Energy Cane Usage for Cellulosic Ethanol: Estimation of Feedstock Costs

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Introduction

Significant energy policies that have influenced the expansion of the ethanol industry are: the banning of Methyl Tertiary Butyl Ether (MTBE), 2005 Energy Policy Act, and the 2007 Energy Independence and Security Act. The designated phasing out of MTBE in 2000 created an opportunity for ethanol to become the primary oxygenate used in the production of gasoline (EIA, 2005). More recently, expansion in the ethanol industry has been partially driven by the passing of the 2005 Energy Policy Act and the 2007 Energy Independence and Security Act. The 2005 Energy Policy Act established a Renewable Fuel Standard (RFS), mandating 4 billion gallons of biofuels annually be produced by 2006 and rising to 7.5 billion gallons annually by 2012 (Tyner, 2007). The RFS has continued to drive the ethanol industry expansion, and both of these mandated levels were surpassed before their deadline, fueling the need for a new RFS. A new 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 placed an emphasis on the production of cellulosic ethanol (OPS, 2007). The addition of cellulosic ethanol could result in biofuels becoming a significant player in the overall U.S. energy portfolio.

In 2007, only 13.1 billion bushels of corn were produced on 93.6 million acres (USDA, 2008). Assuming that all of this corn was converted into ethanol it would produce enough fuel to last the United States about 61 days, given the 2007 level of 9,253,000 barrels of gasoline per day(EIA, 2007)[1]. Additionally, if corn continues to be the primary source of biofuel production approximately 12.9 billion bushels of corn will be required to fulfill the 36 billion gallons of biofuels needed by 2022. This level of corn ethanol is not a sustainable position in the United

[1] Assumes a conversion ratio of 2.75 gallons of ethanol per bushel.

States given the demand for corn for feed grains in the livestock industry, food and fiber system, and the export sectors of the United States economy.

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. For example, in the Midwest, corn will continue to be the crop of choice and for states in the south sugarcane or some other biomass crop may be their choice. Specifically, energy cane could be a crop the southern states (i.e. Florida, Louisiana, and Texas) have a competitive advantage in producing. Energy cane and sugarcane are from the same genus, *saccharum*, and the only difference between them is energy cane is bred for high fiber content and sugarcane is bred for low fiber content but high sugar content.

While energy cane is not a new concept, cellulosic technology is still in the developmental phase. Only a few companies (e.g. Abengoa, Broin, Iogen, and Verenium) are currently experimenting with producing ethanol from bagasse, a by-product of sugarcane, or other cellulosic material (e.g. wheat, switchgrass, forestry products, etc.). Louisiana is home to Verenium's pilot plant operating in Jennings using bagasse in a cellulosic ethanol process. According to the Renewable Fuels Association (2008), there is a potential of 1.3 billion tons of sustainable cellulosic material that could produce an estimated 60 billion gallons of ethanol annually in the U.S. Additionally, the majority of this potential biomass is being harvested from second generation feedstocks, which are feedstocks are not used for foods (BRDi, 2008).

Objectives

Like energy cane, many of the crops including energy cane that are being considered for use in the production of cellulosic ethanol are not traditionally produced crops. A couple of exceptions to this might include switchgrass and corn. Switchgrass can be used to pasture or produce feed for livestock, and corn residue that is left over after harvest can be collected for conversion into ethanol. However, the production of nontraditional crops creates a situation where producers are uncertain about the production costs and the breakeven price needed to maintain production. According to Beierlein et al. (1995), breakeven analysis can be used effectively as a "first screening procedure" or "ballpark technique" for a top-level examination. Khanna et al. (2008) employ a Net Present Value (NPV) framework to determine the breakeven price required to cover the cost of production for both switchgrass (10-year time horizon) and miscanthus (20-year time horizon). Hallam, Anderson, and Buxton (2001), also use a breakeven analysis to determine the require price need to cover the total production costs for reed canarygrass, switchgrass, big bluestem, alfalfa, sweet sorghum, forage sorghum, and maize. In an effort to apply and advance this technique, we've written this paper with two objectives: 1) estimate the breakeven price producers must receive to cover energy cane's cost of production and 2) determine the tons per acre of energy cane that must be grown in order to equate it with corn ethanol production costs

