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Small-scale Fuel Alcohol Production from Corn: Economic Feasibility Prospects

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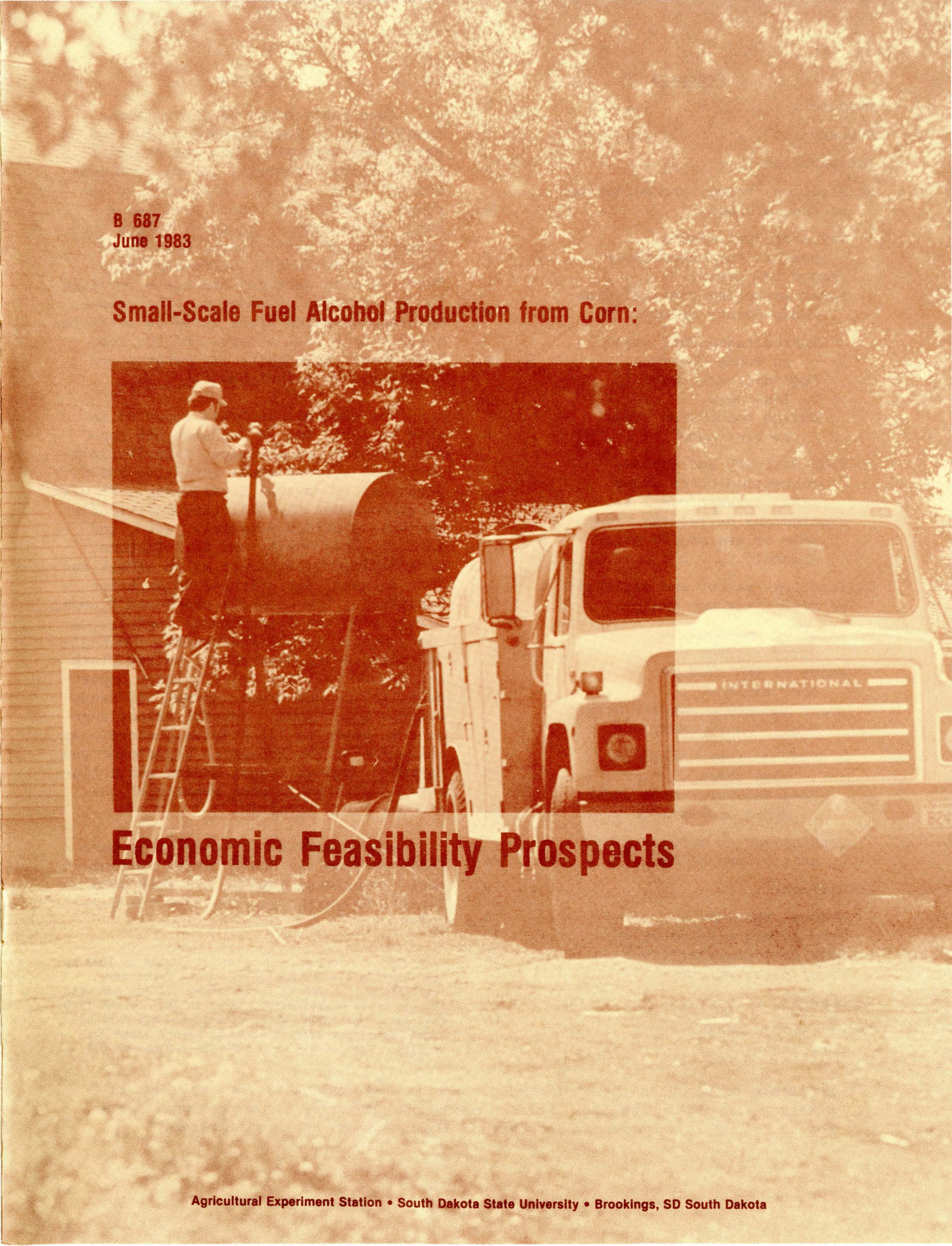

Economic Feasibility Prospects

Agricultural Experiment Station • South Dakota State University • Brookings, SD South Dakota

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Preface

This publication on the economic feasibility of fuel alcohol production is based upon research conducted at South Dakota State University (SDSU) from 1981 through 1983. It is a companion to our recently published report entitled A Small Scale Plant: Costs of Making Fuel Alcohol (SDSU Agricultural Experiment Station Bulletin 686, September 1982). That bulletin detailed the costs involved in fuel alcohol production. The present bulletin compares those costs to estimated returns from fuel alcohol and the feed byproduct. Both costs and returns are calculated on a 1981 basis.

The economic analysis reported in this bulletin and in Bulletin 686 constitutes part of a larger, interdisciplinary fuel alcohol study involving SDSU personnel in several departments. We wish to acknowledge the following individuals who have provided materials, data, and advice: Carl Westby and Bill Gibbons, Microbiology Department; Ralph Alcock and Kurt Bassett, Agricultural Engineering Department; Tom Chisholm and Scott Stampe, formerly in the Agricultural Engineering Department; Clayton Knofczynski, Mechanical Engineering Department; Andrew Clark and Howard Voelker, Dairy Science Department; and L. Ben Bruce, Animal and Range Science Department. Special acknowledgement is given to Dr. Ardelle Lundeen, our colleague in the Economics Department who reviewed various report drafts and collaborated with us in some aspects of the alcohol fuels research.

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Small-Scale Fuel Alcohol Production from Corn:

Economic Feasibility Prospects

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Summary

Returns were compared to costs for a small-scale fuel alcohol plant in this study. Returns were based on use or sale of 185 proof alcohol and a semi-wet distillers wet grain (DWG) feed byproduct. Costs were based on a plant using corn as the feedstock and producing 175,000 gallons of alcohol per year.

Given the assumptions used in our analysis, small- or community-scale alcohol plants similar to the one focused on do not appear economically feasible at present. Only under a combination of optimistic assumptions--about price relationships and other variables--do investments in small-scale plants appear to have much chance of paying off.

Continued improvements in technologies for producing and using fuel alcohol could improve the economic prospects. For example, the ability to efficiently produce anhydrous alcohol in small-scale plants could improve the marketability and economic value of the fuel product. Similarly, future sharp increases in the costs of gasoline would increase the value of fuel alcohol as a substitute or extender, thereby enhancing the economic feasibilty of alcohol plants. It is also possible that certain feedstocks other than corn might result in lower costs per gallon of alcohol.

Introduction

Are small-scale fuel alcohol plants, with corn as the feedstock, economically feasible? We attempt to answer that question in this report by comparing costs of producing hydrous alcohol and distillers wet grain (DWG) in a small-scale alcohol plant and transporting the products to users with returns from the sale or use of the products.

Details of the small-scale alcohol plant cost analysis are contained in a companion bulletin entitled A Small-Scale Plant: Costs of Making Fuel Alcohol (SDSU Agricultural Experiment Station Bulletin 686, September 1982) by Hoffman and Dobbs. Analysis contained in that report was based on interdisciplinary research carried out with the pilot fuel alcohol plant on the South Dakota State University (SDSU) campus.

