. currency against the Brazilian real to around R$2.20/$US in 2006, the cost per gallon has increased to $1.22.

The results of simulating the current sugar mill and the mill augmented with a 35 million gallon per year ethanol plant are summarized in Table 5. The sugar mill has a mean NPV of $4.3 million with a minimum of -$19.6 million and a maximum of $58.2 million. The mill has a 57.2% chance of NPV being positive or the mill being an economic success. Adding the ethanol plant increases the mean NPV to $21.6 million and the proposed business has an 81.6% chance of economic success or earning more than the 15% discount rate on invested capital.

The business will face much greater variability in NPV by adding an ethanol plant as indicated by the standard deviation on NPV. The increased variability of NPV for the ethanol plant is demonstrated in the CDF chart for NPVs (Figure 1). The range of NPV for the sugar mill was about $77.8 million while the range was more than $131 million when an ethanol plant is added.

The stochastic NPVs can be compared to their respective mean NPVs that would result from a deterministic feasibility analysis (Figure 1). The deterministic mean for the sugar mill is overly optimistic ($6.5 million) while the reverse is true for the ethanol plant ($13.1 million). There is a 37.01% change the sugar mill will exceed the deterministic NPV and a 61.39% chance the ethanol plant will exceed its deterministic NPV. In both cases the deterministic feasibility result does not adequately portray the economic viability of the investments.

Annual net cash incomes for both businesses are summarized in Table 5. Average net cash income trends down over the planning horizon for both businesses because the projected mean prices for sugar and molasses are projected to decrease gradually while the prices for other inputs are projected to increase over time. The trend to lower net cash income increases the probability that both businesses will have negative net cash incomes. The probability that annual net cash income for the sugar mill will be negative is less than 3.5% in all years (Table 5). The probability of negative net cash income for the ethanol plant is less than 1% in all years.

Another measure of economic viability for a business is its ending cash reserves. Average annual cash reserves for the sugar mill increases steadily over the planning horizon. The ethanol plant has positive average cash reserves in all years; average ending cash reserves are $22.3 million in the first year and grow to $182.1 million the last year. The probability of negative annual ending cash reserves is thus important for these business plans and is summarized in Table 5. The probability of a negative ending cash reserve is zero in all years for both the sugar mill and the ethanol plant. The probability of negative annual ending cash reserves is best depicted in a StopLight chart (Figures 2 and 3). Both figures show that there is zero probability of having negative ending cash reserves. The green portion of each bar in Figures 2 and 3 represents the probability that cash reserves will exceed $40 million. Hence the sugar mill will have 100% chance of having ending cash reserve of more than $40 million by year 7, while the sugar mill/ethanol plant will have a 100% chance of ending cash exceeding $40 million by year 5.

The CDFs of NPV for the two businesses suggest that the sugar mill/ethanol plant is second degree stochastic dominant over the sugar mill (Figure 1). The SERF analysis of the NPV probability distributions arrives at the same conclusion (Figure 4). The CE for the ethanol plant is greater than the CE for the sugar mill over the range of risk neutral to extremely risk adverse decision makers. So the conclusion is that all classes of decision makers would prefer to invest in a sugar mill/ethanol plant over a sugar mill. A second SERF analysis was done comparing the probability distributions for ending cash reserves in year 10 under the two businesses. The conclusion that the ethanol plant is preferred also holds for all classes of decision makers.

Summary and Conclusions

Corn is the primary feedstock used in U.S. ethanol plants which use a fermentation-distillation process. The number two producer of ethanol is Brazil. Brazil ethanol producers use sugarcane for their feedstock. In terms of ethanol per acre, Midwest corn yields about 400 gallons/acre while sugarcane in Brazil produces about 870 gallons/acre. The U.S. grew 922,600 acres of sugarcane in Texas, Louisiana, and Florida in the 2005-06 season.

The purpose of this research was to analyze the economics of converting a U.S. sugarcane mill to produce ethanol in addition to producing sugar. The Brazilian model calls for making ethanol using molasses from making sugar and from the sugarcane juice. Using this model, U.S. sugarcane producers could increase planted acres of cane and modify their mills to squeeze more cane to produce juice for ethanol. A fermentation-distillation plant would need to be added to process the juice and molasses into ethanol. Added bagasse would be burned in the boiler to generate steam and electricity for the ethanol plant.

