Breaking into the Cellulosic Ethanol Market: Capacity and Storage Strategies

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Introduction

A new Renewable Fuels Standard (RFS) was passed in 2007 with the ratification of the Energy Independence and Security Act, mandating that fuel producers use at least 36 billion gallons of biofuels by 2022 and placing an emphasis on the production of cellulosic ethanol. Of the 36 billion gallons, 16 billion gallons are expected to be produced via "cellulosic ethanol" (OPS, 2007). In order to reach the mandated levels of biofuel production, each region or state within the United States should produce the energy crop for which they have a competitive advantage.

Unlike the conventional corn-to-ethanol supply chain that is well developed, the biomass supply chain still has significant hurdles that it must cross. Two of the most important issues to address are plant capacity and storage strategies. In the conventional ethanol industry, plant sizes tend towards larger capacities as the infrastructure is already geared towards efficient transportation and storage of grain-based feedstocks. In the cellulosic ethanol supply chain, the feedstocks have higher moisture contents and thus pose significant additional transportation and storage issues, potentially leading to a generally smaller plant size.

Numerous feedstocks are being considered for use in the production of cellulosic ethanol. Crops such as switchgrass, miscanthus, big bluestem, sweet sorghum, energy cane, and alfalfa are being evaluated across the country. However, one of the primary issues with these crops is enticing producers to adopt the production of these crops in advance or while a cellulosic ethanol processing facility is under construction.

There are two basic ways in which the development of a cellulosic ethanol industry might take place. First, processors could build the plant and assume that the feedstock needed to

operate the facility will come. Second, processors could contract for the production of energy crops and then build the plant. However, both of these approaches present a first mover problem that must be resolved for the industry to develop. One possible solution to this is to locate a cellulosic ethanol plant in a location that already has one or more feedstocks or by-products that are viewed as waste products.

In order to break into the ethanol market, a plant will have to make use of the feedstocks available. The inbuilt sugarcane infrastructure in south Louisiana makes for a tempting candidate, but sugar is generally too profitable for producers to be interested in diverting any sugarcane to produce conventional ethanol (Salassi, 2006). The large quantities of bagasse produced as a byproduct of the sugarcane milling process might be a different story. The sugarcane industry is one that has large amounts of cellulosic material that is discarded as a by-product that could potentially be used for cellulosic ethanol. Further, using this by-product from this industry helps to solve the first mover problem. Locating a cellulosic ethanol facility next to one or more sugar mills allows for the plant to be constructed and begin operation without first contracting with growers to produce another feedstock. The primary advantage of this is that it gives producers confidence that if they do contract with the plant they a market exists for their energy crop, whereas, other strategies for the development of this industry do not offer this (Day, 2010).

Of particular interest to Louisiana is the possibility of producing commercially-viable quantities of cellulosic ethanol from sugarcane, either via bagasse, which is the fibrous cellulose-based byproduct of milling sugarcane, or high-fiber energy cane varieties. This is one of the primary benefits of locating a cellulosic ethanol plant in Louisiana. In 2008 Louisiana produced 12 million tons of sugarcane producing 1.2 million dry tons of bagasse that is viewed as a waste

product for sugar mills (USDA, 2009). For cellulosic ethanol to become a viable option, two profitability conditions must be met. First, the grower of the feedstock must be profitable, and secondly the biofuel producer must be profitable. The feedstock producer's profit has been examined in previous research, but production profitability has not been examined from the perspective of the biofuel processor. The objective of this research is to explore the possibility of locating a cellulosic ethanol facility in the south Louisiana sugar belt. Three different scenarios are examined using Net Present Value (NPV) analysis to gauge their feasibility. Additionally, a sensitivity analysis is conducted to determine how sensitive the model is to transportation costs, feedstock costs, and ethanol price.

Due to its readily available nature and current status as a waste byproduct, bagasse can help solve the first mover problem. However, it is not a feedstock that can necessarily be relied on in quantities large enough to sustain year-round production for very many years. Much research is actively being done on potential uses for excess bagasse, and competition for this feedstock is expected to drive the price up in the future (Morgan, 2009; Wearegreen, 2010). This, in addition to the large distances needed to travel to buy enough bagasse for year-round operation, means that an ethanol plant in this area will actively seek to diversify its feedstocks shortly after beginning operation. Furthermore, once the plant is up and proven, the Louisiana sugar belt presents several other opportunities for energy crops. High-fiber breeds of sugarcane, called 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.

