The University of Georgia

Center for Agribusiness and Economic Development

College of Agricultural and Environmental Sciences

The Economics of Ethanol Production in Georgia

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Introduction

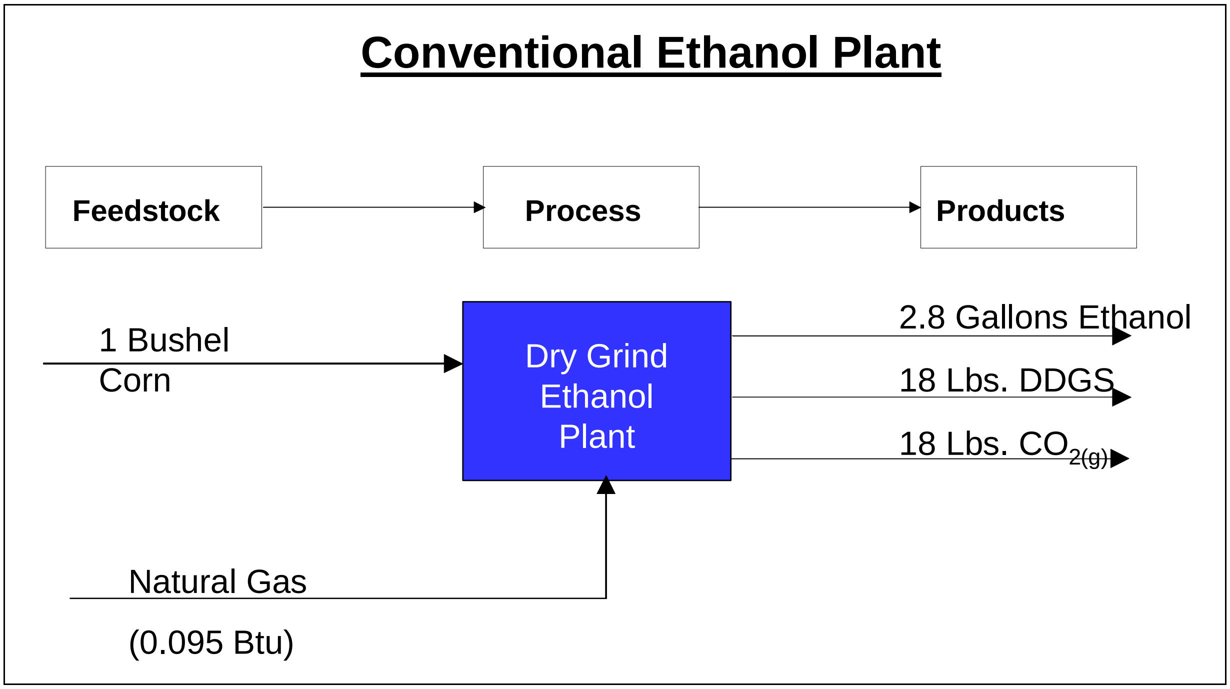
The Georgia Environmental Facilities Authority (GEFA) in cooperation with the National Renewable Energy Laboratory (NREL) contracted with the Center for Agribusiness and Economic Development (CAED) to update a prior feasibility study on the production of ethanol in Central Georgia. This study was to follow up a study that had been done previously, and was to expand the knowledge base of the feasibility of ethanol production in Georgia. The concern of GEFA and NREL was that given the enormous interest by various groups in producing ethanol, adequate information concerning the topic should be made available so that informed decisions could be made. One primary concern was whether or not ethanol production was feasible in Georgia considering given the price of the typical feedstock corn is higher valued in Georgia than in the Midwest where most of the ethanol production capacity currently resides. In answering that question, the study addresses alternative production methodologies, two different plant sizes and alternative feedstocks. The study provides insight into the question of whether Georgia is at a competitive disadvantage to Midwestern ethanol producers.

The CAED subcontracted out the tasks leading to the estimation of the production costs and capital expenditures. They chose the consulting firm Frazier, Barnes and Associates to perform these functions. Frazier, Barnes and Associates (FB & A) are well known for their work in the ethanol industry and have experience with both technologies. FB & A also performed the initial feasibility analysis that lead to the construction of the Commonwealth Agri-Energy plant in Hopkinsville, KY that is in its second year of operation and is currently producing between 23 and 30 million gallons annually.

Scope of Study

The study examines 50 and 100 million gallon conventional dry grind and 50 and 100 million gallon fractionation plants. The study focused on the dry grind and fractionation technologies as they appear to be the most competitive models for pure ethanol production. The wet milling process can produce ethanol but is a technology designed to produce other commodities as well as ethanol, such as various corn starches and corn syrups for further processing. The wet milling process is much more costly from a capital cost perspective. The authors believe the dry milling and fractionation models are more appropriate for the Georgia situation than is wet milling.

The dry milling process uses the entire corn kernel as a feedstock for the ethanol conversion process. It essentially breaks up the whole kernel into small pieces, adds various enzymes and yeasts and ferments the entire lot. The products produced are ethanol and dried distillers grains and solubles (DDGS), a feed product.



General Process Description

Grain Receiving and Milling - Incoming corn is sampled and weighed then unloaded from truck or railcar into silos. Typical corn specifications for an ethanol plant are:

- One bushel corn = 56 lb
- Moisture content ~ 15%
- Mold free

Whole corn is transferred from corn storage and reduced in size by hammer mills. Corn is sized to meet the process requirements; typically one-eighth inch screen openings are used.

Mash Preparation - The ground corn is mixed with water and heated. The initial slurry is typically prepared with ground corn, water, backset (recycled fluids), and alpha amylase enzyme. Alpha amylase is added to reduce the viscosity so that the mixture can be agitated and pumped. Ammonia is also added here for pH adjustment.

Mash Cooking and Liquefaction - In order to complete the gelatinization of the starch, the mash is sent through a hydro heater and raised to an elevated temperature (220ºF to 230 ºF). This elevated temperature also helps to sanitize the mixture which is then cooled to the preferred liquefaction temperature (185ºF). Additional alpha amylase is added here to continue the conversion of the starch to simple sugars (dextrins).

Saccharification and Fermentation - The mash is then cooled to the preferred saccharification temperature. The final conversion of starch to dextrins is done in-line with the addition of the saccharification enzyme glucoamylase. The mixture is then further cooled to 90ºF and sent to fermentation. The fermentation of sugar to ethanol involves two key steps, the growth of yeast, and the production of ethanol. Alcohol production increases during the fermentation cycle until most of the fermentable sugars have been consumed. This process generates heat that must be removed to keep the yeast active. This is typically done with recirculation through plate and frame heat exchangers. The final product from the fermentation process is called beer. In a conventional process the beer is typically 10% to 11% ethanol by weight; the balance of the mixture is water and non-fermentable components.

Distillation - Ethanol has a lower boiling point (174ºF) than water and it is easily boiled off in distillation until it reaches a 95% concentration (190-proof). At this point the ethanol and water form an azeotrope that cannot be further separated by conventional distillation. An azeotrope is a homogeneous mixture of two or more elements that cannot be changed by distillation.

Dehydration - To break the azeotrope and remove the remaining water, molecular sieves are used. The molecular sieve material has a controlled pore size that allows water to be adsorbed while allowing ethanol to pass through. The remaining 5% of the water is removed in this step to produce 200-proof ethanol.

Stillage Separation - After removal of the ethanol from the beer mixture during distillation, a mixture referred to as whole stillage is produced. This mixture consists of non-fermentable solids and liquid (thin stillage). Decanter centrifuges are used to separate the suspended solids (wet cake) from the thin stillage. The wet cake typically contains 35% solids and 65% moisture.

Evaporation - The thin stillage components are further concentrated into condensed distillers solubles (CDS) or more commonly known as syrup. The amount of solids concentration differs in the industry. Typical syrup solid concentration ranges from 33% to 38% (which indicates a moisture level of 67% to 62%, respectively).

DDGS Drying/Cooling - The wet cake from the decanters is mixed with syrup from the evaporators and sent to the DDGS Dryer. Here, the final DDGS product is dried to approximately 10% moisture. The final product discharges from the DDGS dryer and is cooled before being sent to storage.

DDGS Storage and Loadout - The cooled DDGS is sent to storage. Two of the most common ways to store DDGS is flat storage using a front-end loader to load trucks, or specially designed silos, which allow for automatic loading. The ethanol plant capital cost estimates shown later include flat storage only.

Alcohol Storage and Loadout - Ethanol from the mole sieves is cooled and sent to storage. A denaturant, typically unleaded gasoline is added to the ethanol prior to loadout to produce denatured ethanol. The blended product is loaded into trucks and/or railcars for shipment to end-user markets.

Carbon Dioxide Production - Carbon Dioxide (CO_2) is generated during the fermentation cycle. This gas typically contains ethanol, VOCs, and other contaminants. A wet scrubber is used to remove the ethanol and other organic components prior to discharge of the CO_2 into the atmosphere. This CO_2 stream has a 98% purity level that can be piped to a CO_2 plant for purification and marketing or vented to the atmosphere.

Anaerobic Treatment System - An anaerobic treatment system is included to reduce the amount of waste water discharging from the plant. This in turn produces a small amount of methane gas that will be used as a boiler fuel. The major benefit of this system is to reduce the organic acids to a safe level that allows evaporator condensate to be recycled back to the front of the plant. This reduces the fresh water required as well as the amount of discharge water. This results in a zero discharge plant with respect to process contact water. This is a large advantage to the ethanol plant due to the high level of BOD that is present in the process contact water.

Conventional Plant Utility Requirements

Utilities for a 50-mmgpy corn to ethanol plant are listed below.

