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Introduction

Over the course of the last few years ethanol production has expanded at an incredible pace, putting strain on corn markets and transportation systems throughout the Midwest. Driven by the government subsidy and profit possibilities, firm entry rates have spiked. Previous to 2006-2007 the ethanol industry had been consuming feedstock dedicated to export, so little effect was felt by food markets. After 2007 ethanol's demand for corn will begin to weigh on food markets as reduced supply drives up prices. Corn supply is fast becoming a binding constraint to the ethanol's growth rate. The feasibility of its further expansion hinges upon the growth and technological advances of corn production, along with the ability of the industry to function profitably without the subsidy.

Opponents of this expansion often cite data which suggests a large net BTU loss during production; however, this data has been brought into question because much of it is from the 1980s. A survey of reports and articles on the issue indicate BTU input to output remains around 1:1. At this breakeven point both sides of the ethanol debate are capable of finding ways in which to highlight its environmental costs or benefits.

Another determining factor for ethanol's success is its long term competitiveness with gasoline. Typical consumers are fully aware of the reduced gas mileage ethanol produces, as such, ethanol prices levels must remain discounted at the appropriate rate to reflect the reduction. Currently it seems ethanol can not operate at these levels even while including the subsidy paid to producers. Advances in

technology have been slowly eroding this lack of competitiveness but oil prices would still have to rise significantly to give ethanol an advantage at the pump.

Literature Review

Ethanol Opposition

The most often cited anti-ethanol report comes from David Pimentel. His argument against ethanol shows a net loss of 22,119 BTU per gallon produced (*Natural Resources Research*, 2003). Thus 29 percent more energy is required to produce ethanol than what the ethanol itself will yield. Pimentel's argument for the total BTU requirement to produce a hectare of corn, however, is suspect. Many times he sights rather old data. Given the fourteen corn production inputs he details, nine of his figures are from 1980 and eight of those nine are instances where he sights his own work (*Natural Resources Research*, 2003, Table 1, p.128). Not included in his estimate is transportation cost which he later details to be around 5000 BTU/gal. Pimentel's Table 2, which breaks down the total BTU input to produce a gallon of 95 percent ethanol, not only uses old data, it draws on Table 1 for the input cost of corn. Excluding corn, there are seven inputs listed, of those seven figures, three are from 1979, and one is again Pimentel's own work.

Pimentel also addresses the impact of co-products on the energy yield of corn ethanol. Given these co-products can readily be turned into DDG (dry distillers grains) and even corn oil, they offset the original figure from 29 percent negative yield to 20 percent (*Natural Resources Research*, 2003, p. 130). Another factor

Pimentel addresses is environmental pollution caused by ethanol plants. His assessment of air pollution, backed up by a warning issued in 2002 by the EPA is vague, saying only “The EPA (2002) has issued warnings to ethanol plants to reduce their air pollution emissions or be shut down” (*Natural Resources Research*, 2003, p. 130). The “Ethanol Plant Clean Air Act Enforcement Initiative” instituted in 2002 and the subsequent settlement with both Archer Daniels Midland and Cargill, the two largest ethanol producers, resulted in the direct reduction of 63,000 and 25,000 tons of air pollution respectively. In addition, the initial twelve plants investigated by the initiative in Minnesota agreed to install brand new pollution control technology at each of their dry-milling facilities (EPA: Civil Enforcement, 2002). Pimentel shows the cost of removing the sewage waste to be around six cents per gallon of ethanol produced. The figures he uses for this calculation, including the Biological Oxygen Demand, a measure of water quality, are from 1984.

Graboski’s rebuttal to Pimentel (“A Rebuttal to...” 2002) centers around Pimentel’s use of out of date information as previously shown. Graboski details that inputs of energy in ethanol production have declined 15 percent since 1980 while “farm output has increased 33 percent.” Considering the vague nature of this statement and the lack of citation, further investigation shows it to be moderately supported by an April 2006 article from *Amber Waves* which states: “Over the past decade (1996-2005), U.S. corn yields averaged 138 bushels per acre, compared with 115 bushels during the previous decade” (*Amber Waves*, 2006). This represents a 20 percent increase in the past 10 years alone.

