The University of Georgia

Center for Agribusiness and Economic Development

College of Agricultural and Environmental Sciences

The Economic Feasibility of Operating an Advanced Ethanol Production Facility in Georgia

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Center for Agribusiness and Economic Development

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Executive Summary

This feasibility study looked at two types of "advanced" ethanol plants in order to determine their estimated profitability in the central part of Georgia. The two types of plants were corn-only and corn-rye feedstock operations. The corn-only plant showed promise to be a profitable enterprise in Georgia. It had a net income of around $3.75 million and a return on investment of over five percent. The projected capital costs are about $70 million. About $35 million in equity would need to be raised for the project to move forward since lenders typically require around 50 percent owner equity on this type of project. The "advanced" plant has the ability to increase the level of output beyond the 30 million gallons per year due to the production technology it utilizes. It could potentially produce up to five percent more ethanol than its stated capacity increasing profitability. Sensitivity analysis of critical variables shows the plant to be profitable through expected ranges of the variables analyzed. The prices of ethanol and corn are vitally important to profitability and only in the case of the lowest level of ethanol prices and the highest level of corn prices analyzed does the plant become unprofitable.

The "advanced" plant that will utilize two feed-stocks, corn and rye, instead of just corn has a projected capital cost of about $85.5 million. This is $15.5 million more than the "advanced" plant that utilizes only corn. The advantages of using a lower cost feed-stock (rye) are outweighed by the increased capital costs of the plant. At 100 percent capacity, this plant is expected to generate $1.8 million in annual net income. Given the higher capital cost required and the lower projected net income, it is problematic that a dual feedstock ethanol plant would be a leading investment choice in Georgia at the present time. The lower net income combined with the higher capital costs reduces the return on investment to two percent from around five percent with the single feedstock plant. Given the lower net income and reduced return on investment, a sensitivity analysis was not performed on this plant. The sensitivity analysis would not differ significantly from that for the corn-only plant in terms of the magnitudes of the changes, only the starting values for the net income.

In conclusion, the analysis shows that the "advanced" corn-only plant could be profitable in Georgia and with a reasonably good projected outcome. The results also indicate that the corn-rye feedstock plant would not be as profitable as the corn only plant and therefore not as desirable.

The Economic Feasibility
of Operating an
Advanced Ethanol Production Facility in Georgia

Introduction

The Georgia Agricultural Commodity Commission for Corn in association with the Georgia Cooperative Development Center contracted the Center for Agribusiness and Economic Development (CAED) to do a feasibility study on the production of Ethanol in Central Georgia. This study was to follow up a study that had been done two years previously, and was to expand the knowledge base of the feasibility of ethanol production in Georgia. The concern of the corn growers in Georgia was that given the price of feedstock corn is typically higher in Georgia than in the Midwest, a Georgia-based ethanol plant will operate at a competitive disadvantage to Midwest based ethanol plants.

To offset this competitive disadvantage, the Georgia Agricultural Commodity Commission for Corn was interested in examining other ethanol production options besides the typical conventional dry-grind ethanol plant model that is currently the industry standard. The study was to evaluate the potential for using alternative feedstocks as well as implementing a dry fractionation process of the corn prior to conversion to ethanol. Dry fractionation reduces the corn kernel to three parts – the bran, the germ and the endosperm. Fractionation would allow bran from the feedstock to fire the boiler for the plant, thus saving on energy costs. In addition, the dry fractionation process was theorized to increase the protein level of the co-product dried distillers grains and solubles (DDGS) from around 23 - 28 percent to around 40 to 42 percent. It was also thought to be able to increase the efficiency of the plant as well, by running just the endosperm through the plant, therefore increasing the cost efficiency per unit. The corn germ would be sold as a by-product.

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 had an interest in looking at this type of "Advanced" ethanol plant. 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.

The current industry standard plant is a dry grind facility where the entire corn kernel is run through the conversions process. The estimated capital cost for a 30 million gallon per year conventional plant is about $52.5 million with annual operating costs of about $48.9 million. In comparison, the estimated capital costs of an advanced fractionation plant with co-firing capacity is about $70 million with annual operating expenses of about $46.8 million.

Production Advantages of the Advanced Plant

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

There is also a higher co-product value for the "advanced" 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. One of the other co-products, DDGS, also has a higher value than what comes from a conventional ethanol plan since it is higher in protein making it more valuable to livestock producers. The protein level of this product should be over 40 percent which would allow it to compete directly against soybean meal.

The plant evaluated here is designed with an additional 2 million bushel of storage/conditioning capacity allowing management to purchase lower cost large volumes of unconditioned feedstock during harvest. This will lower the average feedstock costs.

The overall advantages of the advanced ethanol plant do have costs associated with them. The upfront investment in this type of plant is estimated to be 40 percent higher than a conventional plant. However, the return on investment was expected to be higher than a conventional plant as well.

Technological Assessment of the Advanced Ethanol Plant Design

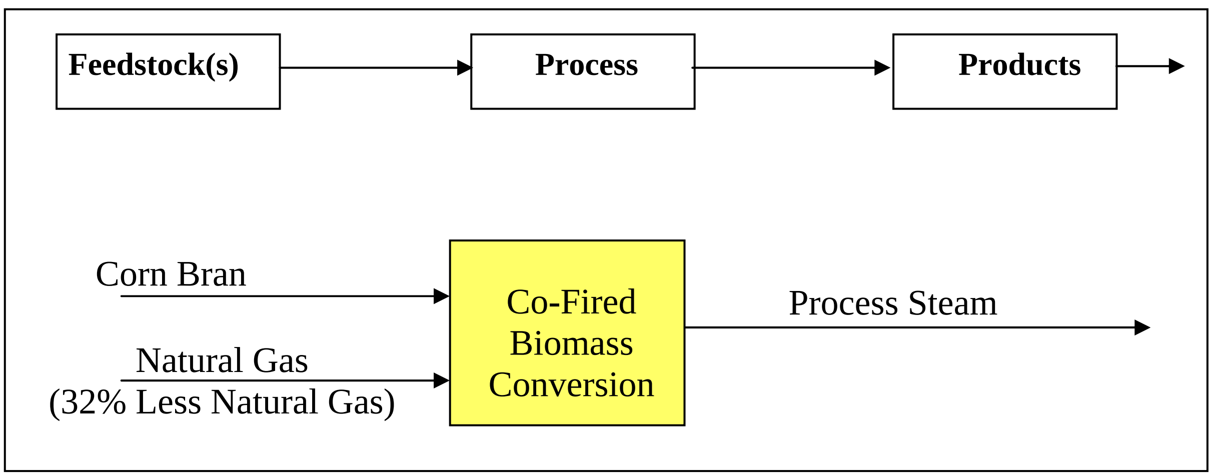
The primary feature of the advanced ethanol plant is the fermentation of only the endosperm also called, de-branned, de-germed corn (DDC) feedstock. DDC has 84 percent starch content dry basis compared to a whole-corn feedstock with 70 percent starch content dry basis. This higher starch content, lower 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. It is reported that one of these technologies is currently being installed at an ethanol plant in Iowa. 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 would reduce the steam production cost for the ethanol plant. It is expected that a 30 million gallon per year (MMGPY) plant with a dry fractionation process will produce 26,099 tons of bran per year. This equates to 43.5 mmBtu/hr. of potential energy source (350 operating days per year). At a natural gas cost of $6.50/mmBtu, burning the bran equates about $2,375,100 savings per year in natural gas costs or about $0.075 per gallon. A conventional ethanol plant of similar capacity has a natural gas consumption of 137.5 mmBtu/hr. At $6.50/mmBtu this equates to a cost of $7,507,500 per year. 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 disposed of 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 at 109mmBtu/hr. This would be a 20 percent reduction in natural gas consumption, equating to a reduction in the energy costs of $1,501,500 per year. With corn fractionation and bran co-firing natural gas consumption would drop further to 43.5mmBtu/hr, which equates to a savings of over $2,000,000 per year in natural gas costs. This is a 32 percent reduction in energy consumption due to bran co-firing. Thus, an advanced ethanol plant with bran co-firing has the potential to operate at about one-half the energy costs of a conventional plant.

Table 1. Comparison of Energy Sources and Costs for Conventional Ethanol Plant and Dry Fractionation Plant with Bran Burning.

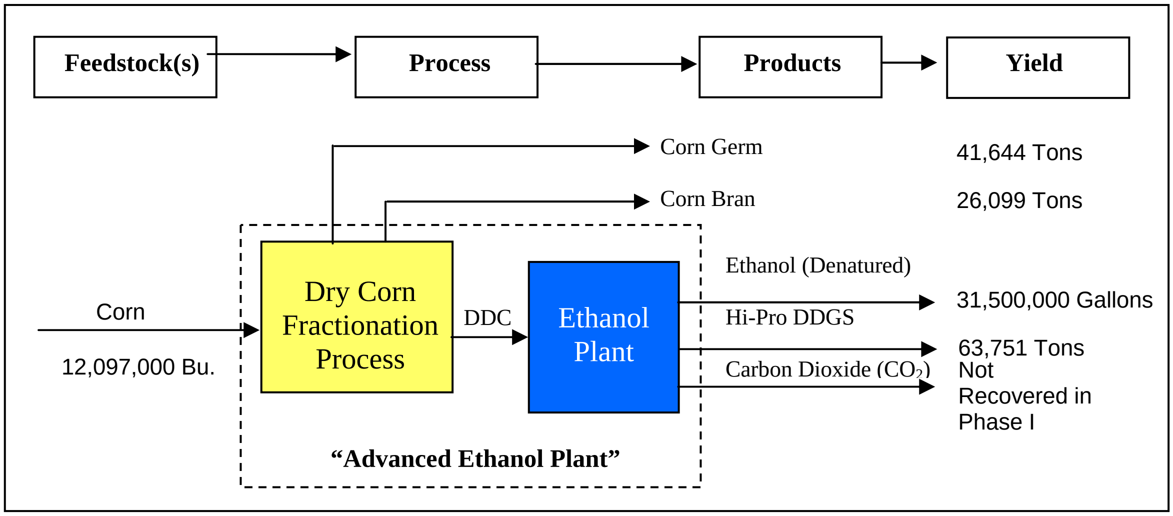
	Dry Fractionation Plant	Conventional Plant
Energy Consumption	109 mmBTU/hr	137.5 mmBTU/hr
Natural Gas Costs	$3.576 million	$7.507 million
Bran Energy Value	$2.375 million	0

Co-Product Yields

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. This would mean that approximately one-third of the output would be in the form of ethanol, one-third carbon dioxide and one-third DDGS. The advanced ethanol plant, however, has two additional co-products resulting from the corn fractionation, the bran and the 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.

Figure 2 below gives some estimates of the co-product quantities produced during the operation of a 30 million gallon per year advanced operation. The amount of denatured ethanol actually produced is 31.5 million gallons. Since the plant is more efficient by not processing the non-productive bran and germ than the conventional plant, it will be able to produce additional ethanol above its stated capacity in time. The quantity of DDGS will be reduced to about 64,000 tons due to the dry fractionation process eliminating some of the throughput, but it will be of higher quality. A little over 41,000 tons of corn germ will be produced as a new co- product from this advanced plant. Corn bran is also produced from the dry fractionation process and will be burned to provide steam for the plant. As stated earlier, the amount of bran produced from 12 million bushels of corn is expected to be around 26 thousand tons.

