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Edited by

Joe L. Outlaw

Agricultural and Food Policy Center
Texas A&M University
College Station, TX

James A. Duffield

Office of Energy Policy and New Uses
US Department of Agriculture
Washington, DC

David P. Ernstes

Agricultural and Food Policy Center
Texas A&M University
College Station, TX

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Mitigating the Fuel and Feed Effects of Increased Ethanol Production Utilizing Sugarcane

Luis A. Ribera, Joe L. Outlaw, James W. Richardson, Jorge A. da Silva and Henry L. Bryant[1]

Introduction

Recent resurgence of interest in ethanol production by rural development groups, politicians, and producers can be attributed to many different factors such as depressed commodity prices, rising gasoline prices, shift in environmental policy, and push towards national fuels self-sufficiency. Annual ethanol production in the United States has increased from 1.77 billion gallons (gal) in 2001 to around 5 billion gal in 2006.

Corn is the primary feedstock used in US 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 Gill (2002), Herbst (2003) and Outlaw *et al.* (2003) 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.*, 2006a). Bryan and Bryan International (2006) reported that in 2005 there were 95 ethanol plants in the United States with combined production capacity of 4.3 billion gal/year. Kenkel and Holcomb (2006) expect the trend of privately owned plants to continue as plants expand into feedstock deficit region.

While corn based ethanol production has been profitable over the past few years, the near doubling of corn prices in late 2006 and early 2007 has significantly reduced ethanol plant profitability (Food and Agricultural Policy Research Institute, 2006). With almost 20% of the US corn crop now being used in ethanol production, the food versus fuel versus feed debate is starting to gain national and worldwide attention. While most believe that the future of ethanol production in the United States and the world lies with cellulosic production, during the transition period, ethanol could potentially be produced in the United States from sugarcane, thereby mitigating some of the problems in the food and feed sectors due to high corn prices.

Brazil is the world leader of ethanol production from sugarcane. Sugarcane based ethanol is produced in many other countries and regions such as India, Colombia, Bolivia, and Central America, among others. The United States has not explored the production of ethanol from sugarcane juice. However, a study by Ribera *et al.* (forthcoming), showed that it is economically feasible to produce ethanol form sugarcane, specially now at current corn, sorghum, and ethanol prices.

One short-coming of sugarcane based ethanol production is that it cannot be produced year round. Ethanol is produced only during sugarcane harvesting and it cannot be stored since sugarcane will decompose and lose its juice. Brazil faces the same problem as ethanol is produced during the harvesting season (April to November) in the Center/South region where over 85% of the ethanol is produced. Ethanol is stored in big tanks for use in the off-months. Therefore, a plant that uses both sugarcane and sorghum might be able to overcome the shortcomings of a sugarcane-based ethanol plant.

Objective

The objective of this paper is to evaluate the economic feasibility of a year round ethanol production plant using both grain sorghum and sugarcane as feedstock.

Economic Feasibility Studies

Many feasibility studies have been made 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). Moreover, only three known studies have been done on the economic feasibility or cost of production of sugarcane-based ethanol for the United States, Bryan and Bryan International, 2003, Shapouri and Salassi, 2006, and Ribera *et al.*, forthcoming. However, the authors do not know of any study done on economic feasibil-

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[1] Ribera, Outlaw, Richardson and Bryant are assistant professor and extension economist; co-director, professor and extension economist; co-director, regents professor and Texas AgriLife senior faculty fellow; and research assistant professor, respectively, at the Agricultural and Food Policy Center, Department of Agricultural Economics, Texas A&M University, College Station, Texas. Da Silva is an associate professor in the Department of Soil & Crop Sciences, Texas AgriLife Research, Weslaco, TX.

ity of the use of both sugarcane and sorghum as feedstock for ethanol production

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 (Richardson *et al.*, 2006a). 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.

