The Feasibility of Producing Biodiesel in the United States Using a Community-Based Facility

by

J. Alan Weber[1]

Abstract: Biodiesel fuel can be made from vegetable oils, animal fats, and waste grease from the food industry. Biodiesel blended with petroleum diesel is being examined as a potential fuel in urban areas to meet Clean Air Act standards. But what about using biodiesel on the farm? Farmer cooperatives in Austria are producing biodiesel for their members. A simulation model was developed to evaluate the feasibility of a community-based 500,000-gallon biodiesel plant in the United States. Soybeans were found to be the most cost-effective feedstock, mainly because the meal is a useful coproduct. Biodiesel costs were heavily dependent upon the prices paid for the beans and received for the meal. The resulting biodiesel is not competitive with the price farmers pay for conventional diesel fuel.

Keywords: Biodiesel, renewable fuels, diesel fuel, soybeans.

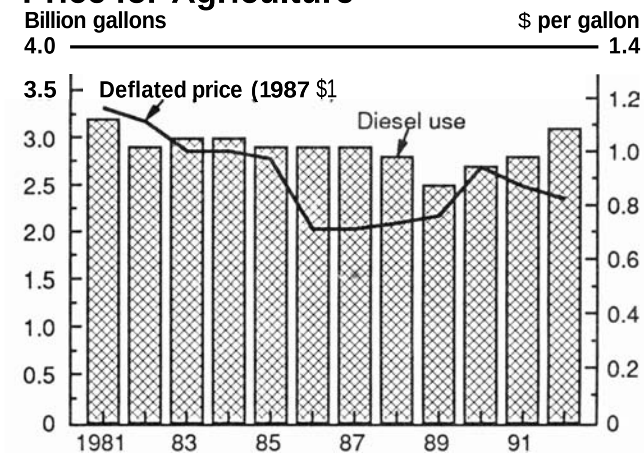
The idea of chemically altering vegetable oils for use as fuel was noted even before World War 11. For example, Walton wrote in 1938, "...to get the utmost value from vegetable oils as fuels it is academically necessary to split off the glycerides and to run on the residual fatty acid" (1). The glycerides are likely to cause excess carbon deposits in comparison with petroleum diesel.

Although not studied extensively until later, animal fats can also be converted into biodiesel. The chemical process used to transform vegetable oils, animal fats, and/or waste grease into usable energy is called "esterification." Esterification changes the large triglyceride molecules in fats and oils into three smaller molecules. The resulting biodiesel has performance characteristics similar to petroleum-based diesel fuel. Biodiesel can be burned in unmodified diesel engines either in pure form or blended with conventional diesel fuel. Extrusion and esterification also yield usable coproducts, like oilseed meal and glycerine.

U.S. Farms Are Significant Users of Diesel Fuel

Real diesel prices for agricultural production declined markedly between 1981 and 1986, stabilized in 1987 and 1988, and then rose slightly in 1989 and 1990 (figure A-1) (2). During this period, on-farm diesel use did not move opposite price as is generally expected. As shown in figure 1, on-farm diesel use trended downward between 1982 and 1989. The two primary reasons for the decrease are greater fuel-efficiency, due to improved technology and a shift toward larger, more fuel-efficient equipment,

Figure A-1
Diesel-Fuel Consumption and Price for Agriculture



and dramatic changes in cropping practices, particularly the widespread adoption of no-till and conservation-till.

Since 1989, however, diesel consumption has moved upwards, even though real diesel prices have fluctuated. Greater on-farm use is most likely due to the depletion of agricultural stocks following the drought of the late 1980's, the subsequent lower acreage reduction requirements of Federal commodity programs, and the low price of diesel fuel relative to other energy sources (2).

Potential Demand for Biodiesel

With the increasingly stringent environmental regulations specified in the Clean Air Act Amendments of 1990, biodiesel is being examined as a possible alternative to

[1]Agricultural Economist, Department of Agricultural Economics, University of Missouri, Columbia, MO.

petroleum-based diesel fuel. Biodiesel is biodegradable and produces less carbon monoxide, sulfur oxides, hydrocarbons, smoke, and particulate matter compared to petroleum-based diesel. (See the fats and oils section for more details.)

Testing suggests that engine power and fuel efficiency of biodiesel and conventional diesel are similar. Biodiesel's viscosity (flow resistance of liquid) is approximately twice that of petroleum-based diesel fuel. Increases in viscosity may cause injector spray problems in some diesel engines. Moreover, the pour point and cloud point of biodiesel are a few degrees higher than regular diesel. Consequently, as with conventional diesel, additives will be necessary to prevent fuel-gelling and/or storage problems in cold weather. On the up side, the higher flash point of biodiesel means safer handling. And biodiesel's cetane rating, which measures a fuel's igniting ability, is greater than that of petroleum-based diesel fuel.