The June 2007 issue of *Futures* details the monumental task of trying to keep up with incredible growth in corn demand. In order to match the near 1 billion bushel demand hike for the coming year, an additional 6.5 million acres of corn must be harvested and the national average must be 153 bushels/acre. With the expansion of farmland into fringe areas, and an ideal season necessary, an average of 153 may be unrealistic (*Futures*, 2007).

Alternative Feedstock and Advances

Shapouri and Salassi's feasibility report (2006) examines the possibility that sugarcane could be a competitive source of ethanol. After decomposing the cost per gallon cost to manufacture ethanol from various forms of fermentable sugar, they assemble Table-1 (see Figures and Tables). The most competitive item is clearly molasses, having a total cost of \$1.27 per gallon (vs. a total cost of \$1.05 for dry-mill corn ethanol). The table is significant in that it shows the very high input costs for feedstock; a factor that explains much of Brazil's success with ethanol. Considering feedstock prices are essentially exogenous, feedstocks that contain a higher ratio of processing cost are potential areas for cost reduction. This is almost a direct condemnation of the use of US sugar cane, in which feedstock costs account for over 80 percent of production cost (Shapouri and Salassi, p. iv). Brazil used around 53 percent of total domestic sugar produced in 2005 for ethanol production; this yielded 4.2 billion gallons of Ethanol.

Rendleman and Shapouri (2007) detail that almost all newly constructed fermenting plants are dry mills, so most new technology has been based on the dry process. Such technology includes the process of dry fractionation, which separates corn more effectively into its components without the soak step required by wet milling (*BioFuels Journal*, 2005d, 2005e). This fractionation helps the mill not only get more out of the high-starch part of the kernel; it gives the mill the ability to produce corn oil from a portion of the byproduct, and feed from the rest (Figure-2).

Beyond simply selling the increased co-product the plant can lower energy cost by using the corn bran as a fuel source. At roughly \$8/mmBTU for natural gas, a 50 million gallon per year plant could save around \$6,550,000 which translates into a 13 cent reduction in production cost per gallon. This does not, however, address the issue of pollutants caused by burning the bran, or embedded costs in controlling such pollutants. Also another benefit to fractionation is that as the bran and germ are removed the cost of processing enzyme goes down. While the ethanol yield per bushel is slightly lower for a plant using this process (2.8 vs. 2.65 gal/bushel), the increased value of co-product easily makes up for this disparity (Shumaker, Luke-Morgan, and McKissick, 2007).

Recent Effects

While it may seem the government subsidy for ethanol is far too high given the large profits being realized by production firms, the publication “Economics of Ethanol” by Purdue University sees this as a positive. Hurt, Tyner, and Doering

explain that the continuation of the large subsidy has sparked a very high rate of entry into the industry, elevating it to a near gold rush status (Hurt, Tyner, and Doering, 2006). The subsidy of 51 cents per gallon had been established when crude prices were hovering around \$30/barrel. Areas that could reduce profits include a possible reduction of the subsidy and an increase in corn prices as more productive capacity is realized. Both of these scenarios would reduce profit margin and thus entry would fall off.

Rapid effects on the Midwest can be seen in Stuefen's examination of corn basis flow from 2000-2004. These effects seem to be telling for much of the region as ethanol production grows. There has been a large scale structural transformation in southern Minnesota and southeastern South Dakota. First, some background on basis and the region- Previous to 2000, the major corn markets had been located along Mississippi or Missouri River ports. Obviously, regions further away from such ports are at a geographic disadvantage. To remain competitive, producers must reduce their prices in an attempt to offset the cost of transport. Basis is calculated by subtracting the local cost of a commodity from the price at which it is being traded on the Chicago Board of Trade.

