II. GASOHOL ECONOMICS

ETHANOL COSTS

Ethanol costs* are influenced by the capital investment in and financing of the distillery, the distillery operating costs, and the byproduct credits. The cost of an ethanol distillery for starch and sugar feedstocks is about $1.00-$2.00 for each gallon per year of capacity. Distilleries that rely upon sugar feedstocks are more expensive than those using starch due to the equipment needed to handle the feedstock and to concentrate the sugar solution to a syrup for storage. Coal-fired distilleries are more expensive than oil or gas fueled distilleries, due to the costs of coal handling and pollution control equipment.

For a coal-fired 50 million gallon per year distillery using starch feedstock, the capital related charges are about $0.35-$0.45 per gallon of ethanol, assuming 100% private equity financing and a 13% after tax return on investment. The comparable figure for 100% debt financing with favorable terms is $0.15-$0.25 per gallon. These charges, however, can vary significantly with depreciation allowances, tax credits and other economic incentives.

The major operating expenses are the fuel and feedstock costs. The coal ($30/ton) would cost about $0.10/gallon of ethanol, which is sufficiently less than oil or natural gas to compensate for the added costs of the coal boiler and handling and pollution control equipment Although increased demand could raise coal prices, the effect on the ethanol costs would be relatively small.

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* Ml dollar figures quoted here are for 1978 and are in 1978 dollars.

The largest cost in ethanol production is the net feedstock cost, or the feedstock cost less the byproduct credit. With corn at $2.50 per bushel, the corn grain costs $0.96 per gallon of ethanol and the byproduct credit is about $0.38 per gallon, resulting in a net feedstock cost of $0.58 per gallon. Since farm commodity prices are extremely volatile, the net feedstock and resultant ethanol cost are also variable. A $0.50/bu. increase in corn grain prices (and a proportionate increase in the byproduct credit), for example, would raise the ethanol cost by $0.12 per gallon.

Distilleries which rely on grain feedstocks depend for their byproduct credit on the cost of distillers' grain as an animal feed supplement. There is uncertainty, however, regarding the amounts of distillers grain which can profitably be added to animal feeds. USDA and others have estimated that byproduct credits could begin to drop due to saturation of the domestic feed market at about 2 billion gallons of ethanol production per year (0.13 million bbl./day of ethanol or about 1.8% of the present gasoline consumption). (10, 21, 22) At significantly higher levels of production, new markets for distillers' grain (e.g., exports, protein extracts) would have to be developed or distillers could lose the byproduct credit, increasing the ethanol cost by $0.38 per gallon.

The costs for ethanol produced from various feedstocks are shown in Tables 2 and 3. Although the costs will vary depending on the size of the distillery, ethanol can be produced from corn ($2.50/bu.) in a coal fired 50 million gallon per year distillery for $1.11 (±$0.10) per gallon with 100% private equity financing (including a 13% return on investment) and $0.91 (~$0.10) per gallon with 100% debt financing.* About $0.10-$0.30 per gallon

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* Details are given in note d of Table 2.

TABLE 2

Late 1978 Production Costs for Ethanol
From Grain and Sugar Crops
In a 50 Million Gallon Per Year Distillery

	Grain[a])	Sugar[b])
Fixed Capital	$59 million	$100 million
Working Capital (10% of F.C.)	$5.9 million	$10 million
Total Investment	$64.9 million	$110 million
Operating Costs:		
	$/gallon of 99.6% ethanol	
Labor	0.04	0.05
Chemicals	0.01	0.01
Water	0.01	0.01
Coal ($30/ton)	0009 -	— 0.00 c)
Sub total	0.15	0.07
Capital Charges:		
15%-30% of Total Investment per year[d])	0018 - 0.38	0.33 - 0.66
Total	0.33- 0.53	0.40 - 0.73

a) Includes drying of distillers' grain

b, Includes equipment for extracting the sugar from the feedstock concentrating it to a syrup for storage.

c) Bagasse fueled distillery appropriate for sweet sorghum and sugarcane.

d) There are many, often complex formulae to compute actual capital costs. Economic factors considered include debt/equity ratio, depreciation schedule, income tax credit, rate of- inflation, terms of debt repayment, operating capital requirements, and investment lifetime. However, a realistic range of possibilities for annual capital costs would lie between 15% and 30% of total capital investment.

