A COMPARISON OF THE ECONOMIC AND TECHNICAL FEASIBILITY OF SMALL-SCALE ALCOHOL AND SUNFLOWER OIL PRODUCTION

BY

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This paper compares the technical and economic feasibilities of small scale production of fuel grade grain alcohol with those of sunflower oil. Three scales of ethanol and sunflower oil production are modeled, and sensitivity analysis is conducted for different operating conditions and costs of feedstocks and by-products. The general conclusion is that, ignoring government subsidies to alcohol production, sunflower oil is competitive with alcohol at these scales of operation.

This study was motivated by two major factors. First, because of the interest in on-farm energy production, we felt it important to have a solid technical and economic comparison of these sources of liquid fuels. Second, we wanted to learn the extent of possible distortions that may be introduced by government policies to subsidize ethanol, but not sunflower oil. Current Federal legislation provides a subsidy for ethanol production of forty cents per gallon, which is not available for sunflower oil production.[1/] In light of the fact that ethanol can substitute for only about 15 percent of the energy requirements of the typical direct injection diesel engine used in agriculture (USDA P. II-31), there is considerable impetus to find a diesel fuel substitute that can be produced on farm with a technology that is comparable in investment cost, complexity, and capital costs to that of on-farm ethanol plants.

[1/] This provision, effective through 1992, is contained in the Crude Oil Windfall Profit Tax Act of 1980.

The approach taken in this study has generally been to consider these liquid fuels production processes to be more similar to scaled down, simplified industrial plants operating at or close to maximum capacity than intermittently operated batch type processes scaled to the fuel requirements of average farms. In this sense these plants, with the exception of the smallest plant in each category, are more similar to plants that might be located at county or cooperative elevators than what is often considered to be an appropriate scale for on-farm plants. Nonetheless, these plants are small enough to be compatible with on farm locations, the potential feedstock production from large farms and moderately large livestock feedlots.

This "industrialized" approach has been taken because of the fairly large investment cost that appears to be necessary in order to efficiently produce liquid fuels of consistently high quality. Accordingly, the capital costs need to be spread over many units of output in order to bring the cost per unit of production into a reasonable range.

This approach has several implications for the design and operation of these plants. The plants have to be designed and built so as to withstand continuous usage over their lifetimes (15 yrs. in all cases). Hired labor is a necessity; a farmer's opportunity cost of labor may be low for certain periods of the year, but if a plant is to be operated 16-24 hours a day, 300 days a year, it is unreasonable that the owner-operator will supply all the labor.

The technology employed in each case in this paper is basically derived from well established practice in the alcohol distillation and the vegetable oil industries. However, the two largest alcohol plants and all of the sunflower oil plants incorporate techniques that are still in a developmental stage at these scales of operation, but that appear to be necessary to produce a fuel that can be used reliably in standard spark ignition and direct injection diesel engines without major engine modifications.

Specifically, alcohol dehydration is accomplished by means of the cracked-corn-column adsorption techniques being developed by Ladisch and Dyck. (1979) This technique is considered capable of producing sufficiently high proof (199) that gasohol can be produced directly on farm. The expected overall energy savings from using the Ladisch technique to remove the final 10 percent of water (by volume) from the product stream completely offsets the current estimate of the additional costs associated with the process.

The sunflower oil plants incorporate a transesterification step in the oil refining process. In this step the glycerol component of the fatty acid esters that are the principle molecular components of the oil are replaced with methanol or ethanol molecules. This reaction proceeds at atmospheric pressure and moderate temperatures (100^{o} C.) in the presence of sodium hydroxide, an inexpensive but non-recycled catalyst. The transesterified, refined sunflower oil (TRSO) has a much lower viscosity than unreacted, refined sunflower oil (RSO) and is somewhat lighter. The viscosity of TRSO is nearly the same as standard No. 2 diesel fuel and avoids the problem of poor atomization, incomplete combustion and engine fouling that characterizes RSO used for extended periods in direct injection diesel engines. (Bruwer) The crude sunflower oil is filtered, degummed, dried and neutralized prior to the transesterification step. After this step it is washed to remove residual sodium hydroxide (and soapstock) and dried again before storage.