Non-Price Factors Spur Growth of Biodiesel Industry

There are two main forces affecting the biodiesel industry in the United States. Environmental benefits are creating increased interest and research, but poor economics is inhibiting production and use. In Europe, biodiesel is considered environmentally friendly and, in some areas, government incentives are being used to encourage biodiesel production and use. Testing in the United States also supports the claim that biodiesel will decrease engine exhaust emissions.

However, in the United States, refined vegetable oils, which are potential feedstocks for biodiesel production, are currently more expensive than petroleum-based diesel fuel. Lower cost inedible tallow and waste grease from restaurants and fast-food establishments may be cheaper feedstocks, but the resulting biodiesel would still be more expensive than standard diesel.

Nevertheless, because of clean air regulations, many users of diesel fuel--such as urban transit agencies--view biodiesel as a potential option. Some industry experts believe a blend of diesel and biodiesel may be the least expensive way to meet the new air quality standards. It may be less costly to purchase slightly more expensive biodiesel-diesel blends than to retrofit or purchase engines that bum other types of fuel, such as compressed natural gas or methanol. In addition, biodiesel can be used in existing handling facilities, unlike some other alternatives.

Until the Clean Air Act provisions are fully implemented, biodiesel cannot compete on price with petroleum-based diesel fuel in urban areas. But what about on farms? Some have argued that if farmers retain ownership of their oilseeds and eliminate some of the typical marketing charges paid to processors and transporters, then biodiesel may be an economically viable alternative for some agricultural producers.

Biodiesel Production and Use in Austria

Such a program is already underway in several Austrian communities. Austrian farmers grow oilseeds and have them processed into biodiesel and high-quality meal for livestock. Of particular interest is a cooperative arrangement in Neulangbach, Austria. They employ a closed-loop system that eliminates the additional costs that normally accrue to feed manufacturers, feed dealers, and transportation companies. Producers retain ownership of their crop and the resulting products during the entire process, and the cooperative charges a processing fee that covers capital and operating costs.

The cooperative has approximately 290 farmer-members. Production from the 1,235 acres of oilseeds--rapeseed and sunflower--amounts to about 150,000 gallons of biodiesel each year. In addition, around 1,000 metric tons of meal are used by the farmers as a protein source in livestock feed.

Labor requirements are relatively small due to the highly automated plant. Only 4 to 5 man-hours are required each day. The process is totally automated, except when the potassium hydroxide catalyst must be mixed with the alcohol to initiate the esterification process. Strict quality control procedures ensure a consistent product that meets proposed Austrian fuel standards. The plant has been in operation since 1990, producing high-quality biodiesel for use in approximately 700 machines owned by cooperative members. The farmers have recently doubled plant capacity.

Many of the components of this system could be transferred to the United States. However, there are policy differences between the two countries that influence its viability. For example, Austrian farmers receive subsidies to convert acreage from cereal grains to oilseeds. Furthermore, biodiesel is exempt from most of the taxes imposed on petroleum-based diesel fuel in Austria. Neither form of government assistance is currently available in the United States.

Evaluating a U.S. Community-Based System

Dedicated biodiesel plants do not presently exist in the United States. Current production is limited to industries that esterify oils for other products. Therefore, in order to analyze the economic feasibility of producing fuel at the community level, information was gathered from private firms that manufacture equipment that could be used for biodiesel production. This study uses a spreadsheet format to simulate potential economic changes resulting from various scenarios including different feedstocks, input costs, and coproduct values. The simulation model was created in an effort to allow farmers to evaluate potential profits of investing in a community-based biodiesel facility.

The model plant for this study closely parallels the Austrian cooperative. The facility is a closed-loop system, operated as a cooperative, in which farmer-members retain ownership of their oilseeds and processed products. Oilseed crushing and biodiesel production occur at the plant. The cooperative charges a processing fee that covers capital and operating costs. Because any triglyceride can be processed into biodiesel, several feedstock options exist. Oilseeds--like soybeans, canola, and sunflower—as well as animal fats and waste grease can be used.

Biodiesel and oilseed meal are intended for use by the farmer-members. However, either of these products can be sold on the open market. The glycerine coproduct can also be sold on the open market as a commodity chemical (see the fats and oils section).

The extrusion and expelling equipment used in this study is a mechanical-press-based system manufactured by Triple "F," Inc. (DesMoines, IA). The extruders/expellers were first developed in the mid-1960's and accurate operating information is available. The continuous-flow esterification unit is designed by Stratco, Inc. (Leawood, KS). This technology has been evaluated only in a pilot plant. All product input and output data, costs of equipment purchase and operation, repairs, utility usage, and other important cost information were provided by Triple "F" and Stratco for use in this analysis.