The upper extreme of 30% may be obtained assuming 100% equity finance and a 13% after tax rate of return on investment. The lower extreme of 15% may be obtained assuming 100% debt financing at a 9% rate of interest. Both calculations assume constant dollars, a 20 year project lifetime, and include a charge for local taxes and insurance equal to 3% of fixed capital costs. For a more detailed treatment of capital costs see OTA, Application of Solar Technology to Today's Energy Needs, Vol. 11, Chapter 1.

Source: OTA and Reference 20.

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TABLE 3

Cost of Ethanol From Various Sources

Feedstock	Price[a]	Net Feedstock Cost[b] ($/gallon ethanol)	Ethanol cost ($/gallon)	Yield[c] (gallons of ethanol per acre)
Corn	$2 .44/bu	0.57	0.90-1.10	220
Wheat	$3.07-4 .04/bu[d]	0 ● 73-1 .08[d]	1.06-1.61	85
Grain Sorghum	$2.23/bu	0049	0.82-1.02	130
Oats	$1.42/bu	0.59	0.92-1.12	75
Sweet Sorghum	$15.00/ton[e]	0.79	1.19-1.52	380[e]
Sugar Cane	$17.03/ton[f]	1.26	1.66 - 1099	520

a) Average of 1974-77 seasonal average prices.

b) The difference in feedstock costs might not hold over the longer term due to equilibration of prices through large scale ethanol production.

c) Average of 1974-1977 national average yields-

d) Range due to different prices for different types of wheats

e) Assuming 20 fresh Wight tons/acre yield, $300/acre production cost-

f) Excludes 1974 data due to the anomalously high sugar prices that Year.

SOURCE: USDA, Agricultural Statistics, 1978 and OTA.

should be added to these costs for deliveries of up to 1,000 miles from the distillery. (The ethanol is currently delivered in tank trucks, but as the production volume grows other forms of transportation, such as barge shipments, rail tank cars, and petroleum product pipelines,* could lower the cost to as low as $0.03 - $0.05 per gallon under favorable circumstances.)

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* Various strategies can be used to eliminate potential problems with the water sometimes found in petroleum pipelines. If ethanol is being transported, the total volume of ethanol in the batch can be kept large enough so that the percentage of water in the delivered ethanol is within tolerable limits. If gasohol is transported, it can be preceded by a few hundred bbl. of ethanol which will absorb any water found in the pipeline, thereby keeping the gasohol dry. Other strategies also exist or can be developed. (23)

VALUE OF ETHANOL IN GASOHOL

For the purpose of this report, value is defined as the price at which ethanol is competitive as a gasoline additive. Calculated simply on the basis of its energy content, ethanol costing $1.10/gal. is equivalent to gasoline selling at the refinery gate for $1.70/gal. (2.5 times the present price), or $44/bbl. crude oil.*

The value of ethanol in gasohol, however, is primarily determined by its octane boosting properties. Although this varies considerably depending on the gasoline and other specifics, OTA estimates the value at 1.9-2.5 times the average crude oil acquisition price (see box on page 26 for the details).

Without subsidies, ethanol presently (July, 1979) has a value of $0.75-$1.00 per gallon. With the federal subsidy of $0.40 per gallon of ethanol ($16.80/bbl. of ethanol or $0.04 per gallon of gasohol), the value is $1.15-$1.40 per gallon; and with some state subsidies of $0.40-$0.70 per gallon ($16.80-$29.40/bbl.) of ethanol, the value is $1.55-$2.10 per gallon.

Ethanol distilled from corn ($2.50/bu.) can be produced in a 50 million gallon per year coal fired distillery and delivered to a service station for $1.20-$1.40 per gallon, making it competitive with the federal subsidy alone if the gasohol is blended at the service station. At this price ethanol

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* Assuming the current value of 1.64 for the ratio of the refinery gate price of unleaded regular to the crude oil acquisition price. (24)

would be competitive without subsidies when U.S. refineries pay an average crude oil price of $20-$ 31/bbl. , or when retail unleaded gasoline costs about $1.10-$1.60 per gallon* on the average.