Economic Comparison of Alcohol and Sunflower Oil Plants

A computerized discounted cash flow model is used to compute the annualised costs of production and returns, internal rates of return and present discounted value of the different liquid fuels plants modeled in this study. A number of financial variables are specified exogenously (see Table No. 1 below) and the model uses these specifications to internally calculate the income tax effects and the net cash flows, both before and after taxes

TABLE 1

FINANCIAL ASSUMPTIONS COMMON TO ALL PLANTS

Item	Value
1. General rate of inflation	.07
2. Average after tax cost of capital	.1225
3. Constant marginal tax rate	.3
4. Investment tax credit	.2
5. Plant lifetime	15 years
6. Depreciable life (straight line)	10 years
7. Salvage value; 10% of initial equipment cost inflated at the general rate of inflation	
8. Inflation rates of energy related process inputs; worst cases:	.125
(intermediate and best cases:	.102)

for each of the time periods (years) over the life of the plants. The model also takes inflation into account in the calculation of the discount rate and the magnitude of expected costs and returns for each period. For example, the assumption of a constant after tax weighted average cost of capital of 12.25 percent and a general rate of inflation of 7 percent over the life of the plants results in a real cost of capital and discount rate of 4.9 percent.

Table No. 2 presents the plant-specific technical assumptions for the ethanol and sunflower oil plants. Since the small ethanol plant does not incorporate any ethanol dehydration its output proof is assumed to be about 190. The yield of ethanol per bushel of feedstock (corn) is also lower than the two larger plants and its yield of stillage solids per bushel is higher. This is due to the low conversion rates that are likely in small scale plants using atmospheric-pressure cooking and saccarification technology. The two larger

TABLE 2

TECHNICAL SPECIFICATIONS FOR ETHANOL AND

SUNFLOWER OIL PLANTS

Ethanol Plants	Scale Small	 Medium	 Large
Ethanol proof	190	199	199
Ethanol yield	2.1 gals/bu.	2.16 gals/bu.	2.16 gals/bu.
Stillage yield (solids)	11.19 lbs./gal.	9.17 lbs./gal.	9.17 lbs./gal.
Starch conversion Technology	batch tank 1 atm.	food extruder 1000 psi	food extruder 1000 psi
Annual Production (gallons/year)	134.4 gals/batch 2 batches/week 30 weeks/yr. (8,040.)	21.6 gals/hr. 16 hrs/day 300 days/year (103,512)	43.1 gals/hr. 24 hours/day 300 days/year (310,500.)
Process heat requirements (delivered)	43,000 BTU/gal.	25,000 BTU/gal.	25,000 BTU/gal.
Sunflower Oil Plants			
Number of presses	2	1	2
TRSO yield	4.7 gals/cwt	5 gals/cwt	5 gals/cwt
Meal yield	9.4 lb./gal.	8.8 lb./gal.	8.8 lb./gal
Refining Technology	batch kettles settling tanks	batch kettles centrifuges (2)	batch kettles centrifuges (4)
Annual production (intermediate case) (gallons/year)	8.2 gals/hr. 8 hours/day 1,000 hours/yr. (8,200.)	21 gals/hr. 16 hours/day 300 days/yr (100,800)	42 gals/hr. 24 hours/day 300 days/yr (302,400)
Process heat requirements (delivered)	3,000 BTU/gal.	2,400 BTU/gal.	2,400 BTU/gal.
Electricity kwh/gal.	1.2	2.2	2.2

plants achieve higher ethanol yields by virtue of the incorporation of high pressure, 300^{o} F. food extruders. (U.S. National Alcohol Fuels Commission) The hourly yields shown are derived from the yields of plants sized on the basis of near maximum achievable conversion of starch to ethanol. (U.S.D.A.) These yields have been accordingly adjusted for lower, more realistic rates of conversion and the production of 199 proof instead of 190 proof. The difference in process heat requirements occurs because of the greater efficiency of distillation to 180 proof with the subsequent removal of residual water by means of cracked corn adsorption.