Sugarcane-Sorghum Ethanol Simulation Model

The proposed ethanol plant produces 100 million gal of ethanol per year, half will be produced from sugarcane and the other half from sorghum or corn. The ethanol plant will be able to grind 16,000 tons of cane per day for about 180 days requiring about 85,000 acres of sugarcane. The ethanol plant will own all the sugarcane harvesting and hauling equipment and charges the service to the sugarcane producers. Moreover, the plant will also loan the producers the initial start-up cost of sugarcane production, around $650/acre, to establish the sugarcane acreage. This loan will be paid back to the plant in years one to three. Cost of production after establishment of sugarcane is $350/acre with an average yield of 28 tons/acre. Producers receive $17/ton which is net of harvesting cost. The plant will produce 100 million gal of ethanol per year, first using available sugarcane juice and then using either sorghum or corn.

The total investment cost for the plant will be $276 million and will be financed with 50% equity, will pay dividends of 15%/year, and 50% debt with at 9% interest over 10 years. The plant will have two separate handling and grinding facilities for each feedstock. Once the juice is extracted from the cane and the mash is extracted from the sorghum, they will go to a common fermentation tank and continue until ethanol is produced. The cost of the proposed plant includes storage tanks, harvesting and hauling equipment, vinasse handling, and sugarcane establishment.

The simulation model to analyze the 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 the 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:

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

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 (pounds sugar/ton),
- price of sugarcane ($/ton),
- price of unleaded gasoline ($/gal),
- price of electricity ($/kilowatt hour),
- price of grain sorghum ($/bu),
- price of distiller's dried grains with solubles (DDGS) ($/ton), and
- price of ethanol ($/gal).

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 sim-

Table 1: Assumptions for the Sugar Mill and Sugar Mill Ethanol Plant.

Variables	Units	Ethanol Plant
Sugarcane Ethanol Production		
Sugar cane crushed for sugar	(fraction)	0.00%
Acres of sugarcane harvested	(acres)	85000
Tons of cane mill grinds per day	(tons/day)	16000
Average sugar cane yield	(tons/acre)	28.00
Cane wasted in handling	(fraction)	0.08
Average price paid for sugar cane	($/ton)	17.00
Cane & raw sugar hauling	(cents/pound raw sugar)	1.5100
General administrative nonlabor	(cents/pound raw sugar)	1.0000
Credit for bagasse for steam	(cents/pound raw sugar)	0.0350
Gallons ethanol/ton of sugarcane	(gallons/ton sugarcane)	19.62
Ethanol Production	(gallons/year)	50,000,000
Grain Ethanol Production		
Ethanol plant electricity	($/gallon)	0.0581
Ethanol plant fuels	($/gallon)	0.2107
Ethanol plant waste management	($/gallon)	0.0067
Ethanol plant water	($/gallon)	0.0034
Ethanol plant enzymes	($/gallon)	0.0416
Ethanol plant yeast	($/gallon)	0.0049
Ethanol plant chemicals	($/gallon)	0.0356
Ethanol plant maintenance	($/gallon)	0.0616
Ethanol plant labor	($/gallon)	0.0578
Ethanol plant administrative	($/gallon)	0.0422
Ethanol plant other	($/gallon)	0.0044
Gallons ethanol/bushel of sorghum	(gallons/bushel)	2.7000
Ethanol Production	(gallons/year)	50,000,000
Assets and Liabilities		
Beginning cash reserves	($s)	0.00
Value of land January 1, 2007	($s)	500,000
Market value of facilities January 1, 2007	($s)	-
Current debt	($s)	-
Fraction of New Plant Financed	(fraction)	0.50
Length of loan	(years)	10.00
Interest rate for ethanol plant loan	(fraction)	0.090
Year start the ethanol plant loan	(year)	2007
Ethanol plant depreciation	($s)	22,095,675
Annual Capital Expenditures	($/gallon)	0.01
Fract year pay interest for operating loan	(fraction)	0.010
Dividend as a fraction of net income	(fraction)	0.150
Discount rate	(fraction)	0.100

ulated 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).

Table 2: Assumed Means for Stochastic Variables in the Sugar Mill/Ethanol Feasibility Analysis.