Several factors, however, can change the estimated value of ethanol. If a special, low octane, low vapor pressure gasoline is sold for blending with ethanol, at low sales volumes the wholesaler might assign a larger overhead charge per gallon sold. Also, the refinery removes relatively inexpensive gasoline components in order to lower the vapor pressure** of the gasoline, and this increases its cost. On the other hand, in areas where gasohol is popular, the large sales volumes lower service station overhead per gallon of gasohol, thus raising ethanol's value. These factors can change the value of ethanol by as much as $.40 per gallon in either direction; and the pricing policies of oil refiners and distributors will, to a large extent, determine whether ethanol is economically attractive as an octane boosting additive.

* Assuming cost relationships, as follows: Refinery gate price equal to 1.64 times crude oil prices plus delivery and retail mark-ups and taxes totalling $0.30-$0.40/gallon. (23)

** The more volatile components of gasoline (e.g., butanes) may be removed to decrease evaporative emissions and reduce the possibility of vapor lock. Although these components can be used as fuel, removing them decreases the quantity of gasoline and the octane boost achieved by the ethanol. Consequently, the advantages of having a less volatile gasoline must be weighed against the resultant decrease in the gasoline quantity and the value of the ethanol. Further research is needed to help resolve the dilemma.

Two Ways to Calculate the Value of Ethanol

Two different values for ethanol can be derived, depending upon where the ethanol is blended to form gasohol.

At the oil refinery, each gallon of ethanol used as an octane booster saves the refinery the equivalent of 0.36 gallons of gasoline by allowing the production of a lower octane gasoline (see section on octane under Technical Aspects of Gasohol). In addition, the gallon of ethanol displaces 0.8 gallons of gasoline directly (2% mileage decrease with gasohol), leading to a total displacement of 1.16 gallons of gasoline per gallon of ethanol. At the refinery gate, unleaded regular costs about 1.64 times the crude oil price, so the ethanol is valued at 1.16 x 1.64 = 1.9 times the crude oil price.

If the gasoline retailer blends the gasohol, the value of the ethanol is somewhat different. Gasoline retailers buy regular unleaded gasoline for about $0.70 per gallon (24) and sell gasohol for a rough average of $0.03 per gallon more than regular unleaded. (9) (The difference between this and the retail price of gasoline is due to taxes and service station mark up, which total about $0.29/gallon. (24) One tenth gallon of ethanol displaces $0.07 worth of gasoline and the mixture sells for $0.03 per gallon more. Therefore, 0.1 gallon of ethanol is valued at $O*1O or $1.00/gallon. This is 2.5 times the July, 1979 average crude oil price of $0.40 per gallon.

Both of these estimates are approximate, and changing price relations between crude oil and gasoline can change the estimates.

SOURCES OF ETHANOL

In the course of developing a large-scale gasohol program, ethanol supplies could be increased by taking advantage of such sources, methods or strategies as the following:

- spoiled and substandard grain
- food processing wastes
- direct imports of ethanol
- reduction of grain exports
- cultivation on set-aside and diverted cropland
- substitution among crops
- substitution of forage for ethanol feedstock crops in livestock rations
- cellulose feedstocks after the late 19801s.

Spoiled and substandard grains and food processing wastes can be utilized to produce ethanol totaling somewhat less than 1% of current gasoline consumption.(1, 2) In some cases, however, they are an unreliable source of supply, or are locally available only in small quantities. Realizing their full production potential will probably involve using them as feedstock supplements for distilleries relying on other sources.

Ethanol can be imported from Brazil for prices lower than it is being produced domestically. Since the imported ethanol costs a minimum of $0.42 per gallon more than the crude oil it could displace, the planned level of imports (120 million gallons per year) would increase our trade deficit by at least $50 million,* and federal plus state subsidies totalling $50 million to $130 million would be paid in the process.