Fresh Water Source - Service water of approximately 424 gallons per minute will be required for a 50-mmgpy modified ethanol plant. This number varies depending on the technology provider and local water quality. Most of this water will be lost to evaporation in the cooling tower.

Natural Gas - The annual natural gas usage for a 50-mmgpy modified ethanol plant is approximately 1,700,000 mmBTU. The natural gas can be purchased from the local utility. An uninterruptible gas supply is recommended; however, a back-up fuel such as fuel oil or propane can be incorporated into the design if needed. Line pressure is typically not an issue. Fifty to one hundred psi is normal for the ethanol plant. Some technology providers prefer the higher pressure (100 psi); this allows smaller pipes in the ethanol plant.

Electricity - The estimated operating load for the ethanol plant is 1.00 kW/denatured gallon. A 50-mmgpy conventional ethanol plant would use approximately 6,000 kW/h.

NOTE: The plant utility requirements summarized above are to be considered estimates only. Several factors that could adjust the ultimate requirements include the facility's site location, and technologies for both fractionation and biomass conversion.

Wastewater - The ethanol plant will have several discharge streams that are considered "non-contact." This means that these streams do not come into direct contact with the process production streams.

The non-contact wastewater discharge will include:

- Boiler blowdown
- Cooling tower blowdown
- Water softener blowdown (if applicable)
- Reverse osmosis reject (if applicable)
- Storm water
- Sanitary sewage

An ethanol plant should be designed for zero process discharge (as discussed in the technical section). There will be no process contact water leaving the facility. All process water is treated and recycled back into the ethanol plant.

Storm Water - Storm water control and management systems will be incorporated into the plant design and also the plant operations. The goal is to eliminate or minimize storm water contact with potential pollutants. To minimize the possibility of a process spill leaving the site, all process operations that require periodic maintenance and regular wash downs are placed inside a building or curbed area. Also, the ethanol storage tanks are in a diked area to contain any spills. The storm water management system typically includes a retention pond that must be designed in accordance with EPA requirements.

Sanitary Sewage - Typically sanitary sewage is sent to the local wastewater treatment facility. If this is not possible, a septic system must be constructed to handle this waste. This stream will likely be sent to the city wastewater treatment facility.

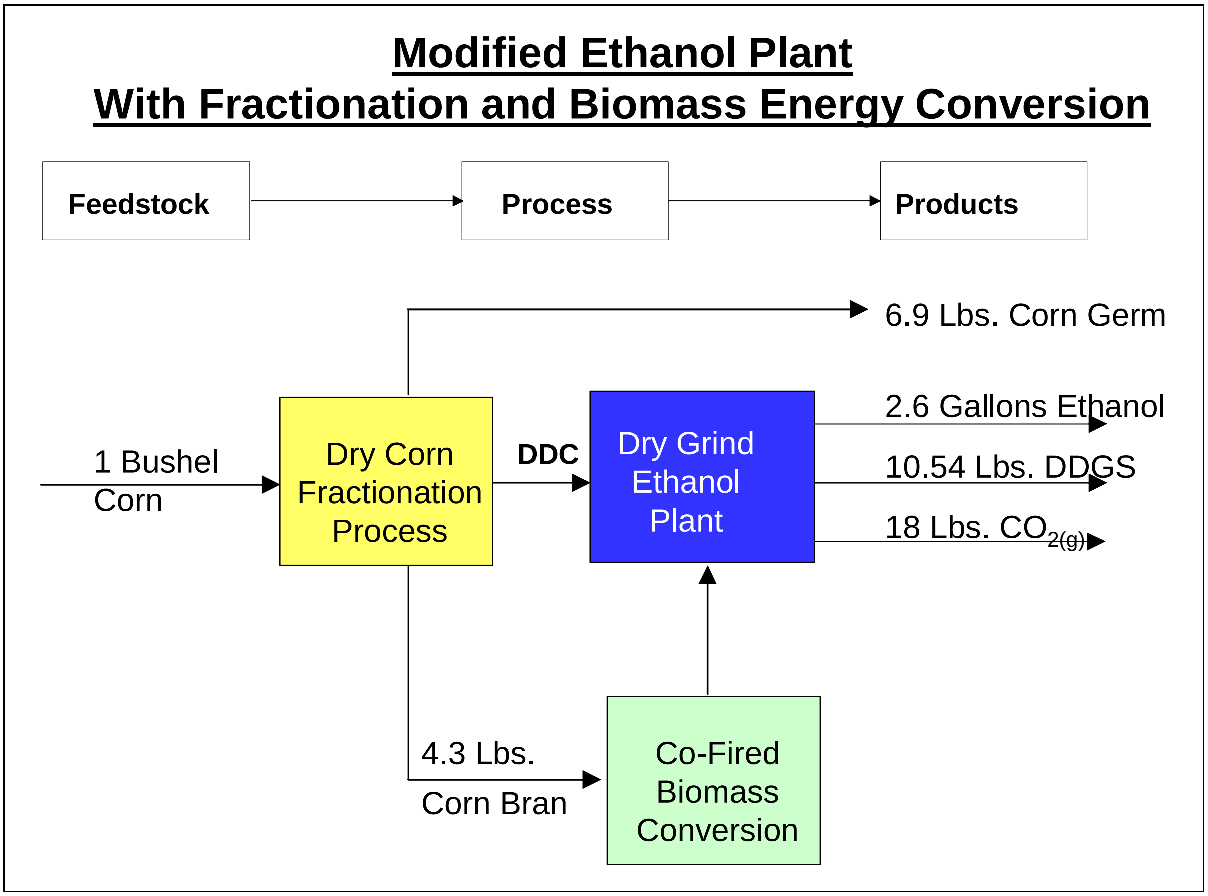
Thus, there are several considerations required when designing each facility's water system:

- Water source, water quality and water permit required.
- Storm water retention, control, and storm water release permit.
- Discharge water quality, location, and discharge permit.

Fractionation Process

The fractionation process is a newer technology in use in a limited number of ethanol plants. This process involves separating the corn kernel into its three essential parts, the bran, the germ or oil segment and the endosperm or the primary starch component prior to fermentation. Only the endosperm is fed into the fermentation process. The germ can be sold as either an oil feedstock to an oilseed crusher or used as a feed ingredient. The bran can be used as a fuel source if the plant is fitting to burn it or it also can be sold as a feed ingredient.

The ethanol yield per unit of feedstock of a dry milling plant is somewhat higher than from a fractionation plant, 2.8 versus 2.65 gallons per bushel of corn. This is because the fractionation process will likely take a small portion of the endosperm along with bran and or germ during the separation process. Given that, the ethanol production of the fractionation plant will be higher per unit of feedstock processed since the ethanol yield of the bran and germ is very low relative to the endosperm. A second advantage is that the bran can be used as a fuel source reducing the cost of production. Another potential advantage of the fractionation process is a higher protein content DDGS which may find a higher market price than dry mill DDGS.



Production Advantages of the Fractionation Plant

There are several advantages to the production process of the fractionation plant. One of these advantages is lower operating costs. These lower operating costs come from several sources. There is a lower level of energy consumption associated with this plant, mostly because of the lower quantity of DDGS produced and dried. Because the bran and germ have been removed from the corn, the processing enzyme cost is also lower. The corn bran can used as a fuel source in the plant lowering the outside energy requirements for the plant (mainly natural gas). The last savings is that of lower per unit fixed operating costs due to increased throughput.

There is also a higher potential co-product value and thus higher revenues from the fractionation plant. The corn germ that is removed during the dry fractionation process has 23% oil content. There is a market for corn germ as a vegetable oil source or as a feed ingredient for poultry, dairy and swine. One of the other co-products, DDGS, may also have a higher value than what comes from a conventional ethanol plant since it is higher in protein making it potentially more valuable to livestock producers. The protein level of this product should be over 35 percent which would allow it to compete more directly against soybean meal.

The overall advantages of the fractionation ethanol plant do have costs associated with them. The upfront investment in this type of plant is estimated to be about 28 percent higher than a conventional plant. However, the projected return on investment was expected to be higher than a conventional plant as well.

Technological Assessment of the Fractionation Ethanol Plant Design

The primary feature of the advanced ethanol plant is the fermentation of only the endosperm also called, de-branned, de-germed corn (DDC) feedstock. DDC has 84 percent starch content dry basis compared to a whole-corn feedstock with 70 percent starch content dry basis. This higher starch content, lower non-fermentable feedstock allows for other alternative downstream processing steps that significantly improve the operation. Conversion of the traditional feedstock to the higher starch DDC is accomplished through the dry fractionation process on the kernel.

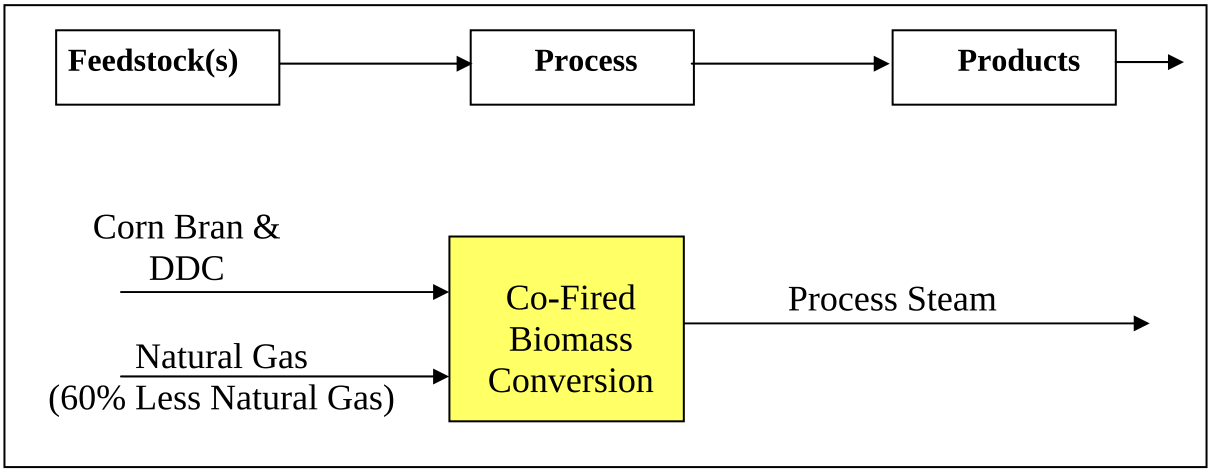
It is expected that the corn fractionation process will result in lower energy costs and higher value products that offset the higher capital and additional feedstock cost. There are several proven technologies that can be utilized to produce the DDC product. This technology would provide an additional fuel source (bran) that could then be used to produce steam for the plant thus reducing fuel costs.