The idea of basis is helpful in that it shows the extent to which a particular producer may be disadvantaged in a market along with effects from local supply and demand. Before 2000, high basis was characteristic of nearly all Minnesota and South Dakota (graphic-1). A more recent graphic of the area (graphic-2) shows a very distinct regional change, all of southern Minnesota and southeastern South Dakota are

exhibiting a low basis. This tells us either local ethanol production has aligned the corn prices with CBOT futures prices or new construction on the region is having scale structural effects on transportation (Stuefen, 2005). Regional economics seem to dictate that beyond a distance of 50 miles the reduction in basis a producer gains from selling to an ethanol plant becomes negligible.

The more corn stocks become diverted from export to ethanol production in the Midwest the more basis weakens in areas further from the Mississippi and Missouri rivers. Figure-1 shows that this year, demand for corn from ethanol production will become greater than corn export. We can expect to see a further reduction in basis throughout much of the northern Midwest. The previously cited *Amber Waves* article suggests that as corn is diverted in greater amounts from export to ethanol production, countries such as Canada and Egypt with higher per capita income and moderate propensity for corn production will be more responsive to a subsequent increase in corn price.

The overall market expectation seems to be that as all exportable corn stocks are consumed by the ethanol industry the food markets will begin to be affected. As this occurs the price of corn will rise, cutting profits and reducing ethanol expansion. This point should be reached by the end of 2008, after which it is expected the productive sector will only be capable of expanding at or below the rate at which corn production expands. This rate may be subject to acceleration as potential profits are now very high, creating an incentive for advancements in crop yield and production techniques.

Analysis

Eliminating the Subsidy

Many opponents of ethanol argue the industry becomes no longer feasible after the elimination of the subsidy. With differing figures that can be proven both true and false currently; as was previously shown. This means, to a large extent, the industries future is closely related to changes in petroleum price. Given that petroleum price is tied to supply-side decisions from organizations such as OPEC, its interesting that many political figures have hailed ethanol as a way to end dependence on foreign oil. It is public knowledge that ethanol produces a mpg rating roughly 25 percent less than traditional gasoline. For ethanol to then be competitive it should be roughly 25 percent cheaper than gasoline, however, we do not currently observe this nationwide. The only states hovering around the 25 percent or better mark are Wisconsin, South Dakota, and Colorado; the national average is around 15.3 percent cheaper as reported by e85prices.com.

Interestingly enough, in an AP announcement on June 17th 2007, many large oil companies are opting to cut back on newly planned refinery construction in light of ethanol's expansion. Given ethanol is just coming out of its infant industry phase, game theory would dictate oil's best chance of fighting its expansion would be to expand capacity, lower prices, and undercut ethanol by eliminating the difference in

prices. Considering people are fully aware of ethanol's reduced gas efficiency, oil could easily win a pricing battle.

The subsequent increase in gasoline prices will have an effect on ethanol prices as E85 still uses 15 percent gasoline. Producers expect demand to remain relatively flat over the next few years as more consumers begin to migrate away from oil. This may not be a realistic expectation, as a developing China will create a much larger demand than in past years, causing oil prices to rise. The subsequent increase in E85 prices will be much smaller causing the price gap to increase above 25 percent, making ethanol a much more attractive gas alternative.

The current subsidy has created the opportunity for incredible profit by the various large production firms and has caused a considerable expansion of the market. While this has been good for the industry in the short term its benefit obviously declines over the long term. The issue then becomes: what is the best way to eliminate the subsidy without bankrupting the industry? There is little risk of short term detriment to the consumer because gasoline is always available as a substitute. The most obvious way to begin is a phased reduction of the subsidy until it is completely gone. An important aspect of this method is a clear report of what each phase would entail and an appropriate amount of time to give the industry an adjustment period.

The current figures show the industry should end up operating around the breakeven point given gas prices moderate or even increase over the adjustment period. This will also create even larger incentives for technological advances pertaining to cost reduction or efficiency. Firm entry should also slow to a rate more

in line with the year-to-year corn production rates. The general sentiment seems to be that by 2012 cellulosic ethanol production will become feasible at current petroleum prices. The most efficient and effective time at which to begin cutting the ethanol subsidy would appear to be around 2010, this would also put an appropriate amount of pressure on firms to fully realize cellulosic production.