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Methodology

Florida and Louisiana are the largest producers of sugarcane in the United States with 375,000 and 390,000 acres in 2007, respectively (USDA, 2008). An established infrastructure and energy cane's ability to produce biomass are two key reasons that make this an attractive crop for this region. Energy cane is lower in sucrose or brix content but higher in fiber content than traditional sugarcanes varieties (e.g. LCP85-384). Table 1 shows a yield comparison between energy cane varieties Ho 00-961 and HoCP 91-552 released in 2007 compared with LCP85-384, which has been the predominate variety of sugarcane grown in Louisiana. An additional energy cane variety L 79-1002 was also released, but there is no yield data yet available. However, there have been reports of this variety yielding over 100 tons of wet cane (wt) per acre, which is significantly higher than the 30 wt/ac the current industry is producing.

There are no operational commercial cellulosic processing facilities operating in the United States; therefore, price data must be estimated because no actual data is available. The *2008 Sugarcane Production in Louisiana* budgets are the key data used for this stage of determining prices (Salassi and Deliberto, 2008). The representative farm size in Louisiana is 1000 acres. All assumptions made in the *Sugarcane Production in the Louisiana* budgets are applied in this study with only minor modifications made to the original budgets. These changes reflect the idea that grower will no longer be paid based on sugar content but paid solely based on total biomass (i.e. wt) delivered to the processor.

Grower Breakeven Costs

This paper considers a breakeven feedstock cost the processor needs to pay growers in order to cover variable, fixed, overhead, land rental, and transporting costs[2]. A one-sixth land rental arrangement is assumed in this paper, following the traditional sugarcane rental arrangement. Additionally, there is an assumption that growers receive a $3.50 per wt transportation credit for every wt delivered to the processor. The development of energy cane

[2] Variable costs, fixed, and overhead costs are summed up into a category called direct costs.

varieties is still in the early stages of research and development; therefore, the true yield potential is unknown. For the purposes of this paper a range of 30 to 75 wt/ac is analyzed.

Energy cane is a perennial crop, and growers have the ability to implement varying stubbling lengths. Before getting into a discussion of stubbling lengths, it is important to discuss the production process of energy cane. The production of either sugarcane or energy cane can be broken up in to several distinct phases. Production of sugarcane typically begins with the purchase of seed cane that is then planted. This plant cane is then harvested and used to expand the sugarcane acres. In the second year the first harvest for use in sugar production is made is known as "1st stubbling". Then in the following years a 2nd, 3rd, and further stubblings are harvested. After a fifth stubbling in Louisiana, the majority of farmers fallow the land for a year before planting back seed cane. Fourth and sixth stubbling rotations can also be implemented and are also considered in the analysis.

Comparison Between Cellulosic and Corn Ethanol

Production costs for corn ethanol and cellulosic ethanol are quite different and the breakdown for each is represented in Figure 2. The major agricultural crop used for ethanol production in the U.S. is corn, which is the benchmark of comparison for cellulosic ethanol. Ethanol production per dry ton (dt) of biomass varies depending on the pretreatment process and the enzyme technology used. In order to account for this variability in cellulosic ethanol production technologies the following factors are analyzed at varied levels: ethanol production per dry ton (e.g. 60 and 80 gal/dt), enzyme costs, other costs (i.e. preprocessing, fermentation, and labor), and capital costs. Corn prices, which account for over 70 percent of the cost of production for corn ethanol are also varied (i.e. from \$3.50 to \$5.00) showing how total costs for corn ethanol production change relative to cellulosic. These values represent a range of numbers that the U.S. average price for corn could be over the next couple of years. Collins (2007) provides the base by-product, enzyme, other, and capital costs used in the analysis.

Results

Producer Breakeven

Viability of energy cane as a cellulosic ethanol feedstock is dependent on the producers' ability to control costs and on the development of new varieties with increased yields and longer stubbling lengths. The price they receive varies by wt per harvested acre and length of stubbling (Table 3). In general as length of stubbling increases, the breakeven price required decreases because planting costs are spread over more years of production. Additionally, as wet ton yield per harvested acre increases the price required inversely decreases.