Policies intended to limit the export of grains, or policies which effectively reduce exports by deliberately raising the price of exported grains (e.g., by fixing the price of corn to that of crude oil), can result in additional feedstocks for ethanol production. Recent grain exports have been 70-80 million metric tons/year. These exports could produce about 6-9 billion gallons of ethanol per year, displacing approximately $3-5 billion in imported crude oil. The loss of $10-12 billion in grain export revenues, however, would result in a $5-9 billion net increase in the trade deficit.

With corn at $2.50 bu., imported crude oil would have to cost about $32-$40/bbl. before it would decrease the trade deficit to curtail corn exports to increase the supply of ethanol feedstocks.** When economic forces (e.g., rising prices) reduce the level of grain exports, however, the situation is more subtle. Increasing the prices of grain would decrease the volume of exports, but it might initially increase slightly the gross income from exports. As grain prices continued to rise, however, the gross income from exports would eventually drop.

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* According to the importer, American Gasohol, the import price is at least $1.00/gallon. (4) Each gallon of ethanol, as it is used now, displaces less than 0.8 gallons of crude oil at $0.50/gallon ($21/bbl). If the octane boosting properties of ethanol are exploited, the displacement is less than 1.16 gallons of crude oil per gallon of ethanol. Therefore $1 worth of ethanol would displace less than $0.58 worth of crude oil, resulting in a net increase in the trade deficit of at least $50 million.

** The situation is more favorable if the distillers' grain byproduct can be exported instead of the corn. In this case, there would be no net change in the trade deficit with the current prices of corn and distillers' grain and with crude oil at $20-$25/bbl. , which is near the current price. Pursuing this strategy, however, would increase the international price of corn and decrease the international price of distillers' grain. Consequently, crude oil prices would have to be somewhat higher than $20-$25/bbl. for the, strategy to decrease the trade deficit.

Cultivation on set aside and diverted acreage is often mentioned as a possible source of ethanol feedstocks. In 1978 there were 18.2 million acres in these categories and the 1979 total is about 11.2 million acres.(25) Although the majority of this land is not suitable for corn production, sufficient feedstocks could have been produced in 1978 and 1979 for about two and one billion gallons of ethanol, respectively. The quantity of set-aside and diverted acreage, however, will vary significantly from year to year and there is no assurance that this land will continue to be available for energy production.

In addition to set-aside and diverted cropland, OTA estimates that at least 30 million acres of potential cropland and cropland pasture can be used for the production of ethanol feedstocks in the 1980?s over and above the land required for food, feed, and fiber production. *(26)* This would be sufficient to produce 5-7 billion gallons of ethanol per year.

Crop yields for this land, however, are likely to be more sensitive to weather variations* than the land currently under cultivation. Consequently, a heavy reliance on this land for grain production is likely to increase the year to year variability in grain supplies. This could lead to greater fluctuations in farm commodity prices and could require a larger grain buffer stock to stabilize prices. The required size of the buffer stock, and its added costs, are unknown, but increasing the buffer stock by 10% of the additional grain produced would cost about $0.01 per gallon of ethanol in federal grain storage subsidies ($0.25/bushel year).

* An often cited reason that this land is not now in production is that the soil does not retain moisture well or is prone to periodic flooding. Consequently the crop growth could be very sensitive to the rainfall pattern and could vary significantly from year to year.

The cost of converting this land to crop production varies from negligible amounts to perhaps $600/acre for some forested land. (26) Although federal grants could eliminate the one time cost of conversion, it is not known how much land would actually be brought into production at any given level of farm commodity prices (see next section). Consequently, the full cost of utilizing this land is unknown.

As the demand for ethanol feedstocks increases and more distillers' grain becomes available several types of market induced substitutions can occur. The distillers' grain can substitute for soybean meal in animal feed, which could result in less soybean production. Land which is presently in soybeans could then be used for additional ethanol feedstock production. In addition, some feed corn could be replaced with a combination of forage grass and distillers' grain. There are numerous uncertainties, however, about how much substitution actually will take place* and how much distillers' grain can profitbly be fed to animals. Assuming these substitutions occur, the total quantity of ethanol could possibly be raised from the 5-7 billion gallons per year from potential cropland and cropland pasture to as much as 10 billion gallons per year.