Since costs in that bulletin were based upon 1981 price levels and methods of technical operation, returns included in the present bulletin are also calculated on a 1981 basis. In the companion bulletin, costs were calculated for two possible plant sizes and levels of annual output. Only the larger size--

capable of producing 175,000 gallons of 185 proof alcohol and 1,356 tons of 70% moisture DWG per year--will be referred to in this bulletin. Costs per gallon of alcohol were less in the larger plant.

Costs presented in Bulletin 686 for the "baseline" case with the larger plant were $1.78 per gallon. That estimate was derived under the following assumptions: (1) each bushel of corn yields 2.6 gallons of 185 proof alcohol; (2) corn costs or is worth $2.50 per bushel; (3) the annual interest rate at which the cost of capital is amortized is 15%; and (4) the feed byproduct is worth $39 per ton, based on its nutritional value in a combination of dairy heifer and cow rations. Changing the values in the assumptions led to a range of cost estimates for alcohol from the larger plant. Those estimates were as low as $1.59 per gallon and as high as $2.30 per gallon. Methods of plant operation other than the "standard" procedure could also lead to different cost estimates. (SDSU staff experimenting with the plant have tried various types of stillage supernatant recycling, for example.)

Feed byproduct credits were deducted in arriving at the above fuel alcohol cost estimates. Only dairy rations were considered as uses for the feed byproduct in Bulletin 686. In the present bulletin, the focus for feed byproduct use is broadened to include beef rations. Consequently, we show how utilization of the feed byproduct for either beef or dairy animals might affect net costs of fuel alcohol production.

An analysis of possible farm utilization and value of 185 proof fuel alcohol was also developed, drawing on SDSU engineering experiments in fuel substitution.

Transportation costs involved in distributing fuel and feed produced by a small-scale plant are also treated in this study. (Those costs were not included in Bulletin 686.) With their inclusion, the necessary ingredients for an economic feasibility analysis of small-scale alcohol production are in place. Transportation costs can be subtracted from fuel and feed use values. Production costs can then be subtracted from the combined returns (net of transportation costs) to indicate whether or not a plant is likely to be profitable.

Tax laws can also affect costs and returns. Income tax credits available for use of hydrous alcohol are accounted for in the treatment of fuel values. Investment tax credits are not treated in detail, but their possible effects on costs are noted.

For purposes of the transportation analysis in this study, it was assumed that the fuel alcohol plant is located in the center of Moody County. That county is situated in eastern South Dakota, along the border with Minnesota. The transportation analysis was intended not only to determine dollar costs of moving fuel and feed to users, but also to indicate the probable marketing territory size for a small- or community-scale plant.

For brevity, many details of our analyses are not included in this report. Details of the cost analysis are contained in Bulletin 686, available from the senior author or from the Bulletin Room at SDSU. The senior author will also provide details of the fuel and feed returns analyses on request.

Utilization, Value, and Marketing of Fuel Alcohol

The alcohol plant used as the model for this analysis is capable of producing alcohol of around 185 proof. Alcohol with this much water cannot readily be mixed with gasoline to be used as gasohol. Therefore, it must be considered as the sole fuel source for gasoline and diesel engines or must be injected into those engines via modified equipment. The extent to which the average farm consumer is able and willing to modify his farm machinery engines to run on alcohol will determine both the value of the alcohol and the marketing area that will be needed to dispose of the plant's annual output.

Value of fuel alcohol in farm operations[1]

Fuel alcohol can be used in both diesel and gasoline farm engines. The amount of fossil fuels assumed replaced by alcohol in this report has been determined from studies conducted by the Agricultural Engineering Department at SDSU and by consultation with SDSU agricultural engineers. One of these studies (Bassett 1981a) involved altering a Ford 8000 diesel tractor for fuel alcohol use by installing an M & W Gear Co. turbocharger and "Aquahol" injection system.

Results showed that this modification allowed 10% of the diesel fuel to be replaced by alcohol fuel without a significant change in power output. However, 1.54 units of 185 proof alcohol were required to replace each unit of diesel fuel. This indicates that 185 proof alcohol used in diesel engines is worth approximately 65% of the value of diesel fuel. In 1981, with diesel fuel at $1.15 per gallon, that would have amounted to $.75 per gallon.

From this value we must subtract the cost of modifying the diesel tractor. The cost of purchasing and installing an M & W injection kit in 1981 would have been approximately $800. If a turbocharger is not already present, that also must be installed. That would cost an additional $900. The total modification cost of $1,700 amortized at 15% over 5 years equals an annual cost of about $500. However, we assume in this analysis that the diesel tractors converted for alcohol use already have turbochargers. Therefore, annual (amortized) engine conversion costs are only $238 per tractor. The annual cost of modification per gallon of alcohol depends, of course, on how much alcohol is used in the tractor over the course of the year.

In another SDSU study, Bassett and Chisholm evaluated the performance of alcohol fuel used in an Oliver 1550 gasoline tractor. Gasoline was used for cold starting, and then the engine was switched to alcohol after warm-up. Installation of a separate fuel tank at the front of the tractor and some carburetor adjustments were required.

The alcohol in their study had an 11% higher thermal efficiency than gasoline, and its maximum power was 19% less than gasoline. Horsepower per gallon was also lower for alcohol than for gasoline. Evaluation of these results led us to assume that ethanol can be substituted for gasoline in farm tractors in a ratio based on relative BTU values of the two fuels.[2] On this basis, it would require 1.65 gallons of 185 proof alcohol to replace each gallon of gasoline. Hence, when used in gasoline engines, 185 proof alcohol is worth 61% of the value of gasoline. In 1981, with gasoline costing about $1.30 per gallon, the alcohol value would have been $.79 per gallon.

As in the case of diesel engines, the cost of modifying a gasoline tractor to run on alcohol should be subtracted from the replacement value of alcohol. The total cost of engine adjustments and extra parts on a gasoline tractor would be approximately $200. Amortizing this cost over 5 years at 15% interest results in an annual modification cost of about $80. The annual modification cost per gallon of alcohol depends on the amount of alcohol used in the tractor during the year.

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[1] For more details concerning the assumptions and calculations in this section, contact the senior author of this bulletin.

[2] This decision was reached in consultations with Mr. Ralph Alcock of the SDSU Agricultural Engineering Department.

Two other studies have also recently been conducted at SDSU involving the replacement of gasoline with ethanol. One, by Kelkar, concerned the performance of alcohol used in a stationary gasoline engine: a 10%-90% mixture of 186 proof alcohol and gasoline could provide power equal to that of gasoline alone, and would not require a larger volume of fuel to be burned. However, because of questions about the stability of this mixture, especially at cooler temperatures, we decided not to assume that hydrous alcohol could be mixed with gasoline in farm applications at this point.

Another study, conducted by Bassett (1981b), involved the use of 190 proof alcohol in a 1974 Dodge pickup. Low mileage, problems with start-ups, and engine kill after stops were initial results.

