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ABSTRACT

The paper explores how continuously expanding world demand for food, feed, and fuel is generating pressure to restructure agricultural land use. In addition, problems related to transfer of agricultural crop land to energy crops are discussed. The technology of energy crops has developed to the point where large-scale commercial production of alcohol from high-yielding energy crops appears to be favorable. As gasoline prices reach $2.00 per gallon, gasahol becomes not only feasible but profitable, particularly when factors such as subsidies and by-product credit are considered. National plans to produce energy crops have been formulated in the United States, South Africa, New Zealand, and Australia. Brazil has already implemented a large scale alcohol fuel program based principally on sugar cane. On the negative side, however, Brazil has already felt the impact of rapidly increasing food prices. The millions who are at the bottom of the economic ladder in Brazil and elsewhere, will be increasingly squeezed as the more affluent increase their claims to cropland. The conclusion is that decision makers in developing and developed nations should carefully assess the impact of energy crop iniatives on food prices and availability before encouraging widespread conversion of cropland into energy crops. (DB)

Food or Fuel: New Competition for the World's Cropland

Lester R. Brown

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As the eighties begin, world oil production is leveling off. Most energy analysts agree that world oil production may not increase much more, if at all. Along with this bleak production prospect, there is a growing uncertainty of supply. At no time since the war decade of the forties has the potential for the disruption of oil supplies been so great. A world price of oil that climbs continually, with no apparent limit in sight, signals a fundamental change in the outlook for liquid fuels. 5

This changing prospect has triggered an intense international search for alternative liquid fuels. Prominent among these are liquefied coal, oil from tar sands and oil shale, and alcohol that can be produced from plant materials. Although there are vast reserves of coal, tar sands, and oil shale, the development of liquid fuel from coal or of oil from these unconventional sources is handicapped by lack of experience. Even under the best of circumstances these are unlikely to become major sources of liquid fuel before the early nineties.

It is against this backdrop that many countries are turning to alcohol distilled from farm commodities as a source of fuel for automobiles. An alcohol fuel industry has several attractions. Automobile engines can readily burn a gasoline/alcohol mixture containing up to 10 percent alcohol without any adjustment. The commercial production of alcohol for industrial purposes is already a well-established industry and the technology for converting plant materials into alcohol is widely dispersed throughout the world. Lastly, distilleries can be built in 6 to 24 months.[1]

This combination of advantages has led several countries to launch agriculturally based alcohol fuel programs. Both Brazil and the United States have announced major programs to convert agricultural commodities into alcohol. Several other food-exporting countries—such as Australia, New Zealand, and South Africa—are actively consider-

I am indebted to my colleague Pamela Shaw for her assistance with the research and analysis underlying this paper. The issue elaborated on in this paper was first discussed in *Running on Empty: The Future of the Automobile in an Oil-Short World* (W. W. Norton), a Worldwatch book by the author, Christopher Flavin, and Colin Norman

ing the conversion of crops into alcohol for fuel on a commercial scale.

This new interest in fuel crops could be a historic landmark. If more and more oil refineries are replaced by alcohol distilleries, the world agricultural economy will be transformed. Although the production of industrial crops, such as cotton, is almost as old as agriculture itself, it has never occupied more than a minute percentage of the world's cropland. Now, with the introduction of fuel crops, the possibility exists for the first time of a major shift of food production capacity to nonfood purposes. The potential demand is virtually limitless: even converting the entire world grain crop to alcohol would not provide enough fuel to operate the current world automobile fleet.

The attractions of an agriculturally based alcohol fuel industry notwithstanding, there are many problems to be considered. The increased production of energy crops will intensify pressures on the earth's cropland—pressures that are already excessive in many parts of the world and that have led to extensive erosion and soil deterioration. Even without the diversion of agricultural production capacity to energy crops, efforts to expand world food production have been losing momentum for nearly a decade. And although the rate of world population growth did slow slightly during the seventies, from 1.9 percent in 1970 to 1.7 percent or less in 1979, the absolute increase in world population continues at around 70 million per year, steadily adding to the number of people to be fed.[2]

The demand by motorists for fuel from energy crops represents a major new variable in the food/population equation. The stage is set for direct competition between the affluent minority, who own the world's 315 million automobiles, and the poorest segments of humanity, for whom getting enough food to stay alive is already a struggle. As the price of gasoline rises, so, too, will the profitability of energy crops. Over time, an expanding agricultural fuel market will mean that more and more farmers will have a choice of producing food for people or fuel for automobiles. They are likely to produce whichever is more profitable.

> "The demand by motorists for fuel from energy crops represents a major new variable in the food/population equation."

The Technology and Economics of Energy Crops

There are essentially two ways to get liquid fuels from vegetative matter—by extracting sap from plants that are naturally high in hydrocarbons or by converting plant materials into alcohol. Although extensive research is under way on plants that will yield a liquid fuel directly, there are already many ways to convert plant materials into alcohol, principally methanol or ethanol. The conversion of forest products into methanol (wood alcohol) is attractive both because of its vast potential and because it does not compete for cropland and other food-producing resources. Methanol's disadvantages are that the technology is not as well established and that its highly corrosive nature presents problems with current automobile engines. It is the production of ethanol, however—likely to be the leading alternative to gasoline in the eighties—that will compete for the world's cropland in a major way.[3] 7

Knowledge of ethanol's potential as an automotive fuel is almost as old as the automobile itself. Henry Ford was an early alcohol fuel enthusiast. Indeed, some of his early cars had carburetors that could be adjusted to use either gasoline or alcohol. Thomas Edison and Alexander Graham Bell were also strong supporters of alcohol as an automotive fuel. In 1922, Bell declared alcohol to be "a beautifully clean and efficient fuel which can be produced from vegetable matter . . . waste products of our farms and even garbage of our cities."[4]

Ethanol (ethyl alcohol) has been produced as an intoxicant from fruits and grains for many centuries. Produced directly from sugar by fermentation or from starches and cellulose that are first converted to sugar and then fermented, ethanol can be obtained from three main categories of crops: sugar crops, such as sugarcane, sugar beets, and sweet sorghum; root crops, mainly cassava, which is also known as manioc; and all the major cereals.

Given the various accepted measurements for crop yields, commodity prices, and alcohol production around the world, both the English and metric systems of measurement are used in this paper, depending on the applicability, with frequent cross-reference to facilitate conversions.

8 Of all the energy crops, sugarcane produces the highest alcohol-yield per hectare. (See Table 1.) Even at the relatively low crop yields prevailing in Brazil, sugarcane produces 3,630 liters of alcohol per hectare compared with only 2,200 liters per hectare of corn, the world's highest yielding cereal. (For comparison purposes, one liter equals .26 gallons or roughly one quart; one hectare equals 2.47 acres.)

Table 1: Alcohol Yield of Selected Crops, United States and Brazil, 1977

Crop	Crop Yield Per Hectare	Alcohol Yield Per Hectare	Alcohol Yield Per Acre
	(metric tons)	(liters)	(gallons)
Sugarcane (Brazil)	54.2	3,630	388
Sweet Sorghum (US)	46.5	3,554	381
Corn (US)	5.7	2,200	235
Cassava (Brazil)	11.9	2,137	228
Grain Sorghum (US)	3.5	1,362	146
Wheat (US)	2.1	773	83

Source: Food and Agriculture Organization; U.S. Department of Energy; Office of Technology Assessment; U.S. Department of Agriculture.

