The Economics of Processing Ethanol at Sugarmills: A Simulation Approach

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Introduction

The global demand for energy is seemingly insatiable. Liquid fuels in particular are a major component of the energy market in every economy in the world. In the US energy market, these liquid fuels primarily consist of fossil fuels from sources outside our own country. 19,480,000 barrels of petroleum were consumed each day in the United States in 2008, and 11,114,000 barrels of that (or 57%) was imported (EIA, 2008).Any viable energy strategy must then recognize the inherent limitations in relying solely on foreign, non-renewable fossil sources for our liquid fuel needs. Aside from the need to manage the supply of these depleting fossil energy sources, the need for energy security is a large motivator for displacing some traditional fuels with renewable, sustainable alternatives. A crucial part of our energy policy going forward will be to find, develop, and maintain renewable domestic sources to satisfy some of our growing energy demands while reducing our dependence on foreign fuels. Domestically-obtainable types of renewable liquid fuels include corn ethanol, non-corn ethanol, and biodiesel.

Ethanol – Current Policy

The Energy Policy Act of 1992 can be seen as starting the modern era of alternative fuel policy. Aside from expanding on earlier regulations concerning vehicle fleets, the law established new incentives for private citizens who wished to purchase alternatively-fueled vehicles or to convert their own vehicles to alternative fuel use. These tax deductions and low-interest loans were also extended to fuel-providers for the installation of equipment specific to the dispensing of alternative fuels.

The 2004 Jobs Creation Act redefined some of the processes and specifics of the ethanol subsidy, and extended the policy into 2010, but there was no net change in the subsidy itself.

2005's Energy Policy Act also had no direct effect on ethanol, but in requiring all alternative-fuel-capable federal fleet vehicles to actually use alternative fuels all the time, the law created a temporary shortage of fuel-ethanol. Additionally, the law greatly expanded the mandated quantity of ethanol that would be required in domestic fuels, incrementally increasing this amount over the next eight years.

Up to 2007, this federal Renewable Fuel Standard (RFS) called simply for the production of billions of gallons of ethanol. Without any further specification, the mandate was largely filled by conventional corn ethanol. The passage of the 2007 Energy Independence and Security Act (EISA) changed that. Of the 36 billion gallons mandated for production in by 2022, 21 billion gallons are to come from non-cornstarch derived biofuels, and 16 billion gallons are to come from cellulosic ethanol.

In February of 2010, the EPA finally concluded its years-long review of the original RFS and released its new standard, the RFS2. The long-term goals didn't change, and the short-term production targets were only changed modestly. However, there is one major change that is relevant to this study. Under the RFS, there is a category of biofuel called "advanced biofuel." In order for a fuel to qualify for this designation, it must be shown to reduced greenhouse gas (GHG) emissions by at least 50% over gasoline. Under the original RFS, there was no specific mention of ethanol derived directly from sugarcane, but under the RFS2, sugarcane ethanol is now considered an advanced biofuel. In fact, their official study found that sugarcane ethanol produced via Brazilian-style methods achieve a 61% reduction on a lifecycle basis. Since the RFS standards call for 21 billion gallons of advanced biofuels by 2022, and 16 billion gallons of that from cellulosic ethanol, that leaves a 5 billion gallon mandate for other advanced biofuels that could be filled by ethanol from sugarcane juice (EPA, 2010).

Sugarcane

Louisiana's climate makes it a good location for the production of multiple biofuel crops. Of particular interest to Louisiana is the possibility of producing commercially-viable quantities of ethanol from sugarcane. There are several possible mechanisms by which this might be accomplished, but the two that have been most frequently explored are "juice" ethanol, obtained by fermenting high-sugar cane juice, and cellulose or biomass ethanol, which is obtained via an enzymatic process performed on the entire biomass portion of the crop. Salassi (2006) found that juice-based sugarcane ethanol is not likely to be economically feasible, given currently-projected gas and ethanol prices. However, the Brazilian method of taking the first two strikes of juice for sugar production and using the remaining juice for ethanol production has never been studied in Louisiana, and may show potential for profitable production here. It is not yet clear how cost-effective a cellulosic ethanol process would be using the full sugarcane stalk, but the biomass content of traditionally harvested varieties is not likely to be high enough for the ethanol produced to be an economically feasible product on its own. There are other varieties that are currently being developed that have much higher biomass yields however, and a full-plant cellulosic ethanol process may indeed end up being a viable option using some of these "energy cane" varieties.

These energy cane varieties represent a large risk for the farmer though, since they contain very low levels of sugar and could not therefore be efficiently ground for sugar production. In order for the farmer to actually be able to switch to energy cane, he would have to be able to generate as much revenue from the ethanol produced as he gives up in lost sugar revenue. Whether or not this could happen is dependent upon market prices for sugar and ethanol, as well as pricing strategies employed by biofuels producers, and the uncertainty in the market makes it unlikely that any farmers will switch to energy cane in the short term. This presents a problem for a processor who is interested in building a cellulosic ethanol plant, as no viable feedstocks will be available for processing at least in the short term. The planting cycle for all cane varieties means that a processor would likely be stuck with the current low-biomass varieties for at least one or two years, and possibly longer.

