Economic Prospects for Small-Scale Fuel Alcohol Production

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Small-scale alcohol plants will have difficulty in supplying fuel that is competitive in cost with petroleum-based fuels. This is based upon economic findings from interdisciplinary research with a pilot fuel alcohol plant. Results of economic-engineering cost analyses and of fuel and feed byproduct returns analyses are shown. Fuel and feed transportation costs are also considered in determining the economic feasibility prospects for small-scale plants producing hydrous ethanol from grain.

Interest in producing fuel alcohol from agricultural crops ran high in the late 1970s. As a result of demands for information, U.S. extension and agricultural experiment station personnel conducted several evaluations of the probable economic prospects for large-scale plants capable of producing 200 proof alcohol (Converse *et al.*; Daves; Kendrick and Murray; Litterman *et al.*). Those studies proved highly useful for placing in overall economic perspective the possibility of using biomass for liquid fuel. In addition, some recent policy oriented studies have shed light on the macroeconomic implications of potential U.S. expansions in fuel alcohol and associated feed byproduct production (Meekhof *et al.*; Sanderson; Webb).

These studies have helped fill information voids faced by land grant and United States Department of Agriculture economists asked by their client groups to provide feasibility and public policy information on fuel alcohol production. However, there has been little solid, research-based information on the economic feasibility of small- or community-scale fuel alcohol plants. Many farm and rural development groups have expressed strong interest in such small-scale plants, with ideas that local investors might own and manage the plants, that the feedstock could be locally produced, and that the fuel and feed byproduct might be used locally.

Some extension and research reports based upon limited data and concerning the economics of small-scale alcohol production appeared in 1980 and 1981 (Atwood and Fischer; Dobbs; Doering; Hutchinson and Dobbs; Jantzen and McKinnon). Since then, a detailed multidisciplinary research project on small-scale fuel alcohol production has been completed at South Dakota State University (SDSU). Microbiologists, agricultural and mechanical engineers, dairy scientists, and

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agricultural economists participated in this research between 1979 and 1983. Data were generated through operation of a small-scale fuel alcohol plant located on the campus. The major focus of work completed in 1983 was on corn as the alcohol feedstock, though the research team has also begun work on other feedstocks.

Major economic findings of this study of small-scale fuel alcohol production are reported in this article. Details of the technical findings have been reported elsewhere (Gibbons and Westby; Schingoethe *et al.*; Stampe *et al.*; Westby and Gibbons). This study should contribute to future decisions of investors (farmers, businessmen, bankers) and policy makers (state and national elected and appointed officials) regarding small-scale fuel alcohol production. Recent policies have attempted to encourage both large- and small-scale alcohol plants. Those policies may need to be seriously re-examined if world oil and grain price conditions should engender renewed public interest in fuel alcohol during the 1980s and 1990s.

Cost-of-production findings are reported in the following section of this article. The next section contains an analysis of the fuel and feed marketing implications of establishing small-scale plants. Conclusions on economic prospects for small-scale plants using grain feedstock are contained in the final section.

Costs of Fuel from Small-Scale Plants

Costs of fuel alcohol from cooperative or commercial plants that could be patterned after the experimental facility at SDSU have been estimated by economic-engineering methods for various levels of annual output capacity. Both costs and returns were calculated on the basis of 1981 prices in South Dakota, although sensitivity analyses in some cases covered price ranges broader than observed that year. At SDSU, corn has been used as the principal feedstock, and 180 to 190 proof alcohol and distillers wet grain (DWG) are normally produced. The latter results from centrifuging whole stillage to reduce moisture content of the feed byproduct to about 70 percent.