Examining the Cost

The International institute for sustainable development estimates the current ethanol subsidy to cost around \$1.05-\$1.38/gallon. With a current production capacity of roughly 7 billion gallons per year this amounts to 7.35-9.66 billion dollars per year in direct ethanol subsidies. It's hard to say whether or not this will be a worthwhile investment for America to be making over the long run without seeing the return on investment that may be present. The structural changes occurring in the Midwest as a direct result of ethanol's expansion seem to be having a positive effect on the corn markets at the very least. The weakening basis displays that producers in more remote regions are no longer at the disadvantage they previously were. New train and transport systems are bringing the prices into line with national averages.

Co-product technology is also on the rise; processes such as fractionation are helping to yield a greater quantity of co-product while also reducing cost. Considering this is one of the major sources of profit for ethanol production facilities this is very important. Previously, it was thought that as more corn was diverted to ethanol production, feed cost would rise drastically. This may not hold true as the most prominent of the co-product is distiller's dry grains with solubles (DDGS). Demand

for DDGS has increased rapidly since it has become a popular replacement for corn and protein in cattle diets and more recently in the diet of poultry as well (*Amber Waves* 2005). The sale and movement of co-products is also being aided by the proximity of production facilities to dairy and beef farms throughout the Midwest.

Viability of Alternatives

Corn alternatives are currently uncompetitive as their feedstock costs are too high. We know as time progresses that technological advances will lower costs and increase output for any process; however, input prices thus far seem relatively stagnant for two reasons: first, as there has been no overwhelming demand increase for alternative feedstocks due to their relatively high cost, prices have remained flat. Second, demand for corn feedstock has not eaten through the total amount previously slated for export. Once that occurs, which will likely be this year, corn feedstock prices will rise as they begin to compose a larger proportion of ethanol production cost. This will translate into higher ethanol cost at the pump and less opportunity for production facilities to reduce cost from their end. This is one of the main issues with the incredible demand created by the subsidy, increases in corn production rates that would have previously resulted in a cost reduction are simply being used to satisfy the ever growing demand as more ethanol plants come online.

As corn prices rise, along with ethanol prices, refining molasses may actually become an attractive option considering it is only 22 cents more expensive to produce than corn. Growth of this industry is directly dependant upon the fluctuations of both corn price and oil price. The lack of co-products, however, is limiting as much of the

revenue facilities generate is a direct result of their ability to effectively create DDGS for sale to nearby farms and use corn germ as a fuel source to reduce energy costs.

Common Sense

One of the principals of economics is that the cost of something is what you give up to get it; this of course includes opportunity cost. If, for example, you were trying to decide whether you should fix your computer yourself or bring it to a repair shop, your decision would involve an analysis of your time. Not only the time it would take to fix, but the time it may take to read up on the particular repair, or the cost of a pc repair course. In the ethanol case some of the non-pecuniary costs associated with this large scale project include the energy and pollution required to build and maintain production facilities, the extra cost associated with building E85 compatible vehicles, potential repercussions of supply side decisions from such organizations as OPEC, and the cost of maintaining a large transportation network to aid the movement of feedstock. Obviously not all results are negative; some can be seen as investments, such as a new transportation network or expanded farmable acreage.

The two most important questions are clearly- is it worth it now?, and will it be worth it later?. Is it worth it now is relatively easy to answer considering without the subsidy the ethanol industry would have serious difficulties turning a profit despite the fact that ethanol is only around 15 percent cheaper than gasoline nationwide when it should be around 25 percent cheaper. Clearly the answer is no. Will it be worth it later is the more interesting question. Most politicians seem to think the answer is easily yes, sighting that ethanol is a renewable source of energy

and will end our dependence on foreign oil. The problem being that ethanol will not have a majority market share in the foreseeable future so America will still be dependent on foreign oil. Also there is a large difference between ethanol being profitable and ethanol being economically profitable. Given the sum of all the subsidies, investment in production facilities, transport, technological research, wages, etc ethanol would have to be wildly successful and profitable to offset this amount, not to mention taking into account the next best way the money invested could be used.