Figure 2. Product Yields for Advanced Ethanol Plant (30 MMGPY)



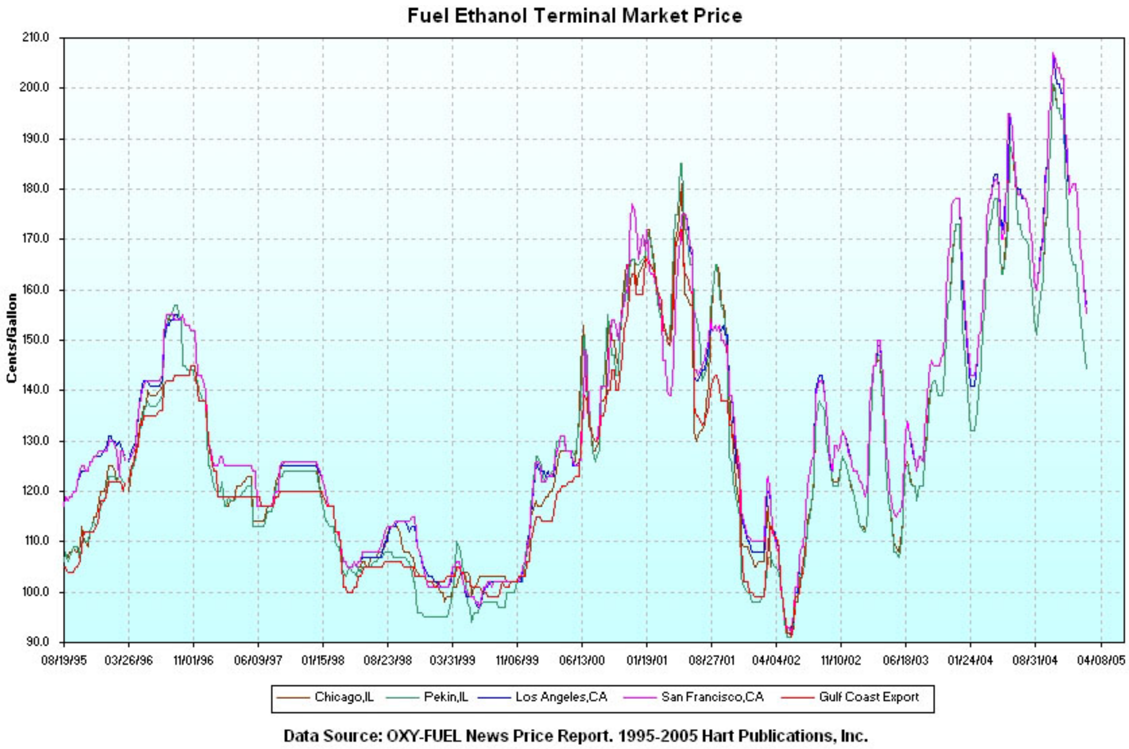
Co-Product Markets

The advanced plant produces four co-products that have potential markets in Georgia and one that will utilized by the plant to produce energy. Ethanol, 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.

The co-product of most significance to an ethanol production facility would be ethanol. This product's market has been volatile over the last several years with the market price moving around the five year average of $1.35 per gallon as shown in Figure 3 below. There are many reasons that the ethanol markets has been so volatile recently. Ethanol production in 2004 surged to a record 3.4 billion gallons. Since that time the addition of 16 new ethanol facilities and the expansion of two existing facilities will bring US total capacity to 4.4 billion gallons annually. These supply increases along with the volatility of the gasoline market have contributed to the volatility in the ethanol market. The market for ethanol has many components and thus makes it difficult to understand.

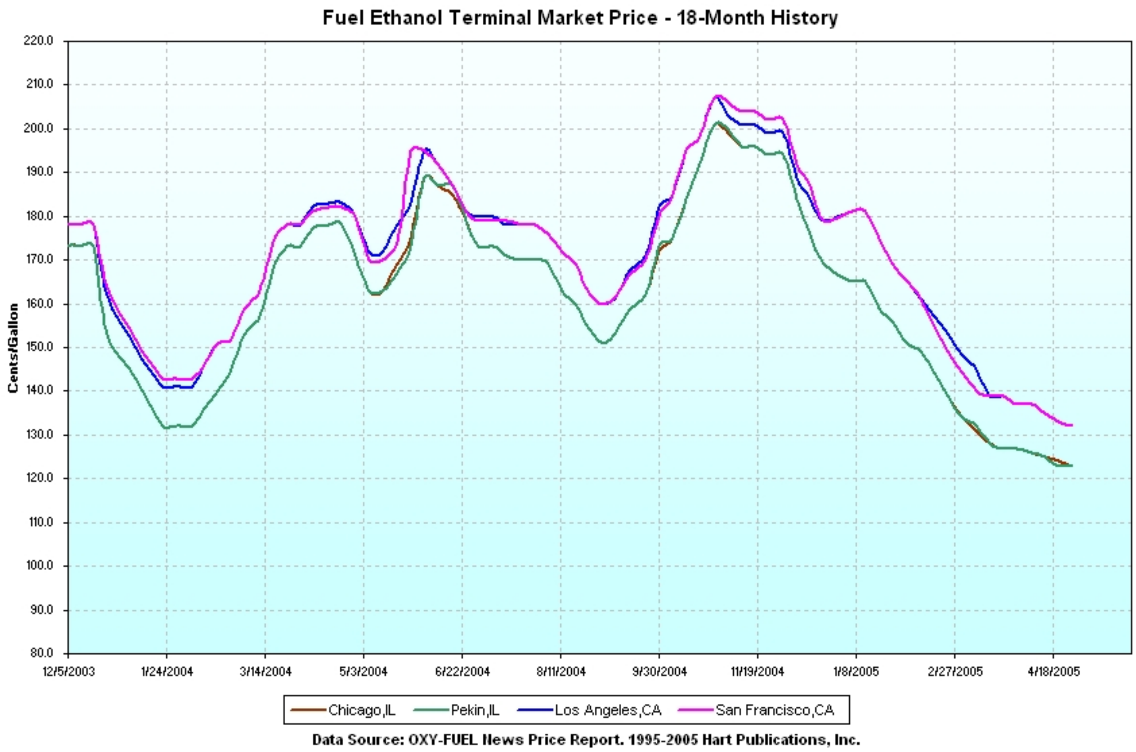
The 1990 Clean Air Act Amendments required that reformulated gasoline sold for consumption in areas of the US that do not meet the Clean Air Act standards must contain at least two percent oxygen by weight. There are two primary sources of oxygenate for gasoline. One, Methyl Tertiary Butyl Ether (MTBE) 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. At the current time, Atlanta, GA does not require the blending of an oxygenate with their gasoline.

Figure 3. Fuel Ethanol Terminal Market Prices June 1995 through July 2005



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. Georgia could ship more corn in to get the necessary quantity and quality, but transporting this corn might prove to be costly. However, producing ethanol in Georgia eliminates the cost of transporting the ethanol into the area from distant production and provides savings on that side.

Figure 4. Fuel Ethanol Terminal Market Prices December 2003 through April 2005



The second most valuable co-product for this production facility would be distillers dried grains and solubles (DDGS). The current United States DDGS production is approaching four million tons per year. It is estimated that in the next three to five years the production will climb to eight 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 a level greater than $140 a 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.

Table 2 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. Table 3 shows the comparison of Soybean Meal to that of High Protein DDGS. 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.

Table 2. 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%

Table 3. 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 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 (42 thousand tons annually) 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 $145 a ton after the transportation costs of $10 per ton and the processing costs of $40 per ton.

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. The current value for CO_2 is around eight dollars a ton. The advanced plant would produce about 96,000 tons of carbon dioxide so the potential value would be about $768,000 per year. We did not assume any revenue from the sale of CO_2 in this study.

Technology and Costs of Production for Conventional and Advanced Plants

Cost estimates of two 30 million gallon ethanol plants were obtained from Frazier, Barnes and Associates (FB & A). The FB & A estimates included what a conventional ethanol plant would cost in addition to the "advanced" ethanol plant with the bran co-fired boiler. The following figure shows the conventional ethanol plant flow diagram. This ethanol plant is of the conventional variety with a hammer mill and a traditional drum dryer for the DDGS. Table 4 shows the estimated costs associated with the construction and startup of a conventional 30 MMGPY ethanol plant. The total capital cost associated with the construction and startup comes to approximately $52.5 million. This includes $2.5 million dollars for grain receiving and storage and $9 million for working capital and startup costs.

Table 4. Conventional Ethanol Plant Capital Cost Projections (30MMGPY)

Component	Capital Cost
Ethanol Plant (30 MMGPY --Includes Natural Gas Boiler)	$34,000,000
Electrical Substation & Utilities	$1,500,000
Professional Services & Permitting	$500,000
Land (80 Acres)	$1,000,000
Construction Contingency	$4,000,000
Feedstock/Product Working Capital & Start-up Cost	$9,000,000
Grain Receiving and Storage	$2,500,000
Projected Conventional Total Capital Cost	**$52,500,000**

Figure 5. Conventional Ethanol Plant Flow Diagram

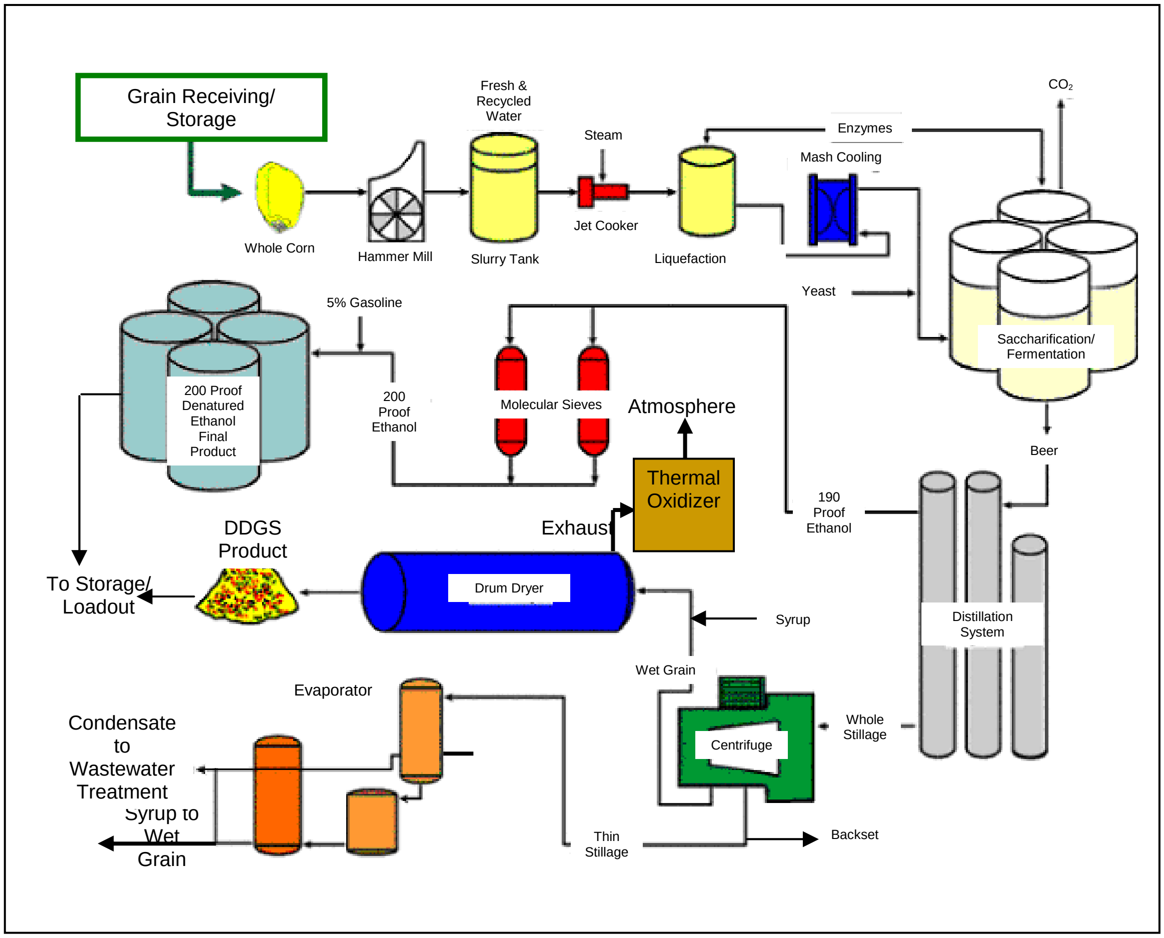


Figure 6 shows the "advanced" ethanol plant flow diagram. The major differences between it and the conventional plant are as follows. Once the corn arrives from grain receiving and storage, it goes through the dry fractionation process and is converted into DDC (de-branned, de-germed corn). The next 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 which is consistent with the feasibility study not taking into account the marketing of the CO_2.

The capital and startup costs for the "advanced" plant are shown in Table 5 on the following page. One of the major differences in costs between the "advanced" and conventional plants is the cost of the dry fractionation equipment. It is estimated to cost around \$7.5 million. Another additional cost is the co-fired boiler which is around \$3 million extra. Two other areas where cost increases are expected were in grain receiving and storage and additional advanced technologies. Quantities of inputs and outputs are from this plant type are listed in Appendix A. Additional considerations dealing with the "advanced" plant utility requirements are included in the Appendix B.