Findings indicate that amortized fixed and operating costs per gallon of 185 proof fuel alcohol—net of feed byproduct credits—may be about $3.90 for a small plant producing 9,000 to 10,000 gallons per year, about $2.70 for 49,000 gallons per year, and about $1.80 for 175,000 gallons per year.[1] There are clearly some economies of size involved, due in part to greater utilization of the plant as annual output goes up. While some additional capital investments are required to make successive, large increases in annual output with alcohol plants similar to that at SDSU, some components require little or no change. For example, the same size of distillation column could be used for annual output up to around 175,000 gallons. Besides more intensive utilization of capital equipment when output capacity is expanded, there are also energy, labor, and other operating efficiencies associated with the *continuous* batch operations that cannot be fully captured in low-volume, *discontinuous* batch operations.

A comparison with data from other studies (Atwood and Fischer; Bowker and Griffin; Jantzen and McKinnon; Meekhof *et al.*; Reining and Tyner; U.S. Department of Agriculture) also shows economies of size to exist. Data indicate that economies at least exist in going from "farm-scale" levels of production (around 10,000 gallons per year) to "community-scale" levels (100,000 to 400,000 gallons per year).

Sensitivity analyses were carried out to determine the effects of assumptions about alcohol yield per bushel of corn, price of

[1] More details of the cost calculations are contained in Hoffman and Dobbs and in Hutchinson and Dobbs.

corn, and interest rates on alcohol costs per gallon. Costs per gallon in those analyses ranged from $1.59 to $2.30, when examining a 175,000 gallon per year plant.

In the "baseline case," a bushel of $2.50 corn yielding 2.6 gallons of alcohol per bushel, with capital costs amortized at a 15 percent interest rate, resulted in a net cost of $1.78 per gallon of denatured alcohol. The "baseline" alcohol yield is probably at the high end of a reasonable range of estimates for small-scale plants. Well-run plants may achieve that yield, but many others probably will not. *Ceteris paribus*, dropping the alcohol yield to 2.3 gallons per bushel of corn raised net costs to $2.01; lowering it to 2.0 gallons resulted in a net cost of $2.30 per gallon. With the "baseline" alcohol yield and with the corn price reduced to $2.00 per bushel, net costs per gallon of alcohol dropped to $1.59; raising the corn price to $3.00 per bushel increased costs to $1.97 per gallon.

Reducing the interest rate to 10 percent lowered costs per gallon of alcohol from $1.78 to $1.72. Raising the interest rate to 20 percent and 30 percent caused the cost per gallon to rise to $1.85 and $1.98, respectively. It is worth noting that private investors would often expect a return on capital that is even higher than these rates when a relatively new technology or otherwise risky investment is involved.

Marketing the Fuel and Feed Byproduct from Small-Scale Plants

One of the often-stated arguments supporting the economic feasibility of small-scale fuel alcohol plants is the advantage of location near the major input (corn or other grains) and near farming operations which could utilize the fuel alcohol and feed byproduct outputs. However, little work has previously been done to determine the precise product utilization and marketing implications for community- or small-scale plants (Dobbs *et al.*). This section reports on alcohol plant "case study" findings regarding: (1) farm utilization of fuel alcohol and the costs of transporting fuel to farms; and (2) utilization of the semi-wet feed byproduct and the costs of transporting feed to consuming farms.

Marketing the fuel. A critical problem at the present time for small-scale plants is the lack of reliable markets for "wet" (hydrous, or less than 200 proof) alcohol, which cannot practically be mixed with gasoline to form gasohol. Although engineering tests have demonstrated possibilities for conversion of gasoline and diesel equipment to run at least partially on wet alcohol, there remain many inconveniences, unknowns about engine wear, and questions of economy.

Selected counties in eastern South Dakota were used as case applications in estimating fuel and feed use potential and transportation costs. For purposes of our economic analysis, it was assumed that around 880 gallons of 185 proof alcohol per year might be used on a typical eastern South Dakota farm, based on 25 percent replacement of the annual gasoline fuel usage.[2]

Nearly 200 eastern South Dakota farms would be required to consume the fuel from a 175,000 gallon per year alcohol plant (U.S. Department of Commerce). This would entail a marketing territory of approximately 130 square miles in a "case" county. The cost of delivering the alcohol fuel to these farms is estimated to be roughly $.02 per gallon (Dobbs and Hoffman). Although that delivery cost seems fairly low, amortized fixed and operating costs of converting one gasoline tractor on each farm to utilize the fuel could total another $.09 per gallon.