The biodiesel facility is assumed to be installed in an existing grain handling facility or feed mill, thus eliminating excessive capital costs. Presently, many small or private grain handling facilities and feed mills are experiencing excess capacity. By utilizing existing facilities overhead costs are minimized. Equipment costs represent the primary capital investment. The annual capacity of the plant is assumed to be 500,000 gallons of biodiesel per year. The unit is highly automated to minimize labor costs.

In order to simplify the analysis, it is assumed that the farmer-members have similar characteristics. They are diversified crop and livestock producers, each able to grow oilseeds and have a need for the meal. They also receive similar prices for their crops and pay similar prices for inputs. Because the model includes the feedstock costs and coproduct values of individual farmers, this assumption is important in order to examine the overall feasibility of the plant. In reality, farmers face various conditions, and individual circumstances would dictate the final residual cost of biodiesel fuels.

As an initial reference point, it is assumed that farmer-members value their oilseeds and meal at the following prices:

- Oilseed prices represent the June 1993 spot market price in central Missouri: $5.60 per bushel for soybeans, $4.25 per bushel for canola, and 11 cents per pound for sunflowers; and

- Two values for soybean meal (44-percent protein) are used: (1) the average 1992 wholesale price ($172 per ton) and (2) the midpoint between the average 1992 wholesale and retail prices (approximately $220 per ton); canola meal (38-percent protein) is valued at $190 per ton; and sunflower meal (28-percent protein) at $140 per ton.[2]

The extrusion/expelling equipment used to simulate a community-based facility is too small to produce 500,000 gallons of soybean-based biodiesel per year. If a higher-content oilseed were used, like canola or sunflower, then the esterification equipment would be fully utilized without purchasing additional extrusion/expelling equipment.

The following additional assumptions were made for this model:

- Utility hookups are available and on-site;

- The extrusion/expelling equipment operates 300 days per year, 24 hours a day;

- Oil yields from crushing are 10 percent for soybeans and 27 percent for canola and sunflowers;[3]

- Esterification equipment operates 330 days per year, 24 hours a day;

- Crude glycerine is valued at 30 cents per pound; and

- Electricity is purchased at 7 cents per kilowatt hour.

The simulation model was designed to consider multiple feedstocks. Soybeans, canola, sunflower, and tallow were evaluated as potential feedstocks (table A-1).

Using Soybeans as the Primary Feedstock

Capital costs for the extrusion and esterification equipment were amortized over 15 years. Under the scenario using soybeans as the primary feedstock, this resulted in an annual cost of $352,109 (table A-2). Soybean and canola purchases account for 79 percent of operating costs. Total annual costs equal $4,288,047.

In 1992, farmers paid approximately $260 per ton for soybean meal, while the average wholesale price was $172--a difference of $88 per ton. Included in this price

[2]The meal values for canola and sunflowers are based on a protein content similar to that for soybean meal.

[3]Mechanical presses remove less oil than solvent extraction. In addition, according to representatives from Triple "F," Inc., leaving some residual oil in the meal creates a higher energy protein source for animal feeds.

Table A-1--Economic comparison of multiple feedstocks in a community-based biodiesel plant

Item	Feedstocks				
	Scenario 1	Scenario 2			
	97 percent soybeans/ 3 percent canola 1/	97 percent soybeans1 3 percent canola 2/	100 percent canola	100 percent sunflower	100 percent tallow 3/
			--Percent--		
Capital as a share of total costs	8	8	19	17	35
Crush capacity used	100	100	38	38	0
			-Dollars per gallon--		
Biodiesel cost	2.82	1.26	1.58	2.48	1.83

1/Farmers pay the average 1992 wholesale price of $172 per ton for soybean meal. 2/ Farmers pay $220 per ton for soybean meal--the midpoint between the average 1992 wholesale and retail prices. 3/The price for tallow used in this analysis was 12 cents per pound.

difference are costs of business and ownership changes, a charge for risk, transportation costs, plus profits accruing to those industries that take the meal from the crusher to the farmer.

Given this large differential, two scenarios were examined. The first scenario values the meal at the wholesale price of $172, which means the farmer-members producing livestock would be getting the entire $88 per ton markup. Thus, the return from the community-based facility would be capitalized in the value of the livestock. Under this scenario, coproduct credits equal $2.9 million per year and the associated price of biodiesel is $2.81 per gallon.

The second scenario assumes that farmer-members pay $220 per ton of soybean meal--the midpoint difference between the 1992 average wholesale and retail prices for soybean meal. In this case, the return from the commodity-based system is capitalized in the price of the biodiesel. Coproduct credits equal $3.7 million per year and the associated price of biodiesel is $1.26 per gallon.

