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Summary of Conclusions

Within the context of current technology and the relatively cheap alternative fuel supplies, gasohol is not economically feasible. It could not be produced for use as a substitute for gasoline without subsidies. And, subsidies of the magnitude required, cannot be justified by benefits accruing to farmers or to any other economic interests. A gasohol production program in South Dakota would increase the income of South Dakota farmers by only about 11 cents per dollar of subsidy necessary to keep the program financially solvent. If farm income support or stabilization would be a goal of such a program, direct income payments to farmers would be much more efficient. A gasohol program would not have a significant positive impact on the national energy balance or on the need for petroleum imports. Both of these conclusions would remain valid even if gasohol were mandated for use nationwide. Within the foreseeable future it is unlikely that changes in the prices of gasoline or of alternative energy sources will be of such magnitude as to make gasohol feasible economically.

Gasohol: Economic Feasibility in South Dakota

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The conversion of grain to ethyl alcohol (ethanol) for use as automotive fuel is an idea that reappears with each period of low grain prices. In the 1930's, the 1950's and 1960's support for construction of ethanol plants was widespread among farmers and others in the Midwest and Great Plains. However, in every case when serious consideration was given to the idea by those who might have been able to finance an ethanol plant (such as the large farmer cooperatives), it was found not to be feasible because of economic considerations.

Once again pressure is growing within the major grain producing states for someone or for some organization to finance and/or build plants for conversion of grains into fuel alcohol. The reason again is low grain prices. However, support is now augmented by an energy crisis with fuel prices at historic highs and by concern about increasing volumes and costs of oil imports.

It again appears highly unlikely that grain can feasibly be used to produce ethanol for use as a fuel. Dr. James Kendrick, professor of Agricultural Economics, University of Nebraska, recently reviewed 15 studies that examined the feasibility of grain alcohol production for use as a fuel (Kendrick, Literature Excerpts). The studies were conducted by a broad spectrum of people from various public and private agencies in several states and Canada. The major conclusion of each study was that production of grain alcohol for fuel is financially feasible only if large and continuing subsidies are made available. Of perhaps more significance, the studies found that ethanol production from grain with current technology has a negative energy balance. That is, more fossil fuel energy is used in conversion of grain into ethanol than the energy value in the ethanol produced. Thus, use of ethanol as a substitute for gasoline or other fossil fuels would increase rather than decrease the demand for these fuels, and could increase the need for oil imports.

Ethanol Production Cost

For the following analysis the basic production unit is assumed to be a fermentation-distillation plant capable of producing 20 million gallons of industrial ethanol (200 proof ethyl alcohol) per year. This plant size is the standard used in most recent analyses and is said by William A. Scheller to be the most economic when both production and market considerations are taken into account (Scheller 10/75, p. 7.)[1] According to Dr. Scheller, a 20 million gallon plant would cost about $23 million in 1977, would require an operating capital fund of $3.5 million, and would use about 7.4 million bushels of corn annually. A conservative estimate of the cost per gallon of ethanol produced by such a plant operating at full capacity is derived in Table 1.

The estimated total net cost per gallon of ethanol is $0.86. It has the following components:

1. A raw product cost of $0.75 consisting of 0.3704 bushels of corn (2.7 gallons of ethanol per bushel); 75 percent valued at the estimated average 1977 cost of producing corn in South Dakota, $2.30 per bushel (Aanderud), and 25 percent considered to be distressed and valued at $1.15 per bushel.[2]

2. Non-capital conversion costs of $0.41, including the costs of plant operations plus storage, transportation and marketing costs.

3. Capital costs of $0.14, including amortization of the plant over 20 years at 8 percent interest, and a 10 percent interest charge on operating capital.

4. A credit of $0.44 for the sale of by-products, primarily distillers dried grains.

The net cost per gallon of ethanol shown in Table 1 can be compared with the cost of the gasoline replaced in producing gasohol (90 percent gasoline, 10 percent ethanol). The cost of a gallon of regular, non-leaded gasoline at the same stage of production, i.e., ready for blending at the refinery, is $0.36 (Kendrick, 6/8/77, p. 1). Thus the cost of ethanol produced under current technology and with South Dakota corn production costs exceeds the cost of the gasoline for which it is a substitute by $0.50 a gallon. Assuming a negligible increase in fuel efficiency for gasohol versus regular non-leaded gasoline,[3] the $0.50 price difference represents the net loss associated with each gallon of ethanol produced for blending with gasoline. Viewed from another perspective, each gallon of gasohol produced would cost $0.41, which is five cents more than the regular gasoline it replaced.