Other assumptions were also tested regarding on-farm fuel utilization, including the assumption that 50 percent of both

[2] Bases for these assumptions are found in Dobbs and Hoffman.

gasoline and diesel fuel usage on farms might be replaced by "wet" alcohol. This reduced the number of consuming farms required in the "case" county to 46.[3] However, because of truck and driver time required, total fuel delivery costs were not much reduced. No estimate was possible for the costs of tractors or tractor conversions that might be required in order to increase the rate of on-farm alcohol fuel substitution to this level.

Based on the relative BTU values implied in our first fuel substitution assumption, 185 proof alcohol would be worth 61 percent of the value of gasoline. The tax-adjusted farm price of gasoline was around $1.13 per gallon in South Dakota during 1981. At that price, the substitution value of alcohol would be $.69 per gallon ($1.13 × .61). Adding the $.30 per gallon income tax credit available in 1981 to users of 185 proof alcohol brings the total per gallon "value" to $.99. Deducting engine conversion costs ($.09) and fuel delivery costs ($.02) leaves a net value of $.88 per gallon.

The income tax credit on direct use of 150 to 189 proof alcohol was increased to $0.375 per gallon in 1983 (U.S. Congress). However, gasoline prices also fell in 1983. The resulting decline in the substitution value of fuel alcohol has roughly offset the higher income tax credit ($.375 compared to the former $.30 per gallon) now available for use of hydrous alcohol.

Marketing the feed. Finding markets for the DWG byproduct of small-scale plants may be less of a problem than finding markets for the alcohol fuel. However, many livestock operators will not be set up or desire to handle a high-moisture protein supplement. Ideally, the kind of small-scale plant referred to in this article would be immediately adjacent to and integrated with a very large beef feedlot or dairy operation which could continuously utilize all of the plant byproduct. If this is not possible, a cooperative or commercial marketing operation will be required in which farmers in the surrounding area either pick up the high protein feed at the plant or have it delivered to them.

Utilization of the feed byproduct in both beef and dairy operations has been analyzed. SDSU feeding experiments with dairy animals were used to determine the value of DWG as a protein supplement. Computer analyses (on the AGNET system) were used to determine the protein supplement value of DWG in beef rations.

Utilizing DWG on beef fattening farms in an eastern South Dakota county, for example, would require about 32 farms covering a 72 square mile marketing area to consume the feed byproduct from an alcohol plant producing 175,000 gallons of fuel and 1,356 tons of DWG annually (Dobbs and Hoffman). Costs of delivering the feed to these farms were estimated to be $.07 per gallon of alcohol. Estimated costs were slightly higher when only every other beef farm closest to the alcohol plant presumably utilized DWG ($.09 per gallon)[4] and slightly lower when DWG was assumed to be used on dairy farms rather than beef farms ($.05 per gallon).[5] The middle-range $.07 per gallon estimate thus seems reasonable for general use.

Analysis showed that use of the DWG in dairy animal rations has more value than use of it in beef fattening rations. Different assumptions about feeding rates,

[3] Per gallon substitution rates are assumed to vary as larger and larger quantities of conventional fuels are replaced by alcohol on any given farm (Dobbs and Hoffman).

[4] Approximately 30 percent of the farms in the case study county for this portion of the analysis fattened beef. The average beef fattening farm marketed 81 head of beef annually. It was first assumed that beef fattening farms closest to the alcohol plant would agree to utilize the DWG. When that assumption was relaxed, the required marketing territory was larger, of course.