However, there may be a third way. In a current sugarcane mill, the cane is ground and three products are produced: raw sugar, molasses, and bagasse. The raw sugar is sent to a refinery where it is processed into refined white sugar. The molasses is sold and generally ends up being used as a livestock feed additive. Most of the bagasse is burned and used to provide electrical power for the mill, offsetting the need to buy natural-gas-generated electricity from the grid or other fuel for the boilers. However, most mills actually produce much more bagasse than would be needed to produce the power they need. Since local utilities rarely allow this power to be sold back to the grid, the boilers are instead run as inefficiently as possible so as to burn as much of the bagasse as they can. Even so, most mills still produce excess bagasse which must then be trucked out and disposed of.

If a cellulosic ethanol plant were available at the sugar mill, ethanol could be produced from some or all of the on-site bagasse, which would not affect the raw sugar or molasses generated by the mill. Given a representative mill that grinds 12,000 tons of cane per day during the harvest season, about 15,000 gallons of ethanol could be produced per day from the mill's excess bagasse (Day, 2010). This would represent about a 6 million gallon annual capacity, if the bagasse were available year-round. If all of the onsite bagasse were used to make ethanol, this figure would be 85,000 gallons daily, or 30 million annually. In the latter scenario, power would have to be generated via some other boiler fuel, such as natural gas. If the ethanol generated from this process had a higher value than the deferred cost of boiler fuel that comes from burning the bagasse, then the ethanol plant would be able to generate added value from the same sugarcane harvest that it already sees. If only the excess were made into ethanol, the entire process would be a value-add, though external feedstocks might have to be acquired in order for the plant to reach commercial levels of production.

Why Louisiana?

One of the advantages of building an ethanol system around Louisiana sugarcane is that much of the infrastructure is already in place. The area has long had sugarcane fields and mills in desirable spatial relationships and the transportation capacity is already very high. From a logistical standpoint, overlapping a sugarcane ethanol system on top of the existing sugar infrastructure makes some sense. If existing sugar mills could also process cane fiber into ethanol and if sugarcane farmers grew some mix of both traditional sugarcane and the higher biomass-content energy cane, they would be able to send all of their harvest to the same place, and the output would be a mix of ethanol and sugar.

In 2008 Louisiana produced 12 million tons of sugarcane, producing 1.2 million dry tons of bagasse, enough to make a theoretical 100 million gallons of cellulosic ethanol (USDA, 2009). Furthermore, the Louisiana sugar belt presents several other opportunities for energy crops. Several high-fiber breeds of energy cane, have been extensively studied and found to have high potential as a cellulosic ethanol feedstock (Alexander, 1985; Turhollow, 1994). However, energy cane does have some disadvantages. The primary source of difficulty is the lifecycle of the crop. Due to the perennial nature of the crop and the fact that it doesn't produce harvestable yields until its second year, energy cane represents a large commitment of time and land for a producer, and is thus likely to meet with some initial resistance in the absence of long-term contracts. As the ethanol plant begins showing profits, contracting for energy cane should become less of a problem (ASCL, 2009).

Until then, sweet sorghum offers an additional route of feedstock diversification. As an annual crop, it represents less of a commitment to the producer and is something that can be contracted for on a yearly basis. Further, sorghum stocks could potentially be added to the plant's input stream starting in the first year, given its short lifecycle. Sweet sorghum growth in south Louisiana has not been studied quite as much as energy cane has, but there is enough to suppose that it could be a reliable energy crop. (Viator et al., 2009).

Objectives

The overall objective of this research is to develop an analytical framework that can be used to study the possibility of collocating ethanol processing capabilities within sugar mills and the structural change of inputs. The primary crop examined in this research will be sugarcane, the processing of which follows a fairly simple pattern, represented in Figure 1.

Sugar is the main source of profit for the mill, and as such the bulk of the profitable sugar will not be sacrificed. The first two cycles of sugar production, called first strike and second strike, remove about 80-85% of the raw sugar from the cane juice. It might be possible to process the remaining juice into ethanol using conventional methods, following the Brazilian model. The first coproduct, molasses, could also potentially be processed into ethanol using conventional methods. For collocation to become a reality though, the structural changes that must take place at the mill need to be examined.