Figure 6. Advanced Ethanol Plant Flow Diagram

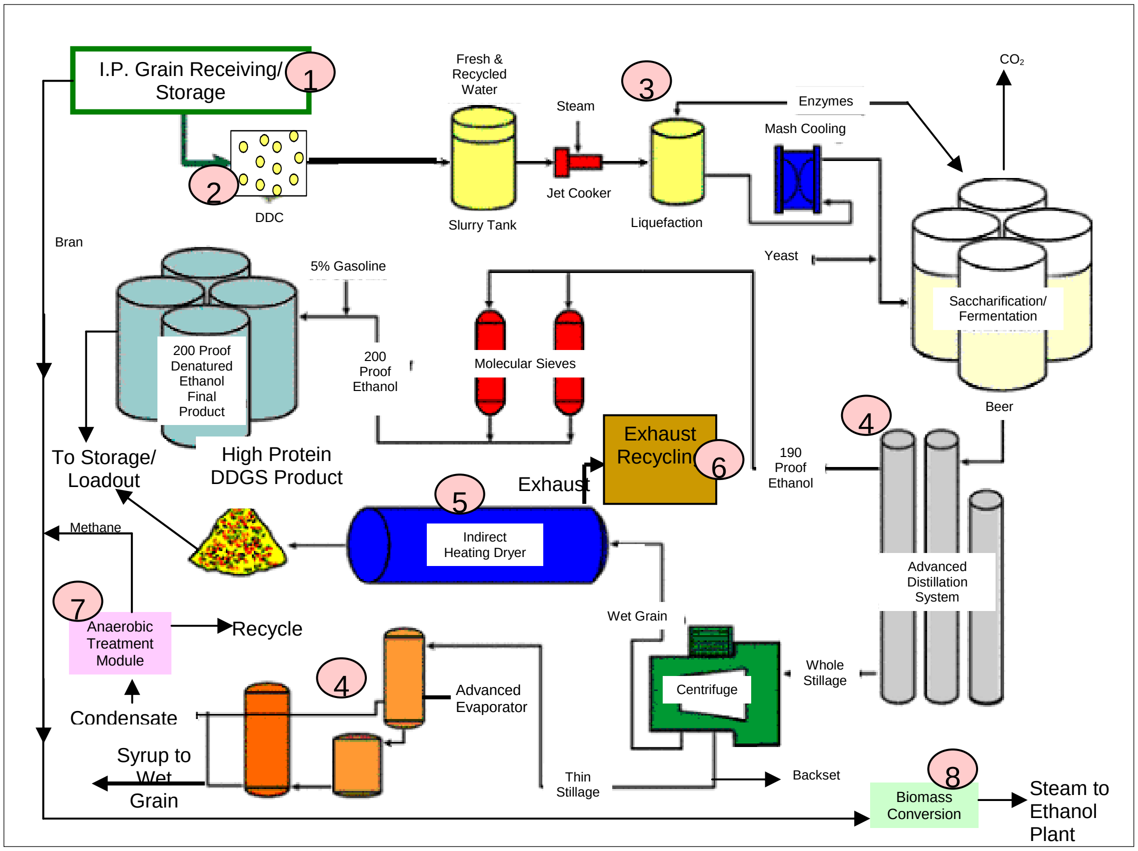


Table 5. Advanced Ethanol Plant Capital Cost Projections (30 MMGPY)

Component	Capital Cost
Grain Receiving and Storage (2.0 Million Bushels)	$7,500,000
Dry Fractionation	$7,500,000
Bran Conversion to Steam	$3,000,000
Additional Advanced Technologies	$2,000,000
Ethanol Plant (30 MMGPY)	$34,000,000
Electrical Substation & Utilities	$1,500,000
Professional Services & Permitting	$500,000
Land (80 Acres)	$1,000,000
Construction Contingency	$4,000,000
Feedstock/Product Working Capital & Startup Cost	$9,000,000
Projected Advanced Total Capital Cost	**$70,000,000**

Pro forma Income Statement for the Advanced Ethanol Plant

A pro forma income statement was derived for the "advanced" plant using the FB & A capital cost estimates and the estimates for the other fixed and variable costs associated with a 30 MMGPY ethanol plant. This income statement is the basis for the sensitivity analysis that will come later. It is important to remember that these are estimated costs and that contingencies are allowed for that reason. The pro forma income statement shows the income derived from all sources: ethanol, high protein DDGS and corn germ. Carbon dioxide will not be used in deriving the total income because it may or may not be an immediate contributor to income. Table 6, shows the co-product incomes as well as the fixed and variable costs associated with the advanced ethanol plant. The plant was assumed to run 24 hours a day, seven days a week, fifty weeks a year. At 100 percent efficiency that plant would produce 90,000 gallons a day or 31.5 million gallons annually. The income from the three saleable co-products is estimated to be a little over $57.6 million, with the sale of ethanol making up $42.5 million of that total.

Processing costs which include labor, chemical, and utility costs total around $12 million. Utilities make up around $4.75 million of that total. The feedstock that is used for this plant is corn only, and a little over 12 million bushels are used annually. This amounts to an annual cost of almost $35 million.

Fixed costs which include taxes, insurance, interest on investment and depreciation total a little over $7 million. Taxes and insurance make up $600,000 of that total with the interest on the investment being $2.45 million. The largest portion of the fixed costs comes from depreciation at $4 million.

When the total costs of production were calculated and subtracted from the co-product's income it was determined that the net income was a little over $3.75 million for the plant. This would give a 5.37 percent return on investment. Assuming 50 percent equity and 50 percent borrowed capital, return on equity would be 10.74 percent.

Table 6. Pro forma Income Statement for the Advanced Ethanol Plant

Pro forma Income Statement for the Advanced Ethanol Plant						
90,000	gallons ethanol per day		100%	Capacity		
7	days per week		242,000	Bushels Corn per week		
50	weeks per year		12,097,000	Bushels Corn Required		
31,500,000	Denatured gallons ethanol per year					
Income:		**Quantity**		**Unit Price**	**Total $**	**Value per bushel**
Ethanol		31,500,000	Gallons	$ 1.35	42,525,000	$ 3.52
High Protein DDGS		63,751	Tons	$ 142.50	9,084,518	$ 0.75
Corn Germ		41,644	Tons	$ 145.00	6,038,380	$ 0.50
Corn Bran		Combusted to save on Natural Gas				
Total					**$ 57,647,898**	**$ 4.77**
Processing Costs:				**Cost Per Gallon**		
Maintenance and Supplies				$ 0.036	$ 1,134,000	
Utilities				$ 0.150	$ 4,725,000	
Chemicals				$ 0.070	$ 2,205,000	
Denaturants				$ 0.040	$ 1,260,000	
Labor and Benefits				$ 0.070	$ 2,205,000	
SG&A				$ 0.015	$ 472,500	
Total Processing and SG&A				**$ 0.381**	**$ 12,001,500**	
Feedstock Cost:		**Quantity**		**Cost Per Gallon**	**Total Cost**	**Cost Per Bushel or Ton**
Corn (bushels)		12,097,000		$ 1.11	$ 34,839,360	$ 2.88
Corn Bran (tons)		26,099		$ 0.07	$ 2,348,910*	$ 90.00
Total Feedstock Cost					34,839,360	
* Values in Green are not actual costs, they are the value of the corn bran used to produce energy						
Total Direct Cost					**$ 46,840,860**	

Table 6 -continued. Pro forma Income Statement for the Advanced Ethanol Plant

Pro forma Income Statement for the Advanced Ethanol Plant				
Fixed Costs:	**Cost Per Gallon**		**Total Costs**	
Insurance and Taxes	$ 0.019	$ 0.019	$ 598,500	
Depreciation - Plant Equipment	$ 0.127		$ 4,000,000	
Interest on Investment - Plant Equipment	$ 0.078	7.00%	$ 2,450,000	
Total Fixed Costs			**$ 7,048,500**	
Total Cost			**$ 53,889,360**	
Profit/Loss			**$3,758,537.50**	
% Equity			**50.00%**	
Financed Portion			**$ 35,000,000**	
Return on Investment			**5.37%**	
Return on Equity			**10.74%**	

General Caveat

One basic assumption used in developing the analysis is that the plant does in fact operate at 100 percent capacity or 24-7 for 50 weeks 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.

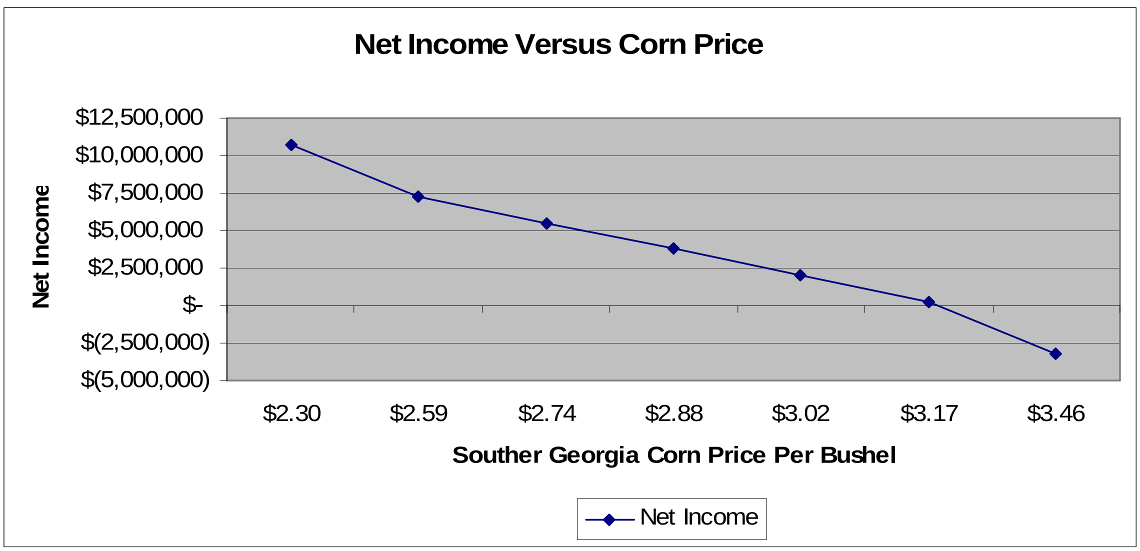
Sensitivity Analysis on Critical Variables for the Advanced Corn-based Plant

Several variables were deemed significant enough to analyze what might happen to the net income or profit of the plant if they turned out to be something different that in the original analysis. This sensitivity analysis is done in order to assess a level of risk associated with potential future changes in these variables.

Corn price has the potential to make a significant impact on the profitability of a 30 million gallon ethanol plant since the advanced plant utilizes a little over 12,000,000 bushels annually. Figure 7, below, shows how the profitability is affected when corn prices are five, ten and twenty percent higher and lower than the average railed in price of $2.88 over the last five years. The ethanol plant is profitable when the corn price is $3.19 or less per bushel. It is important to note that a five percent change in the price of corn from the five year average leads to an increase or decrease in the profitability of the ethanol plant by a little over $1.7 million.

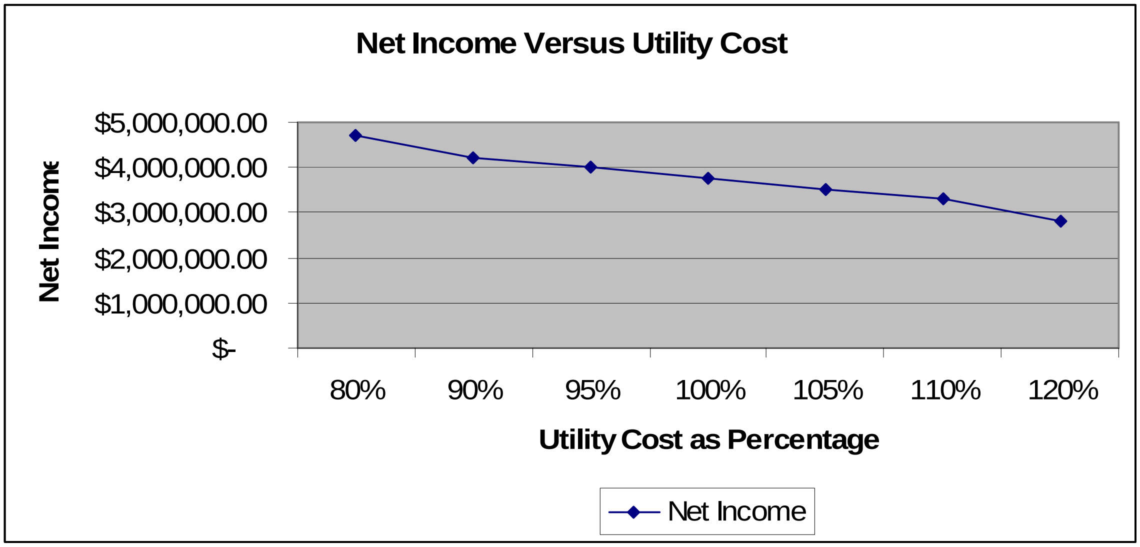
It would also be important to note here that the price of $2.88 over the last five years for railed in corn to southeast Georgia, may not be the price the company would have to pay for the corn. When purchasing the large volumes of corn that would be required to produce 30 million gallons of ethanol, one can expect to pay a discounted price. Estimates of these discounts range from one to five percent. This is equivalent to the price being somewhere between $2.85 and $2.74. At prices in this range the plant would be profitable. The Return on Investment would range from 31 percent for $2.30 a bushel corn to a minus nine percent for $3.46 a bushel corn.