[5] In the examination of dairy farm use of DWG, a different case study county in eastern South Dakota was studied.

rates of gain, feed prices, and so forth might alter that conclusion in some circumstances, however. Estimated DWG returns net of transportation and preservative costs[6] ranged from \$.07 to \$.30 per gallon of alcohol, depending upon the feed and transportation assumptions used. In some cases, the foregoing marketing territory-based \$.07 per gallon estimate of transportation cost (Dobbs and Hoffman) was used. In other cases, a simple 10 percent deduction from DWG returns was used in lieu of a formal transportation cost estimate. The 10 percent deduction was the approach used in Hoffman and Dobbs and implied in the earlier section of this article which dealt with alcohol production costs. In the final section of this article, estimates from both approaches are drawn on.

In sum, combined costs of fuel and feed delivery could be significant for a small-scale plant if it is not adjacent to a large feedlot or dairy operation. Under one particular set of assumptions—for a 175,000 gallon plant in which fuel and feed delivery trucks are purchased—delivery costs were estimated to be \$.09 per gallon of alcohol; this consists of \$.02 per gallon for fuel delivery and \$.07 per gallon of alcohol for feed byproduct delivery.

Economic Prospects

The costs and returns components of this analysis can now be combined to shed light on the economic prospects for small-scale fuel alcohol production. Data referred to in the previous two sections of this article are combined as follows:

$$\text{Returns net of costs} = \text{Returns on alcohol} - \text{Costs net of byproduct credit}$$

where:

$$(1)\quad \text{Returns on alcohol} = \text{Replacement value of alcohol} + \text{Income tax credit} - \text{Engine conversion cost} - \text{Fuel delivery cost}$$

$$(2)\quad \text{Costs net of byproduct credit} = \text{Costs of producing the alcohol and feed byproduct} - \text{Returns on feed byproduct}$$

$$(3)\quad \text{Returns on feed byproduct} = \text{Value of feed byproduct in livestock ration} - \text{Cost of preservative} - \text{Feed delivery cost}$$

Cost data, from Hoffman and Dobbs, are the same as those presented earlier in this article. However, the "returns net of costs" are shown here with various assumptions about feed byproduct returns and transportation costs, rather than with the single set of assumptions implied earlier. Selected estimates of returns net of costs, derived from the above formulation, are presented in Table 1. Returns on alcohol of \$.88 per gallon (determined in the previous section of this paper) are shown in column 2. Costs net of byproduct credit for the baseline case (described earlier in the paper) are shown in column 3. The lowest costs estimated in our sensitivity analyses are shown in column 5. Returns net of costs, shown in columns 4 and 6, were derived by subtracting column 3 data from column 2 data in one case and column 5 data from column 2 data in the other case.

Columns 4 and 6 of that table both indicate negative returns net of costs for the principal assumptions used in the study. In other words, the type of alcohol plant analyzed appears to be economically infeasible.

The costs and returns situation shown in Table 1 appears worst (−\$1.13 per gallon) with baseline production costs, the

[6] Calculations included a \$12.60/ton of DWG deduction for cost of propionic acid used as a preservative.

TABLE 1. Returns Net of Costs for a Small-Scale Alcohol Plant (175,000 Gallons/Year of Alcohol and 1,356 Tons/Year of DWG).

		Baseline Cost Case[a]		Low Cost Case[b]	
(1) When Byproduct is Used as Indicated	(2) Returns on Alcohol	(3) Costs Net of Byproduct Credit	(4) Returns Net of Costs [(2) − (3)]	(5) Costs Net of Byproduct Credit	(6) Returns Net of Costs [(2) − (5)]
(1) *In Beef Animals*	Dollars per gallon of alcohol produced				
(a) With Transp. Costs estimated on basis of marketing territory analysis	.88	2.01	−1.13	1.82	−.94
(b) With Transp. Costs estimated on basis of 10 percent of feed value	.88	1.95	−1.07	1.76	−.88
(2) *In Dairy Animals*					
(a) With Transp. Costs estimated on basis of marketing territory analysis	.88	1.82	−.94	1.63	−.75
(b) With Transp. Costs estimated on basis of 10 percent of feed value	.88	1.78	−.90	1.59	−.71

[a] Baseline cost case in Hoffman and Dobbs, with price of the corn feedstock at $2.50/bushel.
[b] Low cost of production estimate in Hoffman and Dobbs, with price of the corn feedstock at $2.00/bushel.

byproduct fed to beef animals, and the marketing territory estimate of transportation costs. It is least bleak (−$.71 per gallon) with production costs based on $2.00 per bushel corn, the byproduct fed to dairy animals, and transportation costs figured as 10 percent of the feed byproduct value. However, an even more grim outcome could be shown by including some of the other sensitivity analysis results in this table.