The fibrous byproduct, bagasse, can be processed into ethanol using a cellulosic process, which could also be applied independently or jointly with other available or potential sources of biomass. It is this step in the processing cycle that we are primarily interested in. Specifically, this research examines the possibility of collocating a cellulosic ethanol processing plant at the same site as a sugar mill, to run initially on the excess bagasse from the sugar mill. The mill could also potentially run additional fibrous feedstocks through the grinders and make ethanol from the biomass, and even run sugar juice and/or molasses through the latter part of the ethanol facility to make conventional ethanol. Depending on the particular situation, this research might also be applicable to other regions that grow and process high-biomass crops, such as sweet or forage sorghum, miscanthus, switchgrass, and other grasses. To begin with though, no specially-harvested energy crops will be included in the model, only bagasse.

The potential benefits of collocating a cellulosic ethanol plant include reduced transportation costs when using on-site bagasse, fully-established transportation and unloading systems, and the ability to reuse some capital like grinders and storage. The added flexibility to switch conventional feedstocks between ethanol and sugar/molasses production depending on the market prices for each also allows the facility to maximize profits whenever prices of the two commodities change.

The potential to collocate an ethanol-processing plant alongside a sugar mill is an area of research that needs to be explored further. The goal of this research is to model such a mill using simulation techniques, and then explore some questions about the input and output conditions created by the mill. The following are the objectives of this paper:

1) The primary objective of this paper is to develop a simulation model of a sugar mill and examine the sensitivities of this with respect to inputs and output.
2) Additionally, a small collocated conventional ethanol-processing facility will be simulated, using cane juice after the second strike as a feedstock.
3) Following this analysis, a simulation of a cellulosic ethanol facility collocated with the sugar mill is incorporated.

Louisiana sugar mills are one set of stakeholders that would be interested in this research, for several reasons. If building an add-on ethanol processing facility would be a profitable endeavor that would pay for itself and provide additional revenue streams, this would interest any mill owner or cooperative seeking to increase profits. Not only could revenues be increased during the traditional sugarcane harvest season, but if other feedstocks were brought in during different periods of the year, the mill would be able to increase the period over which it has cash inflows. Additionally, the added revenue stream could diversify risk across multiple commodities and spread fixed costs out.

Sugarcane farmers are another group likely to be interested in this line of research. Sugarcane acres in Louisiana peaked in 2000 at 465,000, but since then have been decreasing by an average of two percent annually, as shown in Figure 2 (USDA, 2010). Additionally, revenues from sugar have been decreasing, as have earnings-per-acre (Salassi and Deliberto, 2006; 2007; 2008; 2009). The price of sugar did spike in 2009, but there is no guarantee that it will stay elevated for long. Expanding into the ethanol market would leave sugarcane farmers less exposed to changes in the market price of sugar.

Literature Review

There are several areas of the literature that are important to understand in order to proceed with developing a methodology for this study.

Simulation

The immaturity of the cellulosic ethanol industry presents a data-availability problem that puts some quantitative methods out of reach. However, this problem is ideally suited to the application of simulation techniques. Richardson, Klose, and Gray (2000) provide a framework for how to handle some of the challenges of agricultural simulation models. A major issue with agricultural data is the availability of data collected while the same operational conditions apply. Such conditions include policy regimes, management practices, and farm or processor practices. Richardson (2002) indicates that 20 or more comparable observations are needed to show a distribution is normal, something not likely to be possible for most of the agricultural data for this study. Additionally, to account for the likely correlation of two or more random variables, a multivariate empirical (MVE) distribution will be needed (Richardson and Condra, 1978). While Richardson, Klose, and Gray (2000) suggest that the MVE distribution would be a good approach for those variables for which there is at least a moderate amount of data, a triangular or GRKS distribution is ideal when presented with sparse data, as in Louisiana molasses prices.

Sensitivity Analysis

When developing a linear programming model or a simulation model, assumptions are made about some of the parameters in order to solve the model within the specified constraints. In reality, these assumed-known parameters are simply predictions about future states. To account for the fact that these predictions cannot actually be relied upon, some tests should be conducted to see how the model might be affected if some of these parameters took on other values. According to Hillier and Lieberman (2005) sensitivity analysis serves exactly this function. Conducting such an analysis on the various models built in these papers will demonstrate which variables cannot be changed without changing the solution. It will also show over what ranges other variables can vary without affecting our model solutions. This is valuable not only to show which variables must be watched most closely, but also to show how robust the model is to changes in certain market conditions, or how vulnerable.

Net Present Value

One of the measures by which the tested scenarios will be analyzed is their Net Present Value (NPV). NPV analysis is a technique that is used to determine the total value of a project in present cash value, which is arrived at by subtracting initial cash outlays from a discounted set for cash flows from the project. The model looks like this:

$$NPV = \sum_{n=0}^{N} \frac{F_n}{(1+d)^n} = F_0 + \frac{F_1}{(1+d)^1} + \frac{F_2}{(1+d)^2} + \cdots + \frac{F_N}{(1+d)^N}$$

Where

F_n is the net cash flows that can be realized each year

F_o is the initial cash outlay

N is the planning time span

d is the discount rate

The cash flow from each year is discounted to its present value, and all of these values are added, along with the negative cashflow from the initial setup costs. If this value is positive, the investment is acceptable. If negative, it's not acceptable, and if zero it is indifferent. The size of a project's NPV can also be used to ranking it against rival projects (Barry, et. al., 2000). By using this tool we can, for instance, determine whether a collocated ethanol facility would be a better investment than a similarly-structured stand-alone facility. This will be used for several such comparisons throughout this study.