For an existing ethanol plant processing 40,000 acres of cane in the U.S., it is estimated that sugarcane acreage could be doubled and a 35 million gallon/year ethanol plant could be built for about $92 million. The results of a risk based feasibility study for such a plant show that the resulting business would be significantly more profitable than a stand alone sugar mill.

Using current projections of input prices and costs for 10 years and assuming a $2.00/gallon ethanol price, the average NPV would be $4.3 million for a sugar mill and $21.6 million for a sugar mill/ethanol plant. The probability of making greater than a 15% return on initial wealth is 57% for a sugar mill and 81.6% for a sugar mill/ethanol plant.

The results from this analysis suggest that sugar mills in the U.S. could benefit from investment in a co-located ethanol plant which uses molasses and sugarcane juice. Moreover, given the high ERoEI ratio, lower use of nutrients, and higher ethanol yield per acre, sugarcane-based ethanol seems to be a viable option in the U.S.

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Table 1. U.S. sugarcane acreage, yield and production, 1990-2005

Crop Year	Total Acreage	Sugarcane Yield per Acre	Sugarcane Production
	(1,000 acres)	(tons/acre)	(1,000 tons)
1990/91	794.2	36.4	28,909
1991/92	896.9	34.1	30,584
1992/93	925.2	33.2	30,717
1993/94	948.3	33.2	31,484
1994/95	936.8	33.3	31,195
1995/96	932.2	33.3	31,042
1996/97	888.9	33.4	29,689
1997/98	914.0	34.9	31,899
1998/99	947.1	36.9	34,948
1999/00	993.3	35.7	35,461
2000/01	1023.3	35.1	35,918
2001/02	1027.8	33.8	34,740
2002/03	1023.2	34.9	35,710
2003/04	992.3	34.3	34,036
2004/05	938.2	31.0	29,084
2005/06	922.6	28.8	26,571

Source: Economic Research Service, U.S. Department of Agriculture

Table 2. Assumptions for the Sugar Mill and Sugar Mill Ethanol Plant			
Variables	**Units**	**Sugar Mill**	**Sugar Mill/Ethanol Plant**
Sugar mill			
Sugar cane crushed for sugar	(fraction)	100.00%	0.5
Acres of sugarcane harvested	(acres)	44000	80000
Tons of cane mill grinds per day	(tons/day)	10000	15000
Average sugar cane yield	(tons/acre)	40.00	40
Cane wasted in handling	(fraction)	8%	0.08
Average price paid for sugar cane	($/ton)	17.00	17.00
Averavge price of sugar	($/pound)	0.2163	0.2163
Average price of molasses	($/ton)	60.00	60
Raw sugar per ton of cane crushed	(pounds/ton of net cane)	240.00	240
Pounds of molasses per gallon	(pounds/gallon)	12.5	12.5
Costs to process sugar cane			
Cane & raw sugar hauling	(cents/pound raw sugar)	1.5100	1.5100
Cane processing all other costs(Sugar)	(cents/pound raw sugar)	5.0190	5.0190
General administrative nonlabor	(cents/pound raw sugar)	1.0000	1.0000
Credit for bagasse for steam	(cents/pound raw sugar)	0.0350	0.0350
Sugarmill depreciation	($/year)	2,600,000	2,600,000
Capital Expenditures for Mill	($/ton raw sugar)	-	-
Ethanol Production			
Alcohol per ton of Molasses	(gallons/ton molasses)	-	56.00
Gallons ethanol/ton of sugarcane	(gallons/ton sugarcane)	-	19.62
Ethanol plant capacity	(gallons/year)	-	35,000,000
Ethanol plant depreciation	($s)	-	9,213,000
Grain Ethanol plant costs of production			
Ethanol plant electricity	($/gallon)	0.0581	0.0000
Ethanol plant fuels	($/gallon)	0.2107	0.0000
Ethanol plant waste management	($/gallon)	0.0067	0.0000
Ethanol plant water	($/gallon)	0.0034	0.0000
Ethanol plant enzymes	($/gallon)	0.0416	0.0000
Ethanol plant yeast	($/gallon)	0.0049	0.0000
Ethanol plant chemicals	($/gallon)	0.0356	0.0000
Ethanol plant maintenance	($/gallon)	0.0616	0.0000
Ethanol plant labor	($/gallon)	0.0578	0.0000
Ethanol plant administrative	($/gallon)	0.0422	0.0000
Ethanol plant other	($/gallon)	0.0044	0.0000
Assets and Liabilities			
Beginning cash reserves	($s)	0	0
Value of land January 1, 2007	($s)	500,000	500,000
Market value of facilities January 1, 2007	($s)	85,000,000	85,000,000
Current debt	($s)	19,000,000	19,000,000
Length of loan	(years)	20	20
Original interest rate	(fraction)	0	0.080
First year of original loan	(year)	2,000	2000
Fraction of New Plant Financed	(fraction)	0.5	0.5
Length of loan	(years)	10	10
Interest rate for ethanol plant loan	(fraction)	0.09	0.090
Year start the ethanol plant loan	(year)	2007	2007
Ethanol plant depreciation	($s)	-	9,213,000
Annual Capital Expenditures	($/gallon)	-	0.01
Local Market conditions			
Local basis for ethanol	($/gallon)	0.00	0.05
Basis for local sugar price	(cents/pound)	-0.0158	-0.0158
Basis for molasses	($/ton)	-6.3250	-6.325
Fract year pay interest for operating loan	(fraction)	0.010	0.010
Dividend as a fraction of net income	(fraction)	0.150	0.150
Discount rate	(fraction)	0.100	0.100