	Cane Yield	Sugar Yield	Sugarcane Price	Sorghum Price	DDGS Price	Ethanol Price	Gasoline Price
	(ton/acre)	(lbs/ton cane)	($/ton)	($/bu)	($/ton)	($/gal.)	($/gal.)
2007	28.0	240.0	17.27	3.50	77.00	2.00	1.65
2008	28.0	240.0	17.27	3.50	78.00	2.00	1.62
2009	28.0	240.0	17.27	3.50	79.00	2.00	1.58
2010	28.0	240.0	17.27	3.50	79.00	2.00	1.54
2011	28.0	240.0	17.27	3.50	79.00	2.00	1.48
2012	28.0	240.0	17.27	3.50	79.00	2.00	1.44
2013	28.0	240.0	17.27	3.50	79.00	2.00	1.42
2014	28.0	240.0	17.27	3.50	79.00	2.00	1.45
2015	28.0	240.0	17.27	3.50	78.00	2.00	1.48
2016	28.0	240.0	17.27	3.50	77.00	2.00	1.50

Source: Historical yield and sugar content data exhibited no statistically significant trend so the average for the past 5 years was used without assuming technological improvements. Means for DDGS prices were projected by Food and Agricultural Policy Research Institute (2006). The energy prices were projected by Bryant *et al.* (2006).

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 (Food and Agricultural Policy Research Institute, 2006). Projected annual prices for gasoline came from Bryant *et al.* (2006). Ethanol and sorghum prices were assumed to be $2.00/gal and $3.50/bushel (bu), respectively, 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 than an adequate sample size to insure that all regions of the MVE distributions are sampled.

Information for the sugarcane based ethanol plant consists of fixed and marginal costs for operating the plant and input/output coefficients for production (Table 1). Cost of plant and ethanol production coefficients for the sugarcane based ethanol plant were provided by Rodrigo Campos (2006) the export manager for Alcohol of Dedini, the world's largest manufacturer of sugar mill and ethanol plants, and Ivan Chaves (2006), CEO of Chaves Consultoria, a sugar and ethanol consultant firm, both located in Piracicaba, Brazil. 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). Grain based ethanol costs came from Richardson *et al.*, 2006.

Results

The information used to describe and analyze the economic viability of the proposed ethanol plant is summarized in Table 1. Projected mean values for the stochastic variables affecting the business are summarized in Table 2. Projections available from the FAPRI January 2006 baseline and Bryant (2006) were used as much as possible. As noted in the footnote for Table 2, the annual projected means for other variables were projected using linear trend or the historical means.

The estimated cash cost of production of ethanol from sugarcane is $1.63/gal and from sorghum is $1.73/gal (Table 3). For sugarcane based ethanol, the cost includes a $0.91/gal for the cost of sugarcane and a $0.72/gal for processing cost. For the grain based ethanol, the feedstock cost is $1.41/gal plus a $0.54/gal for processing costs minus a $0.22/gal credit for selling the DDGS. Depreciation cost is estimated at $0.29/gal and $0.15/gal for sugarcane and sorghum ethanol, respec-

Table 3: Estimated Ethanol Production Costs from Sugarcane and Sorghum ($/gal).

	Sugarcane	Sorghum
Feedstock	0.91	1.41
Processing	0.72	0.54
Less DDG Credit		-0.22
Total Cash Cost	1.63	1.73
Depreciation	0.29	0.15
Total Cost	1.92	1.88

tively (Table 3). Therefore, total cost of production of ethanol from sugarcane is $1.92/gal and from sorghum is $1.88/gal.

The results of simulating the proposed ethanol plant are summarized in Table 4. The proposed ethanol plant has a mean NPV of $78.7 million with a minimum of negative $60 million and a maximum of $198.7 million. The plant has a 97.5% chance of NPV being positive or the plant being an economic success. Moreover, the business will face a considerable amount of variability as demonstrated in the cumulative distribution function (CDF) chart for NPVs (Figure 1). The range of NPV was around $258 million. The stochastic NPV can be compared to its respective mean NPV that would result from a deterministic feasibility analysis (Figure 1). The deterministic mean for the business is about the same as the mean for the stochastic model, $70 million compared to $78.7 million, respectively.