Data and Methodology

The hypothesis that we want to test is whether or not a sugarcane mill with a built-in ethanol plant would generate any added value from producing either third-strike sugar ethanol or bagasse-ethanol. The problem is that no such mill exists.

The first goal then is to build a simulation model to approximate the operations of a sugar mill. Additionally, a simulation of a conventional ethanol facility will be added on to the sugar mill model. This facility will have the capability to process simple sugars into ethanol. The first two strikes of raw sugar will remain untouched, and the cane juice after the second strike will be used as an ethanol feedstock. The time period studied will cover 25 years, the limit of EIA's forecasts for some important inputs like natural gas and crude oil. Some factors affecting the mill's performance include:

1. Tons of sugarcane processed per day
    - A function of sugarcane yield/acre. Acres are held constant.
2. Sugar recovery (CRS)
    - Simulated with an empirical distribution based on 20 years of historical data
3. Growers' share of raw sugar and molasses
    - Held constant at 2009 level

4. Market prices of raw sugar and molasses
   - Sugar price is part of the MVE model, molasses is simulated with a GRKS distribution
5. Market price of ethanol
   - Part of the MVE
6. Factory grinding rate (tons per hour/day)
   - Starts at current representative 12000 tons/day, increases at 1% per year
7. Grinding cost per day (*variable cost*)
   - Inflated at 1% per year
8. Cane freight expenses (*variable cost*)
   - Inflated at 1% per year
9. Sugar freight expenses (*variable cost*)
   - Inflated at 1% per year
10. Offseason expenses (*fixed cost*)
    - Inflated at 1% per year
11. Employee expenses (*fixed cost*)
    - Inflated at 1% per year
12. Administrative expenses (*fixed cost*)
    - Inflated at 1% per year
13. Depreciation expenses (*fixed cost*)
    - Inflated at 1% per year

The entire NPV model is built in excel, and Simetar is used for all simulation operations.The MVE model is made up of prices and yields for sugarcane, as well as ethanol and oil prices and yields for energy crops. Molasses data is sparse, so a GRKS distribution is employed. Commercial-recoverable sugar (CRS) is simulated using an empirical distribution built from 20 years of historical data. Following Salassi (2008), the actual formulas driving the mill simulation are:

GROSS PROFIT = SALES – COST OF SALES (1a)

NET INCOME = GROSS PROFIT – FACTORY EXPENSES (1b)

The supporting equations are

SALES = (TONS x TRS x LQF x SP) (2)

+ (TONS x MOL/TON x MP)

+ (TONS x TRS x LQF x 3STRSUG x CONVFAC x EP)

+ (TONS x BAGEX x ETH/BAG x EP)

where TONS = tons of sugarcane processed (tons)

TRS = theoretical recoverable sugar (lbs/ton)

LQF = liquidation factor (%)

SP = raw sugar market price ($/lb)

MOL/TON = molasses production rate (gal/ton)

MP = molasses market price ($/gal)

3STRSUG = third strike sugar percentage (%)

CONVFAC = ethanol conversion factor (gal/lb)

EP = ethanol price

BAGEX = Excess Bagasse Percentage (dry ton rate)

ETH/BAG = gallons of ethanol per dry ton of bagasse (gal/ton)

COSTOFSALES =

[(TONS x TRS x LQF x SP x GSHRS) (3)

+ (TONS x MOL/TON x MP x GSHRM)]

+ [TONS x CANEFREIGHT]

+ [TONS x SUGFREIGHT]

+ DENATURANT

where TONS = tons of sugarcane processed (tons)

TRS = theoretical recoverable sugar (lbs/ton)

LQF = liquidation factor (%)

SP = raw sugar market price ($/lb)

GSHRS = grower's share of sugar

MOL/TON = molasses production rate (gal/ton)

MP = molasses market price ($/gal)

GSHRM = grower's share of molasses

CANEFREIGHT = hauling rate for sugarcane ($/ton)

SUGFREIGHT = raw sugar freight rate ($/ton)

DENATURANT = blended at 4.76% of eth. volume (gal)

FACTORYEXPENSES = (4)

GRINDING COSTS + OFFSEASON COSTS

\+ EMPLOY COSTS + ADMIN COSTS

\+ DEPREC COSTS + COETHCOSTS + *CELLETHCOSTS*

GRINDING COSTS = [(TONS/GRDRATE) x GRDCOST] (4.1)

COETH COSTS = COETH EMPLOY + COETH ADMIN + COETH DEPREC (4.2)