For a 20 million gallon plant operating at full capacity, the total production cost as compared to gasoline cost would be:

20,000,000 gallons of ethanol	@ $0.86 =	$17,200,000
replaces		
20,000,000 gallons of gasoline	@ $0.36 =	7,200,000
Net loss for 200 million gallons of gashohol	=	$10,000,000

The Effects of Lower Investment and Corn Costs

Plant investment costs and the cost of corn clearly affect the cost of ethanol. In this study

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[1] Dr. Scheller has received numerous gasohol research grants and is among the recognized authorities on the technical aspects of gasohol production. Among his numerous responsibilities are: Professor and Chairman, Department of Chemical Engineering, University of Nebraska; Chairman, Nebraska Gasohol Committee; Principal Investigator, Nebraska 2 Million Mile Gasohol Test; President, Nebraska Grain Alcohol and Chemical Company.

[2] Corn is assumed to be the sole product input for this analysis because it has the lowest production cost per unit of fermentable sugar of any of the grains commonly grown in South Dakota.

[3] Scheller found that gasohol gave about 5 percent better gas mileage than gasoline in the Nebraska 2 Million Mile Road Test (Scheller, 1/77). Other evidence indicates no mileage improvement with adoption of gasohol (Battelle, Vol. I, pp. 86-87). Ethanol has only about 65 percent as high an energy content, Btu's, as gasoline (Rogers, summary).

Table 1. Estimated Cost Per Gallon of Ethanol Production from Corn in South Dakota, 1977.

Raw Product Cost	
Corn: 0.3704 bushels*	
75% valued at cost of production ($2.30 per bushel)	$0.75
25% distressed (valued at 1/2 cost of production)	
Non-capital Conversion Cost	
Storage & transportation to plant	0.05
Operating (labor, fuel, etc.)**	0.30
Marketing***	0.01
Transport to refinery***	0.05
	$0.41
Capital Costs	
Amortization & interest on plant investment of $23 million** (20 year life, 8%)	0.12
Interest on $3.5 million operating** capital, at 10%	0.02
	$0.14
Total Cost	$1.29
By-product Revenue**	-0.44
Net Cost	$0.86

*Scheller, 10/76, p. 9.

**Scheller, 1/26/77, pp. 12-13.

***Kendrick, 6/8/77, p. 2.

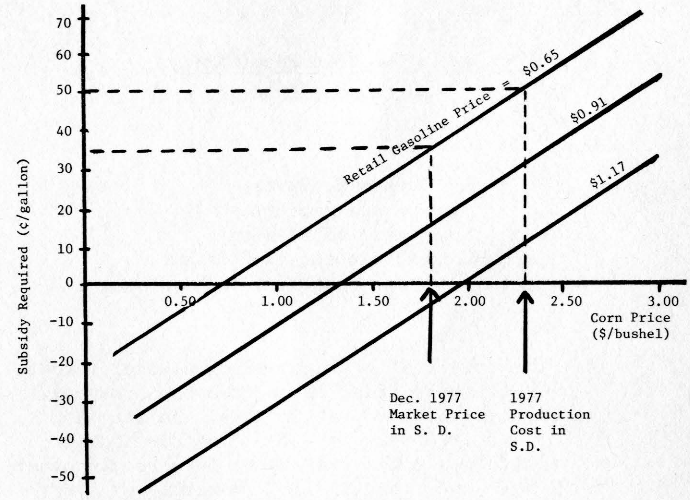

Figure 1. Subsidies required to make ethanol substitution for gasoline financially feasible. (Source: Table 2)