Second after sugarcane in alcohol yield per hectare is sweet sorghum, a crop that has received little commercial attention. As with sugarcane, the stalks are crushed and the syrup is extracted and then distilled to produce alcohol. Although so little sweet sorghum is grown in the United States that no official statistics are kept on its planting, it appears to have an unsurpassed potential as an energy crop in the temperate zone. A modest effort in plant breeding and in research on farming practices to increase yields could pay handsome dividends in terms of overall alcohol yield. In a sense, sweet sorghum is the "sugarcane" of the temperate zone. In North America it can be grown as far north as Minnesota and Michigan. A Battelle Institute study undertaken for the Department of Energy analyzed the potential for alcohol fuel from sugar crops and gave sweet sorghum a very high rating, assuming that a modest investment in research is made to upgrade it. The Battelle study concluded that "of the three sugar crops discussed, sugarcane is the most promising in the near term, sweet sorghum will gain promise in the future, and the sugar beet is so unpromising as to warrant dropping it from the fuels-from-biomass program."[5]

Among the cereals, there is little variation in the rate of conversion to alcohol. Wheat, corn, and grain sorghum all yield approximately the same amount of alcohol per bushel of grain: 2.6 gallons per bushel for corn and grain sorghum, and 2.7 gallons per bushel for wheat. The great variation in alcohol yield per hectare derives almost entirely from the widely varying cereal yields per hectare. The world corn yield per hectare, for example, is nearly triple that of wheat, partly because corn is photosynthetically more efficient and partly because wheat is grown largely under semiarid conditions.[6]

Cassava—also known as manioc—has a promising long-term potential as an energy crop. It can be grown on a wide variety of soils and, although yields are responsive to fertilizers, it does not require modern production inputs. Cassava is also a hardy crop that grows well in semiarid areas. Because of these characteristics, and because it is widely grown by small landholders, it could become an important source of cash income. Manioc can also be cultivated and harvested all year long so that distilleries using it can operate year-round, something they cannot do with sugarcane unless the syrup is extracted at harvest time and then stored.[7]

Any discussion of the feasibility of alcohol fuel must take into account the net energy balance, the net liquid fuel balance, and the costs of production. While the alcohol yield per hectare for various crops can be calculated rather precisely, there is some controversy about whether producing ethanol from crops yields a net energy gain. Part of the confusion arises from the two distinctly different energy balances that must be considered—the total amount of energy consumed and produced in the process, and the amount of liquid fuel involved.

10 According to a calculation by the Department of Energy, producing 100 BTUs of ethanol from corn requires the investment of a total of 109 BTUs—44 BTUs to grow the corn and 65 BTUs to distill the alcohol from it. (See Table 2.) The ethanol contains 8 percent less energy than is invested in its production. If the 14 BTU energy value of the by-product, distillers grain, is included, however, there is a slight net energy gain of 5 percent.

Table 2: Energy Balance of Ethanol Produced from Corn

Energy Consumed	(BTUs)	**Energy Produced**	(BTUs)
Agriculture	44	Ethanol	100
Alcohol processing	65	By-products	14
Total	109	Total	114

Source: U.S. Department of Energy

If the corn is processed in a petroleum-fired distillery and if most of the energy consumed in producing the corn is in the form of oil, there is little if any net gain in liquid fuel. If, however, the distillery is fueled by coal or solar energy, then at least 2.3 gallons of liquid fuel would be produced for every one consumed. If, in addition, the fertilizer used on the corn is produced in a plant that did not use petroleum, then the liquid fuel yield could easily increase to three gallons for each gallon used. New distilleries designed specifically to produce fuel-grade alcohol (as opposed to the older beverage distilleries) promise to increase this ratio to four to one. For a country striving to reduce petroleum imports, this would be an attractive proposition.[8]

One of the advantages of sugarcane as a feedstock is that the fibrous stalks remaining after the cane has been crushed, known as bagasse, can be used to fuel the distillery. This provides a major savings in the energy required for distillation. The combination of a high alcohol

"The high alcohol yield per hectare makes sugarcane exceedingly attractive as an energy crop."

yield per hectare and this built-in source of fuel to operate the distillery makes sugarcane exceedingly attractive as an energy crop.

The energy balance in producing alcohol from crops can also be affected by such other factors as the fertility of the land on which the crop is grown, the distance of the distillery from the final market for the ethanol, and the value of any by-products of the distillation process. When ethanol is produced from grain, the by-product—distillers grain—possesses the original protein of the grain plus some protein from the yeast used in fermentation. Distillers grain can be used as a feed for livestock in communities adjacent to the distillery, or can be dried and transported to more distant markets. Drying the distillers grain requires a substantial amount of energy, however, and therefore lowers the net energy yield of the distillation process.

The high-protein animal feed that results from the distillation process has about twice the crude fiber and one-half the ruminant-digestible protein of soybean meal, the most common high-protein ingredient in livestock feed today. The high fiber content makes it a relatively unsatisfactory feed for poultry and hogs, although it can be used in small amounts if mixed with other high-energy feeds. But dried distillers grain could be a major component of the feed ration for both the dairy industry and in beef-finishing feedlots. Traditionally it has not been used much in feedlots because it has led to somewhat slower weight gain than when more conventional rations are used.[9]

The energy balance and economics of producing and using ethanol as a fuel are enhanced by its octane-boosting properties. When added to gasoline, alcohol "boosts" the octane rating of the gasoline, thus raising the value of the mixture. Instead of simply selling gasohol (90 percent gasoline and 10 percent alcohol) as a higher grade fuel, refineries could take advantage of this effect by producing a less refined gasoline to combine with alcohol. This would save oil at the refinery, thus improving the petroleum "balance" of agriculturally derived alcohol as well as its value as a fuel.

The cost of producing ethanol is determined by such factors as which commodity is used as the feedstock, the effect of weather and loca-

12 tion on the crop yield, the value of any by-products, the size of the distillery and the type of fuel it uses, and the subsidies available for alcohol production and use. Energy crops with the highest alcohol yield per acre do not necessarily result in the cheapest alcohol. (See Table 3.)

Table 3: Estimated Cost of Ethanol From Various Sources

Feedstock	Feedstock Cost	Net Feedstock Cost For Ethanol*	Ethanol Cost
	(dollars)	(dollars/gallon)	(dollars/gallon)
Corn	2.44/bushel	.57	1.00
Wheat	3.56/bushel	.91	1.34
Grain Sorghum	2.23/bushel	.49	.92
Sweet Sorghum	15.00/ton	.79	1.36
Sugarcane	17.03/ton	1.26	1.83

*Includes credit for by-products.

Source: This table is adapted from a much more detailed one compiled by the Office of Technology Assessment in *Gasohol, A Technical Memorandum*.