CELLETH COSTS = ETH EMPLOY + ETH ADMIN + ETH DEPREC (4.3)

where TONS = tons of sugarcane processed (tons)

GRDRATE = grinding rate per day (tons/day)

GRDCOST = grinding cost per day ($/day)

OFFSEASON = off season expenses ($/season)

EMPLOY = employee expenses ($/season)

ADMIN = administrative expenses ($/season)

DEPREC = depreciation expenses ($/season)

COETH EMPLOY = employee expenses for conv. ethanol ($/season)

COETH ADMIN = admin. expenses for conv. ethanol ($/season)

COETH DEPREC = depreciation for conv. ethanol ($/season)

Note: all equations in italics only apply for the case where a cellulosic ethanol facility is built

The outputs are raw sugar, molasses, ethanol, and bagasse. The operations of the mill itself are based on existing mills, with data gathered from personal interviews (Shudmak, 2009) and production studies (Salassi and Deliberto, 2010). On the output side, sugar and molasses prices come from ERS, and bagasse is valued by the heating energy it contains, using the price of industrial electricity from EIA, which also supplies ethanol prices.

The forecasted yields for sugarcane follow the basic formula relating yields to the price of fertilizer. Natural gas is used as a proxy for nitrogen fertilizers since projections are available from EIA. Additionally, the yields were found to have an AR(1) autoregressive process, so a single lag was used, in addition to a time trend. Thus the equation takes the following form:

$$Yield_t = f(Yield_{t-1}, t, Natgas_t) \qquad (5)$$

Ethanol prices are forecasted using an AR(1) process as well. In keeping with historical trends, ethanol price was found to be closely correlated to that of oil. Since EIA maintains projections of the price of oil, it was possible to incorporate that into the forecast equation. The formula takes the following form:

$$EthanolPrice_t = f(EthanolPrice_{t-1}, t, CrudeOilPrice_t) \qquad (6)$$

With the full simulation model, several different issues can be examined. A sensitivity analysis is used to examine how the mill is affected by changes in transportation costs as well as the expected prices of sugar. This analysis also examines whether or not producing conventional ethanol following the Brazilian model can be profitable in the US. As a curiosity, an extreme case where all sugar is diverted to ethanol production is also examined.

The second objective is to simulate an add-on cellulosic ethanol plant and incorporate this into the sugar mill simulation. The cellulosic ethanol plant will be modeled on existing plant data from Aden (2002) and Holcomb (2009) and some of the process parameters come from personal interviews (Day, 2010). The additional processing cycle means that additional prices on the input and output side will be needed. Natural gas prices come from EIA, and bagasse prices are taken from NREL. The same basic methodology is followed to study the base case, where the mill is able to obtain enough bagasse to run its cellulosic ethanol facility all year. Additionally, two other cases are studied, wherein the mill either has to rely solely on its onsite bagasse or is able to contract for enough additional bagasse to run for half the year. Finally, a comparison with a standalone mill is made to discover whether or not there are in fact synergies to be captured by collocation.

Results

In the case of the base sugarmill, the simulation model produces results in line with prior expectations. The baseline case for the sugarmill produces an NPV of $28.7 million. As Table 1(a) shows, this proves highly sensitive to sugar prices, especially on the upside. A 10% increase in the mean price of sugar produces a 35% increase in NPV, while a 15% increase results in an increase of 52%. On the downside, the effects are somewhat different. Both a 10% decrease and a 15% decrease in the mean price of sugar result in a roughly 20% decrease in NPV. The reason for this mitigation of the downside is the US sugar policy which currently has a forfeiture price of 19.81 cents per pound of sugar. When the sugar price trend is allowed to drop by large amounts, that forfeiture price is triggered more and more often, so the sugar price effectively becomes fixed at 19.81 cents per pound.

The mill is much less sensitive to the price of molasses, which is again as expected since molasses makes up a much smaller share of a mill's revenue. In each scenario tested, the largest effect was still less than a 4% change in NPV, as can be seen in Table 1(b).

Table 3 summarizes the results for the two attempts to make Brazilian-style ethanol. As can be clearly seen, the value of the project drops precipitously when the third-strike ethanol plant is added. When all of the sugar production is redirected to ethanol, things get even worse. The central insight here is that there is so little actual ethanol that can be produced in this manner that the add-on ethanol plant cannot generate enough revenue to pay for itself. In Louisiana the sugar production season is about 3 months, which is the only period during which the plant would have feedstock available. In Brazil, this period lasts at least 6 months out of most years. Running at about 25% capacity, our mill simply cannot produce enough product to make it worthwhile.