Conclusions and Recommendations

Currently, ethanol is uncompetitive and inefficient on many levels. There is little empirical evidence to show a net BTU gain from its production even with the addition of DDGS co-product. An unbiased comprehensive study in the current production environment is necessary to illustrate total net gain or loss, as many new technologies have arisen recently which significantly change production yields and cost. It may hold true that the costs associated with fundamental transitional and structural changes throughout the Midwest represent the true underlying cost of ethanol's expansion. The reduction of basis should continue in coming years. More production facilities will come online, giving corn producers in remote areas markets in which their corn can sell for closer to the national average.

Food prices and corn prices will rise in the near future as corn that was previously used for food production is demanded by the ethanol industry. Also, as farmland is converted from crops such as wheat to corn in an attempt to meet demand,

prices of food products derived from wheat will also rise. This is important because an increase in input price for production facilities will be transferred to consumers through higher per gallon prices. Considering the pending price increase, ethanol will become even less competitive, forcing consumers to substitute towards gasoline. This analysis does not even take into account a decrease in the government subsidy which would make production an even less attractive idea.

Ethanol seems to have reached a breaking point, while politicians hail it as an end to foreign oil dependence, the reality of the situation is grim. Without technological advance forthcoming the industry as a whole will be fully reliant upon the government subsidy to at best breakeven. While this does depend on the scale of price movements, without significant advances, production will become less and less profitable in the coming months and years, and in its wake will cause high inflation across food and grain markets.

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Figures and Tables

Table-1

Summary of estimated ethanol production costs (dollars per gallon) 1/

Cost Item	U.S. Corn wet milling	U.S. Corn dry milling	U.S. Sugar cane	U.S. Sugar beets	U.S. Molasses 3/	U.S. Raw sugar 3/	U.S. Refined sugar 3/	Brazil Sugar Cane 4/	E.U. Sugar Beets 4/
Feedstock costs 2/	0.40	0.53	1.48	1.58	0.91	3.12	3.61	0.30	0.97
Processing costs	0.63	0.52	0.92	0.77	0.36	0.36	0.36	0.51	1.92
Total cost	1.03	1.05	2.40	2.35	1.27	3.48	3.97	0.81	2.89

1/ Excludes capital costs.

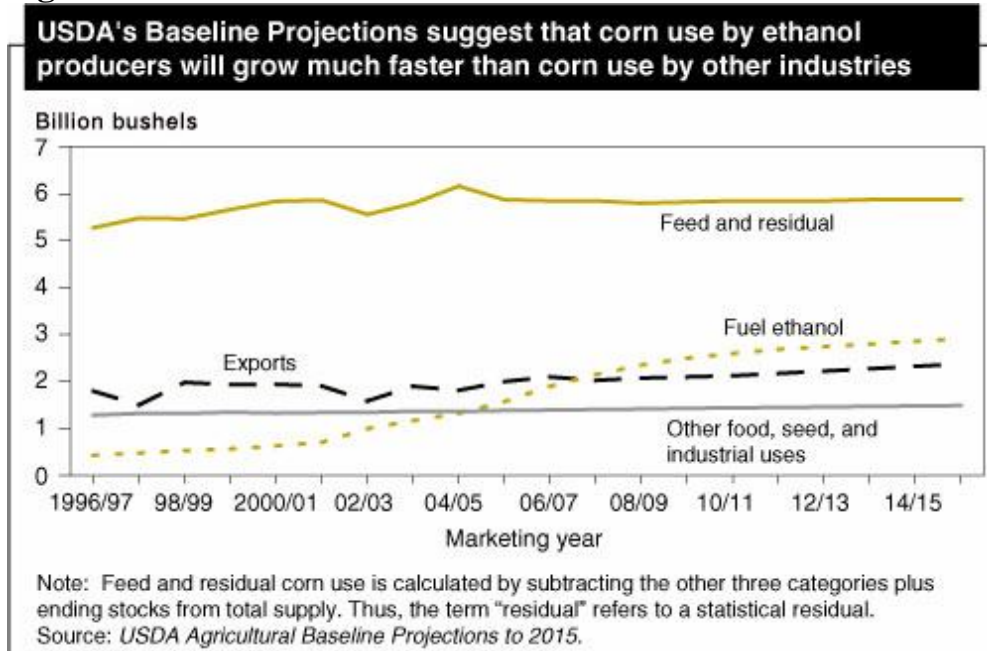
2/ Feedstock costs for U.S. corn wet and dry milling are net feedstock costs; feedstock costs for U.S. sugarcane and sugar beets are gross feedstock costs.