Table 3. Assumed Means for Stochastic Variables in the Sugarmill/Ethanol Feasibility Analysis.

	Cane Yield (ton/acre)	Sugar Yield (lbs/ton cane)	Sugarcane Price ($/ton)	Molasses Price ($/ton)	Sugar Price ($/lb.)	Ethanol Price ($/gal.)	Gasoline Price ($/gal.)
2007	40.0	240.0	18.60	69.94	22.54	2.32	1.88
2008	40.0	240.0	18.60	70.20	22.36	2.29	1.68
2009	40.0	240.0	18.60	65.76	22.09	2.49	1.79
2010	40.0	240.0	18.60	61.76	21.71	2.16	1.78
2011	40.0	240.0	18.60	45.45	20.36	1.98	1.54
2012	40.0	240.0	18.60	55.88	20.30	1.93	1.35
2013	40.0	240.0	18.60	33.06	19.70	1.73	1.00
2014	40.0	240.0	18.60	46.20	20.21	1.67	1.21
2015	40.0	240.0	18.60	32.56	17.35	1.82	1.06
2016	40.0	240.0	18.60	60.83	19.95	2.23	1.80

Source: Historical yield and sugar content data ehibited no statistically significant trend so the average for the past 5 years was used without assuming technological improvements. Means for molasses prices were estimated extrapolating a linear trend estimated from the past 16 years. Means for sugar prices come from the January 2006 FAPRI Baseline assuming continuation of the 2002 farm bill The energy prices were projected by Bryant (2006).

Table 4. Estimated Ethanol Production Costs from Sugarcane (dollars per gallon)

	Brazil[1]	U.S.
Sugarcane Cost	0.84	0.91
Administrative, Processing and Other Costs	0.38	0.64
Capital Cost		0.11
Depreciation		0.21
Total Cost	1.22[2,3,4]	1.87

[1]Source: Chaves, 2006.

[2]Excludes capital costs.

[3]Excludes depreciation due to the plants being old.

[4]Cost of production was $0.89/gallon with exchange rate at R$3.00/$US in 2005.

Table 5. Summary of Simulation Results for Two Business Plans for Sugarmills annd Ethanol Production in the United States

Statistical Summary of Net Present Value

	Sugarmill	Sugar/Ethanol
Mean	4,275,451	21,577,176
StDev	12,333,521	22,245,086
Min	-19,592,019	-27,040,105
Max	58,187,356	106,768,713
Probability of Success		
P(NPV>0)	57.23%	81.60%
Deterministic NPV Values for Two Business		
D.NPV	6,514,531	13,119,400
Probability NPV Exceeds Deterministic NPV		
P(NPV>D.NPV)	37.01%	61.39%