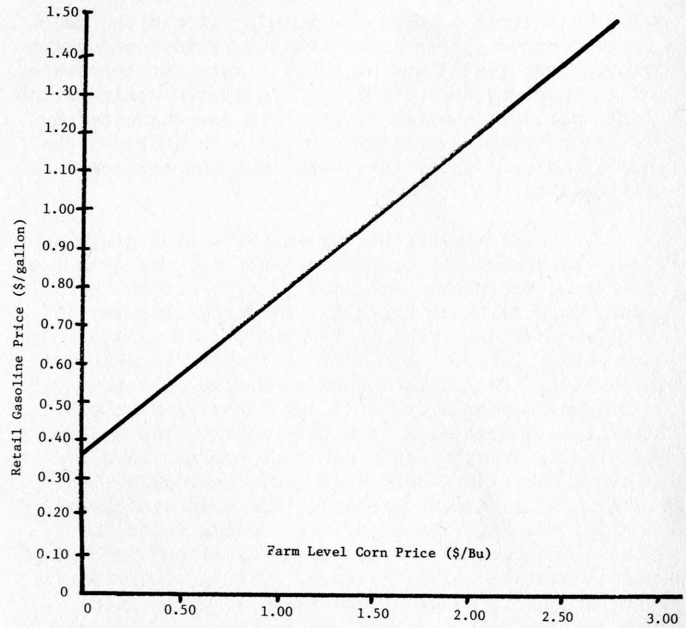

Figure 2. Gasoline - corn price combinations at which substitution of ethanol for gasoline would break even. (Source: Table 2)

Scheller's estimate of $23 million for plant investment was used. Other studies have used plant investment costs ranging from $25.9 million to more than $32 million. However, even if plant investment and corn costs were substantially reduced, ethanol substitution for gasoline would still be only marginally feasible, if at all. For example, if the plant investment was completely financed by grant funds and farmers were willing and able to take one-half of the prices assumed for their corn, ethanol would cost $0.785 per gallon to produce, only $0.015 less than the value of the ethanol plus by-product.[4]

The Effects of Different Corn-Gasoline Price Relationships

The argument is often made that expected future increases in crude oil prices will make ethanol competitive with gasoline. In Table 2 and Figures 1 and 2, the effects of various gasoline and corn price combinations on the profitability of ethanol for fuel are examined. Results of varying corn prices from $1.50 to $3.00 per bushel and retail gasoline prices from $0.65 to $1.30 per gallon indicate that ethanol could be substituted for gasoline without loss (or subsidy) only when corn prices are low and gasoline prices very high relative to current levels.

With corn priced at $2.25 per bushel ($0.05 below estimated 1977 production costs in South Dakota) ethanol could be profitably blended with gasoline only if the retail price of gasoline were to double. Alternatively, with gasoline at current price levels ($0.65 per gallon retail) ethanol substitution for gasoline would be feasible only if farmers were willing to accept $0.70 per bushel for their marketable corn. (Note that for both of these examples, it is assumed that 25 percent of the corn used could be purchased at one-half of the market price.)

Thus, although combinations of corn and gasoline prices can be found that would allow economic substitution of ethanol for gasoline, such combinations are so improbable as to suggest that gasohol (or an ethanol-gasoline blend in any proportions) will never be economic unless fundamental changes in political and/or technological conditions occur. Much higher gasoline prices can not be sustained within the context of even relatively free markets without roughly equivalent increases in the prices of substitute energy sources, such as coal in either solid, liquid or gaseous forms. Additionally,

[4] From Table 1: Assuming that ethanol is worth as much as gasoline ($0.36 per gallon) and with by-products valued at $0.44 per gallon of ethanol produced, the total value of production per gallon of ethanol would be $0.36 + $0.44 = $0.80.

Table 2. Ethanol Price (Cost) Minus Gasoline Price (Cost) At Various Corn and Gasoline Price Levels (¢/gal.)[1]

Gasoline Price (¢/gal.)		Corn Price ($/bu.)[2]				
Refinery	Retail[3]	1.50	1.75	2.00	2.25	3.00
35	65	25	33	41	49	73
45	78	15	23	31	39	63
55	91	5	13	21	29	53
65	104	-5	3	11	19	43
75	117	-15	-7	1	9	33
85	130	-25	-17	-9	-1	23

[1]Coefficients in the table were calculated by adjusting the net cost of ethanol estimate in Table 1 to reflect the alternative corn prices. Then, the various refinery level gasoline prices were subtracted from the ethanol cost estimate. The coefficients can also be considered as the net loss incurred or subsidy required per gallon of ethanol substituted for gasoline. Because the cost of fuel required to convert corn into alcohol is held constant for this analysis, the coefficients are understated for refinery level gasoline prices of above 35¢ per gallon -- if prices of fuels used in conversion, usually coal, would rise with gasoline prices.