Table 2 and Table 3 show the breakeven costs required by growers given various costs for situations analyzed in terms of both wt and dt, respectively. In order for this newly developing industry to take acres away from the mature sugarcane industry and from other crops, the energy cane process will have to provide growers with an acceptable return. The average price of sugarcane on a per acre basis in Louisiana from 2000 to 2007 was $25.67, about $3.00 less than the national average (NASS, 2008). Given that the production practices are the same for both crops, processors will have to provide growers with comparable prices. The combination of averaging 35 wt/ac and reaching the sixth stubbling would provide the grower with a comparable price. However, this only addresses what the processor has to pay the grower for the crop itself and does not account for transporting the biomass to the processing facility. A

$3.50 per wet ton transporting cost for the processor has to be included, which brings the total cost from field to processor to $29.38/wt ($73.95/dt). As the price of fuel rises this transportation factor will become increasingly important, and it is possible the processor could shift the burden of rising transportation costs to the grower.

The current, available energy cane varieties for growers to plant provide approximately the same wt per acre as the typical sugarcane varieties in commercial production. Therefore, as research in the area of energy cane varieties progresses and per acre wt rises, both the processors and growers will be able to accept a lower price per wt on a per acre basis. In order to get the breakeven costs including transportation costs below the average sugarcane price per ton on a 4th stubbling rotation, the energy cane yield should be at least 45 wt/ac. This is a feasible output level given that in years with optimal growing conditions current sugarcane varieties can reach this level. Additionally, according to reports energy cane variety L79-1002 has the potential to produce 100 wt/ac; however, to date no published research can substantiate this. Increasing yield has a positive externality of decreasing the feedstock costs allowing for increased competiveness for cellulosic processors over corn ethanol processors.

Corn Ethanol Production Costs vs. Cellulosic Ethanol Production Costs

Corn is the primary crop used in the United States for ethanol production. The fermentation method used to produce corn ethanol has been employed in the United States in ethanol production for over a century. In order for cellulosic ethanol to be a viable ethanol production process it must be able to produce ethanol at a cost no greater than that of corn ethanol. The distribution of production costs between corn and cellulosic ethanol are quite different (Figure 2). The major areas of difference between the two production processes are found in enzymes, feedstock, and by-products costs. The cellulosic ethanol process is heavily dependent on enzymes to break down biomass. Since the industry is still in its infancy stages, many of the enzymes currently used are still in their research and development stages, thus increasing their cost. Currently, feedstock costs make up a significantly smaller proportion of total costs for cellulosic ethanol, but as other costs and enzyme costs decrease, feedstock costs as a proportion of total costs will increase as seen with corn ethanol. However, in the short-run reducing feedstock costs by increasing yield per acre is the easiest way to decrease the cost of cellulosic ethanol from energy cane. Another hindrance to energy crops is that by-products produced by the cellulosic ethanol industry are less valuable compared to those produced from corn ethanol.

The competiveness of cellulosic ethanol is dependent on several factors such as cost of production and the efficiency of the processing facility (Figures 2-5). Figure 3 shows how production costs vary given corn is \$3.50/bu; cellulosic ethanol can be produced at 60 gal/dt, and have a 5^{th} stubble rotation. Given these parameters, cellulosic ethanol is approximately \$1.15/gal more to produce versus corn ethanol when energy cane is yielding 35 wt/ac. For cellulosic ethanol to be competitive with corn ethanol given these parameters, the cost of cellulosic ethanol needs to decrease \$0.90/gal and energy cane yield increase to between 45 and 50 wt/ac. If the price of corn increases to \$5.00/bu, other parameters held constant, and energy cane yields 35 wt/ac; corn ethanol's advantage decreases to \$0.61/gal (Figure 2). A \$0.30/gal reduction in production costs for cellulosic ethanol and a yield increase for energy cane to approximately 50 wt/ac results in equality of costs of production between the two processes. However, a \$0.60/gal reduction in cellulosic ethanol costs and a yield increase to between 35 and 40 wt/ac would also make cellulosic ethanol production compatible with corn ethanol production. As of this writing, corn is trading at a price higher than $5.00/bu which helps make cellulosic ethanol more competitive. However, overtime the expectation is that the price of corn will settle around a range between $3.50 and $5.00/bu.