For example, the Office of Technology Assessment estimates that the capital investment costs in the United States for a sugarcane distillery that uses bagasse as fuel and that has a capacity of 50 million gallons a year are nearly twice those of a coal-fired, grain-alcohol distillery of the same size. Capital investment costs for each gallon of ethanol produced are consequently higher for cane alcohol than for grain alcohol distilleries. On the other hand, the operating costs of the sugarcane distillery are lower if it is fueled by the bagasse. The initial investment costs plus the daily operating expenses add up to roughly 57¢ per gallon of ethanol produced from sugarcane, and 43¢ per gallon produced from corn. Lastly, the cost and value of the feedstock varies. Assuming a sugarcane price of $17 per ton, distillers producing ethanol from sugarcane would pay $1.26 for the feedstock for each gallon of ethanol. Distillers using corn priced at $2.44 per bushel pay less than $1 per gallon for the feedstock, and can further reduce their costs by selling the by-product, dried distillers grain, recouping 38¢ on each gallon of alcohol produced. These price relationships are not necessarily the same in all countries. In Brazil, for example, the cost of growing sugarcane, and thus of producing alcohol, is lower.[10]

The cost of the feedstock currently accounts for about half the price of ethanol. As gasoline prices rise, dealers will be able to sell gasohol at higher prices, and therefore to pay more for ethanol. This in turn means distillers will be able to use more expensive feedstocks if necessary. The Office of Technology Assessment estimates that, even without subsidies, ethanol produced and delivered to U.S. gas stations at $1.20 to $1.40 per gallon would be competitive as a gasoline additive when the average price of crude oil is $20 to $31 per barrel, at which point unleaded gasoline would be selling for $1.10 to $1.60 per gallon on the average.

As retail gasoline prices reach $2 per gallon, gasohol could be competitive without subsidies or credit for by-products even if distillers were to pay $3.50 a bushel for corn, nearly $1 above the February 1980 corn price. With gas at $2 per gallon, if distillers were able to take advantage of both the subsidy and the present by-product credit, they might well be able to pay over $5 a bushel for corn.

These calculations are based on traditional agricultural concepts, with fuel production being considered as an addition to the current agricultural system. But some analysts have recommended redesigning the food-feed system to produce food, feed, and fuel. Even without energy crops, the continuously expanding world demand for food and feed is generating pressure to restructure agriculture.

Throughout the period of intense agricultural modernization since World War II, U.S. Government programs to limit production have encouraged farmers to leave cropland idle. One effect has been to encourage farming practices that maximize output per acre of a particular crop rather than output per acre per year. With land now

14 becoming scarce, the need to use land more intensively could lead to some fundamental shifts in cropping patterns. For example, one approach that would raise the output of land in an overall food-feed-fuel sense would be to double-crop the land with a winter food grain, such as wheat or barley, and a summer energy crop, such as sweet sorghum. Keeping the land covered with a crop for most of the year would both increase the percentage of incident sunlight converted into biochemical energy and reduce soil erosion.

Biologist Barry Commoner argues that restructuring agriculture to include an expansion of the overall cultivated area, a sharp reduction of the soybean acreage, and a rotation of corn, sugar beets, and hay on a large share of the cropland would greatly increase the plant materials that could be converted into alcohol while maintaining the current level of protein output. This approach, which Commoner believes would yield enough alcohol to satisfy virtually the entire U.S. need for liquid fuels, is based on a number of uncertainties, such as the ability to feed vast quantities of distillers grain to livestock efficiently, and the development of a commercial fermentation process that would permit the conversion of such cellulosic materials as cornstalks or hay into alcohol. Leading agricultural scientists, including Sylvan Wittwer and David Pimentel, have questioned the feasibility of basing an agricultural fuel program on a crop rotation that includes the sugar beet. They point out that it has a low photosynthetic efficiency, a low alcohol yield, and a limited adaptability to many of the heavier soils found in the Midwestern Corn Belt. There is also a risk that the removal of large amounts of plant materials normally returned to the soil, such as cornstalks, could lead to a decline in soil organic matter and, therefore, soil fertility.[11]

Regardless of the specific route followed, the economic conditions for the large-scale commercial production of alcohol from high-yielding energy crops appear to be favorable. Most of the world's 315 million automobile owners have the purchasing power to drive the price of corn, sugar, and other fermentable commodities far above current levels. Although subsidies have played a key role in launching alcohol fuel programs, they may eventually become unnecessary as the price of gasoline rises.

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National Plans to Produce Energy Crops

Among the countries already producing ethanol for fuel or actively considering it are Brazil, the United States, South Africa, New Zealand and Australia. Within this group Brazil is the unquestioned leader. It has moved rapidly to develop and implement a national alcohol fuel program, based principally on sugarcane.

Ethanol's potential as a fuel was recognized in Brazil from the early days of the automobile but it was never competitive with cheap petroleum even when it was produced as a by-product of sugar manufacture. Brazil relies on imports for 85 percent of its oil, yet the country has based its vast transportation system—which has to serve the fifth largest land mass of any country in the world—on highways and motor vehicle transport. By mid-1979 Brazil was spending an estimated $6.5 billion annually on oil and importing nearly one million barrels a day.[12]

Brazil's alcohol fuel program was launched in 1975. At that time, the goal was to become self-sufficient in automotive fuel by the end of the century. After the Iranian revolution and the associated increases in the world price of oil during early 1979, the government accelerated its alcohol fuel program. Although official goals beyond 1985 are rather vague, the actions taken suggest a desire to be self-sufficient by the end of the eighties.[13]

Between 1975, when it was launched, and 1985, an estimated $5 billion will pass through the National Alcohol Program as subsidies for production and consumption of alcohol fuel. Government incentives take the form of concessionary financing to help modernize and expand existing alcohol distilleries, to build new distilleries, and to develop agricultural projects to supply them.[14]

From 1975 to 1979, alcohol production increased from 640 million to three billion liters (790 million gallons). In 1979, alcohol accounted for an estimated 14 percent of Brazil's automotive fuel consumption, most of it as gasohol, but in 1980, when it is expected to constitute 20 percent of the total, some of it will be used in new cars designed to run exclusively on alcohol. The exceedingly rapid growth in alcohol production and use reflects both a dynamic entrepreneurial class in Brazil and strong government support.[15]

Industry sources within Brazil believe they can produce 20 billion liters of alcohol for fuel by 1985, enough to provide 60 to 70 percent of the fuel requirements of the projected automobile fleet of 12 million vehicles. Government officials are less optimistic. They project a production of just under 11 billion liters of alcohol by 1985.[16]

The ambitious Brazilian alcohol fuel program is based largely on sugarcane, the most efficient of all energy crops. Sugarcane currently yields 500 gallons of alcohol per acre, nearly 65 percent more than corn, the major distillery feedstock in the United States. Although only 2 percent of Brazil's total land area would need to be planted to sugarcane to achieve the goal of automotive fuel self-sufficiency, this would equal half the total land area currently planted to all crops. Viewed internationally, Brazil's goal of automotive fuel self-sufficiency will require the planting of 16.9 million hectares of sugarcane—more sugarcane than is planted in the 65 other countries that grow the crop.[17]