Income tax credit

An income tax credit can be obtained for use of straight alcohol (with denaturant) as a fuel in a trade or business. Thus, persons buying and using alcohol from a plant such as the one depicted in this report would be entitled to file for an income tax credit. In 1981, this tax credit provision was worth $.30 per gallon for alcohol of at least 150 but less than 190 proof (Internal Revenue Service). At the present time, however, the credit is now worth $.375 per gallon of alcohol in that proof range (U.S. Congress).[3] A farm user of alcohol fuel who can benefit from additional income tax credits would presumably be willing to pay more for the fuel than he would be in the absence of this tax credit provision. We assume for purposes of analysis that a farmer would pass the full credit on in terms of a higher purchase price for fuel alcohol.

We use here the 1981 credit of $.30 per gallon, to be consistent with other 1981 costs and prices in the analysis. Whether the currently higher credit--approximately $.08 more than it was in 1981 on 185 proof alcohol--is likely to make much difference in the economic feasibility of small-scale alcohol plants is discussed later in the report.

Local marketing possibilities: Moody County example

A cost that should not be overlooked is that of delivering fuel alcohol to farm customers. Transportation costs for delivery from the hypothetical Moody County plant have been estimated on the basis of certain assumptions about average liquid fuel use per farm and the spatial distribution of fuel alcohol consuming farms.

Agricultural fuel usage in Moody County.--The alcohol plant hypothetically located in Moody County is assumed to produce 175,000 denatured gallons of 185 proof alcohol per year. Fuel usage on an average farm in Moody County is needed to determine the number of farms required to consume this amount of fuel alcohol, and ultimately the required number of miles involved in delivering the alcohol. Table 1 depicts the diesel and gasoline usage of such a farm in 1978. The number of gallons of 185 proof alcohol needed to replace 25% of a farm's gasoline usage and 10% of a farm's diesel usage are also shown.

There are obviously a number of assumptions that could be made concerning how much gasoline or diesel fuel might be replaced by ethanol in farm use. For a base case, we have assumed that 25% of each farm's gasoline usage can be replaced by 185 proof alcohol. Under that assumption, each average-sized Moody County farm would be able to utilize 883 gallons of 185 proof alcohol annually. Therefore, a total of 198 farms would be needed to consume the plant's annual alcohol output of 175,000 denatured gallons.

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[3]In 1981, an income tax credit of $.40 per gallon could be obtained for use of alcohol that was at least 190 proof. The credit for alcohol of this proof level is currently $.50 per gallon.

Table 1. Potential annual fuel alcohol use on an average Moody County, South Dakota farm in the base case[1]

Fuel	Total annual fuel usage[2] (gallons)	Volumetric value relative to 185 proof alcohol[3]	Gallons of 185 proof alcohol for 25% replacement of gasoline and 10% replacement of diesel fuel
Gasoline	2,140	1.65	883
Diesel fuel	2,082	1.54	321
Totals	4,222		1,204

[1]An average Moody County farm contained 382 acres of cropland and pasture land in 1978.

[2]Information on fuel usage per farm and number of farms in Moody County was drawn from the 1978 Agricultural Census.

[3]The volumetric value figure for diesel fuel is based on an experiment done by SDSU agricultural engineers in which 10% of diesel fuel volume was replaced by ethanol. The volumetric value of gasoline in comparison to 185 proof alcohol was calculated in this table on a straight BTU substitution basis.

Fuel delivery costs in base case.--The total cost of delivering fuel alcohol to the farms that can make use of it is dependent on two factors: (1) the fixed cost of purchasing or renting a bulk gas truck; and (2) the variable costs of operating the truck, which in turn depend on the number of miles that must be traveled.

Calculating the cost of purchasing a bulk gas truck is a straightforward task, but determining the total mileage of the delivery route involves making two assumptions. The first assumption is that the 782 farms in Moody County are evenly distributed geographically throughout the county. Thus, on average, there are three farms located on every two square miles. This means that the fuel marketing territory necessary to reach 198 farms is about 132 square miles.

The second assumption is that the 198 farms that will be using the alcohol output are those located nearest to the alcohol plant. Hence, fuel delivery costs are based on the lowest possible mileage.

From the above information, a schedule for delivering the fuel alcohol in Moody County was determined as follows:

(1) A bulk gas truck with a tank capacity of 2,500 gallons is used to deliver the alcohol.

(2) Each day that deliveries are scheduled, the truck will deliver 400 gallons of fuel alcohol to each of 12 farms.

(3) The truck will deliver fuel to each of the 198 farms twice per year. A third delivery of 83 gallons will need to be made to

supply the necessary 883 gallons needed annually by each farm. It is assumed that the farmers will be able to spread their alcohol use out evenly for the year, and that the farmers will be responsible for providing on-farm fuel storage capacity that is sufficient to do so.

In Figure 1, the shaded area of Moody County represents the marketing territory (the 198 farms nearest to the alcohol plant). Given all the previously stated assumptions, the total distance the delivery truck would have to travel to make one delivery to each of these farms would be approximately 422 miles for the first two deliveries. The third delivery requires only 197 miles in travel because more farms can be reached per bulk truck tankful due to the smaller volume delivered to each farmstead. Therefore, the total annual mileage for delivery of the fuel alcohol would be 1,041 miles. This mileage was increased 5%, to 1,093 miles, to account for miscellaneous travel.

Costs for delivering the fuel alcohol under these conditions are presented in Table 2. Because the alcohol plant only requires the gas truck one fourth of the time, it is assumed that the truck is available for some other use the remaining time. Therefore, only one fourth of the annual fixed cost of owning the delivery truck is assigned to the alcohol plant, or $.01 per gallon of alcohol produced and delivered.

The operating costs of delivering the fuel alcohol to consuming farms add another $.013 per gallon, of which $.011 goes for labor payments to the truck driver (Table 2). Combining fixed and operating delivery costs indicates that $.02 needs to be added to the cost of producing each gallon of fuel alcohol to account for transportation.[4]