The yield of TRSO is based on the average oil content of common sunflower cultivars (at 10% moisture) adjusted for losses in pressing and refining. Oil losses are lower when centrifugal separation is included in the refining process. The meal produced from undecorticated sunflower is relatively high in fiber and only moderately high in protein. The annual production estimates are derived from the press manufacturers' estimates of output and losses when pressing sunflower. Process heat is required to temper the seed prior to pressing, maintain low viscosity during the refining and heat the oil prior to each drying step and transesterification. The presses and centrifuges require significant amounts of electricity as can be seen.

The after-tax annualized costs of production and credits per gallon of ethanol and sunflower oil are presented on Tables No. 3 and 4, respectively. The The capital costs component of the aggregated annualized costs is also shown. Each process and plant has been modeled under three different sets of assumptions about initial market prices for feedstocks, by product values, rates of inflation of energy related inputs and, in the sunflower plants, different levels of annual production.

In the base case set of assumptions for ethanol plants the initial corn prices are \$3/bu and stillage is valued at \$.058/lb. of solids for the two larger plants. This stillage value is based on the 1980 average cost of

TABLE 3

AFTER-TAX ANNUALIZED COSTS OF PRODUCTION AND CREDITS PER GALLON FOR ETHANOL

	Plant Sizes		
Base Case	Small	Medium	Large
Annual Production ($3./bu. Corn)	8,040 gallons	103,500 gallons	310,500 gal.
Total Cost	2.32	1.87	1.51
Value of stillage	.27	.39	.39
Net Annualized Cost	2.05	1.48	1.12
(Capital Cost)	(.65)	(.30)	(.14)
Best Case			
Annual Production ($2.5/bu. Corn)	10,700.	103,500.	310,500.
Total Cost	2.14	1.68	1.34
Value of Stillage	.20	.30	.30
Net Annualized Cost	1.94	1.38	1.04
(Capital Cost)	(.49)	(.30)	(.14)
Worst Case			
Annual Production ($3.5/bu. Corn)	8,040.	103,500.	310,500.
Total Cost	2.50	2.04	1.68
Value of Stillage	.33	.49	.49
Net Annualized Cost	2.17	1.55	1.19
Annualized Cost ($/MMBTU) Net of Stillage Credit			
Base Case	24.32	17.57	13.29
Best Case	23.01	16.37	12.34
Worst Case	25.74	18.39	14.12

TABLE 4

AFTER-TAX ANNUALIZED COSTS OF PRODUCTION AND

CREDITS PER GALLON FOR SUNFLOWER OIL

	Plant Sizes		
Base Case	Small	Medium	Large
Annual Output ($.11/lb. sunflower)	8,200 gallons	100,000 gallons	300,000 gal.
Total Cost	3.52	2.39	2.13
Value of Meal	.50	.48	.48
Value of Glycerol	.175	.175	.175
Net Annualized Cost	2.83	1.74	1.48
(Capital Cost)	(1.18)	(.30)	(.17)
Best Case			
Annual Output ($.09/lb. sunflower)	59,000.	150,000.	300,000.
Total Cost	2.23	2.00	1.84
Value of Meal	.39	.37	.37
Net Annualized Cost	1.66	1.45	1.30
(Capital Cost)	(.16)	(.20)	(.17)
Worst Case			
Annual Output ($.13/lb. sunflower)	8,200.	50,000.	100,000.
Total Cost	3.81	3.02	2.79
Value of Meal	.61	.57	.57
Net Annualized Cost	3.03	2.27	2.04
(Capital Cost)	(1.18)	(.61)	(.50)
Annualized Cost ($/MMBTU) Net of Meal & Glycerol Credits			
Base Case	23.01	14.22	12.03
Best Case	13.50	11.79	10.57
Worst Case	24.63	18.46	16.59

a corn-soybean meal ration with the same protein content as the stillage solids net of the current cost of a lysine supplement to the stillage. The stillage from the smallest ethanol plant has been valued arbitrarily at one third of the value of the stillage from the largest plants. This is due to the much lower value of rations that contain wet stillage on an intermittent basis instead of the daily, uninterrupted basis that can be achieved with the larger plants that operate on a continuous basis.