Although the overriding objective of the Brazilian alcohol fuel program is to rid the country of dependence on imported oil, there are other goals. The government hopes that by creating jobs for presently unemployed rural workers on land that is now unused, the program will help stem the tide of urban migration, improve the country's skewed income distribution, and foster more balanced development throughout the country. But the key to achieving these goals may lie in the successful adoption of manioc as an alcohol feedstock, because manioc can be produced by smallholders on the marginal land most common in the least developed regions of the country.[18]

While Brazil has moved most rapidly to develop energy crops, the United States is now also beginning to accelerate efforts to encourage an alcohol fuel industry based on energy crops. American enthusi-

"Brazil's goal of automotive fuel self-sufficiency will require the planting of more sugarcane than is planted in the 65 other countries that grow the crop."

asm for alcohol fuel has increased in direct proportion to the rise in gasoline prices. Between March and October 1979, a period of unprecedented gasoline price hikes, the number of service stations selling gasohol jumped from 500 to 2,000.[19]

The first major boost for the U.S. alcohol fuel program came with the Energy Act of 1978, which removed the federal gasoline tax of 4¢ on every gallon of gasohol containing alcohol obtained from nonpetroleum sources. Under this tax exemption, effective January 1, 1979, mixing a gallon of ethanol with nine gallons of gasoline exempts the entire ten-gallon mixture from the federal tax of 4¢ per gallon, thus providing an actual subsidy of 40¢ on each gallon of alcohol used as fuel. As of early 1980, some 16 states have also exempted gasohol from the state gas tax. Among them are Colorado, Indiana, Iowa, Kansas, Montana, Nebraska, South Dakota, and Wyoming.[20]

In Iowa, the net state tax exemption on a gallon of gasohol amounts to a subsidy of 65¢ per gallon for alcohol used in gasohol. Combined with the federal tax exemption, the total subsidy exceeds $1 per gallon for alcohol used as automotive fuel. As these combined subsidies took effect, gasohol sales in Iowa leapt from 600,000 gallons in November 1978 to 8.4 million gallons in December 1979, at which point gasohol accounted for 4 percent of all automotive fuel sold in the state that month.[21]

In January 1980, the U.S. alcohol fuel program received a second big boost when the White House announced major new goals for both 1981 and the mid-eighties. The aim is to produce 500 million gallons of ethanol for fuel in 1981, at least six times the amount produced in 1979. Although U.S. ethanol capacity in 1978 was an estimated 540 million gallons, synthetic production, largely from petroleum, accounted for 60 percent of the total. Idle capacity in distilleries, most of which were designed to produce alcoholic beverages, was estimated at 23 million gallons.[22]

To produce 500 million gallons of ethanol for fuel in 1981 is an obviously ambitious goal, considering it takes nearly two years

18 to build a large alcohol distillery. This goal could be realized only if the new capacity consists largely of smaller on-farm distilleries that can be constructed in six months or less. Distilling 500 million gallons of ethanol requires roughly 200 million bushels of corn, the output from two million acres at current U.S. yields. In tonnage terms, this amounts to five million tons of corn, or about 5 percent of projected U.S. grain exports of nearly 100 million tons in 1980. Although the protein component of the distilled grain would be available as feed, much of the energy lost during distillation would have to be replaced with some other feedstuffs.[23]

For the mid-eighties, President Carter's ethanol production goal is two billion gallons. Mixed with gasoline, this would yield 20 billion gallons of gasohol, or nearly one-fifth of the U.S. 1979 consumption of roughly 110 billion gallons of automotive fuel. The mid-eighties ethanol production goal would require 800 million bushels of corn or its equivalent. This would amount to 20 million tons—one-fifth of the current exportable grain surplus.[24]

The January 1980 announcement outlined a program for the next decade, although the government did not indicate specific goals beyond the mid-eighties. All told, it is proposed that somewhere between $8.5 billion and $13 billion be committed to encouraging the alcohol fuel industry. Many of the incentives in this multi-billion dollar package are already in effect, including the exemption of gasohol from the 4¢-a-gallon federal gasoline tax. In order to provide investors in alcohol fuel distilleries the assurance of a long-term market and profitability for their product, the President proposed that the gasohol tax exemption be made permanent. When queried about the new U.S. fuel crops initiative, Under Secretary of Agriculture James Williams responded, "the purpose . . . is to send the signal that we are ready for going ahead with a massive plant construction program."[25]

The principal new component in the program was $3 billion in proposed new federal loans and in loan guarantees for those investing in alcohol distilleries. This figure includes an estimated $300 million to assist small-scale producers such as individual farmers who wish to produce their own on-farm fuel supplies. In 1979, the Bureau of Alcohol, Tobacco and Firearms received over 4,000 requests for non-commercial distillery licenses, up from only 18 letters in 1978.[26]

Exactly how far the proposed alcohol fuel initiative can proceed based on corn or other cereals remains to be seen. Apart from other constraints, there may be a limit to the amount of distillers grain that can be effectively absorbed as a feedstuff. Producing two billion gallons of alcohol from corn would yield as a by-product 17 times as much distillers grain as was consumed in the United States in 1976. Unless the market for distillers grain can be expanded rapidly, such an enlarged supply could lower prices and the commercial attractiveness of alcohol produced from cereals.[27]

In addition to the program announced by the White House, the Department of Energy is already looking into the use of sweet sorghum to produce ethanol. Over the long term, the energy department believes that sweet sorghum could become the dominant energy crop in the United States. By the end of the century, according to their analysts, 14 million acres of cropland could be planted to sweet sorghum, which would yield 8.3 billion gallons of ethanol per year. This acreage would be rather evenly divided between the Midwest, where the sorghum would replace some corn, and the Southeast.[28]

Another potential source of domestically produced ethanol in the United States is agricultural wastes. The Department of Energy estimates that it is now economically feasible to convert up to four-fifths of the country's cheese whey, citrus wastes, and other food processing wastes into alcohol. If all the distilleries were in place, these sources could yield close to 500 million gallons of ethanol in 1980, increasing to 640 million gallons by the end of the century.[29]

Although ethanol can become a significant source of liquid fuel in the United States, it could not become the dominant fuel source for automobiles if it is produced from grain. Converting the entire U.S. grain harvest into alcohol would not yield more than 30 billion gallons, or 30 percent of U.S. annual gasoline consumption. While Brazil can consider producing automobiles that burn alcohol exclusively, in the United States ethanol will probably be limited to its role as an octane booster when mixed with gasoline in small amounts.