Figure 7. Corn Price Sensitivity Analysis



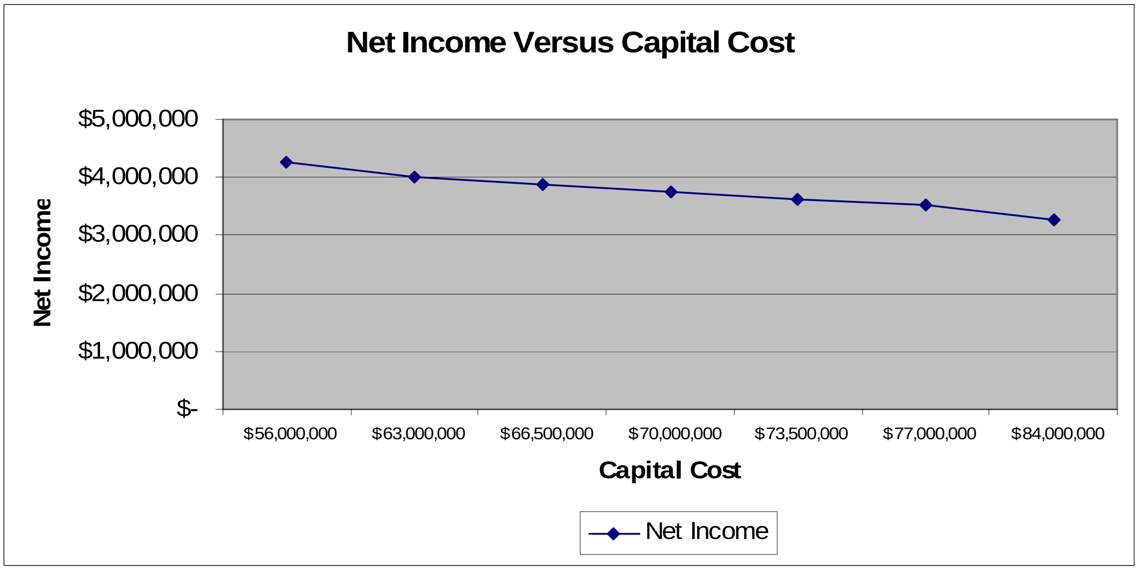
Utilities make up the second highest cost next to corn for the "advanced" ethanol plant. Natural gas and electricity expense together make up almost the entire utility cost for the plant. Figure 8 shows the impact of Utility costs increasing or decreasing by five, 10 and 20 percent. The figure shows that if utility costs run 20 percent higher than expected that the plant still earns an estimated net income of $2.8 million.

Figure 8. Utility Cost Sensitivity Analysis



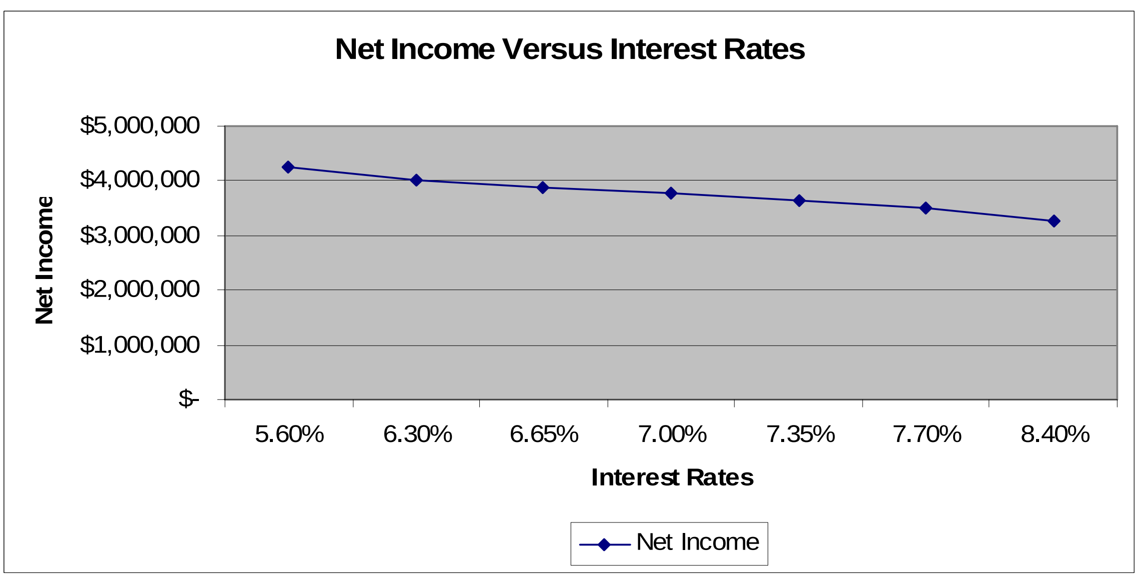
Capital cost is another critically important variable in determining the economic feasibility of a production process. Materials cost can and do change during the construction phase of many projects. Costs also can increase or decrease from the planning phase on into the construction phase, therefore 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.

Figure 9. Capital Cost Price Sensitivity Analysis



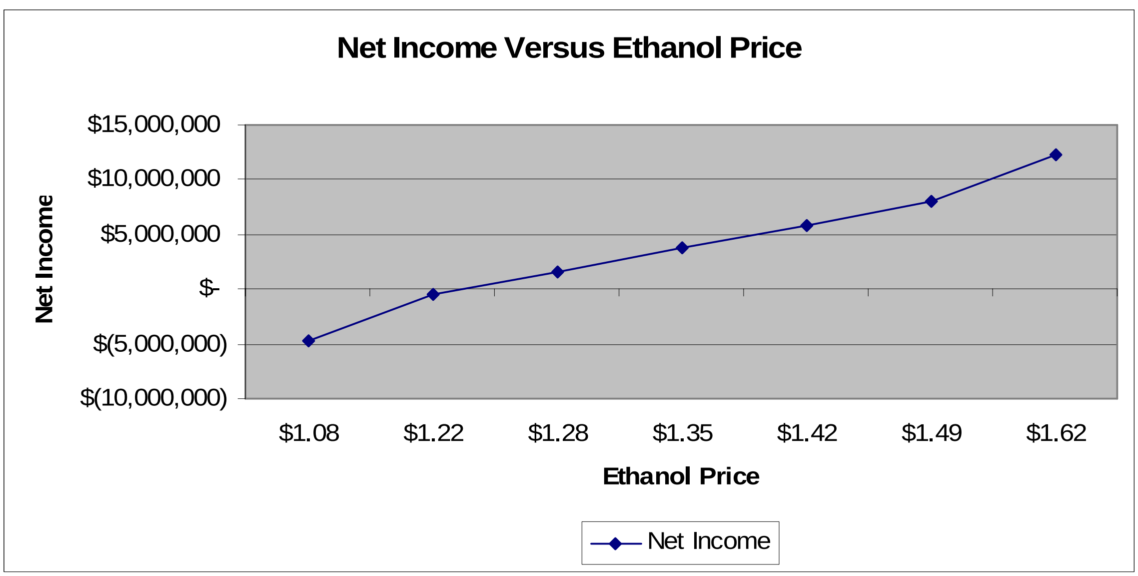
Interest rate fluctuations can be seen as quite similar to the fluctuations in the capital costs of constructing an ethanol plant. For the feasibility study, it was assumed that an interest rate of seven percent was attainable. The sensitivity analysis again analyzed what changes in the cost of capital would have on the profitability of the plant. Figure 10, shows the results from assumed five, ten and twenty percent changes in the interest rate from the base case. This gave a range from 5.6 percent to 8.4 percent. Over this range the plant was always profitable with profit being at $4.2 at the high end and $3.2 at the low end.

Figure 10. Interest Rate Sensitivity Analysis



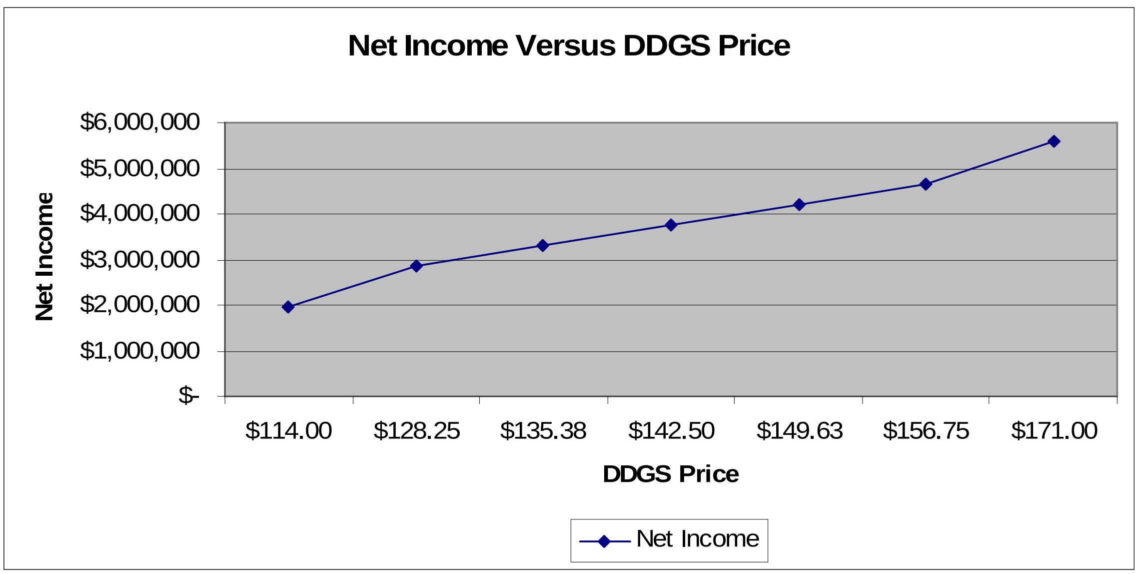
The plant's main purpose is for the production of ethanol, therefore making its price a significant determinant of profitability. One of the problems with predicting the profitability of ethanol production is determining the price of the product, ethanol. Profitability is determined by two fairly unrelated markets, one the petroleum market and the other the corn market. The price of ethanol is not directly related to the petroleum market but does seem to move in the same direction most of the time. It is also not tied to the corn market directly either. This puts ethanol producers in the position that might create a squeeze when corn prices are high and ethanol prices low. Recently, ethanol prices have been quite attractive with the surge in oil prices, however with the number of ethanol plants coming on line in the last two years, ethanol prices haven't quite moved with gas prices. Figure 11 shows how the profitability of the proposed ethanol plant changes with the level of ethanol price. The average price received by producers over the last five years for ethanol has been about $1.35. The net income was calculated for a range of ethanol prices that went from $1.08 a gallon to $1.62 a gallon. This represents both a five, ten and twenty percent increase and decrease in ethanol prices. As can be derived from the figure, the plant breaks even at $1.23 per gallon of ethanol. If the average price of ethanol was to drop 20 percent, the plant would be losing $5 million annually. If prices were to rise to $1.62 over an annual period, the profit from the plant would be around $12.5 million. For every five percent increase in the price of ethanol, net income will increase by $2.1 million.