An increase in the efficiency of the cellulosic ethanol facility resulting in 80 gal/dt also increases the competitiveness of the cellulosic ethanol industry. With corn at $3.50 per bushel, the production cost for cellulosic ethanol needs to be decreased by $0.60/gal and yield needs to be increased to between 50 and 55 wt/ac. With the price of corn at $5.00/bu, the competitive advantage of the cellulosic industry increases given current production costs and increasing yields to between 55 and 60 wt/ac. Under current conditions with corn at $7.00/bu, the production cost for corn ethanol becomes $3.03 per gallon. This is higher than any of the scenarios examined in Figure 4 under the assumptions that corn is $5.00/bu, and the cellulosic ethanol plant conversion rate is 80 gal/dt.

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Table 1: Variety Comparisons

Variety	Gross Cane	Brix	Fiber	Solids		
				Brix	Fiber	Total
	(tons/ac)	(% cane)		(tons/ac)		
Ho 00-961	34.6	17.7	15.9	6.1	5.5	11.6
HoCP 91-552	38.9	16.8	15.2	6.6	6.0	12.6
LCP 85-384	31.5	18.2	14.0	5.6	4.4	10.0

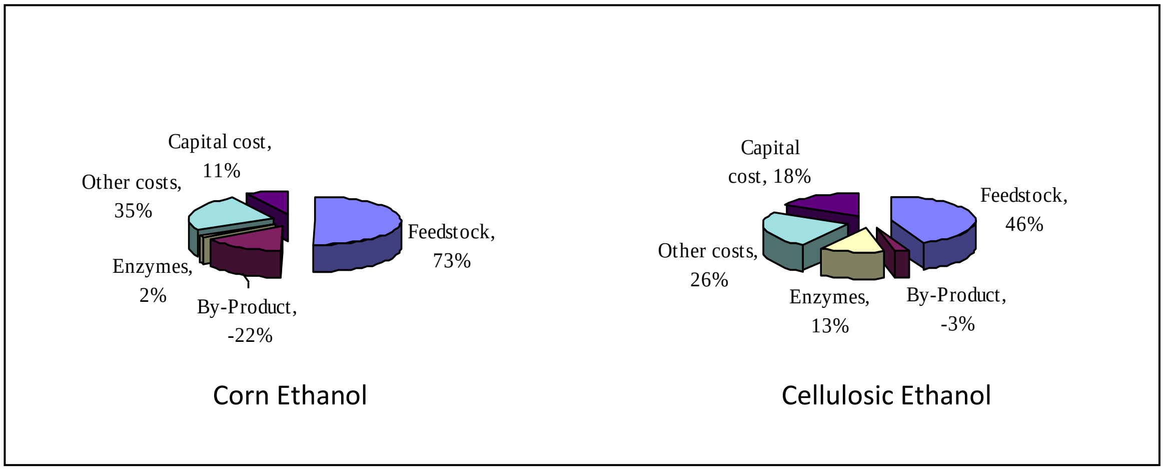
Table 2: Breakeven Grower Cost ($/wt)

	4th Stubble			5th Stubble			6th Stubble		
Yield/Harvested Ac	Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling	Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling	Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling
30	$25.77	$30.94	$34.44	$25.05	$30.07	$33.57	$24.54	$29.46	$32.96
35	$22.57	$27.09	$30.59	$21.98	$26.39	$29.89	$21.56	$25.88	$29.38
40	$20.20	$24.25	$27.75	$19.70	$23.65	$27.15	$19.35	$23.23	$26.73
45	$18.38	$22.06	$25.56	$17.95	$21.55	$25.05	$17.65	$21.19	$24.69
50	$16.94	$20.34	$23.84	$16.56	$19.88	$23.38	$16.30	$19.57	$23.07
55	$15.77	$18.93	$22.43	$15.43	$18.52	$22.02	$15.19	$18.24	$21.74
60	$14.80	$17.77	$21.27	$14.50	$17.41	$20.91	$14.28	$17.14	$20.64
65	$13.98	$16.78	$20.28	$13.71	$16.46	$19.96	$13.51	$16.22	$19.72
70	$13.28	$15.94	$19.44	$13.03	$15.64	$19.14	$12.85	$15.43	$18.93
75	$12.68	$15.22	$18.72	$12.45	$14.95	$18.45	$12.28	$14.74	$18.24

Table 3: Breakeven Grower Cost ($/dt)