Figure 2 presents a fan graph of the annual net cash income (NCI) for the 10-year planning horizon. The fan graph illustrates the range of possible NCI for each year of the planning horizon. The top line represents the 95th percentile line while the bottom line represents the 5th percentile line. This means 90% of the time annual NCI falls between these lines so the two lines represent a 90% confident interval for NCI in each year. The middle line is the average. The lines second from the bottom and top represent the 25th percentile and 75th percentile lines, respectively; so they represent the 50% confidence interval for annual NCI. The fan graph shows a slightly negative trend in NCI and has an abrupt decrease in NCI after year 2009 as the sugarcane producers repaid the initial loan plus interest for establishing the sugarcane crop.

Annual NCI is summarized in Table 4. Average NCI trends down over the planning horizon as the inputs cost increase over time and price of ethanol is fixed at $2.00/gal. The trend to lower NCI increases the probability of having negative NCI. The probability that annual will be negative is less than 17% in all years (Table 4).

Another measure of economic viability for a business is its ending cash reserves (ECR). Average annual ECR for the proposed plant increases steadily over the planning horizon; average ECR are $11.4 million in the first year and grow to $126.8 million in the last year (Table 4). The probability of negative annual ending cash reserves is thus important for the business plans and is summarized in Table 4. The probability of a negative ECR is 27.5% in

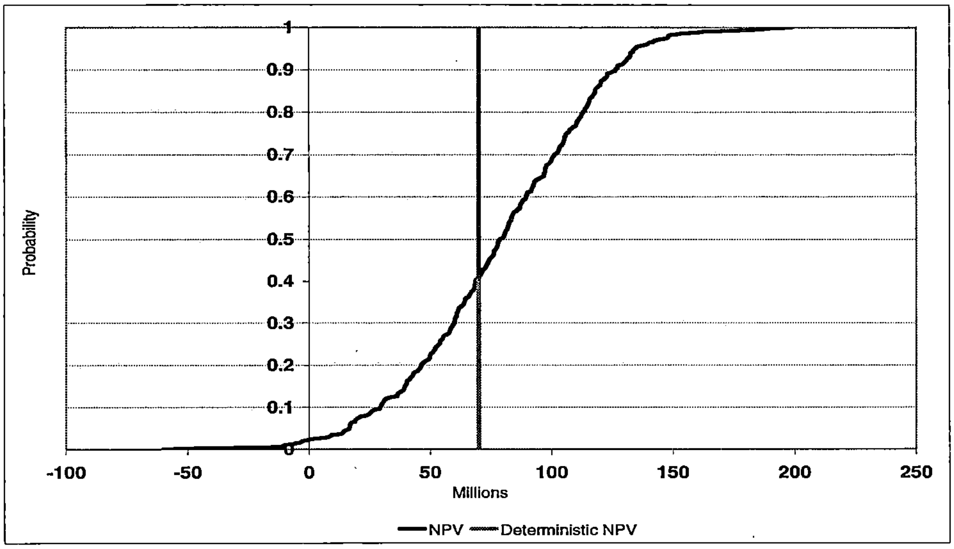

Figure 1: Cumulative Distribution Function of Net Present Value (NPV).

Table 4: Summary of Simulation Results for Ethanol Production in Southeast Texas.