Another country that has examined carefully the potential for producing liquid automotive fuel from agricultural commodities is New Zealand. The most likely feedstock for alcohol distilleries there would be a type of sugar beet or fodder beet. The New Zealand Energy Research and Development Committee reports that "it is technically possible to provide all road transport fuel which present projections say New Zealand will require in 2000" from energy crops. In examining the balance-of-payments consequences of moving toward energy crops as a source of road transport fuel, the committee notes that "energy farming could save as much as $2 of foreign exchange for every $1 of foreign exchange earnings lost by way of displaced agricultural production." What this particular calculation does not reflect, of course, is the impact on food prices outside New Zealand if such a strategy were to be pursued. The authors of the study conclude that "energy farming is one alternative which offers New Zealand a much more secure supply of transport fuel at a cost that is less dependent on international politics and other factors beyond our control."[30]

Achieving transport fuel self-sufficiency in the year 2000 would require New Zealand farmers to plant between 700,000 and 1.3 million hectares of fodder beets, sugar beets, or corn. This compares with a total current cropland area in the country of 835,000 hectares. In effect, New Zealand would need to at least double the current area under crops if it were to become fuel self-sufficient without taking land that is already being used to produce food.[31]

In Australia, which ranks third behind the United States and Canada as an exporter of cereals, a strong commercial interest in liquid fuels is beginning to emerge from the private sector. Australia's AMPOL Petroleum Limited and Biotechnology Australia Proprietary Limited have calculated that within five years Australia could be producing 15 to 20 percent of its fuel for motor vehicles in the form of alcohol distilled from wheat. The two firms estimate that satisfying that amount of motor fuel needs would require roughly as much wheat as Australia currently produces.[32]

The two companies have joined forces to begin operating a pilot plant at a former brewery in Sydney. They plan to use the continuous fermentation process for producing alcohol rather than the batch fermentation process that is used in Brazil and elsewhere. The pilot plant will not only test the process, but will also give the companies better data on costs. The managers of the joint project hope continuous fermentation will mean they can produce 440 million gallons a year within five or six years—enough to satisfy one-tenth of the Australian gasoline market. During the early years of the project they believe grains will be the most desirable feedstock for alcohol manufacture.[33]

An Australian study undertaken by the Commonwealth Scientific and Research Organization analyzed liquid fuel prospects and reported that Australia could get almost three-quarters of its transport fuel from crops, crop residues, and forest products. Such materials as cereal residues, bagasse from sugarcane, and forest refuse could produce as much as 1.3 billion gallons of alcohol. Seen against Australia's current annual consumption of just under four billion gallons of gasoline, this could make a significant contribution.[34]

Yet another country that has recently looked at the production of automotive fuel from crops is Austria. During the late seventies, Austria's population stopped growing but its agricultural output continued to expand, with the result that it is now producing an exportable surplus of grain. The grain surplus, totaling 200,000 to 300,000 tons per year, is being exported to Eastern Europe, principally Poland, which is eager to take the grain. But exporting wheat poses a fiscal problem for Austria, as the domestic wheat price is well above the world market price. Each ton of wheat that was exported during 1978/79 was subsidized at the rate of $84 per ton.[35]

The Fuel From Biomass Project, sponsored by the Austrian Ministry of Science and Research, has seized upon this exportable surplus of grain as a potential source of alcohol for fuel. As a result, Austria is now seriously considering the construction of a small demonstration plant to convert grain into fuel-grade alcohol. The distillers grain remaining after the fermentation is slated for use as a high-protein feed for livestock, which would reduce the demand for imported soybean and fishmeal.[36]

South Africa, which currently leads the world in the production of liquefied fuel from coal, also has a large project to produce alcohol from crops. It is planning to use both cassava, which is a dietary staple in many parts of Africa, and sugarcane as raw materials for the production of alcohol. Current plans call for converting the Makatini Flats in northern Zululand, a semiarid plain with sparse vegetation, into cassava plantations. South Africans talk of converting this arid plain into an "oil field."[37]

The South African cassava project as outlined is exceedingly ambitious. Involving huge plant nurseries that will produce cassava seedlings through a rapid cloning process, it calls for some 13 ethanol distilleries in the Makatini Flats area. These would produce 137 million gallons of liquid fuel annually and employ a total of 2,600 people in cassava production and alcohol distillation. It is also being promoted by the South African Government as a way of encouraging rural development. To the extent that cassava can be grown in areas that were not producing anything of agricultural value and with resources that would not otherwise be used to produce food, these new "oil fields" will not compete with food crops.[38]

The sugarcane part of the South African alcohol fuel project, however, would compete directly with food crops. Indeed, in order to encourage greater sugarcane production, the government is guaranteeing water supplies to farmers who will grow sugarcane explicitly for the production of alcohol. Under this arrangement, sugarcane grown as an energy crop would in all likelihood divert both land and water from food production.[39]

South Africa is also the site of another innovative experiment in liquid fuels. The Department of Agricultural Technical Service is conducting a pilot project using sunflower oil as a fuel substitute in

"The sugarcane part of the South African alcohol fuel project would compete directly with food crops."

diesel-powered tractors. Sunflower seed oil apparently has worked well in the first 100 hours of trials in a diesel engine. If this should prove successful, it is estimated that corn farmers could grow enough sunflowers on just 10 percent of their land to provide all the fuel for their tractors.[40]

Although the national alcohol fuel programs sketched out above are the most advanced, other countries are exploring the potential. Some are looking at agricultural by-products while others are considering the direct conversion of farm commodities into alcohol. Kenya is building an alcohol distillery that will use the molasses by-product of its sugar mills. Designed to use 180,000 tons of molasses a year, it will produce ethanol for blending with gasoline in Nairobi.[41]

The Sudan is also considering molasses-fed distilleries. The production of sugar from the vast new acreage of sugarcane to be planted in the Kenana Project between the White and Blue Niles will generate a large quantity of molasses. With no nearby market for it and with the nearest port 1,600 kilometers away, the conversion of molasses into liquid fuel for local use solves simultaneously the transport problems associated with the export of molasses and the movement of imported liquid fuels to the project area.[42]

Thailand, on the other hand, is interested in an agricultural fuel industry partly as a way to stabilize the prices of its agricultural commodities. It is seeking bids for the construction of distilleries that could be adapted to whatever crop might be in greatest surplus—cassava, maize, rice, sugarcane, or molasses. And in the Philippines, the government has undertaken a crash program to produce alcohol fuel from sugarcane. The production of "alcogas" (gasohol) was originally due to begin in 1982, but the government recently stepped up the program, setting an alcohol production goal for 1981 of some 5.8 million gallons of oil equivalent, and doubling the 1989 goal to an estimated 244 million gallons of oil equivalent. For the time being the alcohol will be derived largely from cane, although the government is also looking into the potential of using cassava and sweet potatoes.[43]

24 Interest in alcohol fuel is also strong in other sugar-surplus, oil-deficit countries of the Third World, where sugar prices have fluctuated while oil import bills have climbed. The balance-of-payment gains from the conversion of sugar into alcohol are obvious to economic policymakers. The Dominican Republic, Guyana, and Jamaica have each initiated feasibility studies of alcohol fuel production. A construction firm based in White Plains, New York, that builds alcohol distilleries reports that it now receives some 30 inquiries per week, mostly from sugarcane-producing countries, compared with perhaps one per week five years ago.[44]

The Impact on Food Supplies and Prices

The numerous national programs to divert agricultural resources to the production of fuel crops come at a time when efforts to expand world food output are losing momentum. Between 1950 and 1971, per capita grain production worldwide increased by some 30 percent, leading to a substantial improvement in nutrition not only in industrial countries but in much of the Third World as well. Since 1971, however, growth in world food output has slowed, scarcely keeping pace with population growth. The failure of world grain output to match the increase in both population and incomes led to rising food prices during the seventies.[45]

As food production has slowed, global food insecurity has increased. Throughout the sixties and early seventies, the world had two major food reserves—large, often burdensome, stocks of grain and a vast area of cropland idled under U.S. farm programs. Together these provided a period of unprecedented stability in world food supplies and prices.