	4th Stubble			5th Stubble			6th Stubble		
Yield/Harvested Ac	Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling	Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling	Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling
11	$73.62	$88.38	$98.38	$71.56	$85.91	$95.91	$70.10	$84.15	$94.15
12	$64.48	$77.41	$87.41	$62.79	$75.38	$85.38	$61.60	$73.95	$83.95
14	$57.72	$69.29	$79.29	$56.30	$67.59	$77.59	$55.29	$66.37	$76.37
16	$52.52	$63.05	$73.05	$51.29	$61.57	$71.57	$50.43	$60.54	$70.54
18	$48.40	$58.10	$68.10	$47.32	$56.81	$66.81	$46.56	$55.89	$65.89
19	$45.05	$54.08	$64.08	$44.09	$52.93	$62.93	$43.41	$52.11	$62.11
21	$42.28	$50.76	$60.76	$41.41	$49.71	$59.71	$40.80	$48.98	$58.98
23	$39.94	$47.95	$57.95	$39.16	$47.01	$57.01	$38.60	$46.34	$56.34
25	$37.95	$45.56	$55.56	$37.23	$44.69	$54.69	$36.72	$44.08	$54.08
26	$36.23	$43.49	$53.49	$35.56	$42.69	$52.69	$35.09	$42.12	$52.12

Figure 1: Comparison of Production Costs for Corn and Cellulosic Ethanol



Source: Collins, K. *The New World of Biofuels: Implications for Agriculture and Energy.* EIA Energy Outlook, Modeling, and Data Conference. March 2007.

Figure 2: Comparison of Production Costs with $3.50/bu Corn and 60 gal/dt Cellulosic Ethanol

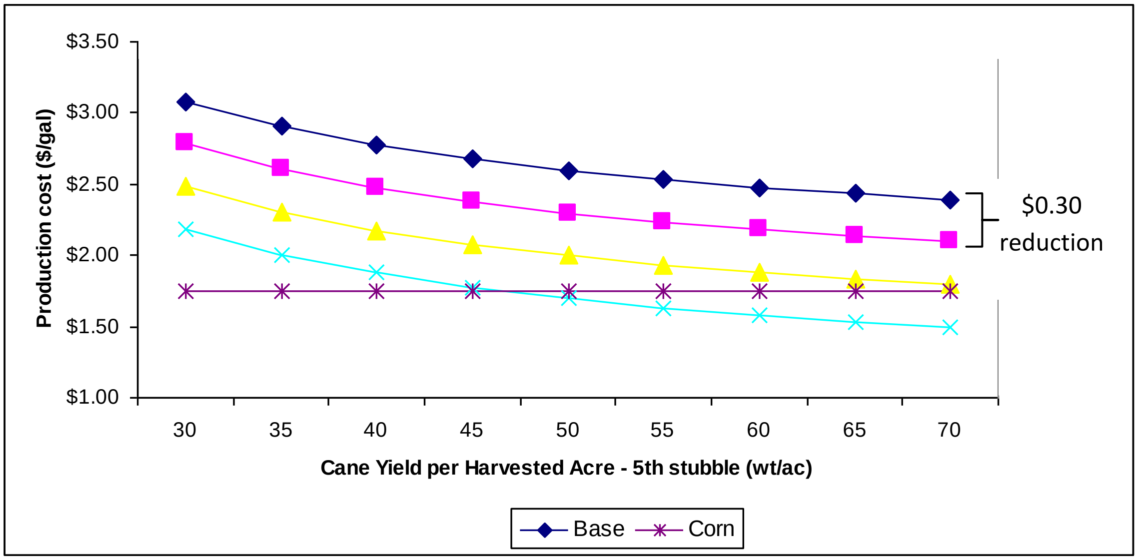


Figure 3: Comparison of Production Costs with $5.00/bu Corn and 60 gal/dt Cellulosic Ethanol