[2]The net cost coefficients were calculated assuming that 75 percent of the corn used would be purchased at the stated prices; 25 percent (distressed) would be purchased at one-half the stated prices.

[3]Retail prices were calculated assuming that 20¢ of the refinery to retail level price mark-up would be constant at all refinery level gasoline prices. The remainder of the mark-up would be equal to 30 percent of the refinery level price.

because current technology uses conventional fossil fuels in both grain and ethanol production processes, the costs of producing grain and of converting it into ethanol would rise with increasing gasoline prices. Consequently, low grain prices and high gasoline prices would be impossible to sustain -- unless, of course, a commitment were made for continuous financial transfusions, i.e., subsidies, from other productive economic sectors.

Subsidies; Financial and Economic Feasibility

Left to operation in the free market under 1977 conditions in South Dakota ($1.80 corn, $0.65 gasoline at retail), a 20 million gallon fuel ethanol plant would suffer losses of about $6.8 million annually. Three such plants would allow conversion of all of the gasoline used in South Dakota in 1977 to gasohol and would lose about $20.4 million annually.

Equivalent subsidies required for continued operation of the plants might come from a variety of sources. (Subsidy amounts indicated below were calculated using the data and procedures from Tables 1 and 2.)

Grant money from the Federal or State Governments or from farmer cooperatives might eliminate the need for property and operating capital debt service. However, given the assumptions about investment and annual capital costs, such a subsidy would reduce the loss from operation of the plant(s) by only about 40 percent, leaving annual losses of $4 million for one plant, $12 million for three.

A reduction of state gasoline taxes by 3.4 cents per gallon of gasohol (not per gallon of ethanol) would make gasohol price competitive with gasoline at the refinery and, if none of the tax reduction were absorbed by gasohol retailers or wholesalers, would cover the total losses. However, it would also reduce the money flowing into the highway trust fund ($36.1 million in fiscal 1977) -- by about 19 percent, 38 percent, or 57 percent depending on whether one, two, or three plants were operational. Reductions of federal taxes for gasohol which might also be used to finance the subsidy would probably be applied uniformly nationwide and would have similar, although perhaps smaller, effects on federal highway funds.

A legal requirement that all automobile fuel sold in South Dakota be at least 10 percent ethanol, i.e., gasohol, would allow the needed subsidy to be collected through the market from consumers. Consumer price resistance and reduction of purchases would probably result in a need for price increases of slightly more than the 3.4 cents per gallon needed with a tax reduction scheme.

A corn producer check-off system applied at a rate of 6.5 cents per bushel on all corn marketed in South Dakota (105 million bushels) could finance the subsidy for one plant. For three plants a check-off of 19.4 cents per bushel would be needed.

Direct state appropriations could be made in the amount of the subsidy needed.

It is clear that gasohol production in South Dakota could be made financially feasible through application of one or a combination of subsidy programs. But, as illustrated by the programs outlined above, subsidy is not free. Something must be given up if subsidies for gasohol are to be paid. And, until a particular financing program is chosen, it is not clear who would have to bear the cost. Nor is it clear who would benefit and by how much.

Effects of A Gasohol Program

Two primary justifications given for replacing some of the gasoline that we consume with ethanol are that it would improve the level and stability of corn prices, and that it would substitute a renewable energy source for a non-renewable source. Whether either of these justifications is valid is questionable.