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 from year to year. 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).

Methods

The ideal method to approach this study would be to start with the waste feedstock (bagasse) and add feedstocks as producers see that the plant represents a viable partner. This requires a model that dynamically switches feedstocks from year to year. However, the current version of the model is static and is not capable of this year-to-year feedstock switching. For now, three different potential cases are instead examined separately: 1) a plant running entirely on bagasse sourced from multiple sugar mills, 2) a plant that sources bagasse from multiple mills and also has supplier(s) for a fairly low-commitment feedstock (sweet sorghum), and 3) a plant that has sweet sorghum supplier(s), at least two bagasse suppliers, and long-term-contracted supplier(s) for energy cane. For each scenario, the net present value (NPV) is calculated, along with internal rate of return (IRR) and return on assets (ROA).

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

The representative sugar mill grinds 10,000 tons of sugarcane a day. This produces about 1,000 dry tons of bagasse each day, about 80-85% of which is burned to supply all the steam power that is needed to run the mill. The remaining bagasse (estimated to be about 150-200 dry tons) is excess, and must be disposed of. Because this excess bagasse represents a waste product, most mills run their boilers very inefficiently and/or let off excess steam, so as to burn off as much total bagasse as possible (Day, 2010).

Based on the above, a relatively small plant size of 10 million gallons per year with an estimated yield of 85 gallons of ethanol per dry ton of bagasse, about 300 dry tons of bagasse per day could supply the plant's input needs. If bagasse is used as it comes in throughout the 90 day Louisiana sugarcane harvest season, the plant could stay supplied if it could source bagasse from 2 or 3 sugar mills.

Scenario 1

Sourcing bagasse from seven or eight sugar mills would provide enough bagasse to operate the 10 million gallon facility at full capacity for a year. This would be a feasible solution in the short run, but competition for the bagasse is assumed to eventually arise, so a 100% bagasse plant is not considered sustainable in the long run.

Scenario 2

The second scenario represents one wherein the low-commitment feedstock (i.e. sweet sorghum) is contracted. With 6000 acres planted, 1000 tons of sweet sorghum is brought in per

day during its July-September harvest window, and the remaining three quarters of the year the plant is still run on bagasse.

Scenario 3

The third scenario adds 6000 acres of energy cane. These acres will supply about 2200 tons of cane per day for the planned 90 day harvest. The fiber is stored and conventional ethanol is produced from the juice during this period. In the following quarter, the stored fiber is used to make cellulosic ethanol. Sweet sorghum is harvested during its summer quarter and bagasse is purchased and processed during the sugarcane harvest quarter. This is currently considered to be the most stable long-run case, involving the least amount of storage costs and losses, as well as the most diversified feedstock portfolio (Table 1).

Data

The plant cost data is adapted from that in an NREL study, an Oklahoma State model, and from personal interviews (Aden 2002; Holcomb, 2009; Day, 2010). The plant uses a lime-based pretreatment process, and grows its own enzymes using a quantity of reserved biomass. Fermentation is done in batches, and distillation is continuous. The waste stream from distillation, or vinasse, is processed in an anaerobic digester. This produces three additional streams, biogas, landfillable solids, and a liquid stream. The liquids are further processed in an aerobic digester, producing additional biogas and a final solid waste.

The final waste, landfillable solids and biogas are all burned in a boiler/turbogenerator using a Circulating Fluidized Bed Combustor (CFBC) which is optimal for its capability to burn a wide range of materials indiscriminately. There are two additional waste streams that have potential value, the lignin released during pretreatment and the primarily-yeast solid residue from

the fermentation stage. Both are potentially marketable, but as no proven market value can really be relied on, both are instead considered to be burned in the boiler as well. This CFBC boiler generates more than enough steam power to run the entire plant. Theoretically the excess power could be sold back to the local grid, but it is currently assumed that that will not happen.

Sugarcane bagasse is (on a dry matter basis) composed of about 60% carbohydrates (cellulose and hemicellulose) and the remainder is lignin and other solids. Those carbohydrates can, via pretreatment and enzymatic hydrolysis, be converted to fermentable sugars. Once these sugars are obtained, fermentation and distillation of ethanol follow the familiar pattern common to other ethanol processes. One mole of these sugars produces one half mole of ethanol and one half mole of carbon dioxide, so the stoichiometric yield is theoretically 91.1 gallons per dry ton. However, due to losses and inefficiencies, the real-world yield is about 85 gallons per ton and this is the figure used (Day, 2010).