Statistical Summary of Net Present Value

Mean	78,691,279
StDev	38,441,453
Min	-60,028,338
Max	198,694,766
Probability of Success	
P(NPV>0)	97.46%
Deterministic NPV Values	
D.NPV	70,029,520
Probability NPV Exceeds Deterministic NPV	
P(NPV>D.NPV)	58.84%

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
Mean	49,784,445	51,018,121	52,257,505	35,285,257	35,113,477	34,839,509	34,017,677	33,372,102	32,525,685	31,683,154
StDev	29,373,333	29,637,557	29,472,063	28,318,151	29,071,574	29,671,995	30,064,819	28,949,337	28,789,740	30,091,998
CV	59.0	58.1	56.4	80.3	82.8	85.2	88.4	86.7	88.5	95.0
Min	-36,072,469	-29,353,256	-24,110,971	-45,360,733	-43,926,515	-45,377,440	-53,370,252	-49,234,002	-42,028,179	-44,569,939
Max	115,256,544	112,209,045	119,519,018	106,457,028	105,910,632	105,935,538	106,316,960	96,138,812	100,268,809	104,876,479

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
Mean	11,441,976	21,840,563	30,878,235	47,919,249	64,107,781	79,412,957	93,309,584	106,108,780	117,409,726	126,784,366
StDev	19,507,686	27,635,851	35,177,918	41,891,355	46,848,339	52,656,599	58,076,029	64,371,225	71,363,018	77,799,293
CV	170.5	126.5	113.9	87.4	73.1	66.3	62.2	60.7	60.8	61.4
Min	-60,198,441	-76,834,718	-122,644,997	-128,838,156	-105,299,447	-117,524,432	-111,371,913	-97,911,161	-143,097,324	-170,024,235
Max	47,652,453	77,507,685	116,218,406	151,657,171	183,876,361	223,389,574	271,956,090	310,769,048	324,859,123	359,653,008

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
4.25%	4.51%	2.84%	12.58%	12.47%	13.96%	13.85%	12.98%	14.72%	16.94%

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
27.48%	22.39%	18.00%	12.61%	8.95%	6.04%	6.35%	5.81%	6.22%	5.55%

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
3.40%	26.96%	44.18%	60.58%	72.11%	79.04%	82.71%	84.37%	85.78%	86.88%

the first year and decreases to 5.5% in the last year of the planning horizon.

The probability of negative annual ECR is best depicted in a "stop light" chart (Figure 3). The "red" portion of each bar in Figure 3 represents the probability that ECR will be less than zero. The "yellow" and "green" portion of each bar represent the probability that ECR will be between $0 and $40 million and probability of ECR be over $40 million, respectively. Hence the business in the first year will have a 27% chance of negative ECR, 69% chance of ECR being between $0 and $40 million, and 4% chance of ECR being over $40 million. Moreover, in year 10 it will have 5%, 8%, and 87% chance of ECR being negative, between $0 and $40 million and above $40 million, respectively.

Summary and Conclusions

Expansion of ethanol production to feedstock deficit regions will likely reduce the profitability of ethanol plants as feedstock cost increases due to increased transportation and also availability of feedstock. Corn and sorghum prices have been rising rapidly over the past few months reaching well over $3.50/bu. Therefore, feasibility studies using alternative feedstock or combination of feedstock for ethanol production is needed. An alternative feedstock that has been proven to work very efficiently is sugarcane.