Figure 11. Ethanol Price Sensitivity Analysis



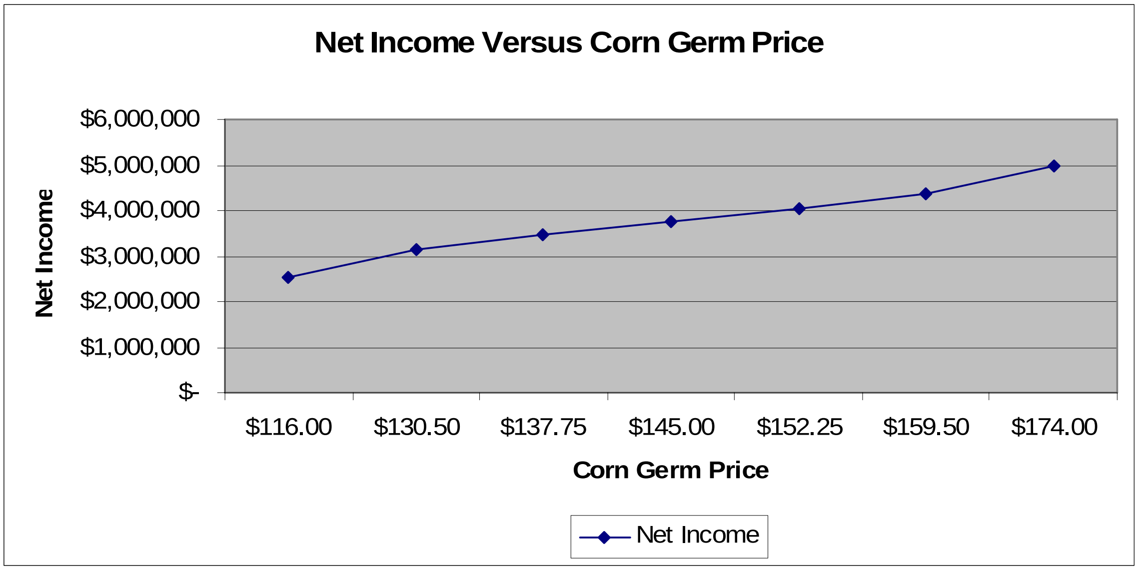
There are three saleable co-products that come from ethanol production, Ethanol, Distillers Dried Grains (DDGS) and Carbon Dioxide. DDGS normally is a product that has potential markets as a livestock feed, including chicken feed in the state of Georgia. The current price that ethanol plants are receiving for their DDGS is around $101.00 a ton. This price is very much related to the price of a substitute that livestock producers can use in their feed rations, soybean meal. However, due to the type of production process that this advanced ethanol plant uses, the DDGS co-product that is produced is a high protein DDGS. Given that the price of DDGS is directly related to the market for soybean meal based on its level of protein, this higher protein DDGS will be more valuable. The price for traditional DDGS has shown to be variable in the Midwestern states due mostly to local supply and demand conditions and the varying price of soybean meal. Since DDGS makes up about one-third of the plant's output, changes in its price can mean significant changes in the plant's profitability. As shown in Figure 12, a DDGS price of $142.50 per ton, the plant makes a little over $3.75 million. When DDGS price increases five percent to $149.63 the plant's net income increases by almost half of a million dollars demonstrating how changes in the price of high protein DDGS can impact the company's net income. However, even a twenty percent decrease in the price of high protein DDGS does not make the company become unprofitable with net income still at a little over $1.9 million.

Figure 12. Distillers Dried Grain Price Sensitivity Analysis



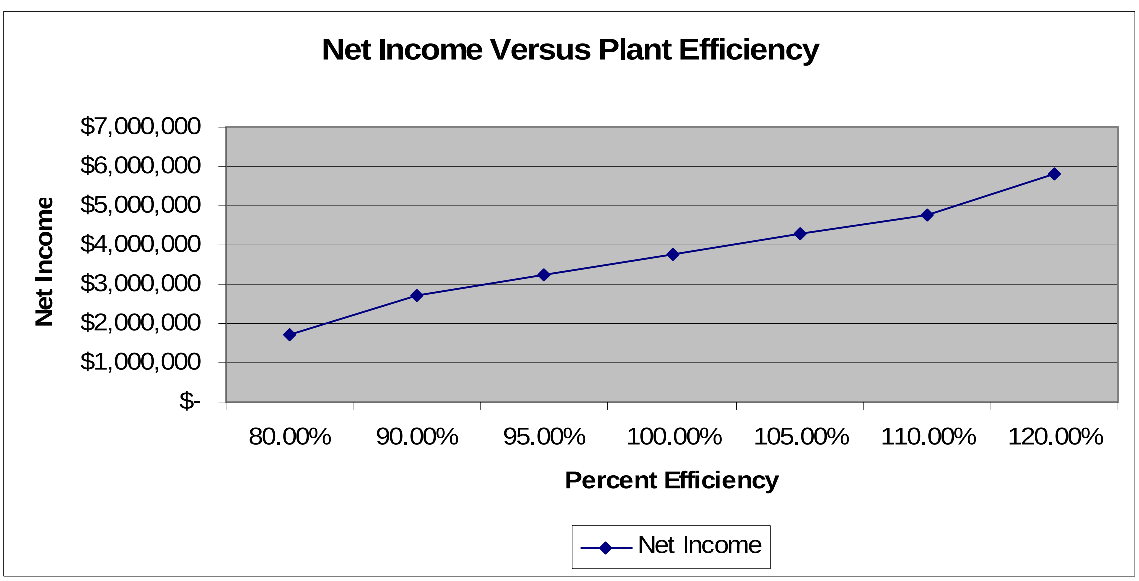
Corn germ is another saleable product for the advanced ethanol plant. Since there is no corn dry fractionation in a traditional plant, there is also no corn germ product to be sold as well. This product is used to produce corn oil that would go on to have many alternative uses. It was assumed for this study that the plant would just sell the corn germ to a further processor and not try to convert the germ to oil onsite. Corn germ is a valuable product with the potential to impact the bottom line of this advanced plant. Forty-one thousand tons of corn germ are produced through the dry fractionation process of twelve million bushels annually. There should also be a market for this co-product in central Georgia as well. While the effects of a price change aren't as dramatic as they would be for DDGS or ethanol price they would still be considered a significant amount of money. Figure 13 shows that a five-percent increase in the price of corn germ will bring about a $300,000 increase in the net income of the plant.

Figure 13. Corn Germ Price Sensitivity Analysis



Plant efficiency is something that plays a large role in the profitability of any ethanol plant. The advanced plant is considered more efficient from the start, due to the dry fractionation process that allows a greater percentage of starch to make its way through the production process. The starch is what converts into the ethanol and this allows for more efficient use of the facility. Efficiency also comes from management, but in order for a plant to remain profitable is has to be run 24 hours a day and seven days a week. So normally plants are going to be expected to run as close to full capacity as possible. At 100 percent capacity the plant will generate just under $4 million in net income. From Figure 14, it can be seen that if efficiency decreases five percent from 100

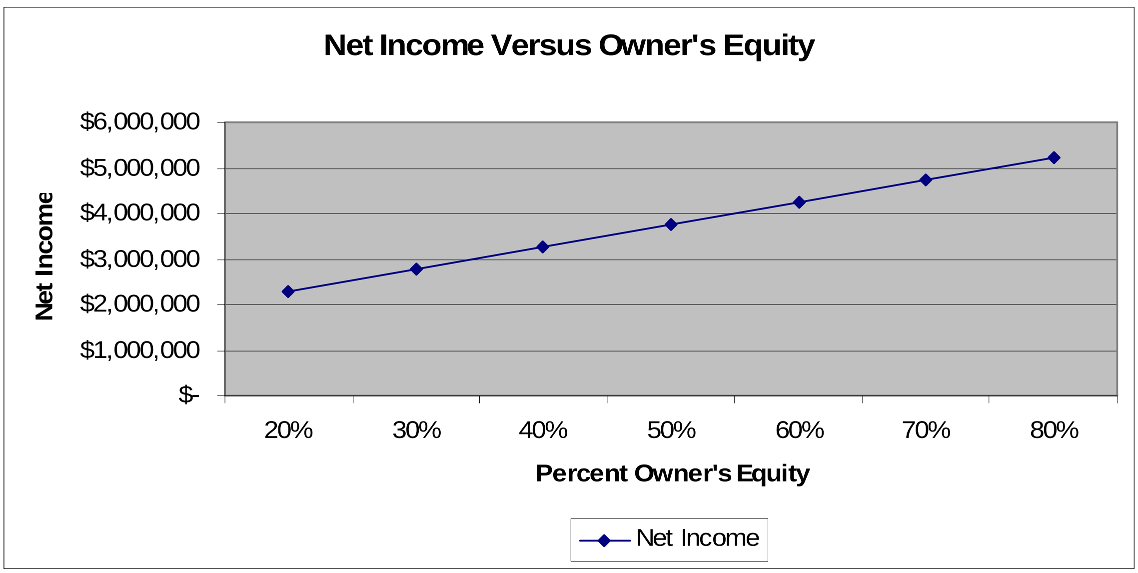
Figure 14. Plant Efficiency Sensitivity Analysis



percent, then net income decreases by a little over half a million dollars. If efficiency were to drop into the 80 percent range, then net income would fall to around $1.7 million dollars.

It is generally considered that a group of investors must be able to raise at least 50 percent of the dollars necessary to construct an ethanol facility in the form of equity before they will be able to get a lending institution to loan them the other 50 percent that would be necessary. The net income based on 50 percent owner's equity would be just over $3.75 million. Figure 15 shows that as owner's equity increases to 60 percent, the net income would increase to almost $4.25 million, an increase of almost half a million dollars.

Figure 15. Percent Owner's Equity Sensitivity Analysis



Net Income Versus Change in Ethanol Price and Corn Cost

Table 7 shows the combined impact of changes in ethanol price and corn price. To use Table 7, find the cell where corn price equals $2.50 and the ethanol price equals $1.40. Those price combinations generate a profit potential of $9.93 million dollars. Net income potential can be determined with this table for corn prices ranging from $2.50 to $3.20 per bushel and ethanol prices from $1.00 to $2.40 per gallon.

Table 7. Net Income vs. Change in Ethanol Price and Corn Cost (Millions of Dollars)

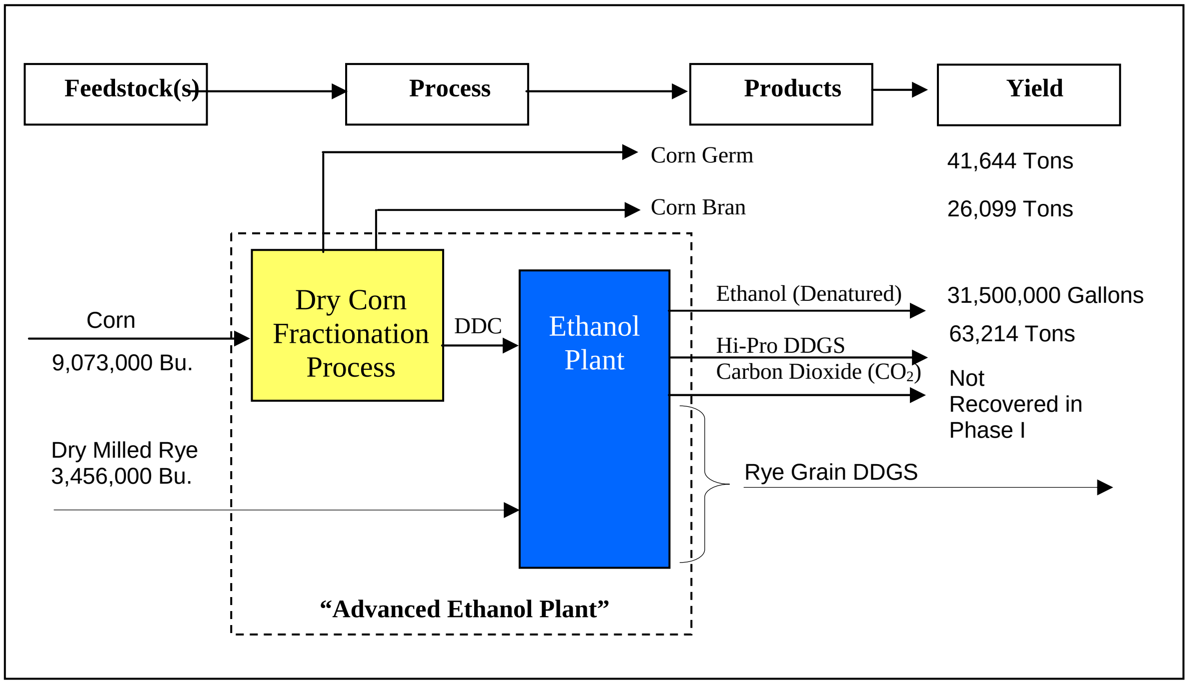
	Ethanol Price/gallon							
Corn Price	**$1.00**	**$1.20**	**$1.40**	**$1.60**	**$1.80**	**$2.00**	**$2.20**	**$2.40**
$2.50	$-2.669	$3.360	$9.930	$16.230	$22.530	$28.830	$35.130	$41.430
$2.60	$-3.879	$2.430	$8.720	$15.020	$21.320	$27.620	$33.920	$40.220
$2.70	$-5.089	$1.210	$7.510	$13.810	$20.110	$26.410	$32.710	$39.010
$2.80	$-6.298	$0.001	$6.301	$12.601	$18,901	$25.201	$31.501	$37.801
$2.90	$-7.508	$-1.208	$5.091	$11.391	$17.691	$23.991	$30.291	$36.591
$3.00	$-8.718	$-2.418	$3.881	$10.181	$16.481	$22.781	$29.081	$35.381
$3.10	$-9.927	$-3.627	$2.672	$8.972	$15.272	$21.572	$27.872	$34.172
$3.20	$-11.137	$-4.837	$1.462	$7.762	$14.062	$20.362	$26.662	$32.962