Based on the sucrose content of energy cane and the yield for sucrose syrup, the juice from energy cane is expected to produce 12.7 gallons per ton of cane (Salassi, 2006). Based on a fiber percentage of 15% the energy cane fiber is estimated to yield 11.9 gallons of cellulosic ethanol per ton. By a similar process, sorghum is estimated to yield 14 gallons of juice ethanol and 10.3 gallons of cellulosic ethanol per ton (Table 2).

Ethanol and gasoline denaturant prices are both taken from EIA projections. This may be replaced by stochastic simulation in a future version of the model. Denaturant is blended at 4.76% of total volume, as per RFA (RFA, 2003).

Results

In general, all scenarios had positive NPVs for the fifteen year time horizon examined. Of the three scenarios the second has the highest positive NPV at $27,074,918 (table 3). However, as the processor diversifies their feedstocks NPV for the plant decreases. The primary reason for this is that as the plant diversified into other feedstocks, the overall gallons per ton of feedstock diminished.

Even though scenario one does not have as large of a positive NPV as scenario two does it still provide evidence that under these assumptions the construction of a 10 million gallon per year bagasse ethanol facility per year would be profitable. Furthermore, it would provide an answer for the first mover problem and let the processor have additional time to allow feedstock producers to be contracted with for the production of alternative feedstocks. The large positive NPV for scenario one also could allow for the possibility of transportation costs to rise significantly. This is important because this plant is a standalone plant and all feedstocks have to be trucked to the plant from one of the eleven sugar mills in the state.

From this analysis it seems that sweet sorghum may be a good option as a second feedstock as shown in scenario two. This is due to several reasons. First, sweet sorghum allows the feedstock producers to respond quicker to market signals coming from the ethanol industry relative to energy cane. Second, 15 ton per acre sweet sorghum is capable of producing the same amount of ethanol per ton as energy cane. Third, the cost to purchase sweet sorghum is significantly lower if sweet sorghum is being produced on the fallow sugarcane lands. If the acres used are not fallow lands, additional planting costs would make the cost of this feedstock almost double, decreasing the NPV.

Scenario three provides the lowest NPV of the scenarios examined. Primarily this is because current energy cane varieties are expensive to source because their yields are nearly the same as sugarcane. As the genetics for this crop improve and yields are driven up the cost to source this feedstock will fall. According to Mark et al. (2009) energy cane yields could reach 50 plus tons per acre, reducing the feedstock cost from $27.00 per ton to less than $20. Furthermore, one other issue with contracting for energy cane is it will reduce the flexibility of the processor and the producer's ability to respond to changing market conditions.

Sensitivity Analysis

In general, scenarios one and two are far less sensitive to increases in cost compared with scenario three. Three key drivers to this model are feedstock costs, ethanol price, and transportation costs.

Given that many of these potential biomass crops are high in moisture content, transportation costs are very important. For scenario one the feedstock costs could rise from $24.73 per ton to $35 and the plant would still show a slightly positive NPV as long as everything else stayed the same. For scenario two if the sweet sorghum price remained constant, the bagasse price could double and NPV would still be positive. Alternatively, if bagasse remains constant then sweet sorghum price could increase to $52 per ton before NPV goes negative. In the third scenario if bagasse changes and the others remain constant then bagasse price would need to increase by more than $14 per ton. If energy cane price is permitted to rise it can only do so by $3. Whereas, if sweet sorghum is permitted to rise it can almost double before NPV goes negative.

Ethanol price is another key driver of plant profitability. In scenario one ethanol prices could decrease by $0.22 per gallon from each year of EIA (2009) ethanol projections before NPV goes negative. For the second scenario, ethanol price could decrease by $0.23 per gallon in each year before NPV falls below zero. Lastly, for scenario three ethanol price can only fall by $0.02 before NPV goes below zero.