In the 1990's, the quantity of land available for energy crop production beyond the needs for food, feed and fiber will probably drop and ethanol producers may have to convert to cellulosic feedstocks. The potential ethanol production from these sources** is over S billion gallons

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* The soybean meal industry, for example, may continue to buy soybeans and attempt to export the meal. The major customer, however, would probably be the EEC, which might impose import restrictions in order to protect its indigenous soybean mal industry. As a result there could be severe competition between distillers' grain and soybean meal, and the outcome is uncertain.

** Assuming potential yields of 100 gallons of ethanol per ton of feedstock.

per year from crop residues, an additional 10-20 billion gallons per year from increased forage grass production, and considerably more from wood. And based on OTA'S assessment of municipal solid waste, (27) an additional 3-4 billion gallons per year could be obtained from paper derived from this source.

With the potential availability of grain feedstocks, the production of ethanol in the next 3-5 years will be limited primarily by the rate that new distilleries are built. Although production could conceivably reach a level of 7-10 billion gallons per year by the 1990's, expanding the total capacity to a level above 1-2 billion gallons per year would make ethanol production compete increasingly with other uses for farm commodities. In the mid- to long-term this competition may be severe, and to maintain or expand a fuel ethanol industry, distilleries may have to turn to cellulosic materials for their feedstocks.

COMPETITION BETWEEN FOOD AND FUEL

At this early stage in the development of the ethanol fuel industry, the cost of feedstock is tied directly to the value of farm commodities as food. As the ethanol industry expands, however, this relationship could reverse itself. A combination of ethanol subsidies and rising crude oil prices could drive up the price of farm commodities and ultimtely the price of food. 'L'he extent to which this will happen depends critically upon how much additional cropland can be brought into production in response to rising food prices and, eventually, on the cost of producing ethanol from cellulosic feedstocks. These and other major uncertainties, such as future weather and crop yields, make it impossible to predict the full economic impact of a large fuel ethanol program.

The relatively low demand for fuel ethanol feedstocks currently exerts negligible pressure on farm commodity prices. As long as fuel ethanol production is sufficiently profitable, however, new distilleries will be built and feedstock purchases will expand. The increased demand will drive corn prices up toward the distillery break even point and thereby increase the price for all purchasers of corn. Under these circumstances food consumers would be indirectly subsidizing the consumption of fuel.

This indirect subsidy is illustrated in the following example. If the price at which ethanol is competitive increases by $0.12 per gallon, due to increased subsidies or a $2.50/bbl. increase in crude oil prices, corn prices would eventually increase by $0.50/bu. Domestic consumption of 4 billion bushels of feed corn (1976-1977) would cost an additional $2 billion. Although there would be a number of market adjustments, the increased corn cost would eventually appear as higher prices for meat and other food products. Excluding downstream markups, U.S. food expenditures could increase by more than 1%. Farm income, however, could increase by more than 3.5%.

The cost of this indirect subsidy per gallon of ethanol would depend on the supply response to increased corn prices. If ethanol production increased 500 million gallons (about 25 times the current fuel ethanol production) in response to a $0.12 per gallon increase in the price at which ethanol is competitive, the indirect subsidy would still be more than $4 per gallon of ethanol. If the supply response were ten times larger, 5 billion gallons, the indirect subsidy could be more than $0.4.O/gallon.

The previous example is perhaps an oversimplification -- actual impacts on feedstock prices and consumer food expenditures may be larger or smaller, depending on a complex of economic factors. Economic forces, however, will tend to couple the prices of food and fuel and transfer instabilities from one sector to the other. Although rising fuel prices will increase farm commodity prices in any case, a large fuel ethanol program could involve significant indirect costs and increase the inflationary impact of rising fuel prices, unless the program is designed to restrain the purchase of ethanol feedstocks in times of short supply. This would of course greatly increase the financial risks for ethanol producers and make the supply of ethanol uncertain.