Technology and Costs of Production for Advanced Plant with Rye Milling

The “advanced” plant with rye milling is more complicated than the corn only “advanced” plant. In order to incorporate an additional feedstock into the process several additional modifications must be made to the plant as well as different processes followed in the production of the ethanol. The grain storage has to be modified by providing additional storage for the rye since it must be kept separate from the corn in the production process. Smaller grains such as wheat and rye also require roller mills instead of the hammer mills that are used for the corn. In addition, lower cooking temperatures are used for wheat and rye, and a longer residence time during this step (four times longer). In addition, the enzyme requirements are different and an additional step is required for rye and wheat during saccharification. The fermentor capacity must also be increased due to the additional foaming tendency of rye and wheat. Additional capacities are also required for the centrifuge and DDGS drying, as well as evaporation capacity.

The following figure shows how the addition of an additional feed stock (rye) changes the input-output process. As can be seen from Figure 16, the quantity of corn

Figure 16. I.P. Dry Corn Fractionation with Alternative Feedstocks



germ being processed is reduced along with the corn bran. It also shows that the total number of bushels (both corn and rye) going into the production of ethanol has been increased over the corn only case. The last significant difference of the plant output is the amount of High-pro DDGS is 63,214 tons. The starch contents and ethanol yields from alternative grains are listed in Appendix C.

Pro Forma Analysis for the Advanced Plant with Rye Milling

The "advanced" plant with rye milling was also analyzed to determine the level of net income and return on investment. The capital and startup costs for the "advanced" plant with rye milling are shown in Table 8 below. There are two major differences in costs between the "advanced" plant and the "advanced" plant with rye milling. The first major difference in the capital cost is that of rye milling equipment and intermediate storage at $7.5 million. The other major difference is the cost of the ethanol plant at $42 million instead of $34 million. The total estimated capital cost for this type of plant is expected to be $85.5 million dollars.

Table 8. Advanced Ethanol Plant with Rye Milling Capital Cost Projections (30 MMGPY)

Component	Capital Cost
Grain Receiving and Storage (2.0 Million Bushels)	$7,500,000
Dry Fractionation	$7,500,000
Bran Conversion to Steam	$3,000,000
Additional Advanced Technologies	$2,000,000
Ethanol Plant (30 MMGPY)	$42,000,000
Rye Milling/ Intermediate Storage	$7,500,000
Electrical Substation & Utilities	$1,500,000
Professional Services & Permitting	$500,000
Land (80 Acres)	$1,000,000
Construction Contingency	$4,000,000
Feedstock/Product Working Capital & Startup Cost	$9,000,000
Projected Advanced Total Capital Cost	**$85,500,000**

Pro forma Income Statement for the Advanced Ethanol Plant with Rye Milling

Using the capital cost estimates shown in Table 8 and the estimates for the other fixed and variable costs associated with a 30 MMGPY advanced ethanol plant with rye milling, a pro forma income statement was derived. It is important to remember that some of these costs are just estimates and that contingencies are allowed for that reason. The income statement shows the income that is derived from all sources, which for this model will be ethanol, high protein DDGS and corn germ. Again, Carbon Dioxide will not be used in deriving the total income because it may or may not be an immediate contributor to income. Table 9, on the next two pages shows the co-product incomes as well as the fixed and variable costs associated with the "advanced" ethanol plant. The plant was assumed to run 24 hours a day, seven days a week, fifty weeks a year. At 100 percent efficiency that plant would produce 90,000 gallons a day or 31.5 million gallons annually. The income from the three saleable co-products is estimated to be a little over $56 million, with the sale of ethanol making up $42.5 million of that total.

Processing costs which include labor, chemical, and utility costs totaled around $12 million, with utilities making up around $4.75 million of that total. Two feed stocks, corn and rye, are used in the plant. A little over 9 million bushels of corn are required with 3.75 million bushels of rye annually. The total annual feed stock cost is lower than the corn only plant at $33.6 million.

Table 9. Pro forma Income Statement for the Advanced Ethanol Plant with Rye Milling

Pro forma Income Statement for the Advanced Ethanol Plant with Rye Milling						
90,000	gallons per day		100%	Capacity		
7	days per week		12,097,000	Bushels Corn		
50	weeks per year		12,097,000	Bushels Corn Required		
31,500,000	gallons per year					
Income:		**Quantity**		**Unit Price**	**Total $**	**Value per bushel**
Ethanol		31,500,000	Gallons	$ 1.35	42,525,000	$ 3.52
High Protein DDGS		63,214	Tons	$ 142.50	9,007,995	$ 0.74
Corn Germ		31,233	Tons	$ 145.00	4,528,785	$ 0.37
Corn Bran		Combusted to save on Natural Gas				
Total					**$ 56,061,780**	**$ 4.63**
Processing Costs:				**Cost Per Gallon**		
Maintenance and Supplies				$ 0.036	$ 1,134,000	
Utilities				$ 0.150	$ 4,725,000	
Chemicals				$ 0.070	$ 2,205,000	
Denaturants				$ 0.040	$ 1,260,000	
Labor and Benefits				$ 0.070	$ 2,205,000	
SG&A				$ 0.015	$ 472,500	
Total Processing and SG&A				**$ 0.381**	**$ 12,001,500**	
Feedstock Cost:		**Quantity**		**Cost Per Gallon**	**Total Cost**	**Cost Per Bushel or Ton**
Rye (bushels)		3,750,000		$ 0.24	$ 7,500,000	$ 2.00
Corn (bushels)		12,097,000		$ 1.11	$ 34,839,360	$ 2.88
Corn Bran (tons)		26,099		$ 0.07	$ 2,348,910*	$ 90.00
Total Feedstock Cost					$ 33,629,520	
* Values in Green are not actual costs, they are the value of the corn bran used to produce energy						
Total Direct Cost					**$ 45,631,020**	

Table 9. Pro forma Income Statement for the Advanced Ethanol Plant with Rye Milling - continued

Pro Forma Income Statement for the Advanced Ethanol Plant with Rye Milling				
Fixed Costs:	**Cost Per Gallon**		**Total Costs**	
Insurance and Taxes	$ 0.019	$ 0.019	$ 598,500	
Depreciation - Plant Equipment	$ 0.127		$ 5,033,333	
Interest on Investment - Plant Equipment	$ 0.078	7.00%	$ 2,992,500	
Total Fixed Costs			**$ 8,624,333**	
Total Cost			**$ 54,255,353**	
Profit/Loss			**$1,806,426.67**	
% Equity			**50.00%**	
Financed Portion			**$ 42,750,000**	
Return on Equity			**4.23%**	

Fixed costs which include taxes, insurance, interest on investment and depreciation totaled a little over $8.6 million. Taxes and insurance make up $600,000 of that total with the interest on the investment being $2.99 million. The largest portion of the fixed costs comes from depreciation at a little over $5 million.

When the total costs of production were calculated and subtracted from the co-product's income it was determined that the net income was a little over $1.8 million for the plant. This would give a return on investment, assuming 50 percent borrowed capital, of 4.23 percent.

Summary and Conclusions

This feasibility study looked at two types of "advanced" ethanol plants in order to determine their estimated profitability in the central part of Georgia. According to the results, the "advanced" plant that operated on corn only, showed promise to be a profitable enterprise in Georgia. It had a net income of around $3.75 million and a return on investment of over five percent on average. However, with a capital cost of $70 million, $35 million would have to be raised in order for the project to move forward since lenders are requiring around 50 percent owner equity on this type of project. This type of "advanced" plant also has the ability to increase the level of output beyond the 30 million gallons per year due to the production technology it utilizes. It could potentially produce up to five percent more ethanol than its stated capacity increasing profitability.

Additionally, the sensitivity analysis shows the plant to be profitable through the ranges of variation in the variables analyzed except for ethanol price and corn price. These two prices are both critically important to profitability and only in the situation of the lowest level of ethanol prices and the highest level of corn prices analyzed does the plant become unprofitable.

The “advanced” plant that will utilize two feed-stocks, corn and rye, instead of only corn has a capital cost of $85.5 million. This is $15.5 million capital more than the “advanced” plant that just utilizes only corn. The advantages of using a lower cost feed-stock (rye) are outweighed by the increased capital costs of the plant. This plant on average at 100 percent capacity is expected to generate $1.8 million in net income annually. As stated before, lenders currently require 50 percent of capital to be owner financed, which with the increased cost of the facility might lead to some difficulty with moving forward with this type of plant. This would mean that an additional $7.75 million would have to be raised to move from the single feed-stock plant to the dual feed-stock plant. In addition, the income is around $1.75 million lower than the single feed-stock plant. The lower net income combined with the higher capital costs reduces the return on investment to two percent from around five percent with the single feedstock plant. With the lower income and ROI, a sensitivity analysis was not done on this type of plant. The sensitivity analysis would not differ that much from the first one in terms of the magnitudes of the changes, only the starting values for the net income.

In conclusion, the analysis shows that the “advanced” plant (corn only) would be profitable in Georgia, and a fairly good investment. The results also show that the two feedstock plant would not be as profitable as the corn only plant, and therefore not as desirable.

Appendix A. Corn Acreage in Southeastern Georgia

County	SDR	Acres
APPLING	9	6,300
BLECKLEY	9	1,891
CANDLER	9	2,287
DODGE	9	2,000
EMANUEL	9	2,262
JEFF DAVIS	9	1,654
JOHNSON	9	1,078
LAURENS	9	4,912
MONTGOMERY	9	1,379
TELFAIR	9	896
TOOMBS	9	2,194
TREUTLEN	9	446
WAYNE	9	7,500
WHEELER	9	532
WILCOX	9	2,553
		37,884
ATKINSON	11	2,285
BACON	11	4,100
BEN HILL	11	5,004
BERRIEN	11	5,759
BRANTLEY	11	1,000
BROOKS	11	3,300
CHARLTON	11	650
CLINCH	11	444
COFFEE	11	5,031
COOK	11	1,300
ECHOLS	11	607
IRWIN	11	12,539
LANIER	11	1,200
LOWNDES	11	5,000
PIERCE	11	13,000
TIFT	11	1,910
TURNER	11	2,429
WARE	11	2,956
		68,514

County	SDR	Acres
BRYAN	12	500
BULLOCH	12	8,044
CAMDEN	12	0
CHATHAM	12	100
EFFINGHAM	12	4,300
EVANS	12	1,557
GLYNN	12	0
LIBERTY	12	165
LONG	12	620
MCINTOSH	12	0
TATTNALL	12	4,375
		19,661
Region		126,059

Appendix B

31,500,000 Gallon Per Year Corn to Ethanol Plant Summary Information

	Gallons/yr (denatured)	Days Per Year	Hrs/Year
Plant Operations	31,500,000	350	8,400

Plant Inputs:

	Unit	Annual	Hourly
Feedstock			
Rate	bushels /	12,096,774	1,440
Energy			
Natural Gas	MMBtu/Hr	Annual	Hourly
Boilers	34	285,306	34
Dryers	31	259,592	31
Misc. Heating	0.38	3,191	0.4
Total		548,088	65
Electricity *	kW/ den. Gal		
Operating Load	0.75	23,815,524	2,835
Water			
Fresh Water	GPM	Annual	Hourly
Boiler	35	17,842,742	2,124
Cooling Tower	177	89,213,710	10,621
Process	48	24,193,548	2,880
Misc and Potable	40	20,160,000	2,400
Total	300	131,250,000	15,625

Note: Water quality affects required flowrates
** Does not include chiller or fire water pump*

Plant Outputs:

	Unit	Annual	Hourly
Ethanol	Gal/bu		
Anhydrous	2.5	30,241,935	3,600
Denatured	2.63	31,754,032	3,780
Hi-Protein DDGS	Lb/bu		
Lb. Per bushel of Corn w/10% moisture	10.54		
Tons of Hi-Pro DDGS produced		63,750	7.6
		91,071	
Corn Germ	Lb/bu		
Lb. Per bushel of Corn processed	6.89		
Tons of Corn Germ Produced		41,644	4.96
Corn Bran	Lb/bu		
Lb. Per bushel of Corn processed	4.32		
Tons of Corn Bran Produced		26,099	3.11
Carbon Dioxide	Lb/bu		
Lbs gas / bushel after scrubber	16		
Tons of CO2 gas produced		96,774	11.5
Water Discharge - Zero Process	GPM		
Process Water	0	0	0
Cooling Tower Blowdown	71	35,745,968	4,255
Boiler Blowdown	12	5,987,903	713
Total	83	41,733,871	4,968

Note: Water quality affects required flowrates
Note: Utility consumption varies with technology suppliers

Appendix C

Advanced Plant Utility Requirements

The utilities listed below are for a 30 MMGPY corn to ethanol plant

Utilities

Fresh Water Source

Service water of approximately 300 to 400 gallons per minute will be required for the plant. This number varies depending on the technology provider and local water quality. Most of this will be lost to evaporation in the cooling tower.