Lastly, transportation costs are very important for cellulosic ethanol facilities. In scenario one the cost of transporting bagasse could increase from $0.25 to $0.81 per ton per mile before the NPV falls below zero. In scenario two if the price of hauling bagasse is held constant then the cost of hauling sweet sorghum can raise by $1.40/ton/mi and vice versa bagasse could increase to $1.55/ton/mi. In case three the model is much more sensitive and cost of transportation for bagasse, energy cane, and sweet sorghum could increase to $0.95, $0.32 and $0.46, respectively.

Conclusions

Louisiana provides some attractive characteristics for cellulosic ethanol locales. First, the sugar industry that provides a cellulosic based waste stream that can be converted into ethanol. Second, a longer growing season than most other states in the union allows for increased biomass production. Third, producers in the sugar industry are searching for alternative crops to produce and they know how to handle large amounts of biomass. In addition to these characteristics this model provides some evidence that under the assumed conditions a 10 million gallon ethanol facility located in the Louisiana Sugarcane Belt could be a profitable investment for a company. Lastly, given the assumptions of this model, a solution can be provided for the first mover issues that many cellulosic ethanol processors are facing.

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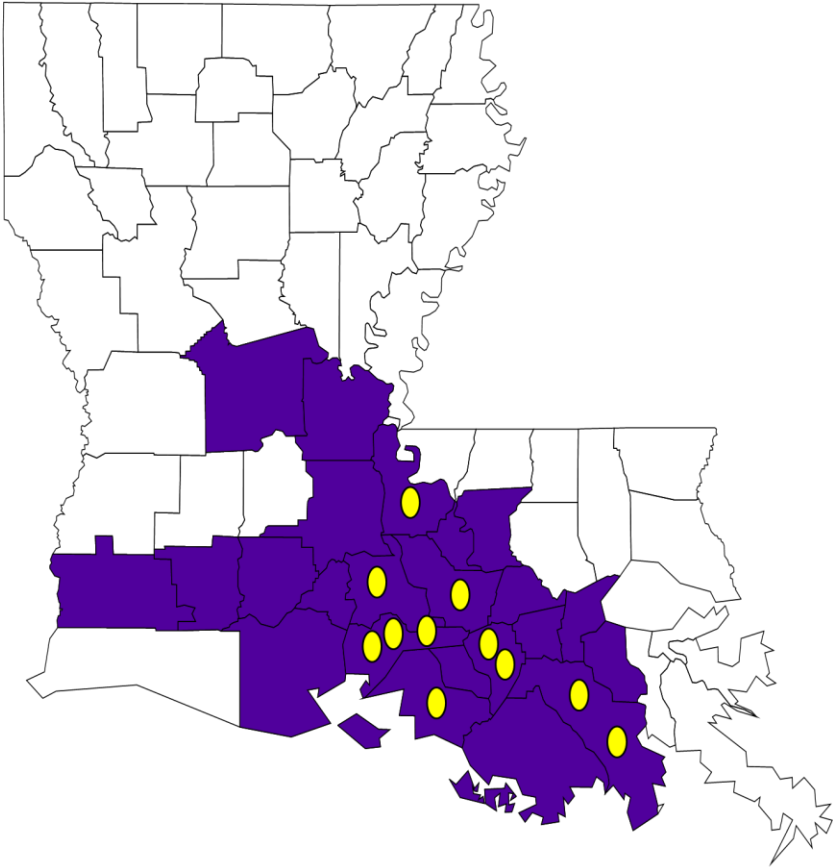WeAreGreen. http://wearegreen.ca/ retrieved on 01/10/10

Figure 1: Sugar Mill Locations

Table 1: Diagram of Cases and Quarters

	January-March	April-June	July-September	October-December
Case 1	Bagasse	Bagasse	Bagasse	Bagasse
Case 2	Bagasse	Bagasse	Sweet Sorghum	Bagasse
Case 3	Energy Cane	Energy Cane	Sweet Sorghum	Bagasse

Table 2: Crop and Ethanol Yields

	Bagasse	Energy Cane	Sweet Sorghum
Yield	n/a	35 tons/acre	15 tons/acre
Gallons/Ton Juice Ethanol	n/a	12.69 gal/ton	14 gal/ton
Gallons/Ton Cellulosic Ethanol	85 gal/dry ton	11.89 gal/ton	10.3 gal/ton

Table 3: Net Present Value Results

	NPV	IRR	ROA
Case 1	$15,545,771	15.85%	6.31%
Case 2	$27,074,918	19.89%	9.07%
Case 3	$4,838,985	11.88%	3.74%