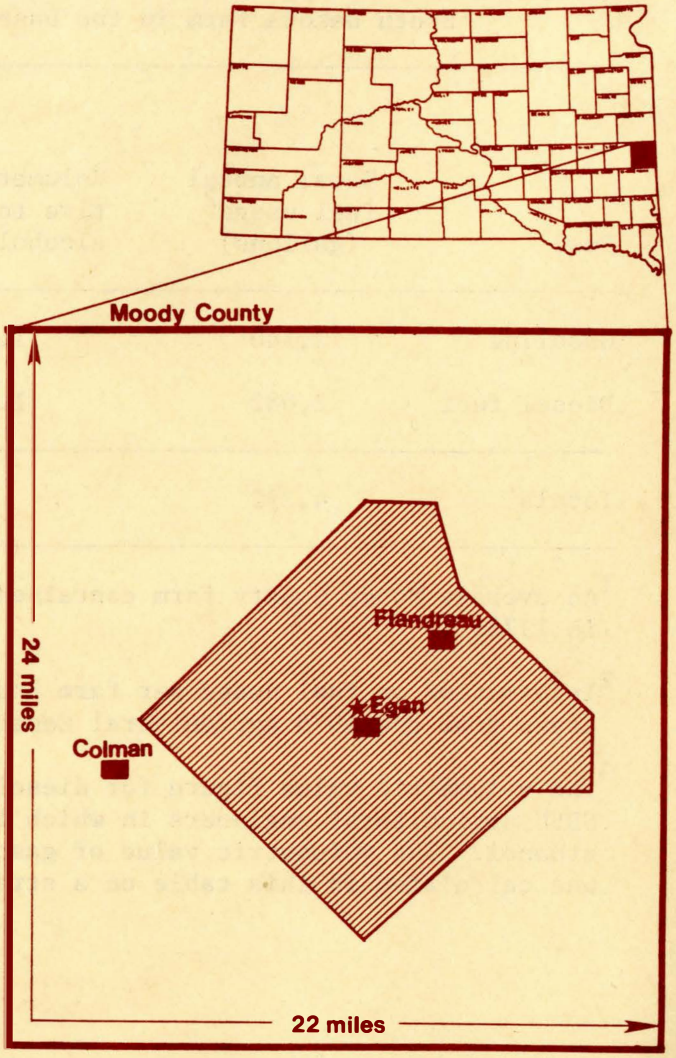

Figure 1: Marketing territory encompassing fuel alcohol delivery to the 198 farms nearest the alcohol plant.

★ Alcohol Plant Site
▨ Area Covered by Delivery Route

Engine conversion costs in base case.--A gasoline driven tractor could be converted to run on straight alcohol for an annual cost of about $80. We assume in the base case that 25% of each farm's annual gasoline usage can be displaced by alcohol. In calculating per gallon

[4]The assumption that the 198 farms closest to the alcohol plant would be those using all of the alcohol is not necessarily totally realistic. However, even if the alcohol marketing territory were to triple in size, it is estimated that per gallon delivery costs would rise by less than 1/2¢.

Table 2. Fixed and operating costs associated with the alcohol fuel delivery truck in the base case (175,000 denatured gallons of 185 proof alcohol delivered)

A. Fixed costs

Item	Full capital cost	Useful life (years)	Full annual amortized cost (15% interest)	1/4 of annual amortized cost	Cost/gallon of alcohol delivered
Bulk gas truck	$25,000	10	$4,975	$1,244	$.007
Vehicle license & insurance	2,300	1	2,300	575	.003
Tires	1,100	5	328	82	.000*
Subtotals	$28,400		$7,603	$1,901	$.010

B. Operating costs

Item	Cost/unit	Units/year	Annual cost	Cost/gallon of alcohol delivered
Gasoline	$1.30/gal	219 gal[1]	$ 284.70	$.002
Oil, filter, grease	$17.25/change	2 changes	34.50	.000*
Labor	$5.00/hr	396 hours[2]	1,980.00	.011
Antifreeze	$15.00/change	1/4 change	3.75	.000*
Tune-up	$200/job	1/4 job	50.00	.000*
Subtotals			$2,352.95	$.013
TOTALS OF A AND B =			$4,253.95	$.023 ($.02, rounded)

*The annual cost per denatured gallon of alcohol is so small that it rounds to 0 at three decimal places.

[1] 1,093 miles/year ÷ 5 miles/gallon = 219 gallons.

[2] 8 hours per day x 16.5 days per route x 3 routes per year = 396 hours

engine conversion costs, it is further assumed that one converted gasoline tractor on each farm will be able to burn all of the alcohol.

Therefore, the cost to each farm for converting a gasoline tractor engine to run on 185 proof alcohol is estimated as follows:

$$\frac{\text{\$80/yr/farm for engine conversion costs}}{\text{883 gal of 185 proof used/farm/yr}} = \text{\$0.09 engine conversion cost/gal of alcohol}$$

Fuel delivery and engine conversion costs under other assumptions

Other fuel displacement assumptions lead to different estimates of delivery costs and engine conversion costs. One different assumption included in the analysis was that farmers in the vicinity of the alcohol plant would replace 10% of their diesel fuel with alcohol--in addition to 25% of their gasoline fuel, as in the base case. The typical Moody County farm would then utilize 1,204 gallons of 185 proof alcohol, compared to 883 gallons in the base case (Table 1). This would reduce the number of farms required to consume the alcohol fuel from 198 to 145, also reducing travel miles to deliver the fuel. However, calculations indicate that delivery costs per gallon of alcohol would be reduced by only a fraction of a cent.

That very small reduction in fuel transport costs would be greatly offset by increased engine conversion costs. For the small amount of diesel fuel displacement, significant engine conversion costs would be involved. Annual diesel and gasoline engine conversion costs combined are estimated to be $.26 per gallon of alcohol, compared to $.09 per gallon in the base case involving only gasoline displacement. Under these circumstances, it clearly would not be reasonable to expect many farmers to purchase fuel alcohol to replace diesel fuel.

Though technical factors appear to greatly limit on-farm use of hydrous alcohol at present, new technology might greatly expand the potential for use of such fuel at some point in the future. Tractors might be designed and manufactured specifically for alcohol fuel use, for example. With the possibility of much greater on-farm use of fuel alcohol in mind, transportation costs were estimated with the assumption that 50% of both diesel and gasoline on farms could be replaced by hydrous alcohol. However, since engine conversion costs in this case or costs of designing and manufacturing tractors to burn fuel alcohol are not known, these costs were not included.

Table 3 contains the set of fuel displacement assumptions for this portion of the analysis. The amount of ethanol required to replace each gallon of gasoline is the same as that shown in Table 1. However, a larger amount of ethanol per gallon of diesel fuel displaced is assumed in Table 3 than in Table 1. With the larger quantity of diesel fuel displaced per farm in Table 3, with no experimental data to draw on for such a large displacement, it seemed advisable to assume that the ethanol would substitute for diesel fuel in quantities proportional to their relative BTU values. On that basis, there is a need for 1.96 gallons of 185 proof alcohol for each gallon of diesel fuel displaced.[5]

The combination of a higher substitution rate of alcohol for diesel fuel and larger replacement percentages for both diesel fuel and gasoline increases annual per farm use of alcohol to 3,806 gallons in Table 3, compared to only 1,204 gallons in Table 1. The number of farms required to consume the plant's 175,000-gallon per year alcohol output is reduced from 198 in the base case (gasoline data from Table 1) to 46 in this case. Those 46 farms would represent a marketing

[5]Information on the BTU contents of ethanol, gasoline, and diesel fuel was drawn from Durland and Kelly and from the U.S. Department of Agriculture.