Analysis of the impact of the new market for South Dakota corn that would be created by a gasohol program within the state reveals that minimal price effect would occur, even with the most liberal assumptions about price responsiveness to reductions of supplies going to traditional markets. If we use the optimistic assumption that a one percent change in corn supply will result in an equal and opposite change in the price of corn, diversion from the market of the 7.4 million bushels of corn needed by

Table 3. The Costs of Liquid Fuels for Transportation from Alternative Sources

Product	Source	Process	$/million Btu
Methanol	Tree crop	Pyrolysis/ synthesis	5.20
Methanol	Municipal solid waste	Pyrolysis/ synthesis	6.45
Methanol	Coal	In situ gasification	2.68
Ethanol	Corn @ $2/bu	Fermentation	12.50
Ethanol	Corn @ $1/bu	Fermentation	8.99
Ethanol	Waste paper	Enzymatic	8.87
Gasoline	Petroleum	35¢/gal at refinery	2.77

SOURCE: Table 1, "Costs of biosolar liquid snyfuels for transportation," in Carl J. Anderson, Biosolar Synfuels for Transportation, Lawrence Livermore Laboratory, University of California, January 1977; as reported in Kendrick, Literature Excerpts, p. 5, and Stroup and Miller, p. 8.

Table 4. Energy Use and Production in the Conversion of Corn to Ethanol

	Btu/gallon of Ethanol
ENERGY USE	
Corn	132,000
Conversion Process	
Grinding, Cooking, Propagation	24,200
Fermentation	600
Beer Still & Centrifuge	40,400
Distillation	28,600
Dehydration	14,200
Subtotal, Ethanol	108,000
By-Product Processing	
Liquid Concentration	43,600
Distiller Grains Drying	19,600
Subtotal, By-Products	63,200
Total Energy Use	303,200
ENERGY PRODUCTION	
Ethanol	75,600
Aldehydes, Fusel Oil	1,100
Distillers Dried Grains	45,000
Total Energy Production	121,700
NET ENERGY BALANCE	-181,500

SOURCE: Scheller and Mohr, 4/76, p. 5.

one 20 million gallon ethanol plant would result in a corn price increase of only about $0.0024 per bushel.[5] When a price increase of this size is multiplied by average corn production in South Dakota over the years 1970 to 1977 (105 million bushels), the estimated increased annual income to farmers is $252,000. Diversion of enough corn to supply three plants (22.2 million bushels) would result in a price increase of $0.0073 and an annual income increase to South Dakota corn producers of $766,500. These increases in corn producers' incomes would be bought at subsidy costs of $6.8 million and $20.4 million, respectively. It is unlikely that benefits accruing to other sectors, e.g. labor and services bought by the new gasohol industry and associated multiplier effects, would make up the deficit.

Even if gasoline were replaced by gasohol in all of the West North Central states, only about 450 million bushels of corn would be required and corn prices paid to farmers would increase by no more than about 10 percent. For South Dakota this would mean $18.4 million more going to farmers, not quite enough to offset the $20.4 million gasohol production subsidy required in the state.

Another factor to keep in mind in consideration of this issue is that if a gasohol program of sufficient size to drive up corn prices were implemented, its very success would increase the raw product costs and the fuel costs of ethanol production and would increase the levels of subsidy required. The fundamental problem that cannot be avoided is that under current conditions ethanol costs more to produce in terms of real resource requirement than do alternative fuels (Table 3). No reasonable amount of juggling of prices and subsidies will change this fact and if a decision is made to implement a gasohol program, output and consumption of other non-energy goods and services must be reduced.

The Energy Balance

Comparison of the cost of producing ethanol from corn with the costs of substitute fuels from other sources suggests consideration of a related question: In an energy accounting framework, does corn conversion to ethanol produce more energy than it uses? The answer to this question is clearly "No." As illustrated by Table 4 -- which is taken directly from a table in one of Dr. Scheller's publications (Scheller & Mohr, 4/76, p. 5) -- 303,200 Btu's of energy inputs are used in the production of a gallon of ethanol from corn. Only 121,700 Btu's of usable outputs are produced. The net energy balance is a negative 181,500 Btu's, i.e., 181,500 Btu's of usable energy are lost or used up in the conversion process. Moreover, the energy content of either the corn input or the fossil fuel used in processing is greater than the total amount of energy available in the ethanol plus by-products obtained.

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[5]This price change is computed as follows:

[% change in corn marketed (in the national market)] x [average S.D. corn price]

$$\left[\frac{7.4 \text{ million bushels}}{5488.0 \text{ million bushels}} \right] \times [\ \$1.80/\text{bushel}\ ] = \$0.0024$$

(1970-77 average U.S. production)

Not included in this calculation are the probable price depressing effects of selling the ethanol by-product, distillers dried grains, in the South Dakota feed grain market, and of the substitution in the market of other grains for corn.

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