Summary Statistics for Annual Net Cash Income

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sugarmill										
Mean	21,413,866	20,809,264	19,864,519	17,128,042	16,110,022	14,490,423	13,586,741	12,312,452	11,360,519	10,869,246
StDev	2,326,644	5,354,802	5,268,549	5,027,191	4,858,738	5,167,534	4,812,132	5,095,730	5,095,608	4,744,744
CV	10.9	25.7	26.5	29.4	30.2	35.7	35.4	41.4	44.9	43.7
Min	13,146,106	3,222,895	4,609,892	1,149,291	1,027,621	-1,514,675	-1,557,524	-3,224,662	-4,778,433	-6,143,435
Max	27,271,622	35,716,277	34,901,017	31,883,670	32,968,922	30,133,276	27,047,098	27,650,547	23,697,386	27,768,683
Sugar and Ethanol										
Mean	34,811,258	34,388,916	33,518,088	31,253,392	30,260,898	28,964,917	28,124,747	27,034,062	26,134,798	24,207,332
StDev	7,906,866	11,042,829	10,418,841	10,955,365	9,942,651	10,509,898	10,266,292	10,692,021	11,116,026	10,351,805
CV	22.7	32.1	31.1	35.1	32.9	36.3	36.5	39.6	42.5	42.8
Min	14,313,566	6,337,732	3,796,705	1,503,396	5,941,746	-1,202,213	4,274,646	-1,075,760	-4,998,570	-1,381,029
Max	56,185,527	70,516,769	70,476,926	63,800,932	60,145,887	60,131,900	64,614,262	57,264,911	59,666,352	60,407,013

Summary Statistics for Annual Ending Cash Reserves

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sugarmill										
Mean	14,992,421	28,983,784	42,294,345	52,848,535	62,723,628	71,665,647	79,974,481	87,539,205	94,682,551	101,459,047
StDev	4,051,097	6,514,198	9,019,012	11,556,403	13,817,109	16,505,042	18,700,087	21,097,570	23,564,869	25,582,568
CV	27.0	22.5	21.3	21.9	22.0	23.0	23.4	24.1	24.9	25.2
Min	6,871,487	13,373,559	17,463,075	27,204,964	34,470,569	36,486,839	43,851,561	48,050,329	52,657,499	53,139,000
Max	20,250,911	42,039,827	63,161,660	82,408,876	102,381,613	125,531,311	147,511,924	170,173,335	190,376,096	213,762,788
Sugar and Ethanol										
Mean	22,259,909	44,061,626	65,274,394	84,803,230	103,562,711	121,256,229	138,137,823	154,022,402	168,930,731	182,066,781
StDev	6,496,951	10,449,937	14,474,352	18,779,954	22,489,876	26,938,383	30,978,084	35,438,035	40,300,377	44,894,200
CV	29.2	23.7	22.2	22.1	21.7	22.2	22.4	23.0	23.9	24.7
Min	7,572,770	17,049,130	26,302,938	36,950,259	44,047,146	60,477,905	65,301,207	78,258,919	73,929,079	83,150,704
Max	34,900,411	70,786,132	107,195,005	140,823,630	168,053,165	204,195,638	244,515,369	276,831,597	309,696,577	347,879,687

Probability of Net Cash Income Less than Zero

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sugarmill	0.00%	0.00%	0.00%	0.00%	0.00%	1.05%	0.58%	3.15%	3.49%	3.31%
Sugar and Ethanol	0.00%	0.00%	0.00%	0.00%	0.00%	0.35%	0.00%	0.65%	0.60%	0.33%

Probability of Ending Cash Reserves Less than Zero

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sugarmill	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sugar and Ethanol	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Probability of Ending Cash Reserves Exceeding $40 Million

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Sugarmill	**0.00%**	**0.86%**	**53.91%**	**85.76%**	**97.67%**	**99.17%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Sugar and Ethanol	**0.00%**	**62.02%**	**95.03%**	**99.39%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Figure 1. CDF of Net Present Value for a Sugar mill and Proposed Sugar mill/Ethanol Plant