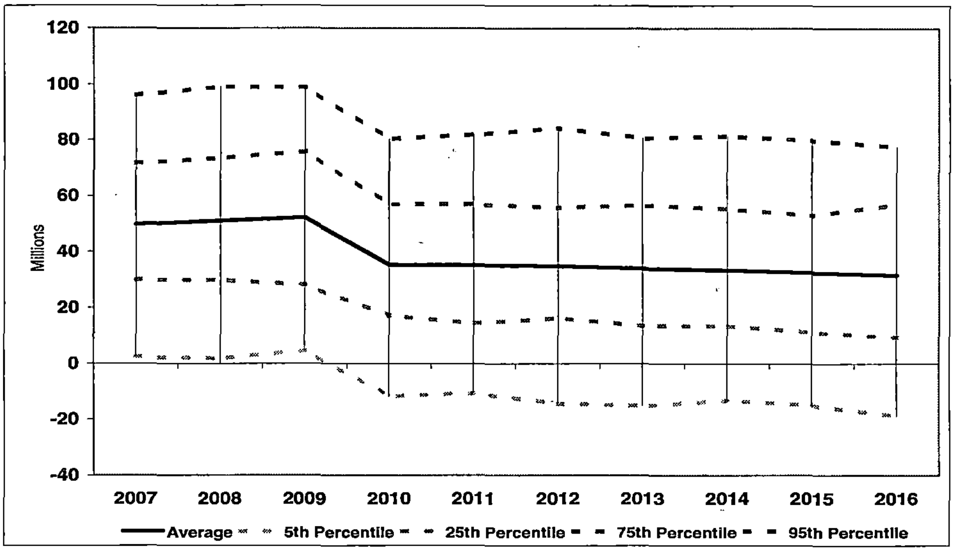

Figure 2: A Fan Graph of Annual Net Cash Farm Income.

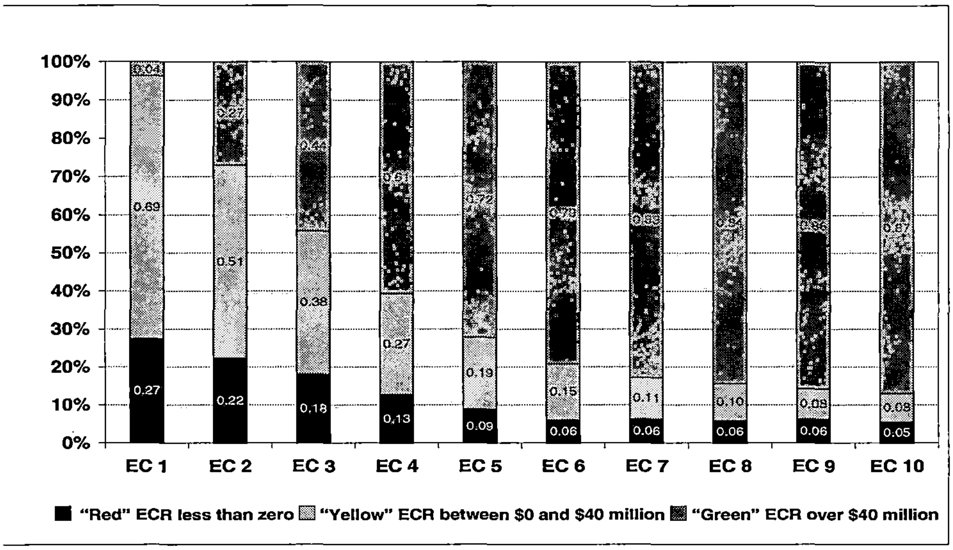

Figure 3: "Stop Light" Chart for Probability of Ending Cash Reserve Less than $0 and Greater than $40 Million.

The purpose of this paper was to analyze the economic feasibility of using a non-feed crop such as sugarcane for ethanol production. The proposed ethanol plant will produce 100 million gal of ethanol per year – half will be produced from sugarcane and the other half from grain sorghum or corn if wanted. The ethanol plant will be able to grind 16,000 tons of cane per day for about 180 days needing around 85,000 acres of sugarcane. The ethanol plant will own all the sugarcane harvesting and hauling equipment and charges the service to the sugarcane producers. Moreover, the plant will also loan the producers the initial start-up cost of sugarcane production, around $650/acre, to establish the sugarcane acreage. This loan will be paid back to the plant in years one to three.

The total investment cost for the plant will be $276 million. The plant will have two separate handling and grinding facilities for each feedstock. Once the juice is extracted from the cane and the mash is extracted from the sorghum, they go to a common fermentation tank and continue until final product. The cost of the proposed plant includes storage tanks, harvesting and hauling equipment, vinasse handling, and sugarcane establishment.

Using current projections of input prices and costs for 10 years and assuming a $3.50/ bu of sorghum and $2.00/gal ethanol price, the average NPV for the proposed plant would be $78.7 million. The probability of making a greater than a 15% return on initial wealth for the proposed plant is 97.5%.

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