Natural Gas

The advanced plant will require substantially less natural gas than the conventional ethanol plant. The natural gas can be purchased from the local utility. Line pressure is typically not an issue. Fifty to 100 psi is normal for the ethanol plant. Some technology providers prefer the higher pressure (100 psi); this allows smaller pipes in the ethanol plant. The average usage is 137.5 mmBtu/hr for the conventional plant and 65.5 mmBtu/hr for the advanced plant.

Electricity

The average operating load for an ethanol plant is 0.75 kW/denatured gallon. This plant would use approximately 2800 kW/h (2.8 MW). These numbers vary depending on the technology provider.

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

If your plant is 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 typically placed inside a building or curbed area. Also, the ethanol storage tanks are typically 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.

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.

Appendix D. An Economic Impact Analysis of Ethanol Production in Georgia

An economic impact analysis evaluates the effects, or economic impacts, of a production enterprise. This economic impact analysis measures projected economic impacts of potential ethanol production due to economic activity associated with plant construction and production in Georgia. Corn is produced throughout the state, and utilizing corn as an input has the potential to stimulate further economic activity in Georgia. Corn is the primary input in ethanol production, and impacts due to increased corn production are isolated in a separate analysis.

IMPLAN is an economic input-output modeling program applied for impact estimation. IMPLAN can interpret the effects of a new enterprise in a number of ways including output (sales), labor income (employee compensation and proprietary income), employment (jobs), and tax revenue. An IMPLAN model can be constructed for the economy of a single county, multi-county, or state region. In general, input-output models work by separating the economy into various sectors, such as agriculture, construction, manufacturing, trade, and services. The model then captures how a change in one industry changes output, labor income, and employment in other industries. These changes, or impacts, are expressed in terms of direct, indirect, and induced effects.

- *Direct effects* represent the initial impact on the economy of some feature (i.e. construction or operations) of a new enterprise.
- *Indirect effects* are changes in other industries caused by the direct effect of a new enterprise.
- *Induced effects* are changes in household spending due to the changes in economic activity generated by both the direct and indirect effects.

Thus, the total economic impact is the sum of the direct, indirect, and induced effects (MIG).

Potential ethanol plants in Georgia are classified as either conventional or advanced by Best, Shumaker, and McKissick. An advanced ethanol plant is more efficient than a conventional plant, but has significantly higher construction costs. A conventional plant is financially feasible only when corn inputs are purchased with quantity discounts This report quantifies economic impacts for an advanced plant in Georgia and a conventional plant in Bacon County, as well as Georgia.

I. Advanced Ethanol Plant

An advanced ethanol plant utilizes 12,097,000 bu. of corn per year. An average yield of 150 bu. leads to 80,647 acres of corn production to meet demand. Data indicate that corn acreage harvested for grain is trending downward. Recent acreage averages less than 300,000 acres after averaging over 500,000 acres in the early 1990's (GASS). Thus, Georgia not only has the capacity to supply corn for an ethanol plant with current production, but has the potential to expand production in order to fulfill additional demands for Georgia corn for grain.

Economic Impact of Advanced Ethanol Plant Construction in Georgia

An economic impact analysis of a new enterprise begins with evaluation of expenditures related to construction of facilities. Construction expenditures include the purchase and installation of facilities and operational equipment. Land acquisition is not included because it is a capital transfer and does not cause additional economic activity. Construction impacts end when the plant is complete and production begins. Capital costs of constructing an advanced ethanol plant are estimated as $56,000,000.

Estimated construction impacts from output, labor income, employment, as well as state and local taxes are presented in Table 1. Reported labor income impacts are components of output impacts. Employment includes both full time and part time jobs.

Table 1. Advanced Plant Construction: One Time Economic Benefits to Georgia

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Output	$56,000,000	$16,448,004	$28,147,070	$100,595,074
Labor Income	$27,740,360	$6,474,386	$9,568,480	$43,783,226
Employment	730	142	289	1160
Tax				$4,028,797

The direct output effect of construction is the cost of construction, $56 million. This figure represents the total projected construction cost of all buildings and the purchase and installation of all operational equipment. The infusion of $56 million in Georgia's economy causes an indirect effect of $16.448 million among supporting industries in the state. The indirect effect represents business-to-business purchases between businesses constructing the facility and their supplying, or supporting, businesses (i.e., purchasing building materials, surveying services, etc.). In addition, the construction project will induce $28.147 million in sales as construction personnel and impacted employees spend their income on consumer products and services. The total economic impact on Georgia from construction of an advanced ethanol plant is $100.595 million in output.

Impact analysis provides information on wages and benefits. In Table 1, labor income indicates the money that households will earn due to the construction project. The direct effect of labor income supported by construction is $27.740 million for Georgia. Combining the direct, indirect and induced effects, total labor income is estimated as $43.783 million.

The construction project is estimated to generate a total of 1160 jobs throughout Georgia, with 730 jobs involved directly with the building project. Total employment represents full and part time jobs, and its impact is broken down to show indirect and induced employment changes. Indirectly, 142 jobs will be created as a result of business-to-business activity associated with construction. An additional 289 jobs will be created to support increased household spending by those workers affected directly and indirectly by the construction project. Economic activity from construction will have an impact on state and local tax revenues totaling $4.029 million.

Table 2 illustrates the total projected economic impact of construction on all major industrial sectors in Georgia. This table shows sector breakouts of output, labor income, and employment reported previously. Building the ethanol plant is a construction activity, and output, labor income, and employment impacts are greatest in this sector. A broad category of services has the second largest impact in each category. Trade, both wholesale and retail are significantly impacted by construction.

Table 2. Advanced Plant Construction: One Time Economic Benefits to Major Sectors, Georgia

Sector	Output	Labor Income	Employment
Agriculture	$358,359	$95,591	5
MU[1]	$1,172,830	$246,176	2
Construction	$56,277,320	$27,866,804	733
Manufacturing	$4,797,466	$1,054,990	22
Transportation	$2,192,168	$892,332	20
Trade	$8,372,451	$3,583,516	105
FIRE[2]	$7,683,527	$2,005,677	42
Services	$15,657,278	$7,890,947	229
Government	$4,083,675	$147,193	4
Total	$100,595,074	$43,783,226	1160

[1]Mining and Utilities

[2]Finance, Insurance, and Real Estate

Economic Impact of Operating an Advanced Ethanol Plant in Georgia

Operation of an ethanol plant leads to annual economic impacts which are due to purchasing of direct inputs and paying incomes to employees. Table 3 shows the itemized costs and other input data for an IMPLAN model for operation of an advanced ethanol plant. Other property income includes capital payments, interest paid, as well as net returns to production (MIG). With net returns included in other property income, all items listed in Table 3 are equal to total revenue (output) for the plant. Employee compensation includes wage and benefits for 24 production workers, as well as 6 workers in sales and administration.

Table 3. IMPLAN Input-Output Data for Advanced Ethanol Plant	
Category	*-dollars-*
Maintenance and Supplies	1,134,000
Utilities	4,725,000
Chemicals	2,205,000
Denaturants (Gasoline)	1,260,000
Corn	34,839,360
Insurance	318,500
Labor and Benefits	2,205,000
Sales and Administrative Staff	472,500
Indirect Business Taxes	280,000
Other Property Income	10,208,538
Output	57,647,898

Total revenue of $57,648 million is output in Table 3, and represents the first round of impacts due to production. This leads to subsequent rounds of indirect spending that are caused by the plant purchasing inputs in Table 3. IMPLAN includes a regional purchase coefficient *(RPC)* for each industrial sector corresponding to input costs. An *RPC* represents percentage of demand that is satisfied by production within Georgia. An assumption of the model is that an ethanol plant will provide markets for crop production within Georgia, and the *RPC* is set to 100 percent for corn. Table 4 shows the economic impact of an advanced ethanol plant operating in Georgia.

Table 4. Advanced Plant Operations: Annual Economic Benefits to Georgia

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Output	$57,647,898	$57,884,670	$18,153,156	$133,685,724
Labor Income	$16,145,402	$5,042,360	$6,153,648	$27,341,410
Employment	30	1554	186	1770
Tax				$4,152,811

The direct effect associated with output creates another $57.885 in output as the operation purchases products and services from other businesses in Georgia. The result of increased household income is an induced effect of $18.153 million. The induced impact represents households spending income on consumer goods (i.e., clothing, eating at restaurants, doctor and dentist visits, etc.). Total economic impact in Georgia is $133.686 million and indicates an output multiplier of 2.32.

Employment includes 30 workers at the plant, as well as another 1554 jobs in supporting businesses. An additional 186 jobs are created due to induced spending, for a total of 1770 full and part time jobs due to operation of the ethanol plant. Total labor income associated with the ethanol plant is $27,341,410. State and local taxes increase by $4.153 million annually.

Table 5 shows how economic sectors are impacted by ethanol production. Manufacturing has the greatest impact of $62.327 million. Agriculture has the next greatest impact of $36.773 million due to the large quantity of corn purchased. Employment in agriculture is impacted the most with 1426 of the 1770 jobs that are created. Labor income in agriculture increases by $15.336 million.

Table 5. Advanced Plant Operations: Annual Economic Benefits to Major Sectors, Georgia

Sector	Output	Labor Income	Employment
Agriculture	$36,733,224	$15,336,364	1426
MC[1]	$418,061	$173,116	4
Utilities	$5,013,106	$949,704	8
Manufacturing	$62,327,252	$966,558	46
Transportation, Warehousing	$1,791,125	$727,530	16
Trade	$5,843,901	$2,483,316	70
FIRE[2]	$8,052,745	$1,842,942	45
Services	$10,107,911	$4,702,420	151
Government	$3,398,399	$159,460	4
Total	$133,685,724	$27,341,410	1770

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

Economic Impact of Corn Production in Georgia

Corn represents the greatest input expenditure for operation of an ethanol plant. Analyzing the impact of corn production indicates the portion of the impacts in Table 4 and Table 5 that is attributable to corn production. An assumption of this analysis is that all corn is purchased in Georgia and all impacts accrue within the state. Table 6 shows that $62.864 (47%) of the output impact in Table 4 is due to corn production, and the output multiplier of 2.32 is greatly influenced by corn production in Georgia. Labor income increases by $23.621 million due to increased corn production, while full and part time jobs total 1653. State and local taxes are $3.245 million per year.