The next phase is to examine the cellulosic ethanol plant to see if it performs any differently. Table 4(a) through 4(c) summarize the results for three basic scenarios. In Table 4(a), the assumption is that the sugarmill is unable to obtain any outside bagasse and so it is limited strictly to the excess bagasse produced onsite and not burned for power. This should be considered a worst-case scenario. In the case where the ethanol plant is collocated (Sugar & Bagasse), the project has a negative NPV. For a standalone plant running the same amount of bagasse (Just Bagasse) the situation is even worse. Needless to say, this project would never go forward unless more bagasse than this were available and contracted for ahead of time.

Table 4(b) summarizes a more realistic scenario. The assumption underlying this case is that the mill has managed to contract for excess bagasse from one or two other mills, securing enough feedstock to run the plant at about half capacity. Unlike with sugar juice, bagasse is a feedstock that can be stored for significant amount of time without catastrophic losses from degradation. There are some losses during storage, but they are manageable, at less than 1% per month. With this additional stored feedstock, the collocated case is much less bad than in the previous scenario. The project actually does have a positive NPV, but the option to take on the project would still have a negative value to a previously-existing sugarmill, as the do-nothing (Just Sugar) case has about $21 million greater value. And again, the standalone case is even worse.

Finally, Table 4(c) summarizes the ideal case, and the one that would be most likely to occur if this plant were ever built. It is unlikely that funding could be secured for the project unless guaranteed feedstocks were contracted for such that the plant could run efficiently. This third case assumes just such a situation, where the ethanol plant can run at or near full capacity. The situation here is dramatically different from the previous two cases. For the collocated plant, the NPV is positive and greater than the do-nothing case, meaning the project has positive value for a previously-existing sugar mill. The standalone plant also has a positive value, roughly equal to the sugarmill's value, coincidentally. What is especially interesting about this case is that it vividly illustrates the actual value of collocation. If you take the sum of the two standalone plants, and subtract this from the collocated plant, the difference comes out to $3 million. This represents the additional value of producing sugar and bagasse-ethanol together at the same facility rather than at separate locations. This value comes from two primary sources: savings on transportation costs, and the freely available nature of the onsite bagasse. It is assumed that all bagasse that comes from an external mill will be purchased, whereas the bagasse used from the onsite excess is free. In fact, there is a negative cost associated with it due to the avoided cost of landfilling the excess, but the the purposes of this model, it was left at zero.

There is still a handling cost associated with the local material, but the savings from transportation and purchasing is great enough to make a strong case for collocation.

Finally, Table 5 shows the sensitivity of this collocated plant to the price of ethanol. The projected means were varied by the percentages shown, and the effects were dramatic. For each 5% change in the price of ethanol, the NPV changed by about 13% in the same direction. This is as expected. Table 6 summarizes the same collocated plant's sensitivity to the price of sugar. On the upside, the plant is still quite sensitive to sugar, though not so much as in the standalone sugarmill case. For each 5% increase in mean sugar prices, the NPV increases by about 9%. On the downside, the sugar forfeit price comes back into play. The first 5% decrease reduces NPV by about 7%, but then the decreases in value taper off until they level out at about an 11% reduction overall, when sugar price is essentially constant at the forfeiture price.

Summary and Conclusions

The basic goal of this study was to determine whether or not it might be worthwhile to collocate an ethanol processing facility with a sugarmill in South Louisiana. Two baseline options were explored: conventional ethanol from sugar juice, and cellulosic ethanol from excess bagasse fiber. As was expected, sugar juice ethanol was not found to be a profitable venture. Even taking just the small third strike of sugar represented a significant loss in value for the mill. However, the real fatal flaw with the plan proved to be the short sugarcane season available in Louisiana. The extremely limited nature of the sugar feedstock meant that the ethanol plant had to run at very limited capacity and was never able to make enough revenue to pay for itself.

Cellulosic ethanol from bagasse presented a rather different picture. So long as the mill could secure enough bagasse to run at or near full capacity, the collocated plant offered significant added value to the sugarmill. The value of collocation was also determined and found to be a significant positive number.

A formal breakeven analysis was not performed, but preliminary results in that line indicate that for the collocated cellulosic ethanol plant to represent added value to a previously existing sugarmill, enough feedstock would have to be secured to run the plant at about 75% capacity. Given the representative mill size of roughly a million tons of cane per season, this means that the mill would have to buy the excess bagasse from 4-5 other sugarmills. This seems like a reasonable possibility, but to secure funding for this sort of project, long-term contracts would have to be in place. So long as such contracts could be written to supply at least that break-even amount, the model indicates that the project has a chance of success. In fact, over the 10,000 iterations simulated, the value of the do-nothing case never exceeded the value of the collocated plant, with full utilization. A stochastic dominance and SERF analysis will be used to examine this situation more fully once the breakeven points are better defined.

This research has several areas of potential expansion. Adding in harvested energy crops could make the cellulosic ethanol plant significantly more robust to feedstock availability, and possibly allow for a larger plant as well. Additionally, a real options valuation approach to this area of study could offer a better picture of viability of the various component projects. This, coupled with a stochastic dominance analysis, would provide an even better decision tool for stakeholders.