Table 3. Potential annual fuel alcohol use on an average Moody County, South Dakota farm, assuming 50% replacement of both gasoline and diesel fuel[1]

Fuel	Total annual fuel usage[2] (gallons)	Volumetric value relative to 185 proof alcohol[3]	Gallons of 185 proof alcohol for 50% replacement of diesel fuel and gasoline
Gasoline	2,140	1.65	1,766
Diesel fuel	2,082	1.96	2,040
Totals =	4,222		3,806

[1]An average Moody County farm contained 382 acres of cropland and pasture land in 1978.

[2]Information on fuel usage per farm and number of farms in Moody County was drawn from the 1978 Agricultural Census.

[3]Volumetric value figures are based on the straight substitution of BTU's per gallon between 185 proof alcohol and both diesel fuel and gasoline.

territory of 31 square miles, about one fourth the base case territory.

In spite of the much smaller fuel marketing territory, estimated delivery costs are only a fraction of a cent per gallon less than in the base case. One reason for this is that fixed costs of owning the delivery truck are about the same in each case. A second reason is that the time a truck driver would need to be hired and paid for is not greatly less in this alternative case than in the base case. Hence, even with the reduced transport miles, fuel delivery costs are still around $.02 per gallon.

Furthermore, the use value of the alcohol would be lower in this case than in the base case. This is due in part to the large amount of alcohol required to replace each gallon of diesel fuel compared to the amount required to replace each gallon in the base (gasoline only) case. In addition, since the value of alcohol is determined by the cost of the fuel it replaces, alcohol would be worth less when replacing large amounts of diesel fuel; the price of diesel fuel is less than that of gasoline.

Conclusions on returns from sale or use of 185 proof alcohol

Estimates of fuel value and delivery costs can now be used to draw conclusions on the possible returns from sale or use of 185 proof alcohol. Estimates from the base case can be used in the following formula:

Return on ethanol = Replacement value of ethanol − Engine conversion cost − Fuel delivery cost + Income tax credit

Placing the per gallon estimates from the base case in this formula yields the following result:

Return per gallon
of ethanol = $.79 - .09 - .02 + .30 = $.98

We can see that the sale value of alcohol from the small-scale plant would be a little less than $1 per gallon under these assumptions. With the current income tax credit on 185 proof alcohol of $.375 per gallon rather than the $.30-credit in effect during 1981, the alcohol return increases to around $1.05 per gallon.

The alternative fuel use assumptions discussed would likely lead to lower net returns than do those in the base case. Hence, the base case fuel returns will be used in the remainder of this report. (Some mention will be made in the Conclusions section about the possibility of marketing hydrous alcohol to plants that would dehydrate it for use in gasohol.)

Utilization, Value, and Marketing of Distillers Wet Grain

Revenues from the sale of distillers wet grain (DWG) will very strongly influence economic feasibility prospects for fuel alcohol plants. Although some other studies have contained estimated revenues from the feed byproducts of alcohol plants, little attention has been devoted to handling and marketing costs. The present study does consider transportation costs, as well as costs of preserving the 70% moisture feed byproduct.

Value of DWG used in dairy rations

Most of the nutrition research done on use of alcohol plant feed byproducts indicates that the use value is greatest in rations of ruminant livestock. Thus, both beef and dairy animals are likely users of DWG supplies. In our earlier study (Hoffman and Dobbs), we examined the use of DWG in dairy rations. The conclusions, based on 1981 feed costs, are: value in dairy heifer rations, $65.85/ton; value in lactating dairy cow rations, $46.15/ton; and an average of the two, $56.00/ton.

From these values, $12.60/ton was subtracted for propionic acid costs. It was felt that propionic acid might be needed in some circumstances to assure that spoilage of DWG is prevented for approximately 2 weeks. This deduction resulted in net feeding values equaling $53.25 for heifers, $33.55 for cows, and $43.40 for an average of the two.

Since transportation costs were not estimated in the earlier study, a discount of 10% was applied to account for special handling and transportation costs. This left net feed sale or use values of $48/ton for heifers, $30/ton for cows, and $39/ton for the average. On a per gallon of alcohol fuel produced basis, the byproduct values resulted in credits of $.37, $.23, and $.30 for heifers, cows, and the average, respectively.

Value of DWG used in beef rations

The AGNET computer system was used to estimate feeding values of DWG in beef rations. The "Feedmix" program was utilized in early 1982, with feed prices as of 1981. The program determines the least-cost ration, given different available feeds, feed prices, and nutrition coefficients for alternative rations. Key assumptions in the beef ration analysis were the following:

(1) the focus would be on feedlot rations,

(2) cattle would enter the feedlot at 700 pounds and leave at 1,100 pounds, and

(3) each animal would gain an average of 2.75 pounds per day--thus allowing for 145 days on rations consisting partially of DWG.

Given various assumptions used in the analysis,[6] we found that DWG could economically substitute for some of the other protein supplements, some alfalfa, and some corn in beef feedlot rations. The least-cost rations included an average of 7.14 pounds of DWG (on a 70% moisture basis) per day per animal. At this level of use, DWG had a value of $30.80/ton in the beef rations.

Subtracting $12.60 per ton for propionic acid results in a value of $18.20/ton. A further 10% deduction for handling and transportation costs yields a net feed sale or use value in beef rations of $16/ton, or $.13 per gallon of alcohol produced. This is a much lower feed byproduct value than was estimated for the dairy animal rations.

The following section contains estimates of transportation costs for distributing the feed byproduct, so that the very rough 10% deduction can be altered.

Local marketing possibilities: Moody County example

The DWG marketing analysis is concerned with determining the costs of transporting DWG from the hypothetical Moody County alcohol plant site to consuming beef farms. The cost estimates are dependent on assumptions about the average amount of DWG that can be consumed per farm and the spatial distribution of beef cattle fattening farms throughout Moody County.

The hypothetical fuel alcohol plant is capable of producing about 1,356 tons of 70% moisture DWG annually. To calculate the costs of delivering that annual output to consuming farms, we had to know the average DWG consumption capability of each individual farm. The 1978 Census of Agriculture shows that an average Moody County beef fattening farm sells 81 head of cattle annually. Given the previous assumptions on DWG consumption per animal, the amount of DWG each beef fattening farm can be expected to purchase each year is computed as follows:

(81 head per farm)(7.14 pounds of DWG/head)(145 days/head in feedlot) = 83,859.3 pounds of DWG fed per farm per year, or about 41.9 tons

With each beef fattening farm using 41.9 tons of DWG annually, the alcohol plant's output of 1,356 tons could be totally consumed by about 32 farms.

Feed delivery costs in base case.--Feed delivery costs are based on the fixed cost of owning or renting a delivery truck and on the variable costs of operating the delivery truck. Variable costs depend on the miles the truck must travel to deliver feed and on the amount of time it takes to travel the delivery route.

In this analysis, the delivery route has been calculated under the assumption that the 237 beef fattening farms of Moody County are evenly distributed geographically throughout the county. This means that there are about four beef fattening farms on each 9 square miles of Moody County. Therefore, the marketing territory enveloping 32 beef fattening farms would be about 72 square miles.

Moreover, it is assumed in the base case that the 32 farms nearest to the alcohol plant will be the ones buying the DWG. Thus, the delivery route mileage will be at its absolute minimum.