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

Some additional cost and return considerations. The returns calculations in this article were 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 state to be marketed and used in a 10 percent 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 analyzed here.

Anhydrous (200 proof) fuel alcohol often brought $1.65–$1.75 per gallon in the upper-midwestern U.S. during the 1981–83 period. Alcohol of 180–190 proof sold for $.40–$.50 per gallon less than the 200 proof product—*when* a market could be found. Using a $1.70 price for the 200 proof product and subtracting $.45 for lower proof gives an estimated market value of $1.25 per gallon for 185 proof alcohol. Even ignoring some transportation costs the seller may well have to bear, the prospects for plant feasibility remain poor. The $1.25 return is $.37 per gallon more than that estimated as the return for alcohol used on farms near the plant.

However, as indicated in columns 4 and 6 of Table 1, costs exceed returns by much more than that in all instances.

Eventually, if well integrated regional systems of small- *and* large-scale alcohol plants were to develop, the price of hydrous alcohol might substantially improve relative to the price of anhydrous alcohol. Large plants might then contract with small plants for regular supplies of hydrous alcohol to dehydrate and market along with their self-produced alcohol; this 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 the data of Table 1 is in the area of feed byproduct values. Estimated returns for byproduct use in dairy heifer rations were higher than in lactating dairy cow rations. Byproduct value estimates implied in the last two rows of Table 1 are 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 higher by $.07 per gallon of alcohol. Although an improvement, this is obviously far from being sufficient to result in an economically feasible plant.

On balance, it is doubtful that the returns are underestimated in this article. In fact, it could be argued in some instances that the returns estimates are too optimistic. It would 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 persuade farmers to utilize the semiwet DWG byproduct.

When we consider costs, our analyses have shown a wide range of estimates, depending on engineering and economic assumptions used. The lowest costs found in our sensitivity analyses (Hoffman and Dobbs) are reflected in column 5 of Table 1. Even those cost estimates do not result in an economically feasible plant.

SDSU scientists (Gibbons and Westby; Westby and Gibbons) 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. One of these modifications—increasing the starch concentration—could reduce costs by approximately $.40 per gallon of alcohol (Gibbons and Westby).

If some of these changes, in combination, could reduce costs by $.50–$.60 per gallon below those shown in our baseline case (column 3 of Table 1), costs net of byproduct credits might be as low as $1.20–$1.30 per gallon in some instances. Such costs are not very likely at the present time for small-scale plants. However, even if such cost reductions were achieved, profitability would require returns on alcohol to be higher than the estimated value for on-farm use. Selling the fuel at $1.25 per gallon to a larger plant that "upgrades" to 200 proof would be, roughly, a break-even proposition under these assumptions.

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

Advances in technology and production methods could result in lower per gallon costs than those figured in the baseline case (column 3 of Table 1). Changes in certain assumptions could push costs higher, however. For instance, a 15 percent interest rate was used to amortize capital costs in the baseline case. A doubling of the interest rate adds $.20 per gallon to costs. Other changes in assumptions, such as lower alcohol yields, could add further to per unit costs.

Costs of production for small-scale alcohol plants may come down over time. For the present, though, our baseline cost estimates are not unrealistically high.

Concluding observation. The analysis presented in this article indicates that small-scale fuel alcohol plants are unlikely to be economically feasible at the present time, at least with grain feedstocks such as corn. Investor experiences with small-scale plants over the past few years have generally borne this out. 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.

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