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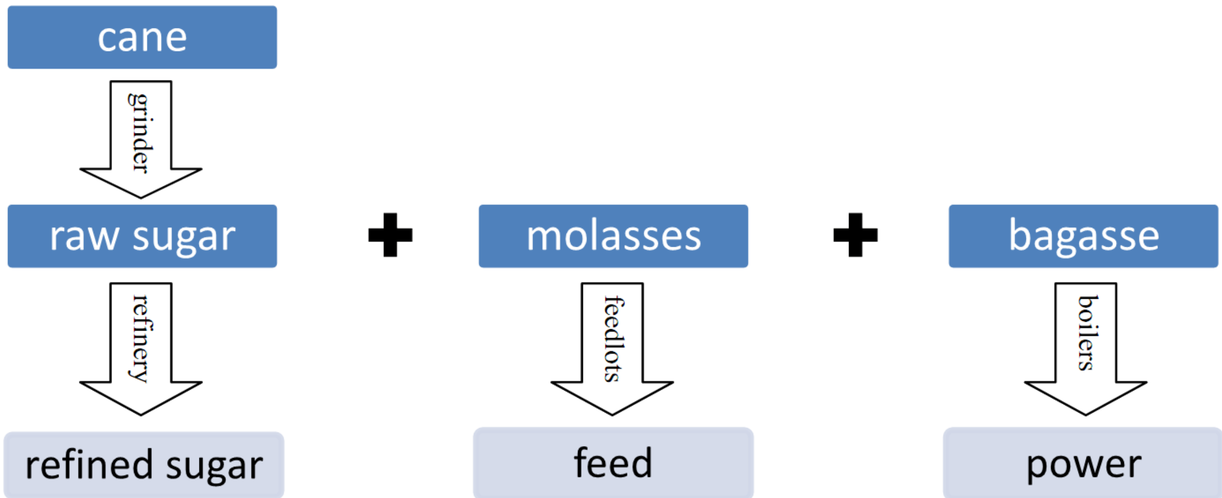
Figure 1



Darby, 2010

Figure 2

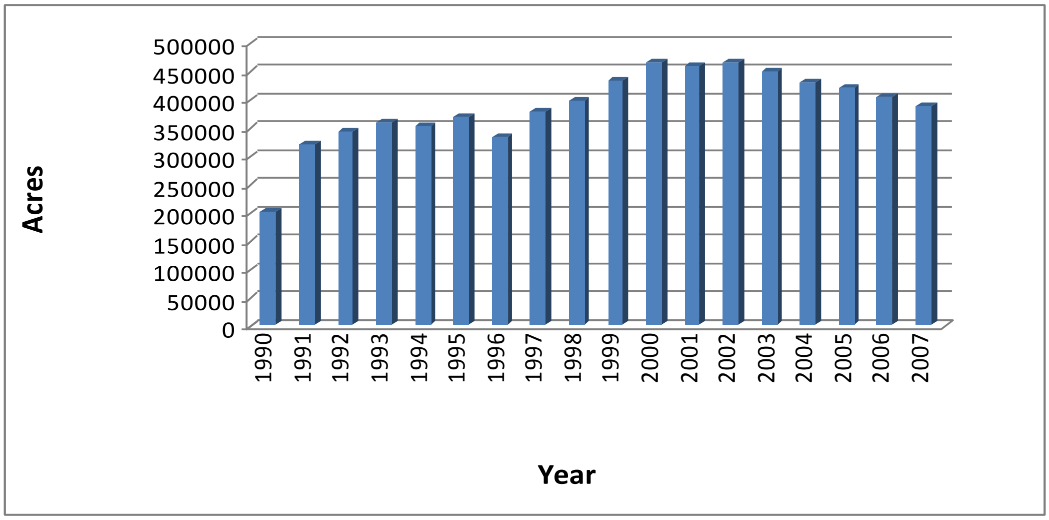


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Table 1: Effect of Sugar and Molasses Prices on NPV

Table 1(a) – Sugar Prices

	Baseline	10% Decrease	10% Increase	15% Decrease	15% Increase
Mean	$ 28,694,267	$ 22,684,973	$ 38,597,035	$ 22,432,440	$ 43,592,730
StDev	$ 2,054,216	$ 1,744,929	$ 2,300,689	$ 1,740,762	$ 2,421,590
CV	7.16	7.69	5.96	7.76	5.56
Min	$ 21,607,318	$ 15,342,794	$ 30,886,183	$ 15,244,753	$ 35,507,248
Max	$ 35,210,527	$ 28,394,484	$ 45,804,080	$ 28,215,693	$ 51,117,330