3/ Excludes transportation costs.

4/ Average of published estimates.

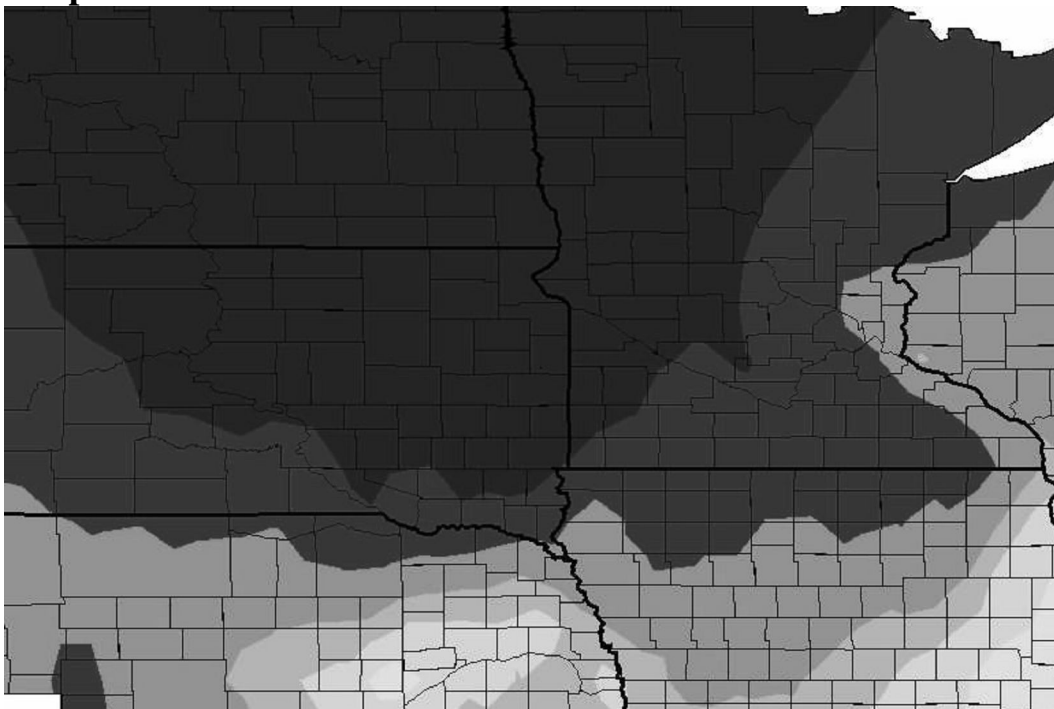
Shapouri and Salassi, 2006, p. iv

Figure-1



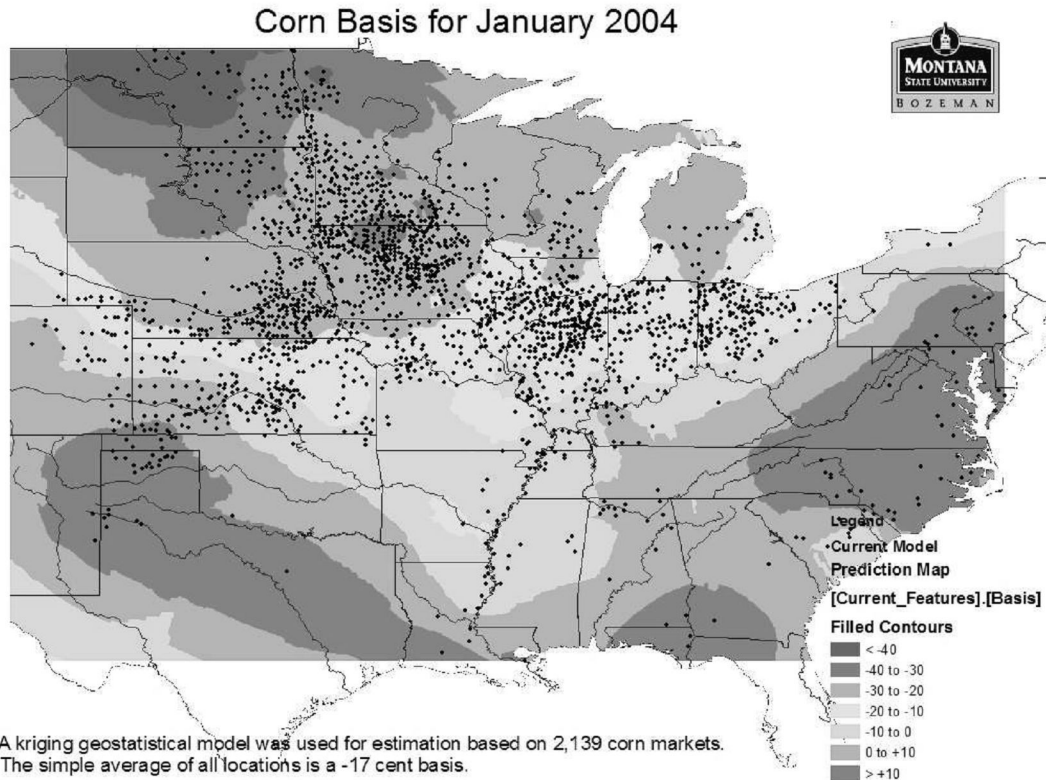
(Amber Waves, 2005)

Graphic-1