As recently as 1972, over 60 million acres of U.S. cropland were idled under farm programs. (See Figure 1.) Since then most of the idled farmland has been returned to production. Even with this addition, however, the production of food in some years has not matched the growth in world demand. As the eighties begin, the world has only one food reserve left—its stocks of grain.

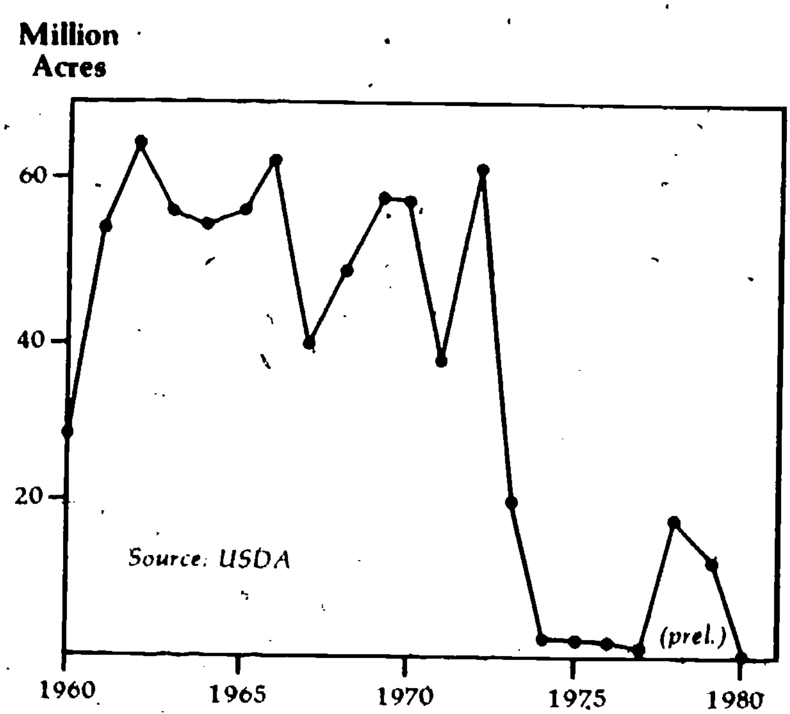

Figure 1: U.S. Cropland Idled Under Farm Programs, 1960-80

In addition to the decline in reserves, production has become more erratic. Efforts to double food output over the last three decades have pushed agriculture into areas of marginal rainfall and onto marginal soils. The result of farming where rainfall is unreliable is dramatically evident in the Soviet Union, where a crop failure every third year or so is commonplace in the virgin lands—the new area brought under the plow during the fifties. The 1972 Soviet decision to offset a crop shortfall through imports rather than through belt tightening, as they had always done in the past, has had an extraordinarily destabilizing effect on the world food economy, leading to wide fluctuations in world grain prices.

26 A further source of instability has been the growing dependence of the entire world on one region, North America, for its food supplies. Both the United States and Canada are affected by the same climatic cycles. As a crop failure in one is likely to be associated with a failure in the other, heavy reliance on the region is even riskier than it at first seems.

World demand for grain has been expanding by some 30 million tons per year over the past decade. Of this total, the bulk is needed to cover the increase in human numbers, leaving little to upgrade diets. While world population growth has slowed, the absolute year-to-year increase remains at 70 million. In effect, the gradual decline in the rate of population growth has been offset by the increase in the size of the population base.[46]

Although population growth has dominated the growth in world food demand, rising incomes have also contributed to the increase, particularly in areas where consumption of livestock products, and the grain to produce them, has been rising rapidly. Prominent among these are a few industrial countries, such as Japan and the USSR, where meat consumption had until recently been relatively low; and the oil-exporting countries, where incomes are rising at an unprecedented rate.

On the supply side, growth in the world cropland base has slowed markedly since mid-century, expanding only one-fifth as fast as population. Other prominent reasons for the slowing growth in world food output are the continuing conversion of prime cropland to nonfarm uses, the excessive erosion of soil on at least one-fifth of the world's cropland base, the rising cost of energy for farmers, and the diminishing returns on additional applications of fertilizer in agriculturally advanced countries.[47]

All the forces that contributed to the loss of momentum on the food front during the seventies seem certain to intensify in the eighties. Even without the competition from energy crops, the world will be hard pressed to avoid a decline in per capita food production during the decade if the projected increases in population materialize.

"**Growth in the world cropland base has slowed markedly since mid-century, expanding only one-fifth as fast as population.**"

It is against this backdrop that the emergence of national energy crops initiatives must be evaluated.

The potential claim of automobiles on future food-producing resources can best be illustrated by comparing the area of cropland required to feed a person with that needed to run an automobile on ethanol. Per capita grain consumption in developing countries averages roughly 400 pounds annually, or just over a pound per day. In the most affluent countries, where diets are rich in livestock products, each person consumes an average of 1,600 pounds of grain, including the amount eaten directly in cereal products and that consumed indirectly in the form of meat, milk, and eggs.[48] At average yields of grain, satisfying the annual food needs of a typical consumer in the Third World requires roughly one-quarter of an acre of cropland, whereas the more affluent consumer requires nearly an acre. (See Table 4.)

Table 4: Annual Per Capita Grain and Cropland Requirements for Food and for Automotive Fuel

	Grain (pounds)	Cropland* (acres)
Subsistence Diet	400	.2
Affluent Diet	1,600	.9
Typical European Automobile** (7,000 miles/yr. at 25 mpg)	6,200	3.3
Typical U.S. Automobile** (10,000 miles/yr. at 15 mpg)	14,600	7.8

*Based on average world grain yields in 1978, according to the U.S. Department of Agriculture
**Fuel use converted at 380 liters of alcohol per metric ton of grain.
Source: Worldwatch Institute.

28 An automobile run on ethanol requires far more grain than a person does. A typical American car fueled by ethanol would require the processing of over seven tons of grain per year. In Western Europe, where cars are more fuel-efficient and are driven less, the typical automobile could be run on a little over three tons of grain per year. These numbers are in a sense hypothetical because, except for Brazil, no country has yet proposed running automobiles exclusively on alcohol. In the United States, only cars owned by farmers with distilleries are likely to be run exclusively on alcohol in the near future. These figures do, however, illustrate how quickly alcohol fuel programs would absorb vast amounts of grain.

Running a typical American automobile entirely on ethanol would require almost eight acres, given the average world grain yield, while a European car would require just over three. Land requirements vary of course with grain yields. If wheat grown in low rainfall areas such as Australia or the U.S. Great Plains is used as the alcohol feedstock, then land requirements are far higher than if corn grown in the U.S. Corn Belt is used. In Brazil, where cars are smaller and where sugarcane with its higher alcohol yield per acre is used, two acres of land might support an automobile.