Energy Consumption

One of the major operating costs in an ethanol plant is natural gas for process steam generation and DDGS drying. If the DDC product is used as a feedstock to the ethanol plant, the separated bran could be used as a supplemental fuel for process steam generation. The bran is estimated to have a heating value of approximately 7,000 Btu per pound. A boiler capable of burning both natural gas and bran could reduce the steam production cost for the ethanol plant. It is expected that a 50 million gallon per year (MMGPY) plant with a dry fractionation process will produce 50,568 tons of bran per year. This equates to 819,201 mmBtu of potential energy source (350 operating days per year). At a natural gas cost of $8.00/mmBtu, burning the bran equates to about $6,553,613 savings per year in natural gas costs or about $0.13 per gallon. The bran has a fuel value of about $129 per ton. A conventional ethanol plant of similar capacity has a natural gas consumption of 1,700,000 mmBtu. At $8.00/mmBtu this equates to a cost of $13.6 million per year. Additional natural gas savings can be realized by burning some degermed, debranned corn as well. An additional $1.6 million can be saved in a 50 million gallon plant by burning DDC corn product.

Figure 1 below, depicts the co-fired biomass conversion process.

Figure 1. Co-fired Biomass Conversion



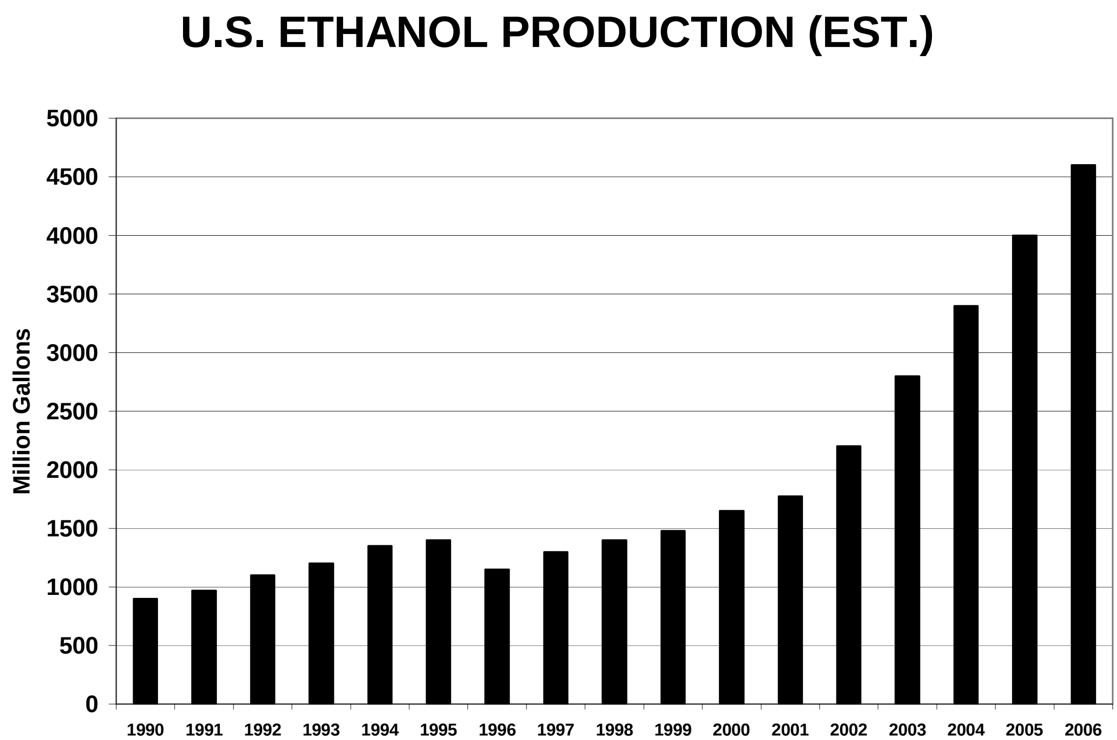
With the dry fractionation process, the bran can either be sold as a feed ingredient or burned to provide energy for steam generation. In either case the energy consumption for the plant would be lower than for the conventional plant as the bran is removed from the process stream. Thus there are fewer tons of DDGS needing to be dried. In a dry fractionation plant using DDC as the feedstock, natural gas consumption would be about 60 percent less than a conventional plant, equating to a reduction in the natural gas costs of $8 million per year.

<u>Co-Product Yields</u>

The typical ethanol plant uses corn as a feedstock and produces three co-products. These co-products are Ethanol, DDGS and Carbon Dioxide. The dry grind production process produces these co-products in approximately equal quantities. The advanced ethanol plant, however, has two additional co-products resulting from the corn fractionation; the bran and the corn germ. The approximate distribution of co-products from the fractionation plant is: 44.8 pounds of DDC which produces about 10.5 pounds of DDGS and 2.65 gallons of ethanol; 4.3 lbs of bran and 6.9 pounds of corn germ. Since the bran is burned rather than processed, the “corn part” of the output is reduced and thus the ratio of output of co-products changes to more ethanol less corn by-product and about the same amount of carbon dioxide. Neither the corn germ nor the bran is necessary in the ethanol production process, but both have potential economic values.

<u>Ethanol</u>

Ethanol production has expanded rapidly over the last few years and is projected to exceed 4.5 billion gallons in 2006. The trend toward expanded production is expected to continue into the near future.

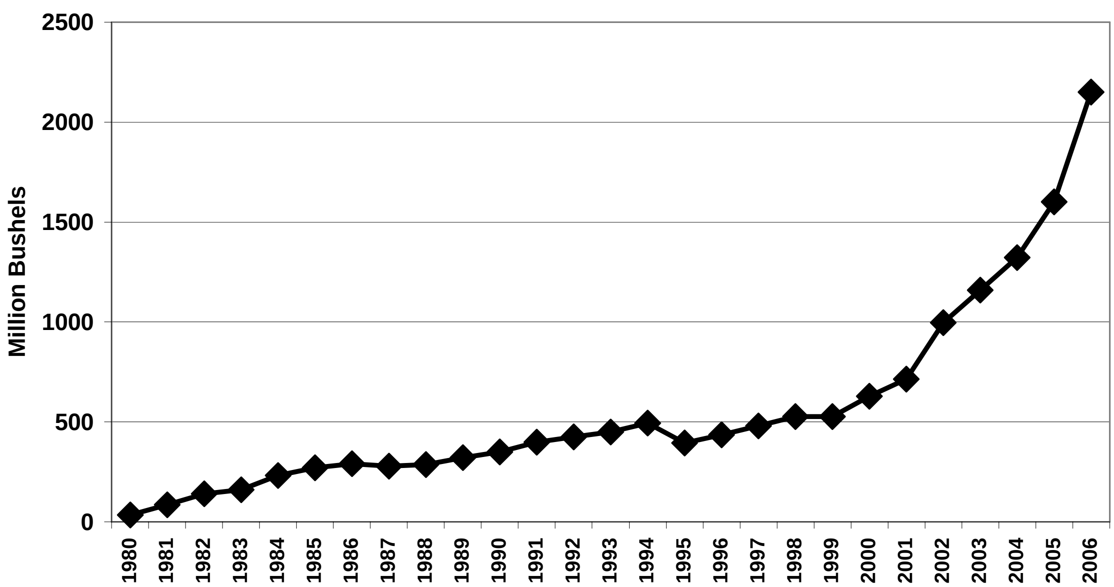


The 1990 Clean Air Act Amendments required that reformulated gasoline sold for consumption in areas of the US that do not meet the Clean Air Act standards must contain at least two percent oxygen by weight. There are two primary sources of oxygenate for gasoline. One, Methyl Tertiary Butyl Ether (MTBE) has been banned in 20 states, leaving the other, ethanol, as the primary oxygenate in those states. The market for ethanol will grow if additional states ban MTBE's.

So one of the issues facing potential Georgia ethanol producers is whether or not the metropolitan areas like Atlanta will have to start blending an oxygenate with their gasoline. The gasoline market in the greater Atlanta area is very large at three billion gallons annually. This would make the potential ethanol market around 300 million gallons once the oxygenation of gasoline is required. With this potentially occurring in the coming year or two, the market could obviously support many ethanol plants the size of the one being studied here. However, one of the drawbacks to producing ethanol in Georgia is the cost of obtaining reasonably priced high quality feed stocks that the managers of ethanol plants desire. Corn consumption in Georgia far exceeds production and a very large volume of corn is railed in from the Midwest. Various Georgia users currently consume about 205 million bushels of corn while USDA estimates the 2006 Georgia corn crop at about 25 million bushels. A 100 million gallon per year conventional ethanol plant would need about 36 million additional bushels. Georgia could ship more corn in to get the necessary quantity and quality, but transporting this corn might prove to be costly and/or problematic. However, producing ethanol in Georgia eliminates the cost of transporting the ethanol into the area from distant production and provides savings on that side.