Biodiesel Costs Most Dependent on Soybean Prices and Meal Values

Because the assumptions for input costs and coproduct values do not represent the conditions in all rural communities that have an oilseed-livestock production base, sensitivity analysis is used to evaluate the economics of these plants under different conditions. Results indicate that the value of the soybean meal coproduct and the price of soybeans are the most important variables in biodiesel production. When soybean meal prices range from $172 to $240 per ton, the costs of biodiesel range from $2.81 per gallon--which is well above the 82 cents per gallon average on-farm price of diesel fuel in 1992--to 62 cents per gallon, which is slightly below the average diesel price (table A-3). In comparison, if soybean prices increased 20 cents from $5.60 to $5.80 per bushel and the meal price remained the same, then the cost of biodiesel would rise 24 cents to $1.50 per gallon. However, since meal and bean prices generally move together, an increase in the bean price without a subsequent increase in the meal price is unlikely.

All other variables have a smaller impact on the residual cost (price) of biodiesel. For example, a 5-cent increase in the price of unrefined glycerine decreases the price by 4 cents per gallon. Moreover, a 1-cent increase in the cost of a kilowatt hour of electricity boosts the price 8 cents per gallon. Lastly, a $100,000 expansion in facilities and/or equipment would increase biodiesel costs 5 cents per gallon.

The Potential for a Community-Based Facility

This analysis indicates the factors and conditions that must exist if biodiesel is to be produced economically at the community level. With soybeans as the primary feedstock, the study demonstrates the relative importance of coproduct meal and bean prices. Namely, a large spread must exist between the price that farmers receive for their soybeans and the price they pay for their protein meal. In addition, such a production facility would have to be located in areas where farmers raise both oilseeds and livestock. However, the trend in U.S. agriculture has been toward more specialized farms.

With 1992 farm prices for conventional diesel fuel at 82 cents per gallon and no regulatory requirements to use biodiesel in rural areas, farmer-members would be better off selling the soybean oil on the market, using the soybean meal in their livestock operations, and purchasing conventional diesel fuel. Further research on production and processing technology will help biodiesel's competitiveness.

References

1. Quick, G.R. "Oilseeds as Energy Crops." ***Oil Crops of the World.*** McGraw-Hill Publishing Co., 1989, pp. 118-131.

2. U.S. Department of Agriculture, Economic Research Service. ***Agricultural Resources: Inputs Situation and Outlook Report,*** October 1992. .

Table A2--Costs and coproduct credits for a 500,000-gallon community-based biodiesel plant in Missouri, 1993

Item	Scenario 1 wholesale price 1/	Scenario 2 midpoint price 2/
	--Dollars--	
Amortized annual capital costs 3/		
Extrusion & expelling	102,559	102,559
Esterification	249,550	249,550
Total	352,109	352,109
Annual operating costs		
Feedstocks		
Soybeans	3,333,455	3,333,455
Canola	34,775	34,775
Oilseed pressing	329,849	329,849
Esterification 4/	144,894	144,894
Sales and administration	83,408	83,408
Maintainence and other associated costs	9,557	9,557
Total	3,935,938	3,935,938
Total annual costs	4,288,047	4,288,047
Coproduct credits		
Soybean meal	2,764,372	3,535,825
Canola meal	21,057	26,881
Glycerine	115,263	115,263
Total	2,900,692	3,677,969
Net cost of biodiesel per year	1,387,355	610,078
	--Dollars/gallon--	
Net cost per gallon	2.77	1.22
Transportation costs 5/	0.04	0.04
Final biodiesel cost 6/	2.81	1.26

1/Farmers pay the average 1992 wholesale price of $172 per ton for soybean meal. 2/ Farmers pay $220 per ton for soybean meal--the midpoint between the average 1992 wholesale and retail prices. 3/ The capital costs provided by Triple "F" and Stratco were amortized assuming a 15-year book life, non-regulated firm with 30 percent equity and 10 percent debt, and no tax preferences. These data were developed based on methodology used in a report published by JACOR (a consulting firm in Arlington, VA). which was based on biomass cost estimates developed at Argonne National Laboratory. 4/ Esterification costs include labor and materials, such as methanol and the catalyst. The methanol was valued at 50 cents per gallon and the catalyst at 30 cents per pound. 5/Transpotiation costs (TC) were approximated by utilizing the following equation: TC = 7 + 0.623 D1. D1 equals the distance traveled. Raw material transportation costs were found to be approximately 4 cents for each gallon of soybean oil. Because biodiesel and soybean oil have approximately the same weight. their per-gallon transportation costs are the same. 6/ Does not include profit margins ebove and beyond the returns to resources assumed needed to bring and hold the resources into use.

Table A-3--Estimated cost of biodiesel from a 500,000-gallon biodiesel plant with varying prices for soybeans and soybean meal

Item	Price	Biodiesel cost
	Dollars per bushel	Dollars per gallon
Soybeans		
	5.25	0.85
	5.50	1.14
	5.60	1.26
	5.80	1.50
	Dollars per ton	
Soybean meal		
	172	2.81
	200	1.91
	220	1.26
	240	0.62