As for gasohol, providing fuel for the typical U.S. car would require 1,460 pounds of grain in order to provide a 10 percent mix of ethanol with gasoline. This is slightly less grain than an affluent North American consumes directly and indirectly as food. Nevertheless, the cropland requirements of an American car owner who switches to gasohol based on grain would nearly double, rising from .9 to 1.7 acres. To the extent that the distillers grain is used for livestock feed, the cropland required per person is reduced.

These calculations on the amount of cropland needed to run an automobile on ethanol or gasohol are in one important sense understated, for they do not take into account the liquid fuel used in the production of alcohol. If the petroleum used to produce one acre of grain or sugarcane is deducted from the liquid fuel that acre produces, it is clear that a substantially larger area of cropland is required to run an automobile on ethanol.

The social and political ramifications of a massive production of energy crops will probably surface first in Brazil, the only country that is committed to running its entire fleet of cars on alcohol. When President Figueiredo signed a protocol in September 1979 with the National Automakers Association confirming the intention of producing 250,000 automobiles in 1980 that would run entirely on alcohol, he was in effect claiming some 200,000 hectares of cropland for sugarcane. Government plans to produce 10.7 billion liters of alcohol by 1985 will require nearly three million hectares of sugarcane, the equivalent of 10 percent of Brazil's cropland. If the far more bullish projections of the alcohol fuel industry materialize, production will reach 20 billion liters and the area planted to sugarcane for fuel will approach one-fifth of the country's cropland.[49]

Brazil has one of the world's most widely skewed income distribution patterns, with a ratio of 36 to 1 between the average income of the richest one-fifth of its population and that of the poorest one-fifth. The population of 121 million Brazilians includes some of the world's wealthiest individuals as well as the largest segment of severely improverished people outside Asia. A 1975 study showed that only one-third of all Brazilians were eating a sufficiently nourishing diet, measured against minimum requirements outlined by the U.N. Food and Agriculture Organization and the World Health Organization. Evidence of malnutrition was found in the country's high infant mortality rate and in the fact that less than half the children under the age of 18 at the time had reached the normal weight for their age.[50]

The decision to turn to energy crops to fuel the country's rapidly growing fleet of automobiles is certain to drive food prices upward, thus leading to more severe malnutrition among the poor. In effect, the more affluent one-fifth of the population who own most of the automobiles will dramatically increase their individual claims on cropland from roughly one to at least three acres, further squeezing the millions who are at the low end of the Brazilian economic ladder.

Although geography textbooks have long described Brazil as a country with a large unrealized food production potential, one to which the rest of the world could turn when shortages developed, its record on the food front has in fact been unimpressive. Despite its vast land resources, Brazil is a chronically grain-deficit country, drawing on grain imported from aboard. (See Table 5.) In 1979, imports soared to a record 5.7 million tons and in 1980 they are projected to go even higher, making Brazil by far the largest grain importer in the Western Hemisphere. While drought in key food-producing

Table 5: Brazil, Net Grain Trade, 1961-80

Year	Quantity*
	(million metric tons)
1961	−2.0
1962	−2.3
1963	−2.6
1964	−1.3
1965	−2.1
1966	−1.4
1967	−2.1
1968	−2.3
1969	−1.2
1970	−1.5
1971	+ .4
1972	−1.1
1973	−2.8
1974	−2.4
1975	− .3
1976	−2.3
1977	−1.2
1978	−2.2
1979	−5.7
1980 (prel.)	−6.1

*Plus sign indicates net exports; minus sign, net imports.
Source: U S Department of Agriculture.

"Energy crops compete not only for land but also for agricultural investment capital, water, fertilizer, farm management skills, agricultural credit, and technical advisory services."

regions at least partly explains this recent upsurge, the diversion of agricultural resources to the production of sugarcane is undoubtedly also a factor.

Brazilian officials claim that the production of energy crops will be in addition to rather than in competition with that of food crops. Yet energy crops compete not only for land but also for agricultural investment capital, water, fertilizer, farm management skills, farm-to-market roads, agricultural credit, and technical advisory services. In the absence of a planned economy where all agricultural inputs are carefully controlled and clearly tagged for the production of either food or energy, it would seem to be impossible to launch a major energy crops program without siphoning resources away from food production. The assumption that energy crops will not compete with food crops may be both naive and politically risky. The upward pressure on food prices that will be generated by the rapid expansion of energy crop production could put a severe strain on the Brazilian social fabric and political system.

The immediate consequences of the Brazilian energy crops program may be more internal than external, but the more recently launched effort in the United States has broader ramifications. If U.S. cropland is shifted to energy crops to fuel automobiles on a massive scale, it will be at the expense of the exportable surplus of grain. Over the past generation, the entire world has come to depend heavily on North American grain exports, with just over four-fifths of the total being from the United States. (See Table 6.)

All but a handful of countries now import grain, most of it from North America. Since World War II, scores of countries have become food importers, yet not one new country has emerged as a significant cereal exporter during this period. Close to a dozen countries —including Algeria, Belgium, Japan, Lebanon, Libya, Senegal, Singapore, Switzerland, and Venezuela—now import more than half their total grain supplies.[51]

The cereals exported from North America—enough to feed 500 million people at Third World consumption levels—consist of large

Table 6: The Changing Pattern of World Grain Trade*

Region	1934-38	1948-52	1960	1970	1978
		(million metric tons)			
North America	+ 5	+23	+39	+56	+104
Latin America	+ 9	+ 1	0	+ 4	0
Western Europe	−24	−22	−25	−30	− 21
East. Europe & USSR	+ 5	0	0	0	− 27
Africa	+ 1	0	− 2	− 5	− 12
Asia	+ 2	− 6	−17	−37	− 53
Australia & N. Zeal.	+ 3	+ 3	+ 6	+12	+ 14

*Plus sign indicates net exports; minus sign, net imports.
Source: Food and Agriculture Organization, U.S. Department of Agriculture, and author's estimates.

quantities of both food and feed grains, principally wheat and corn. Although in industrial countries grains such as corn are used primarily for livestock feed, in some parts of the world corn is a leading food. Indeed, in a dozen countries in Latin America and Africa, it is the food staple.

As more and more alcohol fuel distilleries are built in the United States in order to meet the official goal of producing two billion gallons of ethanol by the mid-eighties, the exportable surplus of grain will be reduced accordingly. In addition to the traditional buyers in the North American grain market—the flour millers, the feedlot operators, and the grain-importing countries—there will be a fourth, potentially large, group: the distillers.

Exactly how high the price of grain could eventually be driven by distillers is difficult to say. Obviously, the higher gasoline prices go, the more distillers can afford to pay per bushel for grain. Experience in other countries, such as France, East Germany, Greece, Singapore, and Turkey, indicates that motorists can and will pay $3 or more per gallon. There is little reason to doubt that American motor-

"**In addition to the traditional buyers in the North American grain market, there will be a fourth, potentially large, group: the distillers.**"

ists, with their much greater purchasing power, will not ultimately pay as much.