In Figure 2, the shaded area of Moody County represents the marketing territory for use of the DWG by the 32 farms nearest to the alcohol plant. A schedule for delivery to those farms was based on the following assumptions:

(1) A 1-ton truck would deliver the DWG.

[6]For more details concerning assumptions (such as prices of feeds other than DWG) and calculations in this section, contact the senior author of this bulletin. It should be noted that DWG could be used as a protein supplement in rations of smaller beef animals (e.g., in the 400-700 lb range), as well.

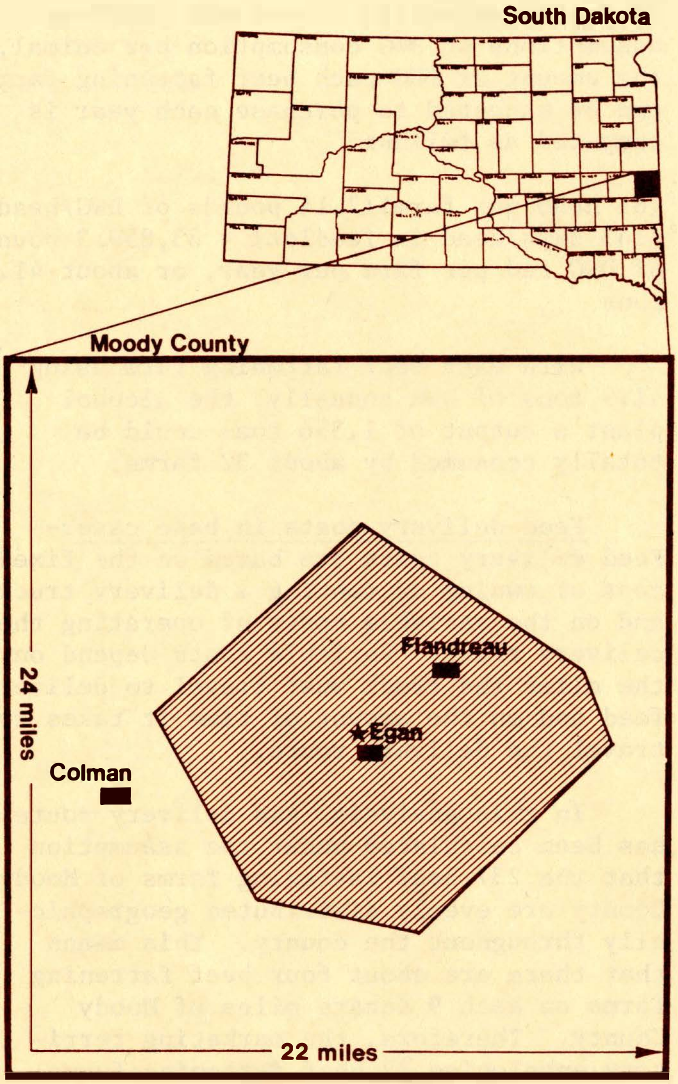

Figure 2: Marketing territory encompassing DWG delivery to the 32 beef fattening farm nearest the alcohol plant.

★ Alcohol Plant Site
▨ Area Covered by Delivery Route

(2) Because it is assumed that the DWG can be stored for only 2 weeks without spoilage, deliveries must be made to each consuming farm every 2 weeks.

(3) The truck must be weighed before each delivery to determine the amount of DWG delivered. Therefore, it would be necessary to travel to each farm, unload, and travel back to the alcohol plant for reloading and weighing before delivering to the next farm.

(4) The delivery truck would need to deliver about 1.6 tons of DWG to between two and three farms daily, on average. This delivery schedule would provide a 2-week supply of DWG to each of the 32 consuming farms every 2 weeks and would permit deliveries consistent with the production capabilities of the alcohol plant. Delivery time is estimated to average 3 hours per day, 365 days per year.

Delivering DWG to the 32 consuming farms would result in total annual delivery mileage of 9,334 miles. Adding 5% for miscellaneous travel gives a total of 9,800 miles.

Costs for DWG delivery are shown in Table 4. All of the fixed costs for the truck are applied to the cost of DWG distribution. Since the truck will be used every working day for at least 3 hours, it is unlikely that the truck could be used practically by some other commercial entity during the remainder of each day. However, the truck could be used for other miscellaneous functions around the alcohol plant. Total fixed costs for DWG delivery amount to $.023 per gallon of alcohol produced.

Operating costs associated with DWG delivery are shown in part B of Table 4. These total $.049 per gallon of alcohol produced. Labor costs of $.031 per gallon account for the largest share of operating costs.

Fixed and operating costs for feed byproduct delivery combined total $.07 per gallon of alcohol produced by the plant. This compares to costs of $.01 to $.04 per gallon if we simply apply 10% deductions for handling and transportation of DWG to previously shown values for use of DWG in dairy and beef rations.

Feed delivery costs under other assumptions.--Feed delivery costs were

Table 4. Fixed and operating costs associated with the DWG delivery truck in the base case (175,000 gallon fuel/year alcohol plant with 1,356 tons/year of DWG)

A. Fixed costs

Item	Full capital cost	Useful life (years)	Full annual amortized cost (15% interest)	Cost/gallon of alcohol delivered
1-ton truck	$14,000	10	$2,786	$.016
Vehicle license & insurance	960	1	960	.005
Tires	900	5	268	.002
Subtotals	$15,860		$4,014	$.023

B. Operating costs

Item	Cost/unit	Units/year	Annual cost	Cost/gallon of alcohol delivered
Gasoline	$1.30/gal	891 gal[1]	$1,158.30	$.007
Oil, filter, grease	$14.75/change	3 changes	44.25	.000*
Labor	$5.00/hr	1,095 hours	5,475.00	.031
Antifreeze	$15.00/change	1 change	15.00	.000*
Tune-up	$200/job	1 job	200.00	.001
Weigh payments[2]	$2.00/weigh	912.5 weighs	1,825.00	.010
Subtotals			$8,717.55	$.049
TOTALS OF A AND B =			$12,731.55	$.072 ($.07, rounded)

*The annual cost per denatured gallon of alcohol is so small that it rounds to 0 at three decimal places.

[1] 9,800 miles/year ÷ 11 miles/gallon = 891 gallons

[2] To weigh the truck carrying DWG, it is assumed that the alcohol firm could use the local grain elevator scale. An average of 2.5 weighs per day at $2/weigh times 365 days/year = $1,825/year

also calculated on the assumption that only every other beef fattening farm reaching out from the plant, rather than each farm closest to the plant, would utilize DWG. This alternative assumption causes the DWG marketing territory to be 144 square miles, compared to 72 square miles in the base case. Delivery mileage therefore increases from 9,800 to 14,140 miles.

The increased mileage causes operating costs for the feed delivery truck to rise from $.049 to $.063 per gallon of alcohol produced.[7] (Fixed costs associated with DWG delivery are assumed unchanged.) Total fixed and operating costs of DWG delivery thus rise from $.07 per gallon of alcohol in the base case to nearly $.09 per gallon in this alternative case.

Other research at SDSU is currently examining feed byproduct use and marketing in a more dairy-oriented county of eastern South Dakota.[8] Preliminary results indicate that feed byproduct delivery costs would come to about $.05 per gallon of alcohol.

We thus have estimates of feed byproduct delivery costs ranging from $.05 to $.09 per gallon of alcohol produced. The middle-range $.07 per gallon estimate from our base case thus seems reasonable.

Conclusions on returns from sale or use of DWG

Our conclusions on returns from sale or use of DWG are presented in Table 5. The byproduct returns net of preservative and transportation costs range from $.07 to $.30 per gallon of fuel alcohol. They were calculated with the following formula:

Return on feed byproduct	=	Value of feed byproduct in livestock ration	-	Cost of preservative

- Transportation cost

For the beef ration with transportation costs as calculated in the market territory analysis (as opposed to the 10% deduction), the calculation looks like this:

Feed byproduct return per gallon of ethanol	= $.24 - .10 - .07 =	$.07/ gallon of ethanol

The calculations for other parts of Table 5 were carried out in the same way. In the last column, however, the transportation cost deduction was simply 10% of the feed value net of preservative cost. That was the procedure used in our previous report (Hoffman and Dobbs), in which we referred to the 10% as a discount for "handling and transportation".

Figures in Table 5 are intended to convey a general picture of possible feed byproduct returns to include in feasiblity analyses of small-scale fuel alcohol plants. They are not intended to be directly used for feeding recommendations.[9] Actual feeding values in any given situation will depend on sizes and types of livestock being fed, alternative feeds available, prices of alternative

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[7] The operating cost increase is due to greater gasoline consumption and more man hours required to cover the delivery route. Manhour requirements increase to 4 hours/day, compared to 3 hours/day in the base case.

[8] This research will be reported in a Masters thesis in Economics by Daryl Brehm. The thesis is currently in draft form. In that study, dairy animals utilize the feed byproduct.

[9] A more detailed analysis of how the "bypass" protein characteristics of DWG affect feeding values might lead to higher value estimates than ours in some cases.

Table 5. Estimated returns from sale or use of DWG (175,000 gallon fuel/year alcohol plant with 1,356 tons/year of DWG)

Assumed use of DWG	Estimated returns net of preservative and transportation costs[1]: If transportation costs $.07/gal of alcohol[2]	If transportation costs are 10% of returns[3]
	--feed byproduct returns per gallon of alcohol produced--	
In beef rations	$.07	$.13
In dairy rations[4]	$.26	$.30

[1]Includes $12.60/ton of DWG deduction for cost of propionic acid used as preservative.

[2]Assumes that alcohol plant is located in Moody County and that feed by-product transportation costs are $.07/gallon, whether delivered to beef or to dairy farms.

[3]The 10% deduction is <u>in lieu of</u> a deduction based on the calculated cost ($.07/gallon of alcohol) of feed byproduct delivery.

[4]Returns based on average of values in use in dairy heifer and dairy cow rations.

protein supplements, ration formulations, etc.

Nevertheless, Table 5 does make clear that net returns on feed byproducts could be quite low in some circumstances. Feeding DWG to some types of animals (fattening beef, in this case) could give much lower returns than feeding it to other types (particularly dairy heifers, in this case). Feeding large numbers of animals in very close proximity to the alcohol plant could increase net byproduct returns in two ways. It could conceivably reduce or eliminate the need for a feed preservative, if the feed is consumed quickly on a year-round basis. Transportation costs could also be reduced or eliminated.

Conclusions

We can pull the pieces of this analysis together by thinking in terms of the following formula:

Returns net of costs = Returns on ethanol - Costs net of byproduct credit

where:

(1) Costs net of byproduct credit = Costs of producing the ethanol and feed byproduct - Returns on feed byproduct

and

(2) Returns on ethanol = Replacement value of ethanol - Engine conversion cost - Fuel delivery cost + Income tax credit

(3) Returns on feed byproduct = Value of feed byproduct in livestock ration - Cost of preservation - Transportation cost

(4) Costs of producing ethanol and feed byproduct = Costs (before deduction of feed byproduct credits) estimated in Bulletin 686 (Hoffman and Dobbs)

General results

An overview, obtained by including our data in the above formula, is contained in Table 6. Columns 4 and 6 of that table both indicate negative "returns net of costs" for various assumptions used in the study. In other words, the type of alcohol plant analyzed appears economically infeasible.

The costs and returns situation appears worst (-$1.03/gallon) with the baseline production cost estimate combined with the feed byproduct being fed to beef animals and transportation costs being estimated according to the routing method used in this report. It is least bleak (-$.61/gallon) when the lowest production cost estimate (from Hoffman and Dobbs) is combined with the feed byproduct being used for dairy animals and transportation costs being simply figured at 10% of the feed value (net of preservative costs). Production costs in this latter case were based on $2.00 per bushel corn, as compared to $2.50 per bushel corn in the baseline case (Hoffman and Dobbs, Table 4).

According to these findings, either returns on the alcohol fuel and the feed byproduct would need to substantially increase or costs of production would need to substantially decrease for a small-scale plant to be economically feasible with corn as the feedstock.

Some return considerations

The returns calculations in Table 6 were based on the $.30 per gallon income tax credit available in 1981 for users of 150 to 189 proof alcohol. However, it is clear that figuring the current $.375 per gallon credit on alcohol of this proof would make little overall difference in the prospects for economic feasibility. The income tax credit would have to be more than three times its 1981 level to bring even the most optimistic situation depicted in Table 6 into an economically feasible realm.

Our returns calculations in this report were all based on the assumption that the hydrous alcohol would be used on farms. However, it is sometimes possible to sell hydrous alcohol to refiners who take this product to the anhydrous stage to be marketed and used in a 10% blend with gasoline (as "gasohol," "super-unleaded gasoline," or whatever term is used). However, it is doubtful that even that possibility would at present provide sufficient fuel returns to make feasible the kind of small-scale plant we have analyzed.

In late 1982, anhydrous (200 proof) fuel alcohol was worth $1.70 per gallon in Omaha, NE. The price of anhydrous alcohol

Table 6. Returns net of costs for a small-scale alcohol plant (175,000 gallon fuel/year alcohol and 1,356 tons/year of DWG) when returns on alcohol are $.98/gallon

		Baseline cost case[2]		Low cost case[3]	
(1) When byproduct is used as indicated	(2) Returns on feed byproduct[1]	(3) Costs net of byproduct credit	(4) Returns net of costs	(5) Costs net of byproduct credit	(6) Returns net of costs
		-----dollars per gallon of alcohol produced-----			
(1) In beef animals					
(a) With transp. costs estimated on basis of route analysis[4]	.07	2.01	-1.03	1.82	-.84
(b) With transp. costs estimated on 10% of basis of feed value	.13	1.95	- .97	1.76	-.78
(2) In dairy animals					
(a) With transp. costs estimated on basis of route analysis	.26	1.82	- .84	1.63	-.65
(b) With transp. costs estimated on 10% basis of feed value[4]	.30	1.78	- .80	1.59	-.61

[1]Information taken from Table 5.