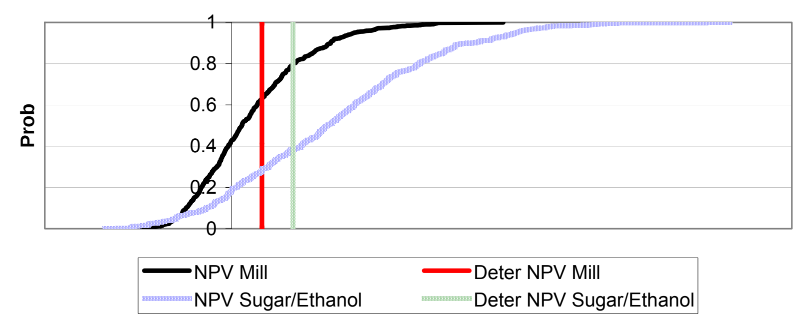

Figure 2. StopLight Chart for Probability of Ending Cash Reserve Greater Than $40,000,000 for a Sugar Mill

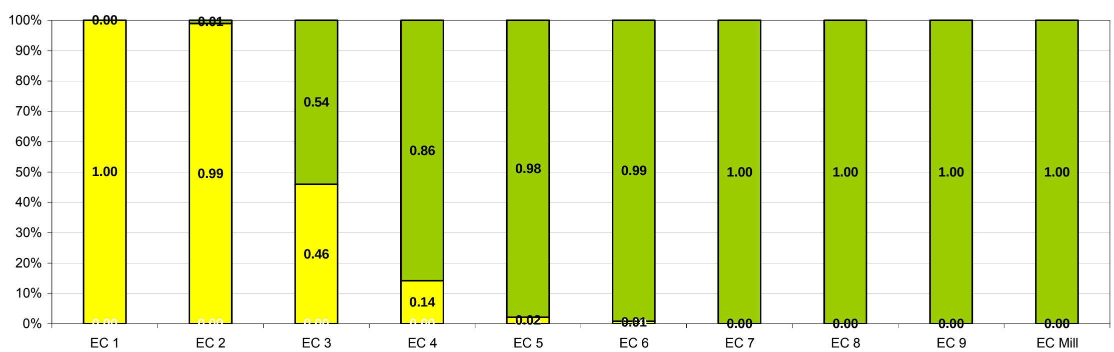

Figure 3. StopLight Chart for Probability of Ending Cash Reserve Greater Than $40,000,000 for a Sugar Mill/Ethanol Plant

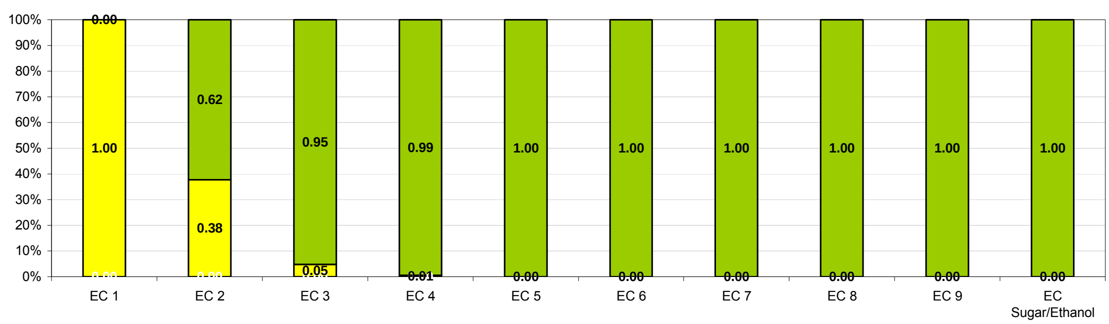

Figure 4. SERF Ranking of Two NPV Probability Distributions over the Range of Risk Neutral to Extremely Risk Averse

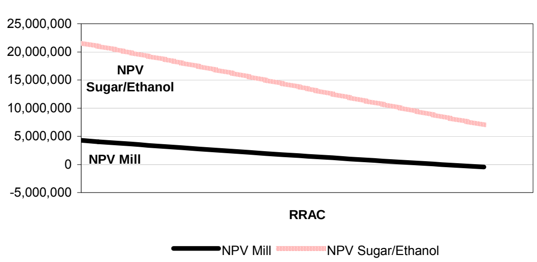

Figure 5. SERF Ranking of Two Ending Cash Reserve Probability Distributions over the Range of Risk Neutral to Extremely Risk Averse