Table 1(b) – Molasses Prices

	Baseline	5% Decrease	5% Increase	15% Decrease	15% Increase
Mean	$ 28,694,267	$ 28,374,523	$ 29,013,962	$ 27,734,903	$ 29,653,160
StDev	$ 2,054,216	$ 2,048,850	$ 2,059,740	$ 2,038,596	$ 2,071,367
CV	7.16	7.22	7.10	7.35	6.99
Min	$ 21,607,318	$ 21,319,948	$ 21,894,688	$ 20,744,786	$ 22,469,428
Max	$ 35,210,527	$ 34,849,888	$ 35,571,166	$ 34,128,610	$ 36,292,444

Table 2: Effect of Increased Transportation Costs

	Baseline	5% Decrease	5% increase	10% increase	15% increase
Mean	$ 28,690,548.15	$ 30,303,413.18	$ 27,076,023.71	$ 25,458,862.64	$ 23,837,567.56
StDev	2081521.846	2097891.487	2066188.926	2052031.396	2039785.193
CV	7.255078695	6.922954435	7.631064843	8.060184877	8.557019033
Min	$ 22,207,323.64	$ 23,804,654.30	$ 20,598,771.05	$ 18,983,091.54	$ 17,362,607.69
Max	$ 34,688,600.27	$ 36,362,067.19	$ 33,015,133.35	$ 31,341,666.43	$ 29,668,199.52

Table 3: Sugar and Ethanol

	Just Sugar	Third Strike	All Ethanol
Mean	$ 28,686,613	$ (21,665,159)	$ (22,737,815)
StDev	2061498.28	2831911.823	11834959.84
CV	7.186272855	-13.07127181	-52.04968015
Min	$ 21,781,635	$ (30,659,568)	$ (57,514,750)
Max	$ 35,160,532	$ (12,522,653)	$ 15,785,328

Table 4: Adding Bagasse

Table 4(a): 90 day supply

	Just Sugar	Sugar & Bagasse	Just Bagasse
Mean	$ 28,686,613	$ (12,727,244)	$ (47,562,931)
StDev	2061498.28	2911268.079	1204340.271
CV	7.186272855	-22.87430087	-2.532098531
Min	$ 21,781,635	$ (22,167,077)	$ (50,893,708)
Max	$ 35,160,532	$ (2,949,335)	$ (43,654,517)

Table 4(b): 180 day supply

	Just Sugar	Sugar & Bagasse	Just Bagasse
Mean	$ 28,686,613	$ 7,864,223	$ (25,376,703)
StDev	2061498.28	3311463.957	2211555.379
CV	7.186272855	42.10796357	-8.71490425
Min	$ 21,781,635	$ (2,999,005)	$ (31,536,563)
Max	$ 35,160,532	$ 19,156,393	$ (18,229,546)

Table 4(c): Year-round supply

	Just Sugar	Sugar & Bagasse	Just Bagasse
Mean	$ 28,686,613	$ 60,739,533	$ 28,938,278
StDev	2061498.28	5578802.842	5510013.156
CV	7.186272855	9.184796989	19.04057009
Min	$ 21,781,635	$ 44,735,439	$ 12,693,719
Max	$ 35,160,532	$ 78,692,558	$ 46,433,384

Table 5: The Effect of Ethanol Price on Collocated Plant

	Baseline	5% Decrease	5% Increase	10% Decrease	10% Increase	15% Decrease	15% Increase
Mean	$ 60,788,348	$ 52,845,243	$ 68,614,340	$ 44,769,238	$ 76,329,371	$ 36,569,240	$ 83,948,278
StDev	$ 5,905,555	$ 5,818,884	$ 5,995,777	$ 5,712,743	$ 6,092,763	$ 5,564,404	$ 6,195,476
CV	9.71	11.01	8.74	12.76	7.98	15.22	7.38
Min	$ 39,270,139	$ 32,038,336	$ 46,501,941	$ 24,806,534	$ 53,733,743	$ 17,574,732	$ 60,965,545
Max	$ 82,204,542	$ 74,053,704	$ 90,355,381	$ 65,834,851	$ 98,506,219	$ 57,190,579	$ 106,657,058

Table 6: The Effect of Sugar Price on Collocated Plant

	Baseline	5% Decrease	5% Increase	10% Decrease	10% Increase	15% Decrease	15% Increase
Mean	$ 60,788,348	$ 56,279,776	$ 66,139,278	$ 54,119,841	$ 71,508,912	$ 53,822,106	$ 76,801,103
StDev	$ 5,905,555	$ 5,944,046	$ 5,829,175	$ 5,932,918	$ 5,756,368	$ 5,937,628	$ 5,690,453
CV	9.71	10.56	8.81	10.96	8.05	11.03	7.41
Min	$ 39,270,139	$ 34,014,009	$ 45,180,789	$ 30,532,084	$ 51,098,347	$ 29,974,276	$ 56,463,565
Max	$ 82,204,542	$ 77,456,642	$ 87,301,700	$ 75,559,686	$ 92,448,529	$ 75,314,871	$ 97,595,359