There are some concerns being raised on a national basis as to whether or not we can produce enough corn to meet the growing ethanol industry. The rise in ethanol production has required a corresponding rise in corn supplies. About 2.15 billion bushels of corn will be processed into ethanol during 2006. Perhaps, fortunately, the U.S. has had excellent corn crops over the last several years and corn stocks have been plentiful to meet the demand. Corn used for ethanol production is now the second largest use category behind livestock feed use and surpassed exports during 2004.

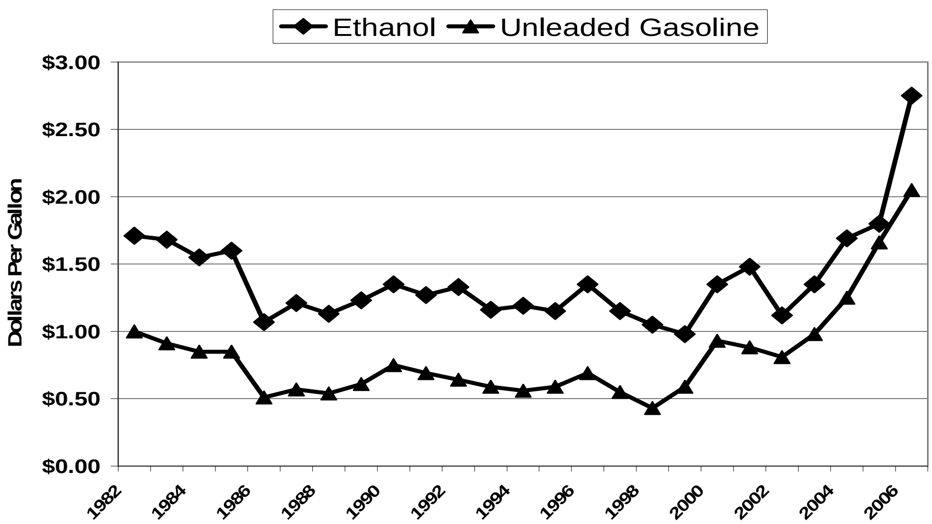
CORN USED FOR ETHANOL PRODUCTION



Ethanol Prices

The market for ethanol has been volatile over the last several years with the market price rising with the general increase in the price of petroleum as shown below.

Ethanol Rack Prices - Annual Data



Co-Product Markets

The advanced plant produces four co-products in addition to ethanol that have potential markets in Georgia and one that will utilized by the plant to produce energy. High protein distillers dried grains and solubles (HP DDGS) for monogastric animals, corn germ and carbon dioxide will all have markets available at some level, while the corn bran will be utilized by the plant to realize a savings on natural gas expense.

Distillers Dried Grains and Solubles (DDGS)

The second most valuable co-product for this production facility would be distillers dried grains and solubles (DDGS). The estimated current United States DDGS production is approaching 11 million tons per year (about 10.5 lbs per bushel of corn). It is estimated that in the next three to five years the production will climb to twenty million tons per year. A major concern in the industry today is where to market the growing DDGS supply.

One of the expected benefits of the advanced ethanol plant is that the DDGS will have a higher protein level than that from a conventional plant. DDGS is commercially used as a livestock feed and could potentially be utilized by cattle feedlots (for which there are relatively few in or near Georgia) and poultry producers (which there are many in Georgia). High-protein DDGS was tested by the University of Georgia Department of Veterinary Science and found to have a protein level of over 42 percent or 44 percent dry basis. This makes it more valuable to both poultry and cattle producers. This protein estimate puts its value on the marketplace at about $118 per ton. The value is based on comparisons with the current market for soybean meal, which would be its main competitor. The soybean meal price over the past five years in central Georgia averaged an estimated to be $202 per ton. Georgia also rails in a significant amount of soybeans and soybean meal indicating that there may be a market available for the DDGS.

The following tables shows a comparison of the University of Georgia test results for High Protein DDGS to the conventional DDGS. It shows that protein level is increased to around 43 percent while the fiber increased and the fat content decreased. High protein DDGS is lower in protein and slightly higher in fiber and fat content than soybean meal. The High Protein DDGS also had a level of amino acids that averaged 166 percent higher than that for conventional DDGS.

High Protein DDGS Versus Conventional DDGS

Product	Protein	Fiber	Fat
Conventional DDGS	28%	7%	11%
High Protein DDGS	42.3% to 44.6%	9.3% to 9.8%	5.3% to 5.6%

High Protein DDGS Versus Soybean Meal

Product	Protein	Fiber	Fat
Soybean Meal	47.5%	3.5%	1%
High Protein DDGS	42.3% to 44.6%	9.3% to 9.8%	5.3% to 5.6%

According to Dale and Batal, University of Georgia Poultry Scientists, DDGS has only rarely been a component of broiler and layer feeds, despite the dramatic growth of both the poultry and ethanol industries in the U.S. It can be said, however, that the lack of DDGS interest in Georgia seems to stem from a relatively limited supply, competing use in ruminant feeds without having to dry the product and concerns over an occasionally inconsistent composition. Dale and Batal research on DDGS (with 27 percent protein) in poultry rations showed that the product was highly acceptable feed ingredient for both broilers and layers. This was in agreement with earlier research conducted at the University of Minnesota. They also determined that poultry rations containing six to twelve percent DDGS can be used safely in starter feeds. However, it should be noted here that there has currently been no work done on High Protein DDGS with protein levels above the 40 percent level. It is thought, though, that this type of DDGS would increase the amount that could be used in a ration without impacting the performance of the chickens.

Corn Germ

Corn germ is another co-product that has value in the marketplace. Its economic value is as an input in the production of corn oil. The value of the germ is determined by the marketplace for corn oil and to a lesser degree by the cost of processing required to convert corn into corn oil. Due to the limited amount of corn germ that would be produced by this ethanol facility, it would not be economical to do the processing onsite with a solvent extraction plant. Therefore, the corn germ would need to be marketed to a company with the necessary facilities to extract the oil from the germ. There are facilities in Georgia that are capable of doing this and given current vegetable oil market conditions it is expected to be worth around $109 a ton.

Carbon Dioxide

The last saleable co-product of the advanced ethanol plant is Carbon Dioxide. It has uses in both the carbonated beverage industry and the dry ice industry. The value of this co-product is variable but can amount to hundreds of thousands of dollars. However, one must be able to find a company willing to locate adjacent to the plant in order to have a saleable product. This is a co-product that some plants find easier to just vent to the atmosphere. Over time, given the food beverage industry in Georgia, one would think that this would be a valuable co-product for an ethanol plant. Since carbon dioxide needs to be processed in close proximity to where it is produced, this study assumes that none will be sold initially. We did not assume any revenue from the sale of CO_2 in this study.

Input and Output Price Risk Management

Corn feedstock costs are a major part of the cost of producing ethanol. Managing the risk of price change must be a priority for the long term success of the business. Similarly, managing the risk of ethanol price changes must also be a priority. Fortunately, there are futures market contracts for both corn and ethanol available as price risk transfer mechanisms. The corn futures market is a well developed mature market with a large volume of trade and ready entrance and exit. It is well suited as a tool for managing price risk through hedging.

The ethanol futures market is relatively young and immature due to the newness of the commodity in general. Volume of trade has increased as the industry has grown and expectations are that it will continue to develop along with the industry. It offers the potential to be a viable risk transfer mechanism and should be used to limit down side risk in ethanol prices.

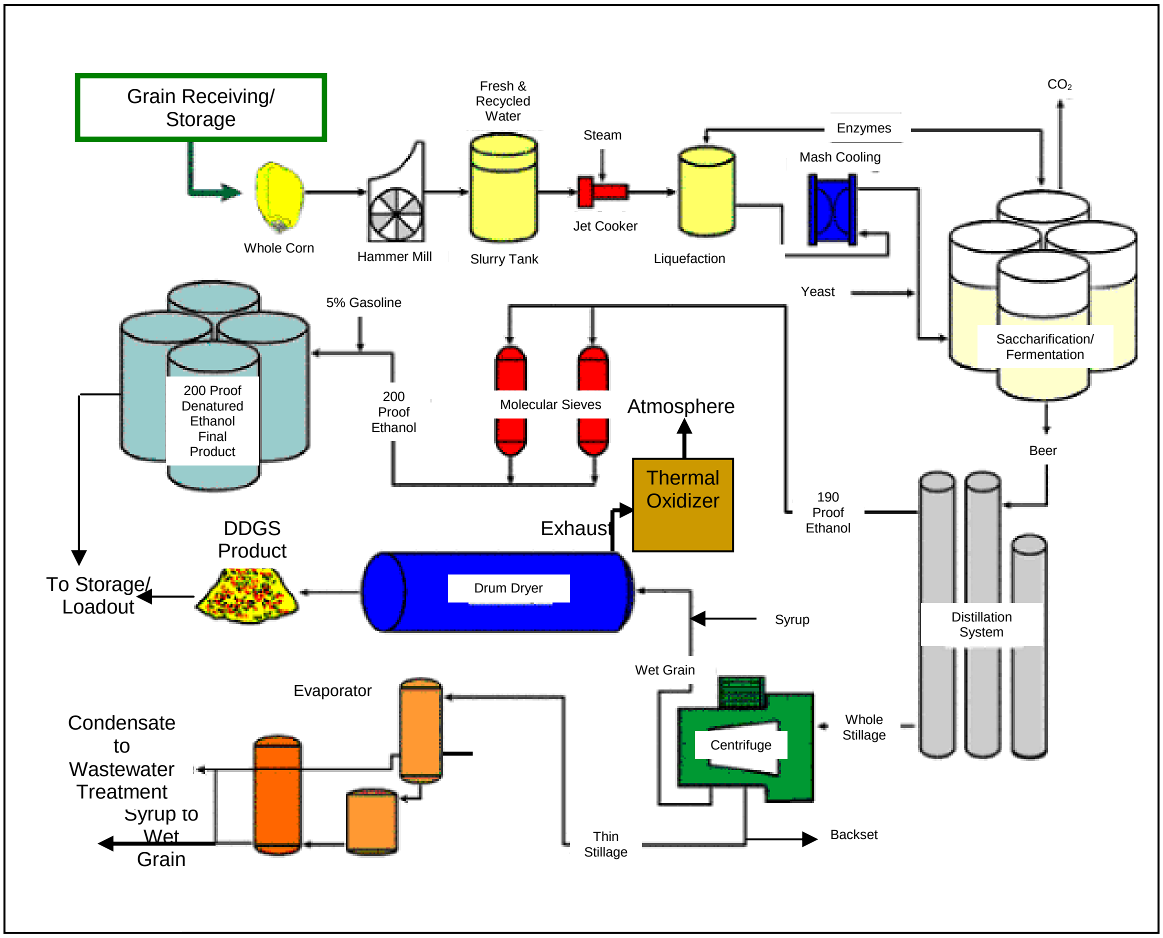
Technology and Costs of Production for Conventional and Fractionation Plants