COMPETITION WITH OTHER LIQUID FUELS

Whether or not ethanol is worth its cost, including both direct and indirect subsidies depends upon the cost and availability of other liquid fuels and the cost of energy conservation. Ethanol shares an advantage with existing conservation technologies in that it uses current technology and thus it may be an important fuel during the 1980's before possibly less expensive synfuels and newer or improved conservation technologies can be made available. Table 4 permits cost comparisons among some alternative fuel sources.

As an octane boosting additive, ethanol is nearly competitive today. The development of less expensive octane boosters or automobile engines which do not require high octane fuels, however, could seriously curtail the market for ethanol as an octane booster. In this case, ethanol would have to be marketed on its fuel value alone.

As a stand alone fuel, ethanol is unlikely to be competitive with methanol from coal, but it might be competitive as a fuel additive to the more expensive synfuels. The cost uncertainties, however, are too great to reliably predict whether a strong demand for fuel ethanol will continue into the 1990ts.

The long-term viability of the fuel ethanol industry, will depend not only on sustained market demand, but also on the costs of conversion processes utilizing cellulosic feestocks. A major constraint may be the availability of capital for the large investments that are likely to be needed to convert distilleries to the cellulosic processes. These investments, for example, could be as large or larger than the cost of new

TABLE 4

ESTIMATED COSTS IN 1978 DOLLARS OF ALTERNATIVE LIQUID FUELS[1])

Fuel Source	$/MMBTU (RaW Liquid)	$/MMBTU (Refined Motor Fue1[2]))	1990 Potent ial (000 bbl./day)
Fuels Requiring No Automobile Modification			
Imported Crude	3.40	6.20	4500 - 8500
Enhanced Oil Recovery	1.70 - 5.90	3.10 - 10.90	300 - 1500
Oil Shale	4.20 - 6.80	8.90 - 14.103)	30 - 300
Syncrude from Coal	4.70 - 7.60	10.30 - 16.20[4])	50 - 500
Fuels Requiring Automobile Modifications If Used as Stand-Alone Fuels			
Methanol from Coal		5.50 - 7.90	50 - 5005)
Methanol from Biomass		8.20 - 14.60	50 - 500
Ethanol From Biomass		10.70 - 17.80	50 - 500

1) Cost estimtes for synfuels may be low because commercial scale plants have not yet been built. The values given encompass currently accepted best estimates.

2) In order to compare refined liquids (e.g., methanol and ethanol) with unrefined liquids (e.g., crude oil, shale oil, and syncrude), the following methodology is used. Where necessary (shale oil and syncrude), upgrading costs are added to the raw liquid costs. The cost per gallon of refined liquids is then assumed to be 1.64 times the cost per gallon of the upgraded raw liquid, which is the current ratio of the cost of refinery gate regular unleaded gasoline and the average crude oil acquisition cost.

3) Raw liquid cost of $25 - $40/bbl. plus $3.50 - $5.00/bbl. for upgrading-

4) Raw liquid cost of $28 - $45/bbl. plus $S.00 - $7.00/bbl. for upgrading.

5) This is not additive to the potential of syncrude from coal.

SOURCE: OTA, K.A. Rogers and R.F. Hill, Coal Conversion Comparison, prepared for U.S. Department of Energy under contract EF-77-C-01-2468, and Coal Liquids and Shale Oil as Transportation Fuels, A Discussion Paper of the Automotive Transportation Center, Purdue University, West Lafayette, Indiana, July 6, 1979.

oil shale or coal liquification plants of comparable capacity. And comparable investments or subsidies designed to encourage increased conservation and enhanced oil recovery could yield much larger supplies of liquid fuel. Although an assessment of the alternatives has not been conducted, these are important questions which can influence the desirability of fuel ethanol production in the 1990ts.

Although synfuels from coal and shale are expected to be produced during the 1990's, atmospheric build-up of C02 could alter these plans. If C02 becomes an overriding concern, ethanol from crop residues and wood would become much more attractive.

Until the uncertainties are resolved, however, investment in ethanol distilleries is likely to be limited to total production levels below that which is physically possible and economically viable in the 1980's.