Table 6. Corn Production - Advanced Plant: Annual Economic Benefits to Georgia

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Output	$34,839,360	$12,259,423	$15,765,213	$62,863,996
Labor Income	$14,030,015	$4,246,729	$5,344,169	$23,620,913
Employment	1357	134	162	1653
Tax				$3,245,064

Impacts of corn production on sectors are presented in Table 7. Almost all of the agricultural impacts in Table 5 are due to corn production, and all but one agricultural job is due to corn production. Jobs due to corn production account for 1653 of the 1770 jobs created by ethanol production in Table 5.

Table 7. Corn Production - Advanced Plant: Annual Economic Benefits to Major Sectors, Georgia

Sector	Output	Labor Income	Employment
Agriculture	$36,684,032	$15,323,015	1425
MC[1]	$276,840	$123,239	3
Utilities	$947,647	$199,625	2
Manufacturing	$2,776,106	$532,739	10
Transportation	$1,369,703	$577,499	13
Trade	$4,653,903	$1,969,959	54
FIRE[2]	$6,651,663	$1,470,396	37
Services	$6,905,857	$3,291,322	105
Government	$2,598,245	$133,119	4
Total	$62,863,996	$23,620,913	1653

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

Conventional Ethanol Plant

The state of Georgia has designated 12 state service delivery regions *(SDR)* in order to foster regional collaboration in economic development (CAED). Impact analysis of a conventional ethanol plant in Bacon County includes *SDRs* 9, 11, and 12 as the local impact area. Corn acreage for included counties is presented in the appendix (UGA).

Economic Impact of Conventional Ethanol Plant Construction in Southeastern Georgia

Costs of constructing a conventional ethanol plant are estimated as $38,500,000. Estimated construction impacts from output, labor income, employment, as well as state and local taxes are presented in Table 8. Direct output represents total projected construction cost of all buildings, as well as the purchase and installation of all operational equipment. The infusion of $38.5 million in the regional economy causes an indirect effect of $8.145 million among supporting industries. The indirect effect represents business-to-business purchases between businesses constructing the facility. In addition, the construction project will induce $12.549 in sales as construction personnel and impacted employees spend their income on consumer products and services. The total economic impact on southeastern Georgia from construction of a conventional ethanol plant is $59.194 million.

Table 8. Conventional Plant Construction: One Time Economic Benefits to SE Georgia

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Output	$38,500,000	$8,144,862	$12,548,976	$59,193,837
Labor Income	$16,992,772	$2,974,584	$4,099,003	$24,066,359
Employment	587	92	161	839
Tax				$1,987,888

In Table 8, labor income indicates the money that households will earn due to the construction project. The direct effect of labor income supported by construction is $16.993 million for southeastern Georgia. Combining the direct, indirect and induced effects, total labor income is estimated as $24.066 million.

The construction project is estimated to generate a total of 839 jobs throughout the region, with 587 jobs involved directly in the building project. Indirectly, 92 jobs will be created as a result of business-to-business activity associated with construction. An additional 161 jobs will be created to support increased household spending by those workers affected directly and indirectly by the construction project. Economic activity from construction will have an impact on state and local tax revenues totaling $1.988 million.

Table 9 illustrates the total projected economic impact of construction on all major industrial sectors in southeastern Georgia. Output, labor income, and employment impacts are greatest in the construction sector. Services have the second largest impact in each category, while wholesale and retail are significantly impacted by construction.

Table 9. Conventional Plant Construction: One Time Economic Benefits to Major Sectors, SE Georgia

Sector	Output	Labor Income	Employment
Agriculture	$279,018	$80,023	4
MU[1]	$566,735	$124,976	1
Construction	$38,634,660	$17,045,094	589
Manufacturing	$2,251,538	$414,801	12
Transportation	$1,316,088	$496,151	13
Trade	$3,542,417	$1,551,856	62
FIRE[2]	$2,760,356	$631,327	20
Services	$7,582,909	$3,637,970	136
Government	$2,260,117	$84,161	2
Total	$59,193,837	$24,066,359	839

[1]Mining and Utilities

[2]Finance, Insurance, and Real Estate

Economic Impact of Operating a Conventional Ethanol Plant in Southeastern Georgia

Table 10 shows the itemized costs and other input data for an IMPLAN model of operating a conventional ethanol plant. Employee compensation includes wage and benefits for 24 production workers, as well as 6 workers in sales and administration. Total revenue of $53.231 million represents the first round of impacts due to production. Subsequent rounds of indirect spending caused by the plant purchasing inputs are specified in Table 10.

Table 10. IMPLAN Input-Output Data for Conventional Ethanol Plant

Category	*-dollars-*
Maintenance and Supplies	1,134,000
Utilities	8,505,000
Chemicals	2,205,000
Denaturants (Gasoline)	1,260,000
Corn	31,123,720
Insurance	388,500
Labor and Benefits	2,205,000
Sales and Administrative Staff	472,500
Indirect Business Taxes	210,000
Other Property Income	5,727,280
Output	53,231,000

An assumption of the conventional plant is that the 12,097,000 bu. of corn are purchased at quantity discounts so that corn costs are lower in Table 10 than in Table 3. Southeastern Georgia corn acreage in the appendix indicates that the region would likely not produce enough corn to supply the annual demand from an ethanol plant while meeting current needs of corn utilization. For the Bacon County ethanol plant model it is assumed that 33% of corn purchased is produced within the region.

Table 11 shows the economic impact of a conventional ethanol plant operating in southeastern Georgia. The direct effect associated with output creates another $22.310 million indirectly as the operation purchases products and services from other businesses in the region. The result of increased household income from the creation of new jobs is an induced effect of $4.763 million. Total economic impact in southeastern Georgia is $80.304 million and indicates an output multiplier of 1.51.

Table 11. Conventional Plant Operations: Annual Economic Benefits to SE Georgia

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Output	$53,231,000	$22,310,417	$4,762,774	$80,304,191
Labor Income	$5,744,288	$1,500,020	$1,555,943	$8,800,251
Employment	30	549	61	640
Tax				$1,432,041

Employment includes 30 workers at the plant, as well as another 549 jobs in supporting businesses. An additional 61 jobs are created due to induced spending, for a total of 640 jobs due to operation of the ethanol plant. Total labor income associated with the ethanol plant is $8.8 million. State and local taxes increase by $1.432 million annually.

Table 12 shows how economic sectors are impacted by ethanol production. Manufacturing has the greatest impact of $55.644 million. Agriculture has the second greatest impact of $10.947 million. Employment in agriculture has the greatest impact with 470 of the 640 jobs that are created. Labor income in agriculture increases by $4.584 million.

Table 12. Conventional Plant Operations: Annual Economic Benefits to Major Sectors, SE Georgia

Sector	Output	Labor Income	Employment
Agriculture	$10,946,537	$4,584,464	470
MC[1]	$106,682	$41,726	1
Utilities	$3,718,578	$545,497	8
Manufacturing	$55,644,473	$404,321	38
Transportation, Warehousing	$880,814	$280,467	7
Trade	$1,589,897	$695,724	28
FIRE[2]	$1,821,379	$393,203	14
Services	$4,200,314	$1,793,191	72
Government	$1,395,517	$61,659	2
Total	$80,304,191	$8,800,251	640

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

Economic Impact of Corn Production in Southeastern Georgia

Analyzing the impact of corn production shows the impacts in Table 11 and Table 12 that are attributable to corn production. An assumption of this analysis is that 33% of corn inputs are purchased in southeastern Georgia. Table 13 shows that $16.614 of the output impact in Table 11 is due to corn production. Labor income increases by $6.268 million due to increased corn production, while full and part time jobs total 530. State and local taxes are $0.795 million per year.

Table 13. Corn Production - Conventional Plant: Annual Economic Benefits to SE Georgia

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Output	$10,270,828	$2,890,994	$3,452,408	$16,614,230
Labor Income	$4,137,608	$1,002,799	$1,127,937	$6,268,345
Employment	445	41	44	530
Tax				$794,733

Impacts of corn production on sectors are presented in Table 14. Almost all of the agricultural impacts in Table 12 are due to corn production. Agricultural labor income increases by $4.568 million. Comparisons with Table 7 show how utilization of corn produced in a local impact area is important to total economic impact. Total output in Table 14 is 26% of total output in Table 7. There are 68% fewer jobs created in the southeastern region due to most corn being imported from other parts of Georgia.

Table 14. Corn Production - Conventional Plant: Annual Economic Benefits to Major Sectors, SE Georgia

Sector	Output	Labor Income	Employment
Agriculture	$10,891,675	$4,568,050	469
MC[1]	$56,479	$22,130	1
Utilities	$217,199	$48,683	1
Manufacturing	$794,146	$128,798	3
Transportation	$371,389	$146,148	4
Trade	$839,474	$364,532	14
FIRE[2]	$1,127,102	$224,628	9
Services	$1,595,289	$725,525	29
Government	$721,479	$39,851	1
Total	$16,614,230	$6,268,345	530

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

Economic Impact of Operating a Conventional Ethanol Plant in Southeastern Georgia to the Economy of Georgia

An ethanol plant constructed in Bacon County will have statewide benefits that extend beyond the local impact area of southeastern Georgia. Regions within a state often purchase inputs from elsewhere in the state, and indirect impacts of a region are diminished by a limited capacity to provide goods and services. As the local impact area of the conventional plant is expanded to include all of Georgia, more supporting inputs come from within the state and the output multiplier increases.

Table 15 presents output for the conventional ethanol plant in Table 10 when Georgia is considered as the impact area. Total output effects of $125.508 million compare to $133.686 million for the advanced plant in Table 4. Although total output is lower in Table 15, the output multiplier for a conventional plant in Georgia increases to 2.36. As with the advanced plant, the multiplier for a conventional plant in Georgia is dependent upon all corn coming from Georgia sources.

Table 15. Conventional Plant Operations: Annual Economic Benefits to Georgia

	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Output	$53,231,000	$55,477,991	$16,799,091	$125,508,083
Labor Income	$14,974,746	$4,656,252	$5,694,643	$25,325,641
Employment	30	1395	172	1598
Tax				$4,061,800

Table 16 shows impacts of the conventional plant on economic sectors of Georgia. Agricultural impacts come from corn production which is mostly responsible for job creation in ethanol production. Comparing Table 16 with Table 5 indicates there are substantial economic benefits throughout industrial sectors of Georgia with operation of either a conventional ethanol plant or an advanced plant.

Table 16. Conventional Plant Operations: Annual Economic Benefits to Major Sectors, Georgia

Sector	Output	Labor Income	Employment
Agriculture	$32,818,212	$13,701,438	1274
MC[1]	$456,302	$177,366	4
Utilities	$7,754,384	$1,413,503	13
Manufacturing	$57,601,929	$908,264	45
Transportation, Warehousing	$1,768,337	$688,462	15
Trade	$5,295,400	$2,250,238	63
FIRE[2]	$7,401,837	$1,703,483	41
Services	$9,336,220	$4,338,349	139
Government	$3,075,463	$144,538	4
Total	$125,508,083	$25,325,641	1598

[1]Mining and Construction

[2]Finance, Insurance, and Real Estate

Summary

Ethanol production is a potential source of increased demand for Georgia corn producers. Advanced and conventional types of ethanol plants are evaluated for economic impacts of each. Manufacturing of ethanol requires inputs from other industrial sectors that cause indirect economic benefits from businesses and their employees.

Operation of an advanced ethanol in Georgia is estimated to lead to a total economic impact of $133.686 million, while creating 1770 jobs. Increased corn production is responsible for 47% of output impact created by ethanol production. A conventional ethanol plant constructed in Bacon County has a total economic impact on Georgia that is $125.508 million, or 94% of the impact from an advanced plant.

A conventional ethanol plant in Bacon County would have an impact on southeastern Georgia as ethanol sales cause indirect economic activity. Output valued at $53.231 million is estimated to cause an additional $27.073 million in economic activity. This total of $80.304 million for the region compares to the $125.508 million that the conventional plant has on the state economy.

Appendix E Alternative Cereal Grains Starch Content and Ethanol Yield

	Whole Grain Pounds/ Bushel (w.b.)	Whole Grain % Starch (d.b.)	Milled Compone nt % Starch (d.b.)	Starch (Pounds/ Bushel) (d.b.)	Whole Grain Ethanol Yield (Gal/Bu)	Milled Compone nt and Ethanol Yield
Barley	48	61%	73%	25.5	2.02	1.88
Wheat	60	70%	84%	36.5	2.88	2.68
Millet	50	67%	80%	29.1	2.30	2.14
Rye	56	61%	73%	29.7	2.35	2.19
Corn	56	71%	85%	33.8	2.67	2.48

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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