Cost estimates for four ethanol plants were obtained from Frazier, Barnes and Associates (FB & A). The cost estimates are for two conventional plants and for two fractionation plants of 50 and 100 million gallon annual capacity. The following table is a summary of the estimated capital costs associated with the construction and startup of each type and size of plant.

CAPITAL COST ESTIMATES FOR SELECTED ETHANOL PLANTS

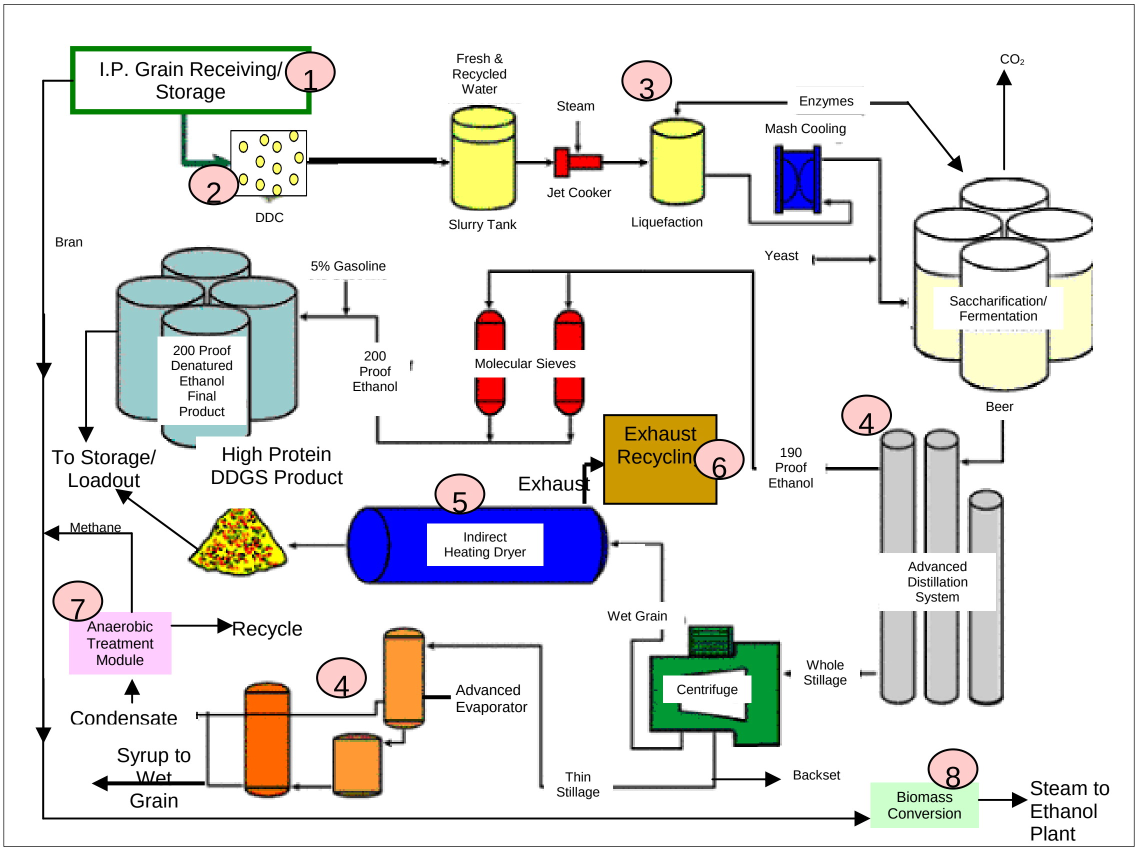
	Conventional		Fractionation	
	50 mm Gal	100 mm Gal	50 mm Gal	100 mm Gal
Ethanol Plant	$70,000,000	$140,000,000	$93,000,000	$186,000,000
Railroad system	$2,800,000	$2,800,000	$2,800,000	$2,800,000
Site Prep/Underground/Fire	$7,000,000	$7,000,000	$7,000,000	$7,000,000
Construction Contingency (5%)	$4,137,400	$7,694,900	$5,287,400	$9,994,900
Engineering & Permitting	$328,000	$328,000	$328,000	$328,000
Phase I & II Environmental	$10,000	$10,000	$10,000	$10,000
Electrical & Utilities	$2,000,000	$3,000,000	$2,000,000	$3,000,000
Admin Building	$300,000	$300,000	$300,000	$300,000
Land	$300,000	$450,000	$300,000	$450,000
Site Survey	$10,000	$10,000	$10,000	$10,000
Feedstock/Working/Start-up	$5,500,000	$9,000,000	$5,500,000	$9,000,000
Total Capital Cost Estimate	$92,385,400	$170,592,900	$116,535,400	$218,892,900

Conventional Ethanol Plant Flow Diagram



The following figure shows the fractionation ethanol plant flow diagram. The major differences between it and the conventional plant are as follows. Once the corn arrives from grain receiving and storage, it goes through the dry fractionation process and is converted into DDC (de-branned, de-germed corn). The next major difference is the indirect heating dryer with the exhaust recycling. The last significant difference in the flow is that the bran removed from the corn as it is converted into DDC generates steam by way of a bran co-fired boiler. In both diagrams, carbon dioxide is shown venting into the air consistent with the feasibility study not accounting the marketing of the CO_2.

Fractionation Ethanol Plant Flow Diagram



Economic Feasibility of Ethanol Production

The following chart summarizes the economic feasibility of ethanol production under the following assumptions:

1. Ethanol sales price of $1.75 per gallon, corn cost of $2.80 per bushel.
2. DDGs sales from the conventional plants at $86.25 per ton and the high protein DDGS from the fractionation plants at $118.00 per ton.
3. Corn germ and DDC sales from the fractionation plants at $109.50 and $97.00 per ton, respectively.
4. A return of 7 percent is given to all capital costs.
5. A return of 5 percent of all capital is given to management.
6. Full operation for 350 days per year with all production saleable at the given prices.
7. Capital costs are financed with 50 percent owner equity and fifty percent debt capital.

ECONOMIC FEASIBILITY OF SELECTED ETHANOL PLANTS

ECONOMIC COSTS AND RETURNS

	50 mmGal Conventional	100 mmGal Conventional	50 mmGal Fractionation	100 mmGal Fractionation
Revenue		Million Dollars		
Ethanol Sales @$1.75/gl	$85.0	$170.0	$85.0	$170.0
DDGS Sales @$86.25/tn	$13.8	$27.6	$11.9	$23.8
DDC & Corn Germ			$16.9	$34.0
Total	$98.8	$197.6	$114.0	$228.0
Production Costs				
Feedstock Costs	$49.8	$99.6	$65.8	$132.0
Processing Costs	$22.3	$44.6	$14.2	$28.3
Labor	$1.5	$1.8	$2.0	$2.9
Repairs and Maintenance	$1.0	$2.0	$1.0	$2.0
Insurance	$0.4	$0.8	$0.4	$0.8
Marketing and Freight	$3.5	$7.0	$3.5	$7.0
Interest on Short term debt	$0.3	$0.5	$0.3	$0.5
Other, SG&A	$4.0	$8.2	$1.6	$3.3
Total Production Cost	$82.1	$164.6	$89.0	$176.5
Fixed Costs				
Depreciation	$5.8	$10.7	$7.4	$14.0
Return to all Capital @ 7%	$6.1	$11.3	$7.8	$14.7
Return to Management @ 5%	$4.3	$8.1	$5.6	$10.5
Total Fixed Costs	$16.2	$30.1	$20.7	$39.1
Total Economic Cost of Oper.	$99	$194.7	$109.7	$215.6
Economic Return	($0.3)	$2.9	$4.3	$12.4
Return on Investment	(0.3%)	1.8%	3.9%	5.9%

The first test of a proposed venture is whether or not it can return a fair market value return to the resources used to create a product. The resources used are essentially land, labor, capital and management. Each of these resources should be paid a fair market value. Land is included in the capital resource and is paid a 7 percent return. Labor is included in the production cost at the assumed wage rate and management receives a return equal to 5 percent of the total capital expenditure. The remaining returns, if positive indicate that the venture has a true economic probability of success. Ethanol production is economically feasible for the 100 mmGPY conventional plant and for both of the fractionation plants in that given the assumptions used in the analysis, these plants will cover all the costs of operation and return net proceeds.

FINANCIAL FEASIBILITY OF SELECTED ETHANOL PLANTS

PRO FORMA INCOME STATEMENTS

	50 mmGal Conventional	100 mmGal Conventional	50 mmGal Fractionation	100 mmGal Fractionation
Revenue		Million Dollars		
Ethanol Sales @$1.75/gl	$85.0	$170.0	$85.0	$170.0
DDGS Sales @$86.25/tn	$13.8	$27.6	$11.9	$23.8
DDC & Corn Germ			$16.9	$34.0
Total	$98.8	$197.6	$114.0	$228.0
Production Costs				
Feedstock Costs	$49.8	$99.6	$65.8	$132.0
Processing Costs	$22.3	$44.6	$14.2	$28.3
Labor	$1.5	$1.8	$2.0	$2.9
Repairs and Maintenance	$1.0	$2.0	$1.0	$2.0
Insurance	$0.4	$0.8	$0.4	$0.8
Marketing and Freight	$3.5	$7.0	$3.5	$7.0
Interest on Short term debt	$0.3	$0.5	$0.3	$0.5
Other, SG&A	$4.0	$8.2	$1.6	$3.3
Total Production Cost	$82.1	$164.6	$89.0	$176.5
Fixed Costs				
Depreciation	$5.8	$10.7	$7.4	$14.0
Interest	$4.2	$7.9	$5.4	$10.2
Total Fixed Costs	$10.0	$18.6	$12.8	$24.2
Total Cost of Operation	$92.9	$183.2	$104.5	$205.0
Net Returns	$5.9	$14.4	$9.5	$23.0
Return on Investment	6.8%	9.0%	8.6%	10.9%

From a financial perspective, all four of the ethanol plants will generate a positive return above expenses, given the assumptions stated above. There is sufficient revenue generated to cover all cash costs and depreciation or capital replacement costs.

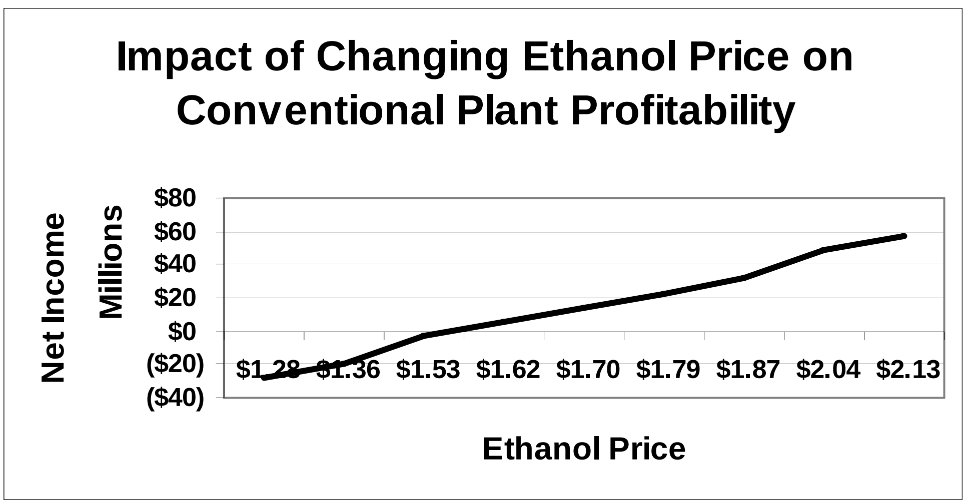
General Caveat

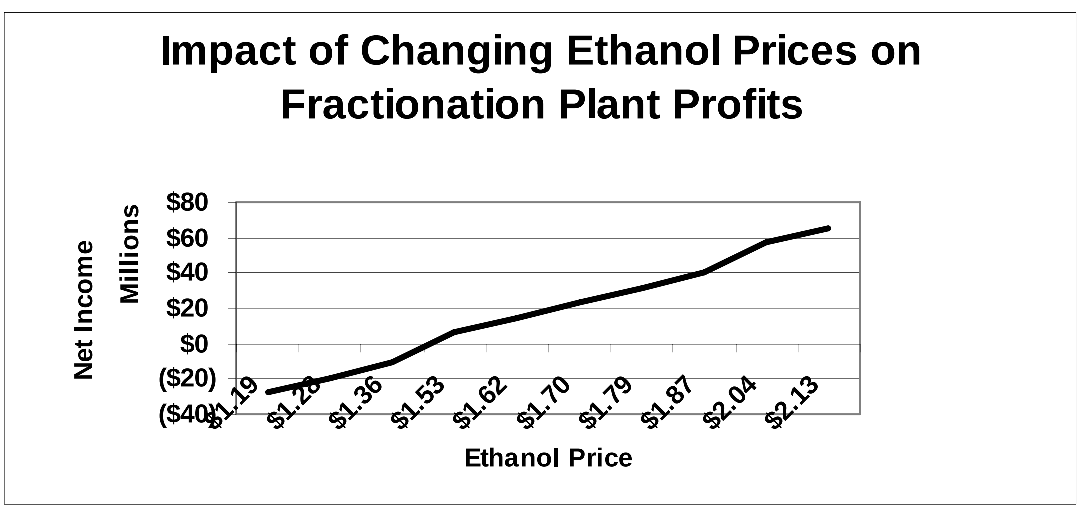
One basic assumption used in developing the analyses is that the plant does in fact operate at 100 percent capacity or 24-7 for 350 days per year. It is unlikely that any operation will begin and continue to operate as designed without hitch. A later sensitivity analysis attempts to frame this concern demonstrating changes in profitability to changes in efficiency. Over time, given quality plant design and construction, excellent management and experience and improvements to the plant and operation, it is possible to exceed the stated capacity. Many plants accomplish that feat with resulting improved profitability.

Sensitivity Analysis on Critical Variables for the Advanced Corn-based Plant

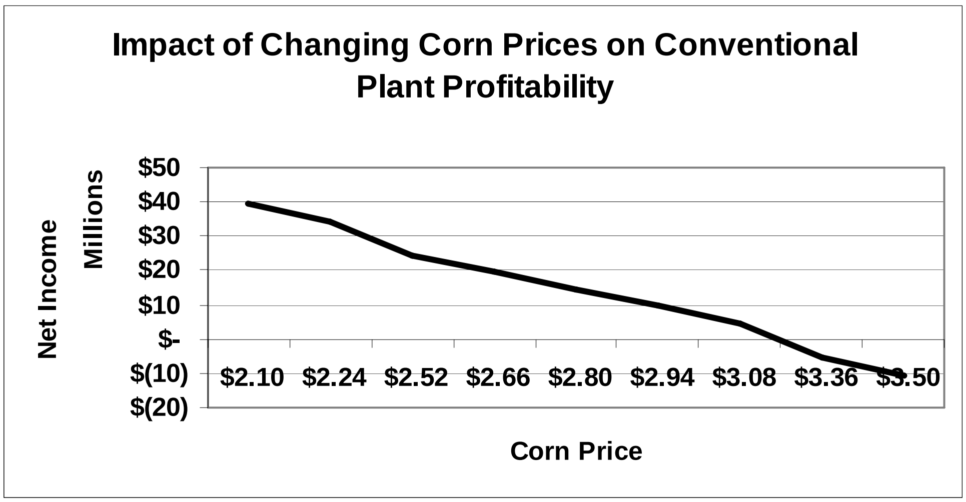
There are some variables that have a significant impact upon net income. A sensitivity analysis demonstrates the impact of changes in those variable and the resulting changes in net income. Sensitivity analysis is done in order to assess a level of risk associated with potential future changes in these variables.

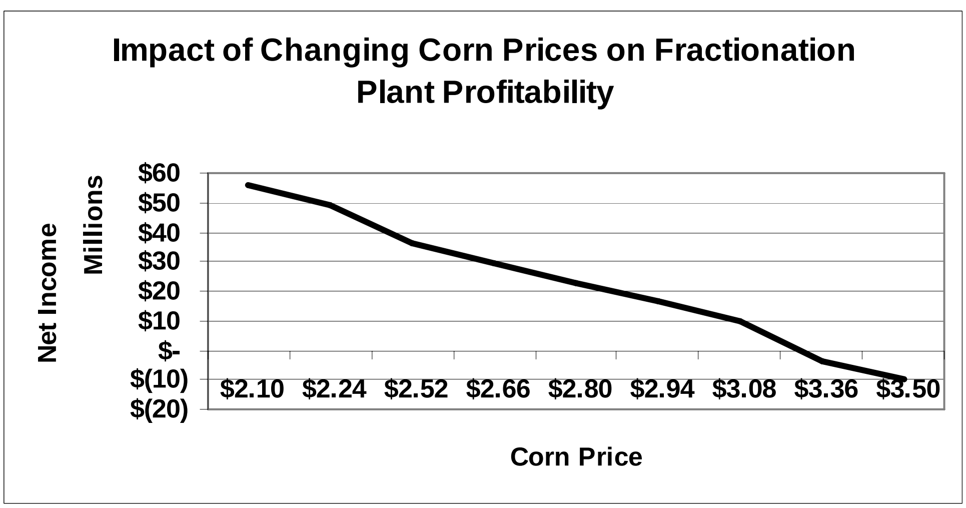
The sales price of the ethanol produced is a primary determinant of profitability. The following two charts illustrate the impact upon net income of changes in the selling price of ethanol (all other variable held constant) for the two large size plants, 100 mmGal conventional and 100 mmGal fractionation plants. The breakeven sales price of ethanol for the conventional plant is about $1.56 per gallon while the breakeven sales price for the fractionation plant is about $1.48 per gallon. So, from an ethanol sales price perspective, the fractionation technology appears to have a slight advantage over the conventional plant.



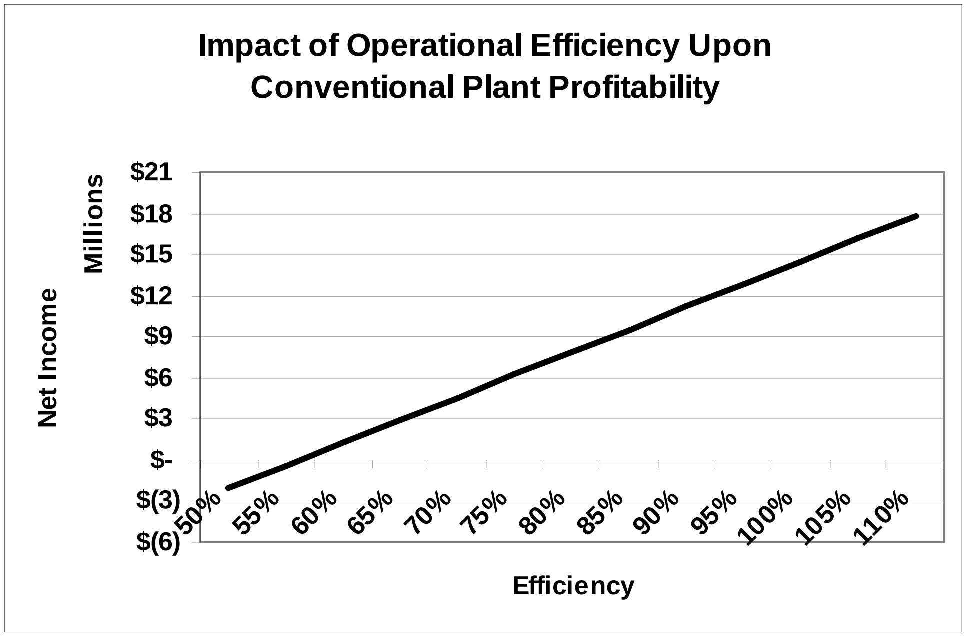


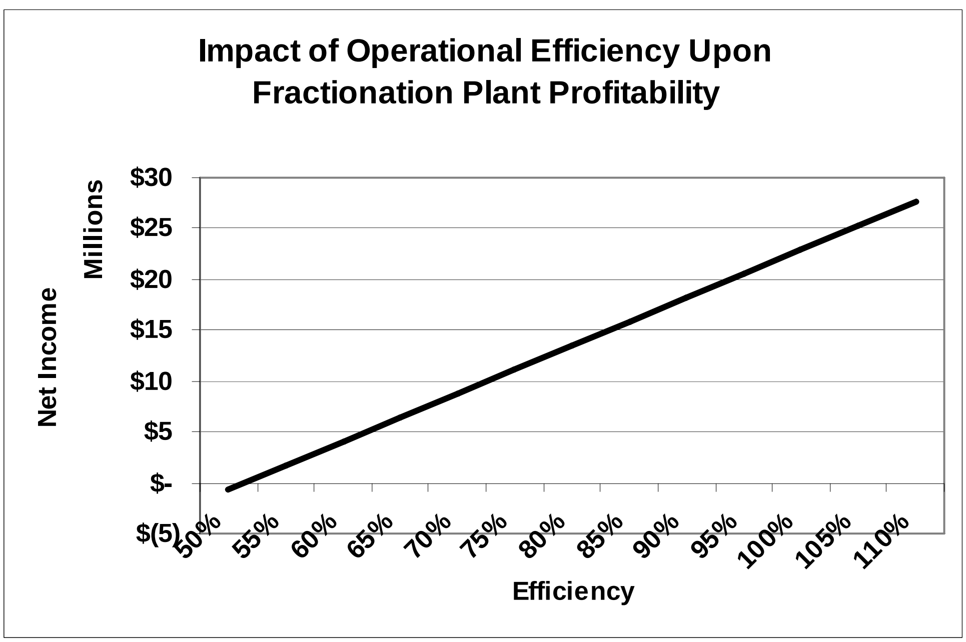
The price of corn, the primary input in ethanol production has the potential to make a significant impact on profitability. Purchased corn represents about 53 percent of total costs for the conventional plants and about 63 percent of total costs for the fractionation plants. The two following charts demonstrate how the profitability of the two 100 mmGPY plants is affected when corn prices change from the base price of $2.80 (all other variable held constant). The conventional ethanol plant is profitable when the corn price is $3.19 per bushel or less while the fractionation plant is profitable at corn prices of $3.26 per bushel or less. The fractionation technology appears to provide a slight advantage relative to the conventional plant in terms of breakeven corn prices.





The last variable studied for its impact upon ethanol profitability is operational efficiency or the percent of operations compared to the "advertised" plant capacity. The purpose of this analysis is to determine the lowest level of operations that will generate breakeven costs and revenues. The following two charts illustrate the operational efficiency of the conventional and fractionation plants. The conventional plant must operate at at least 56 percent of advertised capacity, or produce at least 560,000 gallons of ethanol on an annual basis to breakeven. The fractionation plant must produce about 510,000 gallons on an annual basis to cover all costs.





Capital cost is another critically important variable in determining the economic feasibility of a production process. Materials cost can and do change during the construction phase of many projects. Costs also can increase or decrease from the planning phase on into the construction phase, therefore it is important to see what the impact can be from these cost changes. However, in the case of a typical “cookie cutter” variety of ethanol plant the costs of construction can be narrowed to a number that is not quite that risky due to there not being too many unknowns. With the additional and somewhat yet to be proven production elements in the “Advanced” plant, the construction costs could be a little more variable than the typical plant. The cost estimate for this plant was at $70.0 million dollars and already includes some leeway in the cost estimates for the dry fractionation process and the co-fired boiler. Figure 8 shows the effect on profitability of incremental changes in the cost of production by five, ten and twenty percent in both directions. For each change of five percent, the profit increases or decreases a little over $123,000. This shows that a five percent ($3.5 million increment) change in the cost of constructing the plant has relatively little impact on the profitability of the ethanol plant. Over the range of varying capital costs the plant was always profitable.

Net Income at Various Ethanol Prices and Corn Costs

The following tables show the combined impact of changes in net income for various ethanol price and corn price. To read the tables, seek out the cell corresponding to say, $1.50 ethanol price and $2.60 corn price and find the value $1,582,918. That value would be the net income for those prices in a conventional ethanol plant. The other values in the matrixes represent net incomes at various other price combinations. Similarly, find the net income values in the lower table for the fractionation plant. The values in red indicate ethanol/corn price combinations that would result in a loss.

Relationship Between Corn and Ethanol Prices and the Impact on Net Income For a 100 mmGal Conventional Plant.

Corn			Ethanol Prices		
Prices	**$1.20**	**$1.40**	**$1.50**	**$1.60**	**$1.80**
$2.20	($14,184,872)	$5,815,128	$15,815,128	$25,815,128	$45,815,128
$2.40	($21,300,977)	($1,300,977)	$8,699,023	$18,699,023	$38,699,023
$2.60	($28,417,082)	($8,417,082)	$1,582,918	$11,582,918	$31,582,918
$2.80	($35,533,187)	($15,533,187)	($5,533,187)	$4,466,813	$24,466,813
$3.00	($42,649,292)	($22,649,292)	($12,649,292)	($2,649,292)	$17,350,708

Relationship Between Corn and Ethanol Prices and the Impact on Net Income For a 100 mmGal Fractionation Plant.

Corn Prices	Ethanol Prices $1.20	$1.40	$1.50	$1.60	$1.80
$2.20	$1,173,846	$21,173,846	$31,173,846	$41,173,846	$61,173,846
$2.40	($8,234,154)	$11,765,846	$21,765,846	$31,765,846	$51,765,846
$2.60	($17,642,154)	$2,357,846	$12,357,846	$22,357,846	$42,357,846
$2.80	($27,050,154)	($7,050,154)	$2,949,846	$12,949,846	$32,949,846
$3.00	($36,458,154)	($16,458,154)	($6,458,154)	$3,541,846	$23,541,846

Summary and Conclusions

The study analyzed two types of ethanol production technologies in two different sized plants to determine their estimated profitability in Georgia. Results indicate that the larger conventional plant and the two fractionation plants are economically feasible and that all plants could operate profitable given high enough ethanol sales prices and low enough corn costs. Additionally, the sensitivity analysis shows the plant to be profitable through the ranges of variation in the variables analyzed.

Economic Impacts of Ethanol Production in Georgia

Executive Summary

Construction and operation of an ethanol plant in Georgia has the potential to create economic benefits throughout the state. Total revenue is the direct output of the operation and is projected as $197.6 million from ethanol sales and co products. Construction of a 100 million gallon ethanol plant creates a one-time economic output impact of $130.0 million to the Georgia economy. Economic activity related to construction generates $51.7 million in labor income for 1,203 jobs. Production of ethanol creates annual economic output impacts of $335.8 million. Plant operations account for 50.2% of the total output impact, while 49.8% of the output impact is attributable to feedstock from corn produced in Georgia. Ethanol production leads to $37.6 million in labor income for 1,030 jobs in the Georgia economy. Not including any sales or fuel taxes, ethanol production generates $3.8 million for the state treasury and $3.1 million for local governments in the state.

Economic Impacts of Ethanol Production in Georgia

Construction and operation of an ethanol plant in Georgia has the potential to create economic benefits throughout the state. Impacts due to construction of an ethanol plant are one-time benefits occurring within the period of construction. Total construction costs of a 100 million gallon plant are $153.4 million. Ethanol production impacts occur annually and derive from utilized operating inputs. Total revenue is the direct output of the operation and is projected as $197.6 million from sales of ethanol, as well as co product sales consisting of distillers dried grains and solubles (DDGS), corn germ, and carbon dioxide.

Input-Output Models and Economic Impact Analysis

Economic impacts are estimated with input-output models that separate the economy into various sectors, such as agriculture, construction, manufacturing, trade, and services. The input-output model calculates how a change in one industry changes output, income, and employment in other industries. These changes, or impacts, are expressed in terms of direct, indirect, and induced effects. Direct impacts represent the initial impact on the economy of some feature (i.e. construction or operations) of an enterprise. Indirect impacts are changes in other industries caused by direct effects of an enterprise. Induced impacts are changes in household spending due to changes in economic activity generated by both direct and indirect impacts. Thus, the total economic impact is the sum of direct, indirect, and induced impacts. This report combines indirect impacts and induced impacts into one category referred to as indirect impacts. Input-output analysis interprets the impacts of an enterprise as output (sales), labor income (employee compensation and proprietary income), employment (jobs), and tax revenue.

Economic impacts result from a multiplier effect that begins with expenditures of an enterprise stimulating business to business spending, personal income, employment, and tax revenue. IMPLAN models include a regional purchase coefficient (*RPC)* for each impact variable that represents percentage of demand that is satisfied by production within an impact area. Enterprises vary in their multiplier effects due to differing expenditure levels, *RPC's*, and sectors in which their expenditures are directed. Impact analysis involves quantification of spending levels and proper allocation to impacted sectors.

Output impacts are a measure of economic activity that results from enterprise expenditures in a specific industrial sector. Output is equivalent to sales, and this multiplier offers insights into how initial economic activity in one sector leads to sales in other sectors. Personal income impacts measure purchasing power that is created due to the output impacts. This impact provides the best measure of how standards of living are affected for residents in the impact area.

An enterprise involves a specified number of employees that is determined by the technology of the enterprise. Employment multipliers indicate the effect on employment resulting from the enterprise initiating economic activity. IMPLAN indirect and induced employment includes both full-time and part-time jobs without any distinction. Jobs calculated within an IMPLAN industrial sector are not limited to whole numbers and fractional amounts represent additional hours worked without an additional employee. With no measure of hours involved in employment impacts, IMPLAN summations for industrial sectors which include fractional employment represent both jobs and job equivalents. Since employment may result from some employees working additional hours in existing jobs, instead of terming indirect and induced employment impacts as “creating” jobs, a more accurate term is “involving” jobs.

Construction Impacts

One-time construction impacts for Georgia are presented in Table 1. Direct output of $70.8 million is less than total construction costs because many construction items involve economic activity outside the impact area of Georgia. Economic activities occurring outside of Georgia that are related to plant construction are leakages to the state economy. Direct output during the construction period leads to additional output resulting in a total output impact of $130.0 million. This output generates income of $51.7 million for proprietors and employees. A total of 1,203 full-time and part-time jobs are impacted by construction, and total labor income averages $42,953 in wages and benefits. Georgia realizes $3.5 million in state tax revenue, while local governments throughout the state receive $2.2 million during the construction period. Appendix 1 shows the distribution of output, income, and employment in the major industrial sectors.

Table 1. Plant Construction: One-time Georgia Economic Impacts

	Direct Impact	Indirect Impact	Total Impact
Output ($)	70,809,675	59,217,731	130,027,406
Labor Income ($)	31,770,886	19,901,627	51,672,513
Employment	657	546	1,203
State Taxes ($)			3,510,485
Local Taxes ($)			2,212,147

Operation Impacts

Annual benefits accrue in the state economy each year a plant is in production. Reported impacts in this section do not include potential impacts from utilizing Georgia corn as a feedstock. Impacts due to Georgia corn production are reported in the following section. Impacts for Georgia presented in Table 2 indicate that plant operations have a direct output impact of $98.0 million. Direct impacts lead to an additional $70.5 million in output for a total output impact of $168.5 million from ethanol plant operations. Total direct salaries and benefits for production and administrative employees are $1.8 million for 46 employees. Additional income of $19.0 million for impacted proprietors and employees results in $20.8 million of income due to operation of the ethanol plant. Total labor income averages $48,831 for 426 full-time and part-time jobs. State tax revenues generated are $2.5 million and local tax revenues are $2.2 million. Reported tax revenues in this report do not include any sales tax on output sold as a finished product by the operation. The distribution of output, income, and employment among the major industrial sectors is presented in Appendix 2.

Table 2. Ethanol Production Without Feedstock: Annual Georgia Economic Impacts

	Direct Impact	Indirect Impact	Total Impact
Output ($)	97,993,915	70,534,338	168,528,253
Labor Income ($)	1,841,423	18,960,742	20,802,165
Employment	46	380	426
State Taxes[1] ($)			2,475,735
Local Taxes[1] ($)			2,234,106

[1]Does not include sales or fuel taxes on ethanol sales.

Impacts of Georgia Corn as Feedstock

Utilization of corn produced in Georgia as an ethanol feedstock generates additional output, employment, labor income and taxes in the Georgia economy. Annual feedstock needs of an ethanol plant are $99.6 million. State economic impacts for corn produced in Georgia are presented in Table 3. Corn produced in Georgia for a 100 million gallon ethanol plant leads to a $67.6 million indirect output impact for a total output impact of $167.3 million. Total labor income impacts are $16.8 million for 604 jobs. Wages and benefits average $27,803 per job. Results in Table 3 are only valid for circumstances in which corn production beyond current levels consists of new agricultural land going into production that is presently idle. Corn acreage that replaces acreage currently in other agricultural production such as cotton and peanuts generates economic impacts only at the expense of lost impacts due to displaced production.

Table 3. Corn Production: Annual Economic Benefits to Georgia

	Direct Effect	Indirect Effect	Total Effect
Output ($)	99,625,467	67,629,437	167,254,904
Labor Income ($)	11,080,661	5,712,134	16,792,795
Employment	442	162	604
State Taxes ($)			1,311,538
Local Taxes ($)			900,854

Summing direct output impacts in Table 2 and Table 3 result in a $197.6 million total direct impact of ethanol production for a 100 million gallon plant. Indirect output impacts sum to $138.2 million. Total output impacts are $335.8 under assumptions that all feedstock is corn produced in Georgia. Plant operations account for 50.2% of the total output impact, while 49.8% of the output impact is attributable to corn as a feedstock. Ethanol production leads to $37.6 million in labor income for 1,030 jobs in the Georgia economy. Not including any sales or fuel taxes, ethanol production generates $3.8 million for the state treasury and $3.1 million for local governments in the state.

Summary

Construction of a 100 million gallon ethanol plant creates a one-time economic output impact of $130.0 million to the Georgia economy. Economic activity related to construction generates $51.7 million in labor income for 1,203 jobs. Production of ethanol creates annual economic output impacts of $335.8 million. Plant operations account for 50.2% of the total output impact, while 49.8% of the output impact is attributable to corn produced in Georgia. Ethanol production leads to $37.6 million in labor income for 1,030 jobs in the Georgia economy. Ethanol production generates $3.8 million for the state treasury and $3.1 million for local governments in the state.

Appendix 1. Plant Construction: One-time Economic Impacts to Major Sectors, Georgia

Sector	Output ($)	Labor Income ($)	Employment
Agriculture	673,804	178,200	6
MC[1]	52,826,395	22,227,841	542
Utilities	9,279,468	3,688,368	38
Manufacturing	9,546,508	2,071,902	41
Transportation, Warehousing	2,341,460	1,011,007	23
Trade	12,948,233	4,965,422	162
FIRE[2]	7,884,222	2,128,180	45
Services	27,027,153	12,770,216	325
Government & Non NAIC's	7,500,164	2,631,377	22
Total	130,027,406	51,672,513	1,203

[1] Mining and Construction

[2] Finance, Insurance, and Real Estate

Appendix 2. Ethanol Production Without Feedstock: Annual Economic Impacts to Major Sectors, Georgia

Sector	Output ($)	Labor Income ($)	Employment
Agriculture	188,050	57,285	2
MC[1]	729,549	237,010	4
Utilities	27,116,788	4,909,066	35
Manufacturing	103,328,424	2,505,711	56
Transportation, Warehousing	8,771,328	3,027,698	72
Trade	3,936,811	1,527,365	45
FIRE[2]	4,718,920	1,308,209	26
Services	17,239,281	7,127,319	184
Government & Non NAIC's	2,499,103	102,503	2
Total	168,528,253	20,802,165	426

[1]Mining and Construction
[2]Finance, Insurance, and Real Estate

Appendix 3. Corn Production: Annual Economic Benefits to Major Sectors, Georgia

Sector	Output ($)	Labor Income ($)	Employment
Agriculture	103,914,176	11,485,681	462
MC[1]	512,040	62,730	1
Utilities	1,957,918	120,509	1
Manufacturing	10,445,611	333,095	6
Transportation, Warehousing	2,913,508	333,162	8
Trade	10,499,349	1,140,849	31
FIRE[2]	13,059,342	966,041	24
Services	17,845,538	2,260,483	71
Government & Non NAIC's	6,107,422	90,245	2
Total	167,254,904	16,792,795	604

[1]Mining and Construction
[2]Finance, Insurance, and Real Estate

The Center for Agribusiness and Economic Development

The Center for Agribusiness and Economic Development is a unit of the College of Agricultural and Environmental Sciences of the University of Georgia, combining the missions of research and extension. The Center has among its objectives:

> To provide feasibility and other short term studies for current or potential Georgia agribusiness firms and/or emerging food and fiber industries.
>
> To provide agricultural, natural resource, and demographic data for private and public decision makers.

To find out more, visit our Web site at: http://www.caed.uga.edu

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Scott Angle, Dean and Director