[2]Baseline case in the earlier report by Hoffman and Dobbs, where costs of production before deduction of feed byproduct credit are $2.08/gallon.

[3]Low estimate in the earlier report by Hoffman and Dobbs, where costs of production before deduction of feed byproduct credit are $1.89/gallon.

[4]In this base case, beef farms closest to the plant utilized the DWG.

across the country was about $.05 per gallon less than it had been a year earlier, in late 1981. Thus, let us assume that anhydrous alcohol in this region was worth about $1.75 per gallon in late 1981. Over the past year or so, 185 proof alcohol sold for about $.40-.50 per gallon less than 200 proof alcohol--when a market could be found. If we subtract $.45 from $1.75, that leaves an estimated market value of $1.30 per gallon of 185 proof alcohol. Even ignoring some transportation costs the seller may well have to bear, the prospects for plant feasibility still do not appear good. The $1.30 return is only $.32 per gallon more than that estimated as the return for alcohol used on farms near the plant. We can see in columns 4 and 6 of Table 6 that costs exceed returns by much more than that in all instances.

Eventually, if a well integrated regional system of small- and large-scale alcohol plants were to develop, the price of hydrous alcohol might substantially improve relative to the price of anhydrous. Large plants might then contract with small plants for regular supplies of hydrous alcohol, to dehydrate and market along with their self-produced alcohol. If this were to come about, it could help to improve the prospects for economic feasibility of small-scale plants. At the present time, however, the market for hydrous alcohol is not well developed in many parts of the country.

Another possibility for higher returns than those imbedded in Table 6 is in the area of feed byproduct values. Estimated returns for use in dairy heifer rations were higher than in lactating dairy cow rations. The estimate in the last two rows of column 2 in Table 6 is based on an average of the two dairy ration values. Had we used the dairy heifer ration value alone, the byproduct returns for dairy use (and associated alcohol plant returns net of costs) would have been $.07 per gallon of alcohol higher. Although that is an improvement, it is obviously far from being sufficient to result in an economically feasible plant.

On balance, it is doubtful that our returns estimates are too low for 1981 or for the present time. In fact, it could be argued in some instances that the returns estimates are too optimistic. It may be very difficult at present, for example, to convince farmers in the vicinity of an alcohol plant to make tractor conversions to utilize hydrous alcohol. It may also be difficult in some instances to get farmers to utilize the semi-wet DWG byproduct without more of a price discount than is suggested by our figures.

Some cost considerations

Our companion publication (Hoffman and Dobbs) on alcohol production costs contains a wide range of per gallon cost estimates. Costs from the low end of that range are reflected in column 5 of Table 6. That column reflects costs when corn is priced at $2.00 per bushel, compared to $2.50 per bushel in the baseline cost analysis case.[10] We can see, however, that even these cost estimates do not result in an economically feasible plant.

Westby and Gibbons (1982 and 1983) have carried out various experiments regarding plant design and operation to determine if costs might be reduced, examining such measures as recycling of stillage supernatant, using continuous cascade rather than batch fermentation, and varying mash starch concentration. Some of these modifications appear to hold promise for reducing costs of production. Gibbons and Westby (1983) report that one of these measures--increasing the starch concentration--could reduce costs by approximately $0.40 per gallon of alcohol.

If some of these changes in combination could reduce costs by $.50-.60 per

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[10] Sensitivity analyses were also done on costs by varying alcohol yields (per bushel of corn) and interest rates. None of those sensitivity tests yielded lower costs than are shown in Table 6, however.

gallon below those shown in our baseline case (column 3 of Table 6), one might have costs net of byproduct credits as low as roughly $1.20-1.30 per gallon in some instances. Such costs are not very likely at the present time for small-scale plants. However, if achieved, they would bring such plants much closer to economic feasibility than is indicated by the data in Table 6. Even at costs of $1.20-1.30 per gallon, returns on alcohol would need to be higher than have been estimated in our farm fuel utilization analysis for an alcohol plant to operate profitably.

Another factor that could reduce costs from an individual investor standpoint is the existence of investment tax credits. In addition to the permanent business investment tax credit of 10%, fuel alcohol plant investors are eligible under certain circumstances for a 10% energy investment tax credit (U.S. National Alcohol Fuels Commission). If one applies the full 20% credit to our capital cost figures (in Hoffman and Dobbs), a reduction of roughly $.04 per gallon is obtained. This is hardly sufficient to tip the feasibility balance, given the estimates of costs and returns presented in this report.

Some advances in technology and methods could result in lower per gallon costs than those figured in our baseline case. Changes in other assumptions could push costs higher, however. For instance, a 15% interest rate was used to amortize capital costs in the baseline case. Most private investors would demand a much higher return than 15% on money invested in risky new ventures such as fuel alcohol production. A doubling of the interest rate (to 30%) used in amortizing capital adds $.20 per gallon to costs. Other changes in assumptions (e.g., lower yields of alcohol) could further add to per unit costs.

Costs of production for small-scale alcohol plants may come down over time. At present, though, our baseline cost estimates appear reasonable.

Final observations

The analysis presented in this report indicates that small-scale fuel alcohol plants are not likely to be economically feasible at the present time. Only under a combination of rather optimistic assumptions, given recent and current technologies and price relationships, do investments in small-scale plants appear to have much chance of paying off.

Continued improvements in technologies for producing and using fuel alcohol could improve the economic prospects. The ability to efficiently produce anhydrous alcohol in small-scale plants, for example, could improve the marketability and economic value of the fuel product. Likewise, future sharp increases in the costs of gasoline and diesel fuel would increase the value of fuel alcohol as a substitute or extender, thereby enhancing the economic feasibility of alcohol plants.

It is also possible that certain feedstocks other than corn might result in lower costs per gallon of alcohol. Current research at South Dakota State University is now focusing on some of the alternative feedstock possibilities.

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ANNEX

Metric Measurement Conversions

Contained here are certain conversions of English to metric measurement units. These conversions will be of use to individuals wishing to determine and state inputs, outputs, or costs found in this report in metric units.

Symbol	When You Know	Multiply By	To Find	Symbol
MASS (WGT)				
oz	ounces	28.0	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
	long tons (2,240 lb)	1.01	tonnes	t
g	grams	0.035	ounce	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
t	tonnes (1,000 kg)	0.98	long tons	
VOLUME				
tsp	teaspoons	5.0	milliliters	ml
tbsp	tablespoons	15.0	milliliters	ml
fl oz	fluid ounces	30.0	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons (U.S.)	3.8	liters	l
gal	gallons (Imp)	4.5	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons (U.S.)	gal (U.S.)
l	liters	0.22	gallons (Imp)	gal (Imp)
m^3	cubic meters	35.0	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3