When gasoline reaches $2 per gallon, given the existing gasohol subsidies, U.S. distillers could probably afford to pay $5 a bushel for corn. If the price of gasoline should reach $3 per gallon, as it has in many other countries, distillers might be able to pay close to $6 per bushel for corn without subsidies and credits. If the phased decontrol of oil prices in the United States proceeds on schedule and oil prices move to the world market level by the end of 1981, gasoline prices will rise accordingly.[52]

Under these circumstances, U.S. distillers will be in a strong position to bid for a growing share of the U.S. grain harvest. In the absence of governmental intervention to restrict the amount of grain that will be converted to alcohol, the world price of grain will be driven steadily upward. Only when the price of alcohol produced from grain reaches equilibrium with the price of gasoline produced from petroleum will the growing conversion of agricultural commodities into alcohol come to a halt.

Agriculturally based alcohol fuel programs designed to produce fuel for automobiles in Brazil and the United States are evolving in a way that threatens to divert food resources to nonfood uses and thus to raise food prices. Yet a carefully designed alcohol fuel program that gave farmers first priority in the use of ethanol for tractors, farm trucks, and irrigation pumps would help ensure future food supplies when oil supplies begin to dwindle. Such an emphasis would be a major step toward the creation of a sustainable food production system and of a sustainable society.

Choosing Food or Fuel

Turning to energy crops as a source of automotive fuel opens a new chapter in the history of human efforts to achieve an adequate food supply. For the first time since agriculture began, the world is faced with a potentially massive diversion of agricultural resources to the production of nonfood crops. Unfortunately, this is beginning to happen at a time when efforts to expand world food output are losing momentum, when food prices are rising, and when malnutrition is increasing.

Whether the use of cropland to produce fuel for automobiles can be justified is a complex issue, one that political leaders will be wrestling with for years to come. Of the many considerations, the most critical one may be the difference between the perceived national interest in energy crops of food-surplus countries and that of food-deficit countries.

The attractions of alcohol fuel are clear. For countries buffeted by soaring oil prices and possible supply disruptions, the prospect of an easily available substitute for some of the imported oil is an inviting one. Although the world's oil reserves are concentrated in a handful of countries, the potential for producing energy crops is as widely diffused as agriculture itself.

There are also some solid environmental reasons to support alcohol fuel: it is clean-burning when used alone and, when mixed with gasoline, it can substitute for lead as an octane booster. In contrast to the burning of petroleum, liquefied coal, or other automotive fuels of fossil origin, alcohol produced from plant materials does not increase the amount of carbon dioxide in the atmosphere, unless of course it leads to an overall reduction in the plant material in the world. In addition, alcohol is a renewable resource, a potentially important component in any effort to create a sustainable economy.

Economically, the move toward alcohol fuel is often justified by the additional employment it would create. Energy crops production and alcohol distillation are far more labor-intensive than are oil production and refining. And because distilleries are dispersed throughout the countryside, close to their feedstock supplies, they generate industrial as well as on-farm employment in rural areas where unemployment is usually highest. Jobs created in the countryside of the Third World can also help slow the migration to the mushrooming squatter settlements that surround so many cities.

One inevitable consequence of energy crops programs will be a reassessment of national population policies. As food-exporting countries, particularly the United States, attempt to increase automotive fuel self-sufficiency by converting exportable grain supplies into fuel, food-deficit countries will be forced to become more self-sufficient. In the scores of countries where rapid population growth has led to a greater dependence on U.S. food exports, the need to accelerate population education and family planning programs will be brought into sharper focus.

Programs to produce energy crops domestically have found a ready constituency. Distillers have an obvious interest, one that is certain to expand as the number of distilleries increases. For farmers, an automotive fuel industry based on agricultural commodities has a strong economic appeal. They see alcohol fuel as a way not only of expanding the market and boosting the price for their products but also, if they distill their own fuel, of becoming energy self-sufficient. Within the United States, members of Congress from the Midwestern Corn Belt have been among the most active supporters of the gasohol program.

Alcohol fuel has a powerful political appeal to motorists who bear the brunt of rising gasoline prices and who feel vulnerable to possible oil supply disruptions. The political influence of automobile owners in countries at intermediate stages of economic development, such as Brazil, should not be underestimated. The people who own cars in these societies are the urban elite who also dominate the political power structure. As governments in the Third World consider diverting cropland to the production of fuel crops rather than food, those who own automobiles may have a disproportionately large say in the matter.

These attractions of agriculturally derived alcohol fuel must be set against its potential impact on world food prices. By far the most serious environmental impact of energy crops will be the additional pressures they put on cropland. The doubling of world food output over the past generation has led to the adoption of cropping practices that are resulting in excessive soil erosion. At least one-fifth of the world's cropland is now losing topsoil at a rate that is undermining its productivity. With the demand for food projected to double again over the next generation, it will be difficult to lighten the demands on soils and to arrest their long-term deterioration. If, in addition, vast areas are planted to energy crops, the problem will become even more unmanageable.

As the number of distilleries multiplies, the production of energy crops will expand until an economic equilibrium is reached between the price of agricultural commodities used as distillery feedstock and those used for food or feed. In the absence of any governmental limitations on the conversion of agricultural commodities into fuel, the price of oil could eventually set the price of food.

The expanding production of fuel crops will underline the vast disparities in income within and among societies as perhaps nothing else has ever done. Until recently, the average per capita claim on the earth's food-producing resources has not usually varied from the richest to the poorest countries by more than a factor of five to one. With the advent of energy crops, however, the ratio could increase dramatically. In effect, the use of energy crops to fuel automobiles permits the world's affluent to expand greatly their claim on the world's cropland area.

In the absence of governmental intervention to restrict the conversion of foodstuffs into fuel, affluent motorists will be able to bid food resources away from the world's poor. As the price of oil rises, so will the profitability of producing agriculturally derived fuels. In the United States, which has 40 percent of the world's automobiles and which accounts for fully half of all the gasoline consumed in automobiles, the political pressures to produce liquid fuels domestically will be particularly strong.[33] The phased decontrol of oil prices in the United States, scheduled to be completed by October 1981, will raise the domestic price of oil to the world level, whatever it is at that time. By late 1981, when the price of gasoline will almost certainly be

"In the absence of governmental limitations on the conversion of agricultural commodities into fuel, the price of oil could set the price of food."

above $2 and may be closer to $3 a gallon, the production of automotive fuels from agricultural commodities may be highly profitable even without government subsidies on gasohol.

As the social cost of diverting a growing share of the world's food-producing resources to the production of automotive fuel becomes evident, so, too, may the need to reexamine existing transportation policies. The social consequences of turning to energy crops raise doubts about whether industrial societies should continue to rely so heavily on cars and whether developing countries should attempt to make the automobile the centerpiece of their transportation systems.

Where the goal is to reduce oil imports, alternative measures to achieve the same end deserve to be examined. Relatively modest improvements in public transportation, for example, could markedly reduce dependence on automobiles in urban areas. Within the United States, such modest measures as the banning of automatic transmissions in new automobiles, except those for the physically handicapped, would save more fuel by the mid-eighties than the ambitious alcohol fuel program is expected to yield.[54] Such a step would obviously involve some "sacrifice" on the part of drivers preferring automatic transmissions, but this should be weighed against the worldwide social costs of diverting food production resources to energy crops.

The question is not whether there should be an alcohol fuel industry. Clearly, there are many possibilities for converting agricultural wastes and other sources of plant materials into automotive fuels that need to be urgently pursued. