Project E120–210

FUEL ALCOHOL PRODUCTION IN GEORGIA

A Preliminary Study

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GEORGIA INSTITUTE OF TECHNOLOGY

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SUMMARY

Alcohol fuels can potentially be produced from any biomass materials such as grains, sugar cane, wood, etc. The feedstocks most viable in the immediate future are agricultural commodities containing starch. Of these, the most plentiful in Georgia is corn. A second choice would be grain sorghum and a third crop likely to play a role in Georgia is sweet potatoes.

Alcohol fuel production requires steam generated by a boiler. Since a prime reason for producing alcohol fuels is to conserve oil and gas, the choice of boiler fuel has to be weighted in favor of biomass materials such as wood wastes and peanut hulls, which are plentiful in Georgia. Energy requirements vary to a great extent under different production conditions, considering feedstock used, end product produced, by-product treatments, boiler type, process and equipment chosen, and conservation practices adopted.

The market potential of fuel alcohol can be estimated on the basis of a 9 to 1 blend of gasoline and alcohol. In 1979, Georgia consumed approximately 3.2 billion gallons of gasoline for transportation. In order to convert this volume to gasohol, 320 million gallons of anhydrous ethanol would be required; over 200 plants with 1.5 million gallons annual production capacity each would be needed. At present, there is no alcohol fuel production in Georgia. Additional market potential exists for hydrated alcohol for direct engine burning, for diesel fuels in blends or in hydrated condition, and for industrial applications.

Wet stillage or distillers dried grain (DDG) are the major income-producing by-products. The yield of stillage is about 30 gallons per bushel of corn feedstock, or about 17 pounds of DDG. Both wet stillage and DDG are fine feed materials for animals and poultry, especially for ruminants. The market potential for these by-products can be estimated on the basis of the number of animals and poultry existing currently in Georgia. Daily production of 6,205,798 gallons (or annual production of 2,265,116,270 gallons) of anhydrous alcohol would generate enough stillage or DDG to feed present populations. This would require 1,510 plants with annual capacity of 1.5 million gallons each.

Discharges from alcohol fuel production are particulates and ash from boiler fuel, waste water from fermentation and steam generation, and CO_2 associated with fermentation. Standard smoke control devices can be installed, ash can be disposed of in landfills or as farm fertilizer, and waste water can be recycled in the production or discharged through local sewage systems.

A 1.5 million gallon plant is adopted as the model in this report. The given production conditions are 1) corn as feedstock, 2) wood waste as boiler fuel, 3) stillage sold immediately without drying, and 4) 24-hour daily operation for 330 working days per year. The total capital requirements are estimated at $3,011,000, of which $2,861,000 is for fixed capital investments and $150,000 for working capital.

Total production costs for the model are estimated at $3,185,689, of which 73% is for variable costs and 27% is for fixed overhead costs. Gross returns are projected at $3,674,100 per year. With federal investment tax credits estimate at $534,200 (exempting federal taxes for 2.6 years), the model would yield 12.5% profit margin, 15.25% return on total assets, and 75.15% rate of return on common equity. After exhaustion of federal investment tax credits, estimates are 6.91% profit margin, 8.43% return on total assets, and 41.56% rate of return on common equity. The payout period is projected at 9.75 years.

Three break-even points are calculated: to cover total production costs, 959,488 gallons; to cover out-of-pocket costs, 741,125 gallons; and to cover manufacturing costs, 211,967 gallons.

In order to encourage the production of alternative liquid fuels to replace oil and gas in the United States, the federal government has established various financial incentives to stimulate the widespread production and use of alcohol fuels. These incentives include motor fuel tax exemptions, investment tax credits, investment loan guarantees, entitlement benefits for producers, research grants, etc.

INTRODUCTION

Encouraging the production of ethanol at home to replace imported oil and gas is a national policy. President Carter announced in January 1980 that the Administration is seeking a production level of 500 million gallons of alcohol to be brought on line by the end of 1981, which would mean that 10% of all unleaded gasoline would be gasohol by the end of 1980. Given current production of alcohol fuels of around 80 million gallons per year, reaching the target level would require a four-fold increase within the next two years. The government has offered many incentives toward that end.

Although intense interest has been expressed by public and private sectors, there still has been no alcohol fuel production in Georgia. In the six southeastern states neighboring Georgia, there is only one small plant in Selma, Alabama, initiated less than a year ago.

The technology for alcohol production has long been established; however, it is largely confined to beverage and large-scale production. For fuel-grade alcohol and small-scale production, the technology is still under refinement. To enter the field now, one must know exactly what he is doing, technically and economically.

The Economic Development Laboratory of Georgia Tech's Engineering Experiment Station has devoted considerable attention to alcohol fuel production in recent years. Lacking public support for a needed research project on the behalf of potential investors in Georgia, a very modest budget was allocated internally for this preliminary investigation. The purpose of this study is to examine production conditions for alcohol fuels in Georgia from a broad perspective. Raw material conditions, boiler fuels, and the markets for alcohol and by-products are examined; the study is culminated with an economic analysis of a model plant with annual production capacity of 1.5 million gallons of anhydrous ethanol.

The study is organized in eight sections: raw materials, boiler fuels, alcohol market, by-product market, environmental considerations, outline of a prototype fuel alcohol plant, projected production costs and returns, and financial incentives and contacts. An in-depth study of both small scale and commercial scale production should be carried out, if funding for such a study is made available.

RAW MATERIALS

Theoretically, ethanol can be produced from any biomass material which contains simple sugars or which can be converted to simple sugars. This encompasses a wide range of potential feedstocks containing substantial amounts of sugar, starch, or cellulose. Some feedstocks commonly considered for ethanol production which contain simple sugars are sugar cane, molasses, and sugar beets. Starch-containing feedstocks include grains such as corn, milo, wheat, and rye, as well as Irish potatoes and sweet potatoes. Materials with substantial cellulose content include wood wastes such as sawdust, bark, shavings and chips, newspaper, municipal solid waste, and agricultural residues such as corn stalks and cobs, soybean stalks, and peanut hay and hulls.

In the State of Georgia, the most plentiful potential feedstock is wood biomass. Vast supplies of wood wastes are currently available in the form of mill and forest residues, surplus growth, and non-commercial timber. However, the commercial utilization of cellulosic feedstock is not feasible at this time. The technology for converting cellulosic material is still in the developmental stage. In addition, the economic feasibility of collecting forest residues and non-commercial timber for such uses has not been demonstrated.

The most viable feedstocks for the immediate future are agricultural commodities containing starch. The technology for converting starch to alcohol has been well developed by the beverage alcohol industry and is available for immediate implementation. In Georgia, the most plentiful starch feedstock is corn, which is produced in substantial quantities, especially in the southwestern part of the state. Estimates by the Crop Reporting Service for 1979 show that 100,750,000 bushels of corn were produced in the state, with an average yield of 65 bushels per acre. If all this corn were converted to alcohol, it would produce approximately .25 billion gallons.* In addition, there is the possibility of increased corn acreage if an alcohol fuel industry can provide a steady market.

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*Alcohol yield figures throughout this section are for anhydrous alcohol.

A second grain which has potential as an alcohol feedstock in Georgia is grain sorghum. The alcohol yield from a bushel of grain sorghum is about the same as for corn. Estimates for 1979 show that 1,911,000 bushels were produced in the state, with an average yield of 39 bushels per acre. Although this production is relatively small currently, it could be increased, primarily through multiple cropping. The ability to produce more than one crop per year, plus the lower production cost of grain sorghum compared to corn, make this an attractive feedstock to both the farmer and the alcohol producer.

A third crop which will likely play a role in Georgia's alcohol fuel development is sweet potatoes. A particularly attractive feature of this crop is the greater yield of starch (and alcohol) per acre, compared to corn. Production records from commercial growers indicate that yields of 300 bushels per acre are typical. With an estimated alcohol yield of 1.2 gallons per bushel, about 360 gallons of alcohol per acre could be obtained, compared to about 165 gallons per acre using corn. Estimates for 1979 show that 1,254,545 bushels of sweet potatoes were produced in the state. Here again, there is the possibility that greater markets created by alcohol production would result in more acreage of the crop.

Table 1 summarizes production and yield figures for these three commodities.

Table 1

PRODUCTION AND ALCOHOL YIELD
FOR CORN, GRAIN SORGHUM & SWEET POTATOES

	Gal.alcohol per bushel	Bushels/acre	Gal.alcohol per acre	Bushels prod. in 1979
Corn	2.5	65	163	100,750,000
Grain sorghum	2.5	39	98	1,911,000
Sweet potatoes*	1.2	300	360	1,254,545

*Estimated

BOILER FUELS

Two basic types of energy are used in fuel alcohol production--steam and electricity. Steam for cooking the mash and distilling the alcohol has to be generated on site, commonly with a boiler, unless waste steam from some other source is available. Electrical power is needed in relatively small amounts and would usually be purchased from utility companies rather than generated on site. The choice of boiler depends upon the kind of fuel used. Oil, gas, coal, wood, and agricultural wastes such as peanut hulls, corn stalks, bagasse, etc., are potential boiler fuels. Since a prime reason for producing fuel alcohol is to conserve imported oil and gas, the choice of boiler and fuel type has to be weighted in the favor of biomass and coal. Although boilers designed for biomass and coal are two to three times higher in initial capital cost than oil-gas boilers, they may be more economical in the long run because of lower fuel costs.

A third alternative which may provide the benefits of a renewable fuel supply as well as lower boiler costs is the use of methane generated from a livestock feedlot adjacent to the plant. If used on site, methane from anaerobic digestion of animal wastes can be an acceptable, relatively low-cost process fuel.

Energy requirements for fuel alcohol production vary to a great extent depending upon the following factors:

1. Feedstocks. Raw materials used differ in cooking requirements. Sugar syrup requires no cooking. Cooking time for starchy feedstocks varies.

2. End Products. Anhydrous ethanol requires more processing than water-content (hydrated) ethanol.

3. By-product treatments. Distillers dried grain (DDG) requires drying and evaporating equipment, while stillage can be sold to nearby farms directly without drying. The difference in energy requirements is substantial.

4. Boiler type. Boiler efficiency differs according to fuel type and design. As a result, energy requirements differ as well.

5. Process and equipment. The choice of process and equipment will be constrained by energy requirements. Since the need for fuel alcohol has been recognized only in recent years, energy-efficient production processes are still under development.

6. Energy conservation practices. Many conservation practices can be adopted in a fuel alcohol plant in order to reduce energy requirements. These practices, such as recycling heated or cool water for different purposes, tightening of joints to prevent leaks, insulation of piping, the use of solar energy, etc., could mean a lot in terms of energy saved.

Because of varied production conditions, there is no consensus on energy requirements per unit of alcohol produced, which may vary from 20,000 Btu to 100,000 Btu. Two tables are developed for reference purposes. Table 2 shows the amount of fuel needed per gallon of alcohol under different Btu per gallon, based on four fuel types (natural gas, wood pellets, sawdust, and peanut hulls). The requirements are calculated on the basis of per gallon and per year. For example, if 50,000 Btu is required to produce one gallon of alcohol, then 60.6 cu. ft. of natural gas, or 9.5 lbs. of wood pellets, or 17.1 lbs. of sawdust, or 9.8 lbs. of peanut hulls would be needed. One year's volume for each fuel type is given. The calculations are based on assumptions of different boiler efficiencies, different moisture contents of fuels, and different Btu value of fuels.

Cost per gallon of alcohol produced for the four fuel types is given in Table 3. For example, if 50,000 Btu is required to produce one gallon of alcohol, then the cost of using natural gas is $0.23, using wood pellets is $0.19, using sawdust is $0.08, and using peanut hulls is $0.03. These calculations are based on current fuel costs. Obviously, the costs for using biomass such as sawdust and peanut hulls are substantially lower than the cost of using natural gas or oils.

Table 2

AMOUNT OF FUEL NEEDED FOR FOUR FUEL TYPES

I. Per Gallon Alcohol

BTU/gal (x1000)	Cu. Ft. Natural Gas.	lbs. Wood Pellets	lbs. Sawdust	lbs. Peanut Hulls
100	121.1	19.0	34.2	19.7
90	109.0	17.1	30.8	17.8
80	96.9	15.2	27.4	15.8
70	84.8	13.3	23.9	13.8
60	72.7	11.4	20.5	11.8
50	60.6	9.5	17.1	9.9
40	48.4	7.6	13.7	7.9
30	36.3	5.7	10.3	5.9
20	24.2	3.8	6.8	3.9

II. Per Year

Btu/gal. (x1000)	Therms Natural Gas	Tons Wood Pellets	Tons Wood Waste	Tons Peanut Hulls
100	1,875,000	14,250	26,250	14,775
90	1,687,500	12,825	23,100	13,275
80	1,500,000	11,400	20,475	11,775
70	1,312,500	9,975	17,925	10,350
60	1,125,000	8,550	15,375	8,850
50	937,500	7,125	12,825	7,350
40	750,000	5,700	10,275	5,925
30	562,500	4,275	7,725	4,425
20	375,000	2,850	5,100	2,925

Assumptions

1. Boiler efficiencies:

Natural Gas	80%
Wood Pellets	65%
Sawdust	65%
Peanut Hulls	65%

2. Moisture Content:

Wood Pellets	10%
Sawdust	50%
Peanut Hulls	10%

3. BTU Values:

Natural Gas	1032/cu.ft.
Wood Pellets	8100/lb.
Sawdust	4500/lb.
Peanut Hulls	7800/lb.

Table 3

COST PER GALLON OF ALCOHOL FOR FOUR FUEL TYPES

BTU/gal (x1000)	Nat Gas.	Wood Pellets	Sawdust (50% M.C.)	Peanut Hulls
100	.47	.38	.17	.06
90	.42	.35	.15	.05
80	.37	.31	.13	.05
70	.33	.27	.12	.04
60	.28	.23	.10	.04
50	.23	.19	.08	.03
40	.19	.15	.07	.02
30	.14	.12	.05	.02
20	.09	.08	.03	.01

Assumptions

1. Cost of fuels:

Natural Gas	$3.85/1000 cu. ft.
Wood Pellets	40.00/ton
Sawdust	10.00/ton (incl. $2.00/ton trans.)
Peanut Hulls	6.00/ton (incl. $3.00/ton trans.)

2. Boiler efficiencies:

Natural Gas	80%
Wood Pellets	65%
Sawdust	65%
Peanut Hulls	65%

3. Moisture Content:

Wood Pellets	10%
Sawdust	50%
Peanut Hulls	10%

4. BTU Values:

Natural Gas	1032/cu.ft.
Wood Pellets	8100/lb.
Sawdust	4500/lb.
Peanut Hulls	7800/lb.

ALCOHOL MARKET

The most viable near-term market for fuel alcohol is in blends with gasoline for use in spark-ignition engines. Gasohol, a blend of 90% unleaded gasoline and 10% anhydrous ethanol, is being marketed successfully at retail outlets around the country. As of June 1979, the U.S. Department of Energy reported that over 800 outlets in 28 states were selling gasohol. At present the available supply of anhydrous alcohol is not sufficient to meet the strong public demand for gasohol. The total U.S. production of fuel alcohol is now less than 100 million gallons per year, which is sufficient to convert less than 1% of the gasoline used in the country to gasohol.

At present there is no commercial production of anhydrous alcohol for making gasohol in the state of Georgia. In 1979, approximately 3.2 billion gallons of gasoline were used for transportation purposes in the State. In order to convert all gasoline in the state to gasohol, 320 million gallons of anhydrous ethanol would be required. Thus, if all commercial plants in the state averaged 1.5 million gallons of production per year, over 200 such plants would be required to supply the alcohol needed for in-state use.

According to the Department of Energy, the acceptance of gasohol by the consumer is based on three primary factors: a) perceptions by the consumer of improved driving performance, b) consumer preference for renewable fuels, and c) lower selling price for gasohol than for other high octane gasolines. Gasohol has an octane rating of 2-3 points higher than the unleaded gasoline with which the alcohol is blended. As a result, performance is usually improved with vehicles designed to run on unleaded gasoline. Several reports have indicated that mileage is also improved somewhat with gasohol, but there is some conflicting evidence on this point.

In addition to gasohol, alcohol fuels may also be used in hydrated form (containing some water) as a replacement for gasoline. Existing gasoline engines can be converted to run on alcohol with water content as high as 30% with modifications to the engine and fuel system. Because of the necessity for engine modification, the market for this alcohol is not developed at this point. In the next few years, however, this may become a more viable market for alcohol fuels as public awareness of alcohol fuels increases and the technology for this use is developed.

A second potential use of alcohol fuels in the state of Georgia is in diesel engines, both in the farm and transportation sectors. Anhydrous alcohol can be blended with diesel fuel in much the same way that alcohol is blended with gasoline. The resulting product, often called "diesohol", can be used with no modifications in diesel engines. However, reports of diesohol use indicate losses in both power and fuel economy in many cases.

There are other approaches to alcohol use in diesel engines which may prove to be more viable than blends of alcohol and diesel fuel. These involve the use of hydrated rather than anhydrous alcohol. In one option, alcohol is used as a replacement for diesel fuel. This requires the addition of some type of lubricating oil to the alcohol.

Another alternative is to use alcohol in an injection system to supplement diesel fuel. Since both of these alternatives require some engine modification, the development of these markets is not as advanced as that of gasohol. However, as further developmental work is completed, these markets will undoubtedly become substantial. A particular advantage of both these approaches is that only low-proof alcohol (100-160 Proof) is required. This will reduce the level of sophistication of the technology required to produce alcohol and will lower the cost of production.

Outside the area of transportation, other markets for alcohol in industrial applications may also develop. For example, alcohol fuels can be used as a replacement for fuel oils or natural gas in turbine engines in power generating plants as well as oil and gas pipeline and pumping stations. Since there are already constraints on the use of natural gas in electrical generating plants and environmental constraints on the use of fuel oil, the use of alcohol fuels in these applications may have merit in the years to come.

BY-PRODUCT MARKET

Stillage or distillers grain and carbon dioxide are the two main by-products from fuel alcohol production. Although carbon dioxide can be used in greenhouses for stimulating plant growth or be compressed and used as a refrigerant, as yet it is generally not captured during the fermentation process because of limited market outlets and cost considerations. On the other hand, distillers grain is already recognized as a valuable coproduct of ethanol production.

The stillage from cereal grains is being used as a high-protein component in animal feed rations, particularly for ruminants such as steers or dairy cows. Corn, the most commonly used raw material for fuel alcohol production, is a major crop in Georgia and is used as the base for computation of stillage conversion in this section of this report. The yield of stillage is about 30 gallons per bushel of corn input. If it is dried, the yield ratio would be about 17 pounds of distillers dried grain (DDG) per bushel of corn.

Distillers grain, either wet or dried, is widely accepted as animal feed. For poultry feed, it is usually in dried condition or DDG. The market value of DDG is determined largely by the protein content (24-30%) relative to the protein content of soybean meal (44%). The price of DDG usually varies from 60% to 85% of the market price of soybean meal.

Since stillage and DDG are used for animal and poultry feed, the number of animals and poultry in a given area times daily feed volume would provide some idea of the size of the feed market. For example, one cow would consume in one day the amount of stillage from one gallon of ethanol produced, or 6.8 pounds of DDG. In the same manner, one calf would consume stillage from 0.7 gallon of ethanol; one pig, stillage from 0.4 gallon; and one chicken, stillage from 0.0074 gallon. Table 4 provides the number of animals and poultry in Georgia, gallons of alcohol to generate stillage for feeding per animal per day, and total gallons of ethanol required to provide the stillage.

In one year, 2,265,116,270 gallons of alcohol would be required to generate the amount of stillage to feed Georgia's populations of these animals and poultry. This means that 1,510 fuel alcohol plants with annual output capacity of 1.5 million gallons each would be required.

Table 4

GEORGIA LIVESTOCK POPULATIONS AND GALLONS OF ALCOHOL REQUIRED TO GENERATE FEED STILLAGE

Type of Livestock	Population	Alcohol-Stillage Converting Factor for Feeding***	Gallons of Alcohol/Day
Cattle	825,000*	1.0	825,000
Calves	825,000*	.7	577,500
All pigs and hogs	1,800,000**	.4	720,000
All chickens	551,797,000**	.0074	4,083,298
		Total	6,205,798

*1979 estimate

**1978 estimate

***Gallons of alcohol produced to generate designated amount of stillage per animal per day

It should be pointed out that the number of animals in a given area cannot be used as the basis for estimating a potential market for stillage; this must be computed on the basis of letters of intent to purchase, not just on the existence of a local feedlot. The value of stillage will never exceed the directly corresponding cost of protein from other sources.

For a small-scale fuel alcohol plant, it is important to sell the stillage wihtout drying because a significant cost increase occurs if a drying process has to be installed. However, the solids of the stillage can be easily separated from the liquid with a screening and dewatering press, reaching 65% water content. These damp solids can be packed in airtight containers in CO_2 atmosphere and be shipped moderate distances before major spoilage takes place. The liquid from the screening and pressing still contains a significant proportion of dissolved proteins and carbohydrates. It can be concentrated by evaporation, but the energy consumption is high unless multiple-effect evaporators are used. These evaporators are large and expensive, and may need careful management.

Dewatered solids and concentrated liquids or syrup can be dried to about 10% moisture content as distillers dried grain (DDG), which can be stored for a long time and shipped to distant markets.

Stillage from aflatoxin-contaminated grains and those treated with antibiotics is prohibited as animal feed.

Gold Kist, Inc., one of the major feed manufacturers in Georgia, produces about 125,000 tons of dairy and beef feeds each year. The feed would permit up to 500 pounds of DDG per ton to be used or about 62.5 million pounds of DDG each year. This would mean producing about 9.2 million gallons of fuel alcohol to generate the volume of DDG required by the company's three feed mills in Georgia and one in Alabama. The company has indicated that DDG is a desirable ingredient which, they hope, can be produced in Georgia. However, the DDG must not be burned or scorched; this makes it bitter and unpalatable to dairy cows.

ENVIRONMENTAL CONSIDERATIONS

The major potential environmental impacts of an alcohol production facility are associated with discharges from the plant. The first of these, boiler emissions, are of particular concern for boilers which burn solid fuels such as coal, wood wastes, agricultural residues, or municipal solid waste because these fuels produce greater quantities of particulate emissions than oil or gas. Such boilers should be equipped with particulate discharge collectors to insure compliance with EPA and local regulations. When coal is used, flue gases, odorous vapors, and sulfur dioxide are also emitted and must be controlled. The use of solid fuels also results in a residue of ash, less with wood than with coal. The disposal of this ash should not present major problems, but it should be accomplished in compliance with local regulations which exist in some areas.

A second type of discharge of potential concern is waste water. This can come from two sources, the fermentation process or the steam generating system. In most cases, water from the fermentation process (called "thin stillage") will not present a disposal problem since the water contains valuable nutrients which will usually be recovered. In one recovery approach, the thin stillage is added to the residue of solids remaining after fermentation and the mixture is sold as livestock feed, thus eliminating the need for further disposal. Another approach involves drying the grain residues for sale as distillers dried grains. In this case the nutrients in solution in the thin stillage are usually separated from the water by evaporation, thus leaving only distilled water. This water is usually recycled and used within the plant in processing more alcohol. In the event that the thin stillage were not utilized in some way to recover the nutrients in it, its disposal would require treatment in accordance with waste water treatment regulations since it will have a relatively high BOD value.

Waste water from the boiler system should present no problem in terms of its content. If discharged into an existing river, stream, pond, or lake, its temperature must be within specified limits of prevailing water temperature.

The final discharge to be considered is the CO_2 generated in the fermentation. At present there are no federal regulations concerning the discharge of CO_2 and it can be vented freely into the air.

OUTLINE OF A MODEL FUEL ALCOHOL PLANT

Product Description, Plant Size, and Production Procedure

The fuel alcohol described here is anhydrous ethanol (200 proof), which can be mixed with gasoline for gasohol or with diesel fuel for diesohol; an anhydrous product is essential because separation occurs under some conditions when hydrated (less than 200 proof) alcohol is mixed with petroleum fuels.

The model fuel alcohol plant would produce 1,500,000 gallons of anhydrous ethanol a year. It is assumed that corn would be the main feedstock, wet stillage would be sold to nearby farms as animal feed without further drying, and wood wastes and sawdust would be the main boiler fuel used in the plant.

In the production process, corn must be broken down by milling or grinding, thereby breaking the kernels to make all of the material available to the water. From this mixture, a slurry can be prepared and heated to break the cell walls of the starch with proper proportion of enzyme added before the cell walls rupture. The mash should be held at the proper temperature and pH until conversion of the starch to glucose is complete.

This fermentation is accomplished using yeast under controlled temperature, nutritional requirements, and sugar concentration. The ethanol is removed by a distillation process which yields a solution of ethanol and water that cannot exceed 95.6% (at normal pressure) due to the physical properties of the ethanol-water mixture. In the final step the water is removed to produce dry ethanol. This is accomplished by adding to the solution a chemical that changes these physical properties and by distilling once again.

A simplified ethanol production flow diagram is given in Figure 1.

Investment Requirements

Investment requirements for the model fuel alcohol plant involve outlays for fixed capital requirements and for working capital. The fixed investment requirements are estimated on the basis of price quotations supplied by equipment manufacturers and engineering firms in the United States. A summary of major items for the fixed capital outlays is given in Table 5. Total fixed capital outlays were estimated at $2,861,000.

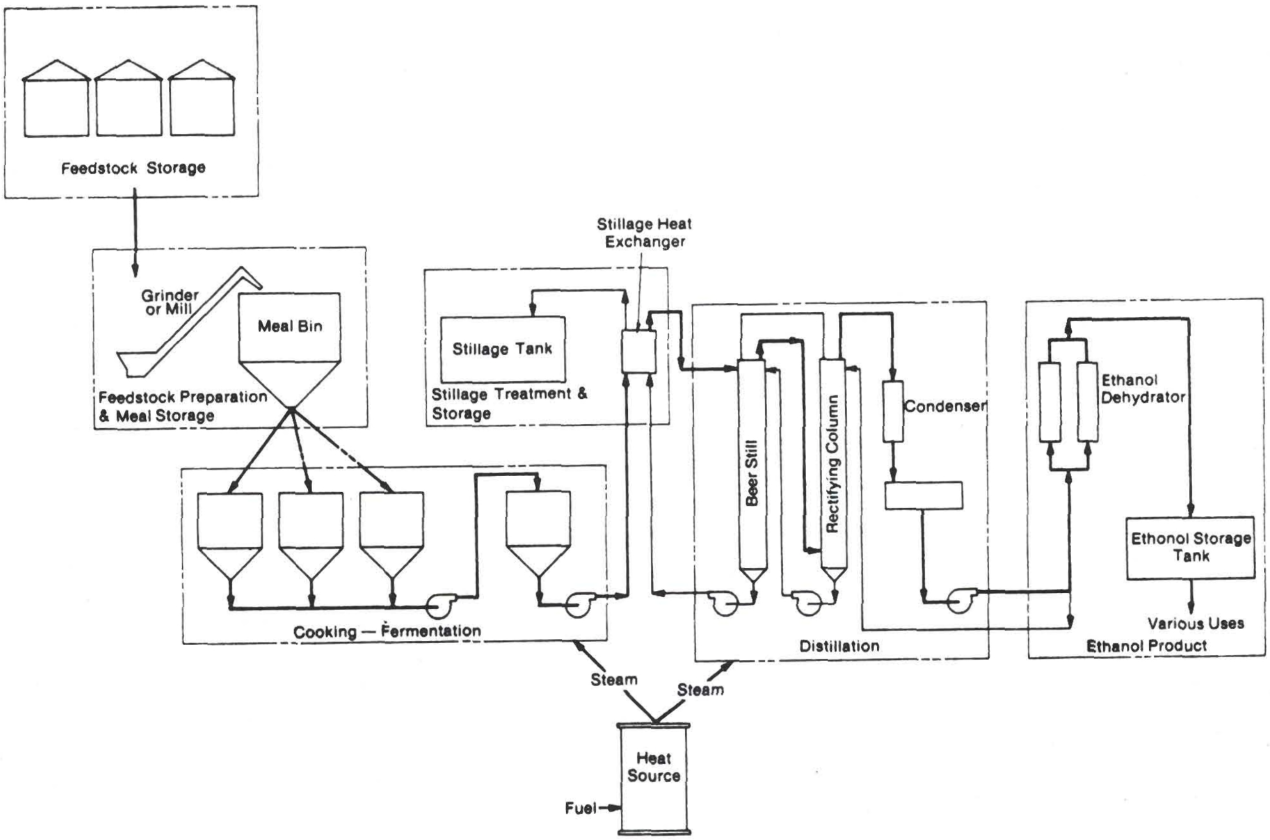


Figure 1. Ethanol Production Flow Diagram

Table 5

FIXED CAPITAL REQUIREMENTS FOR A MODEL PLANT

Item			Cost
1.	Land: 5 acres @ $5000		$ 25,000
2.	Ground & Site Preparation Building 50x100 = 5,000 sq.ft. + Misc. area = 5,000 sq.ft. = 10,000 sq.ft. x $2/sq.ft.		$ 20,000
3.	Road & Rail Connections		$ 60,000
	Blacktop-paved access road to main highway	$20,000	
	Rail car siding and charges	40,000	
4.	Plant Building		$ 45,000
	Pref. metal 50x100 = 5,000 sq.ft. @ $7/sq.ft.	= 35,000	
	Office space inside the pref. metal building 1,500 sq.ft. at $6.6/sq.ft.	= 10,000	
5.	Wood Boiler 225 H.P. including feeding system & smoke control		$300,000
6.	Grain Storage Bins 3 @ 16,000 bushel each & auxiliaries		$ 50,000
7.	Grain Unloading Systems		$155,000
	By truck - scale (1) $25,000		
	facilities 30,000		
	By rail - facilities 100,000		
8.	Grain handling & grinding facilities		$ 24,000
9.	Distillers grain storage = 15,000 gallons @ $1/gal.		$ 15,000
10.	Processing equipment = cooking, fermentation, distillation, and alcohol storage		$1,750,000
11.	Freight in		$ 80,000
12.	Trucks 1 large @ $20,000 2 medium @ $10,000		$ 40,000
13.	Trailers, 6 for distillers grain @ $2,000		$ 12,000
14.	Miscellaneous Erection, fire protection, electrical wiring, lighting, etc.		$ 285,000
	Total		$2,861,000

Estimated working capital for the model production is given in Table 6. Working capital is estimated on the basis of 90-day corn supplies, 3-day boiler fuel, 30-day chemicals, one month's pay for salaries and wages, and some cash. Corn payment is based on bonded warehouse practice of paying 20% of total cost initially with the balance paid in succeeding months. The working capital is estimated at $150,000.

Table 6

ESTIMATED WORKING CAPITAL REQUIREMENTS FOR A MODEL PLANT

Item		Cost
Corn, 90-day supply		$ 98,182
Boiler Fuel, 3-day supply		1,166
Chemicals, 30-day supply		16,364
Salaries and Wages, one month		19,958
Cash		14,330
	Total	$150,000

Total capital requirements for the model production are estimated at $3,011,000, including fixed capital investments and working capital. These capital requirements are estimated on the basis of 1980 costs.

PROJECTED PRODUCTION COSTS AND RETURNS

Production Costs

Production costs consist of variable costs and fixed costs. Variable costs are those which vary with the level of production. The level of production is controlled by machinery processing capacity and time. The production conditions of the model plant are given below:

- Production time
  330 days per year
  24 hours per day
  7920 hours per year

- Processing capacity
  1,500,000 gallons per year, anhydrous ethanol
  4,545.45 gallons per day
  189.39 gallons per hour

Bainbridge (Decatur County), Georgia, is chosen as the focal point for various cost estimates. Various cost and return calculations presented in this section may apply to many locations in Georgia.

Variable Costs. Variable costs for the model production are corn, chemicals, labor, and utilities. Detailed calculations for each cost element are given separately.

1. Corn. It is the most commonly used feedstock for ethanol production in the nation and it is an important crop in Georgia. The yield ratio is 2.5 gallons of alcohol per bushel of corn. The cost of corn varies slightly from location to location. In Georgia, the average cost is three dollars per bushel at the present time. Annual cost for corn is given as follows:

   1,500,000 gallons = 2.5 x $3 = $1,800,000

2. Chemicals. Enzymes, yeast, and other chemical additives required in the production process. The cost of these chemicals is estimated at 12 cents per gallon.

3. Boiler fuel. It is estimated to require 50,000 Btu to process one gallon of ethanol (without drying distillers grain) or about 17.1 pounds of wood waste at 50% moisture content and at 65% boiler efficiency. The cost of woodwaste or sawdust is estimated at $10 per ton delivered:

   1,500,000 galllons x 17.1 lbs. ÷ 2,000 x $10 = $128,250

4. Labor. The model plant would require four shift supervisors, 12 operators, two truck drivers, and one maintenance person. The costs are estimated as follows:

Shift supervisors	4 @ $15,000	$ 60,000
Operators & drivers	14 @ $ 8,125	113,750
Maintenance	1 @ $12,000	12,000
Annual labor costs		$ 185,750

5. Utilities. Water and elecctrical power are required. Water requirements are estimated at 12 gallons per gallon of alcohol produced. Water and sewage charges are estimated at $1,000 per month. Electrical power requirements are estimated at 15,000 KWH per month.

Water and sewage	$1,000 x 12 =	$ 12,000
Electrical power	15,000 KWH x 12 x $.07 =	12,600
Annual costs		$ 24,600

Fixed Costs. Fixed costs are those which remain constant and are not influenced by the level of production under normal operating conditions. These costs are administrative salaries, maintenance, ad valorem taxes, insurance, miscellaneous and office expenses, interest and debt service, and depreciation. These fixed costs are described and estimated as follows:

1. Salaries. Approximately four persons are necessary as administrative personnel for the model production.

Position	Number	Annual Salary
Plant manager	1	$ 30,000
Fermentation manager	1	20,000
Secretary and clerk	2 @ $10,000	20,000
	Total	$ 70,000

2. Maintenance. Upkeep expenses for road, building, equipment and other facilities are estimated at three cents per gallon.

1,500,000 galllons x $0.03 = $45,000.

3. Ad valorem taxes. Based on the Decatur County tax base and on the given fixed investments and inventories, total ad valorem taxes are estimated at $12,445 a year. Detailed calculations are as follows:

Fixed investments	$ 2,861,000
Inventories	231,758
Total tax base	$ 3,092,758
At 40% valuation	$ 1,237,103
Tax rate $10.06/$1,000	$ 12,445

4. Insurance. Insurance rates on an industrial plant depend on building materials, fire prevention equipment installed, water availability at the plant, and products and raw materials stored. Insurance costs for the plant are estimated as follows:

Item	
Inventories	
Materials (corn and chemicals, 30 days)	$ 165,000
Boiler fuel, 3 days	1,166
Distillers grain, 1 day	1,956
Fuel alcohol, 7 days	63,636
Fixed investments less land	2,836,000
Total insured amount	$3,067,758
Insurance rate at .90/$100	27,610
Workmen's compensation insurance	6,500
Total insurance costs	34,110

5. Miscellaneous and office expenses. It is estimated at two cents per gallon to cover miscellaneous expenses such as legal and CPA services, telephone and telegraph, office supplies, heat, etc.

1,500,000 gallons x $0.02 = $ 30,000.

6. Interest and debt services. The investment capital required would be supplied from two sources -- equity capital and long-term borrowing. It is assumed that about 20% of the investments would be financed by equity capital and the balance would come from borrowing. Interest and debt retirement have been worked out in two plans: one is based on a 10-year borrowing at 15% per annum on borrowed capital; the second plan is based on a 10-year term with 10% interest rate per annum, which may be obtainable from government loans or from bonds issued by local government.

Fixed capital requirements	$2,861,000
Working capital	150,000
Total investments	$3,011,000
Assumed equity capital	- 611,000
Borrowed capital	$2,400,000
Annual payment based on a 10-year plan at 15% per annum (interest and debt)	$ 478,200
Annual payment based on a 10-year plan at 10% per annum (interest and debt)	$ 390,600

7. Depreciation. Depreciation is a noncash cost. It is important for entrepreneurs to set aside sufficient funds for the cost of depreciation. For this study, a 15-year straight-line depreciation method is adopted for

machinery, equipment, and building. A 5-year straight-line depreciation is selected for trucks and trailers. Total depreciation costs are estimated at $197,334 a year.

Item	Invested value	Annual Rate	Annual Depreciation
Machinery and building	$2,774,000	6.6667%	$184,934
Trucks and trailers	62,000	20%	12,400
Total			$197,334

A summary of annual production costs is provided in Table 7. The manufacturing costs are the sum of variable costs and fixed costs. Adding interest and debt retirement to the manufacturing cost is equal to out-of-pocket costs. Total production costs are equal to the sum of out-of-pocket costs and depreciation.

Total annual costs are estimated at $3,185,689 for producing 1,500,000 gallons of anhydrous ethanol in Georgia. On a per gallon basis, the production cost is estimated at $2.1238, of which nearly 73% goes to variable costs and the balance is for fixed costs. Corn feedstock alone constitutes 56% of the production costs.

Projected Returns

In order to project annual gross returns for the model production, three sources of income have to be decided. They are anhydrous ethanol, entitlement benefits offered by the Department of Energy, and by-product (distillers grains).

The current value of anhydrous fuel ethanol is $2 per gallon in Georgia, compared with $1.85 per gallon at Decatur, Illinois, reflecting the higher feedstock price in Georgia and the Southeast. If the fuel alcohol is imported from the Midwestern states, the transportation cost would be approximately equal to the difference in feedstock cost in the Southeast.

The value of distillers grain is determined by the protein content and is affected by the value of soybean meal, which is the dominant feed material in the market. In turn the value of soybean meal is influenced by soybean crop, cattle number, and exports. The market price for DDG assumed in this analysis is $116 per ton.

Table 7

ESTIMATED ANNUAL PRODUCTION COST FOR A MODEL PLANT
(1,500,000 gallons a year)

Variable Cost	Total	Per Gallon
Corn	$1,800,000	$1.20
Chemicals	180,000	0.12
Boiler fuel	128,250	0.0855
Labor	185,750	0.1238
Utilities	24,600	0.0164
Subtotal	$2,318,600	$1.5457
Fixed Costs		
Salaries	$ 70,000	$0.0467
Maintenance	45,000	0.0300
Ad Valorem taxes	12,445	0.0083
Insurance	34,110	0.0227
Miscellaneous	30,000	0.0200
Subtotal	$ 191,555	$0.1277
Manufacturing Cost	$2,510,155	1.6734
Interest and debt retirement	478,200	0.3188
Out-of-Pocket Costs	$2,988,355	$1.9922
Depreciation	197,334	0.1316
Total Production Costs	$3,185,689	$2.1238

With the yield ratio of 17 pounds of DDG (or approximately 30 gallons in stillage or slop) per bushel of corn processed, the by-product value is estimated at $0.986 per bushel of corn processed or 3.2867 cents per gallon of slop. Annual by product value of the production is estimated at $591,600 based on 600,000 bushels of corn processed and 18 million gallons of slop generated.

Additional benefits are available to fuel alcohol producers through the entitlements program administered by the Economic Regulatory Administration of the Department of Energy. At present, these benefits provide approximately 5.5 cents subsidy per gallon of anhydrous ethanol produced in the United States for fuel purposes.

A statement of estimated costs and profits on the model production is summarized in Table 8. As indicated above, the gross returns are derived from the sales of fuel alcohol and distillers grain and from a 5.5 cent subsidy on each gallon of alcohol produced. Manufacturing costs, consisting of variable and fixed costs, are deducted from gross returns to obtain operating profits. To determine net profit before taxes, interest and debt retirement and depreciation must be deducted from operating profits. Net profit after taxes is determined by deducting approximately 46% of the profit for federal taxes and 6% for state taxes.

The model plant would have a gross return of $3,674,100 in a normal year, which includes the incomes from alcohol fuel, distillers grain, and DOE entitlement benefits. After deducting the manufacturing costs, interest and debt retirement, and depreciation, net profit before taxes is projected at $488,411.

A total of 20% investment tax credit is allowed for facilities that convert alternative feedstocks (including crops and biomass) into "synthetic liquid fuels," including ethanol. This investment tax credit for the model production is estimated at $534,200, which would allow production free of federal taxes for 2.6 normal operating years.

Net profit after taxes is estimated at $459,106 with investment tax credits. The profitability of the production can be indicated by several ratios: profit margin, 12.5%; return on total assets, 15.25%; and rate of

Table 8

SUMMARY STATEMENT OF ESTIMATED ANNUAL COSTS AND PROFITS
FOR A MODEL PLANT WITH FEDERAL INVESTMENT TAX CREDITS, 1980
(1,500,000 gallons a year)

Gross Return	Total	Per Gallon
Fuel Alcohol	$3,000,000	$ 2.0000
DOE Entitlement Benefits	82,500	0.0550
Distillers Grains	591,600	0.3944
Total	$3,674,100	$ 2.4494
Manufacturing Costs		
Variable	$2,318,600	$ 1.5457
Fixed	191,555	0.1277
Operating Profit	$1,163,945	$ 0.7760
Interest and Debt Retirement	478,200	0.3188
Depreciation	197,334	0.1316
Net Profit Before Taxes	$ 488,411	$ 0.3256
Federal Taxes	0	0
State Taxes, 6%	29,305	0.0195
Net Profit After Taxes	$ 459,106	$ 0.3061
Profit Margin	12.50%	
Return on Total Assets	15.25%	
Rate of Return on Common Equity	75.15%	
Payout Period	9.75 years	

return on common equity, 75.15%. The payout period would be 9.75 years. The proposed venture would get a reasonable return.

After the federal investment tax credits are used up, federal taxes approximately 46% of gross profit are applied. Net profit after taxes, profit margin, return on total assets, and the rate of return on common equity would be reduced about 46%. The detailed figures are given below in Table 9.

Table 9

SUMMARY STATEMENT OF ESTIMATED ANNUAL COSTS AND PROFITS FOR A MODEL PLANT WITHOUT FEDERAL INVESTMENT TAX CREDITS

(1,500,000 Gallons a year, based on 1980 costs)

Gross Returns	Total	Per Gallon
Fuel alcohol	$3,000,000	$2.0000
DOE entitlement benefits	82,500	0.0550
Distillers grains	591,600	0.3944
Total	$3,674,100	$2.4494
Manufacturing Costs		
Variable	$2,318,600	$1.5457
Fixed	191,555	0.1277
Operating Profits	$1,163,945	$0.7760
Interest & debt retirement	478,200	0.3188
Depreciation	197,334	0.1316
Net Profit Before Taxes	$ 488,411	$0.3256
Federal taxes, 46%	205,199	0.1368
State taxes, 6%	29,305	0.0195
Net Profit After Taxes	$ 253,907	$0.1693
Profit Margin	6.91%	
Return on Total Assets	8.43%	
Rate of Return on Common Equity	41.56%	

If the borrowed capital, $2,400,000, can be obtained from government loan programs or from bonds issued by local government at 10% per annum on a 10-year plan, the financial returns on the model production (not including federal investment tax credits) would be improved as follows:

Net profit before taxes	$576,011
Federal taxes, 46%	246,715
State taxes, 6%	34,561
Net profit after taxes	$295,735
Profit margin	8.05%
Return on total assets	9.82%
Rate of return on common equity	48.40%

Break-Even Analysis

The break-even point is that level of production where the total production costs are exactly covered by the revenues generated from the volume produced and sold. Two other break-even points are also calculated to cover manufacturing costs and to cover out-of-pocket costs. Detailed calculations and break-even points for the model production are given in Table 10. To cover total production costs, the plant would have to produce and sell 959,488 gallons annually; to cover out-of-pocket costs, 741,125 gallons annually, and to cover manufacturing costs, 211,967 gallons annually.

These break-even points are presented in graphic form in Figure 2. All of them amount to less than 75% of the full annual operation level of 1,500,000 gallons. If sales go beyond the break-even point for total production costs, profit will occur; on the other hand, if sales lag behind this point, losses will occur.

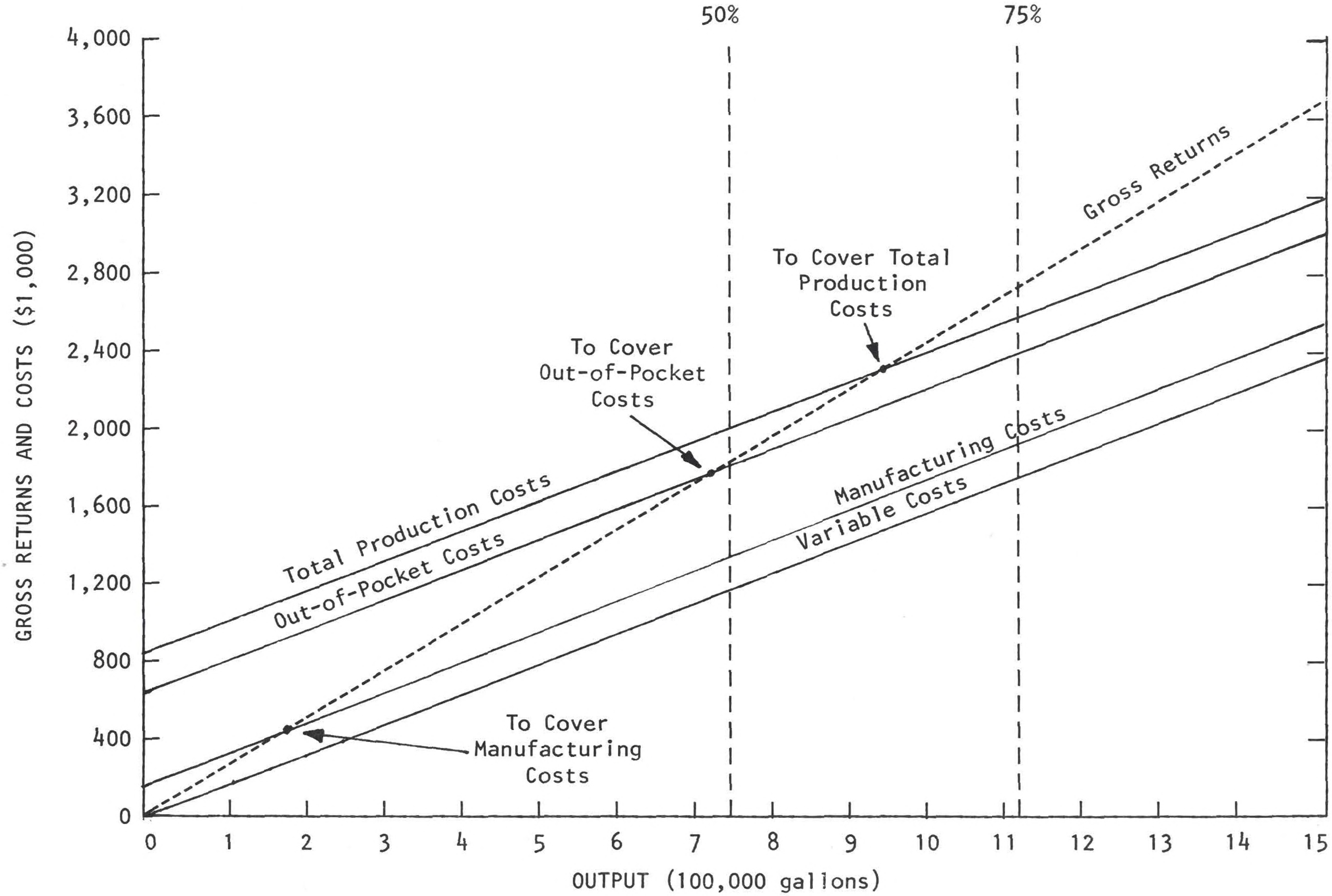
Table 10

BREAK-EVEN POINTS BASED ON PRODUCTION
OF 1.5 MILLION GALLONS PER YEAR, 1980 COSTS

Basic Calculation & Break-Even Points	Unit	Projected Volume
Gross return per gallon	Dollars	2.4494
Variable costs per gallon	Dollars	1.5457
Profit/gallon before fixed costs (A)	Dollars	0.9037
Annual fixed costs (B)	Dollars	191,555
Interest & debt retirement (C)	Dollars	478,200
Depreciation (D)	Dollars	197,334
Break-even for mfg. costs: B/A	Gallons	211,967
Break-even for out-of-pocket costs: (B + C)/A	Gallons	741,125
Break-even for total production costs: (B + C + D)/A	Gallons	959,488

Figure 2

BREAK-EVEN CHART FOR AN ANHYDROUS ETHANOL PLANT IN GEORGIA, BASED ON ANNUAL PRODUCTION OF 1,500,000 GALLONS, 1980



FINANCIAL INCENTIVES AND CONTACTS

In recognition of alcohol fuel's potential to extend this nation's liquid fuel supplies, the Federal Government has moved to establish incentives that will stimulate the widespread production and use of alcohol fuels. Two recent publications have detailed information on these incentives. One is Federal Agency Compendium - Federal Agency and Department Alcohol Fuels Programs, U.S. National Alcohol Fuels Commission, 412 First St., S.E., Washington, D.C., 20003, March 1980. The other publication is Alcohol Fuels Tax Incentives, A Summary: Alcohol Fuels Provisions of the Crude Oil Windfall Profit Tax Act, U.S. National Alcohol Fuels Commission, April 1980. In addition, a speech by Marilyn J. Herman, Deputy Executive Director, National Alcohol Fuel Commission, at the Georgia Institute of Technology Short Course on Alcohol Fuels, on January 29, 1980, provided a broad review of federal programs on alcohol fuels.

A summary of major incentives provided by the Federal Government on alcohol fuels is given below:

- A motor fuel excise tax exemption on gasoline/alcohol blends, worth $0.04 per gallon of blend, for alcohol made from sources other than petroleum, natural gas, or coal.

  For further information, contact:
  4 Cent Excise Tax Exemption for Gasohol
  Jack Hamilton, Group Chief, T:I:WEA:1:2,
  1111 Constitution Avenue, N.W., Washington, D.C. 20224
  Phone: (202) 566-3540

- Refunds for excise taxes paid on gasoline blended with at least ten percent alcohol. The Windfall Profit Tax Act of 1980 allows a person who purchases tax-paid gasoline and uses it to make a tax-exempted alcohol-gasoline blend to claim a refundable income tax credit equal to the taxes paid on such gasoline.

  For further information, contact:
  Jack Hamilton: (202) 566-3540

- New income tax credits for blenders of alcohol-gasoline blends, and for users of straight alcohol fuel. For the period October 1, 1980, through December 31, 1992, a person who blends alcohol fuel with gasoline for use in an internal combustion engine may claim an income tax credit. To qualify the blender must, in the course of his trade or business, sell the blended fuel for use as a fuel, or use it as a fuel himself.

The credit is forty cents per gallon of alcohol of at least 190 proof, and thirty cents per gallon of alcohol at least 150 proof but less than 190 proof. The tax credit is reduced by the amount of federal excise taxes exemption applicable to the blended fuel.

For further information, contact:
Jack Hamilton: (202) 566-3540

- A 10% additional investment tax credit for facilities that convert alternative substances or feedstocks (including coal and biomass) into "synthetic liquid fuels" for a total of 20% investment tax credit.

  For further information, contact:
  Energy Investment Tax Credit
  William Dwyer, Group Chief, T:C:E:I:2,
  1111 Constitution Avenue, N.W., Washington, D.C. 20224
  Phone: (202) 566-3755

- Eleven million dollars in loans, grants, and loan guarantees to aid in the construction of the 100 small-scale alcohol fuel facilities.

  For further information, contact:
  National Office: David Papermaster
  Phone: (202) 377-3027
  State Office: EDA Economic Development Representative

- Eligibility by alcohol producers for inclusion in the Economic Regulatory Administration's Entitlement Program worth approximately 5.5 cents per gallon of alcohol.

  For further information, contact:
  Peter Antonelli: (202) 254-7434
  David Welsh: (202) 254-3336

- Provisions by the Office of Hearings and Appeals, Economic Regulatory

Administration, DOE, to provide exceptions from the petroleum allocation regulations in order to provide gasoline for blending with alcohol.

For further information, contact:
Maurice Boehl: (202) 254-5246 (Pricing)
James Berry: (202) 254-5010 (Allocation)
Christopher Was: (202) 252-6744 (General Counsel)

- DOE has provided $3.2 billion funding for non-nuclear energy research and development on commercial size plants which include alcohol fuel projects of at least one million gallons per year capacity.
  1. One hundred million for feasibility studies and $100 million for cooperative agreements.
  2. Loan guarantees are $1.5 billion.
  3. Purchase commitments and price guarantees are $1.5 billion.

  For further information, contact:
  Larry Lukens: (202) 633-8377

- Science and Education Administration, U.S.D.A., has allocated $485,000 to award colleges or universities for research on the production and marketing of alcohols and industrial hydrocarbons from agricultural commodities and forest products in 1980.

  For further information, contact:
  Gene Spory: (202) 235-2680
  Edward C. Miller: (202) 447-6050

- DOE has allocated $9.8 million to the Solar Energy Research Institute (SERI) to be used in both advanced alcohol process contracts and the new Alcohol Fuels Information Center for FY 1980 and requested $14.6 million for FY 1981.

  For further information, contact:
  DOE - Dr. Beverly Burger: (202) 376-9739
  SERI - Paul Notari: (303) 231-1205
  SERI - Alcohol Fuels Information Center: (800) 525-5555

- DOE has appropriated $8 million for research, concept development and demonstration of small scale renewable energy sources. Grants available to both public and private sectors.

For further information, contact:
Ruth Heimburg, DOE: (202) 376-4524

- DOE has appropriated $4.03 million for alcohol fuel contracts to aid the highway transportation sector and some off-highway vehicle and construction equiment use.

  For further information, contact:
  Eugene Ecklund (Alcohol fuels): (202) 252-8055

There are many other federal programs which could apply to alcohol fuels. For example, Farmers Home Administration, U.S.D.A., has current funding of $1.5 billion (FY 1980) for loan guarantees on large and medium scale plants to be located in rural communities and small towns. Small Business Administration, U.S.D.C., has current funding of $75 million for loan guarantees to small businesses to purchase and use energy conversion or conservation equipment in FY 1980. These fundings include alcohol fuel plants or equipment.

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