In the "best" assumption set, corn is priced at the January 1980 price while stillage solids are valued as in the base case with corn and soybeans meal prices at the January 1980 level. In the "worst" assumption set corn is initially priced at $3.5/bushel while stillage values are based on the levels in the intermediate case, but without an adjustment for lysine deficiency. In the "best" case energy related inputs are assumed to inflate at a real rate of 3 percent as compared with 5 percent on the other cases. In all cases the annualized after-tax cost per gallon net of the relevant stillage values is presented at the bottom of each set of assumptions.[2/] As can be seen, the impact of changes in feedstock prices on annualized costs is largely offset by the changes in by product values assumed in these cases. The net annualized cost in terms of dollars per million BTU is presented at the bottom of the table with anhydrous ethanol valued at 84,300 BTU per gallon and 190 proof ethanol valued at 80,085 BTU per gallon.

The same procedure has been followed for the sunflower oil plants. In the base case, initial prices correspond with the approximate 1980 market

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[2/] These cost estimates are lower than some recent estimates in other studies. These differences are largely explained by the inclusion of income tax effects in this study as compared with Fischer and placing a higher value on wet stillage than that used in the U. S. National Fuel Alcohol Commission study. If wet stillage is not valued as highly as it is in this study, then ethanol is even less competitive with sunflower oil.

average, while the meal is valued according to its protein content equivalent in a corn and soybean meal ration valued at 1980 average prices net of supplemental lysine. One significant difference between sunflower oil and ethanol production is that the meal does not spoil rapidly; a storage life of up to two months is expected. As a result, the meal from the smallest plant is valued at the same rate as the others. The unrefined glycerol produced in the transesterification process is valued conservatively at 50 percent of the market price for refined glycerol. The glycerol credit shown in the base case is applied to all cases. As with the ethanol plants, the best and worst cases incorporate changes in the price of feedstock and value of sunflower meal. Changes in the initial price of feedstock are largely offset by the changes in the value of the by-product meal. The variable that has the largest impact on the net annualized cost is the different levels of annual usage. This is well illustrated in the three cases of the largest plant, where the cost per gallon changes substantially only when the annual output is reduced from 302,400 gallons to 100,800 gallons.

The annualized after-tax cost net of by-products in dollars per million BTU is presented at the bottom of the page. TRSO has 95 percent of the density of RSO and is valued at 95 percent of the BTU content of RSO.

Conclusions

The cost of producing a gallon of TRSO net of credits for meal and glycerol is in all cases higher than the unsubsidized cost of producing a gallon of anhydrous or 190 proof ethanol net of stillage credit at comparable rates of production and under comparable conditions. However, since TRSO contains about 1.45 times as many BTUs per gallon as does anhydrous ethanol (123,000 and 84,300 respectively), the cost per BTU of TRSO is less than the cost per BTU of ethanol in all comparable cases. (See Tables No. 3 and 4).

As can be seen from Table No. 5 however, inclusion of the $.40/gal. Federal subsidy as a credit annualized over the life of the plants at zero percent inflation reverses the ranking of the plants at the small and large scales. In other words, it seriously distorts the relative cost of producing renewable liquid fuels at a small scale.

This result has important implications for policy formation. The fact that the existing subsidy applies only to alcohol fuels and not to renewable liquid energy sources in general means that the choice between sources and technologies is distorted by the subsidy. Farmers who would adopt sunflower oil using market forces may be induced to adopt alcohol instead merely because of the subsidy on alcohol. This change could occur despite the fact that sunflower oil is more compatible with the existing fleet of diesel tractors. Our results indicate that the subsidy should be modified to include any renewable liquid energy source -- assuming a subsidy will continue to exist.

TABLE 5

COMPARISON OF THE COST PER MMBTU FOR ETHANOL WITH AND WITHOUT THE FEDERAL SUBSIDY AND SUNFLOWER OIL USING INTERMEDIATE CASE VARIABLES

	Small	Medium	Large
Ethanol without Subsidy	$24.32	$17.57	$13.29
Ethanol with Subsidy	22.18	15.42	11.15
Sunflower Oil	23.01	14.22	12.03

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