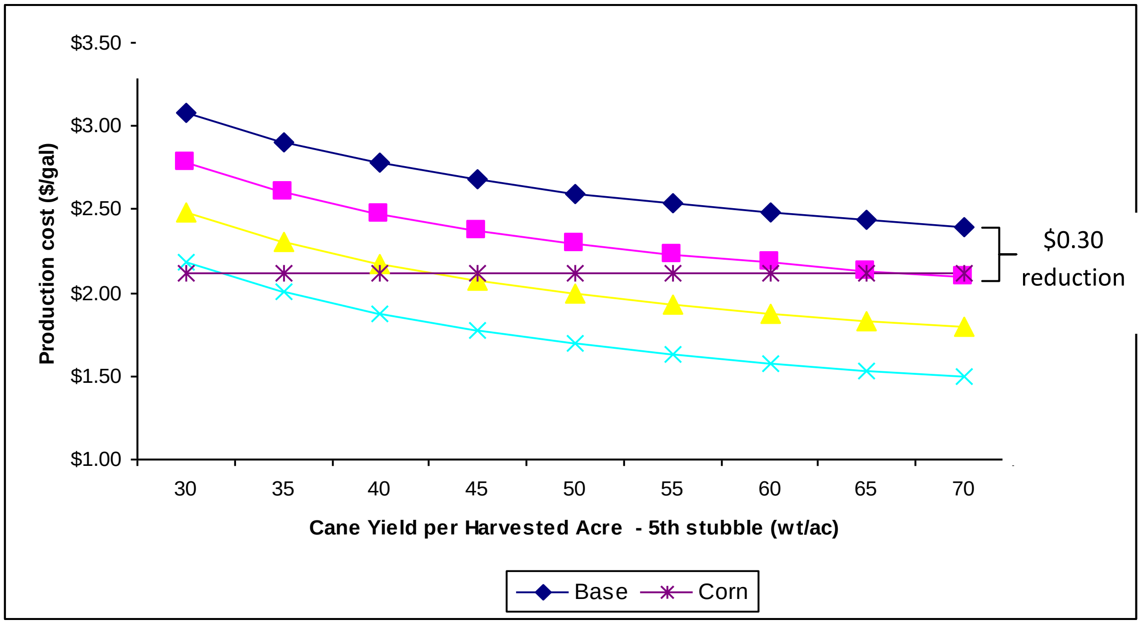


Figure 4: Comparison of Production Costs with $3.00/bu Corn and 80 gal/dt Cellulosic Ethanol

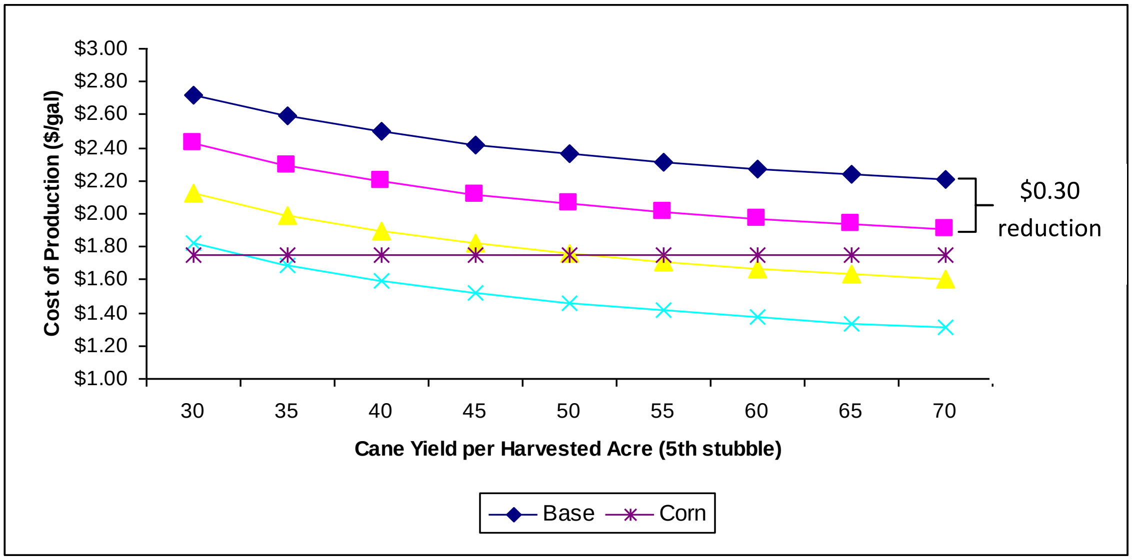


Figure 5: Comparison of Production Costs with $5.00/bu Corn and 80 gal/dt Cellulosic Ethanol