(Stuefen, December 2005, p. 6) Darker shading indicates higher basis.

Graphic-2



(Stuefen, December 2005, p. 7)

Figure-2

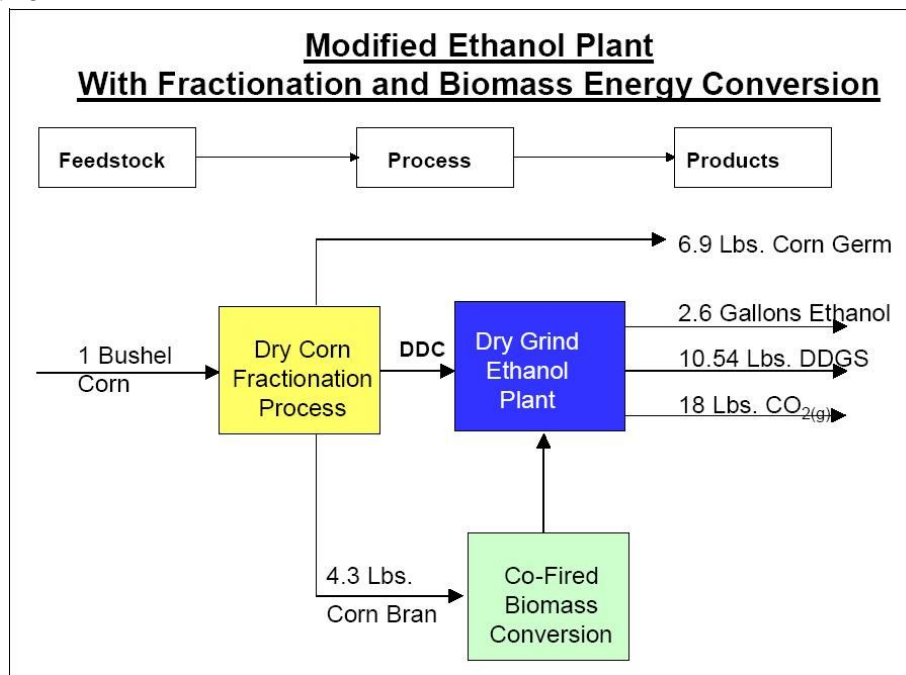


Figure 1 (George A. Shumaker, Audrey Luke-Morgan and John C. McKissick, P. 17)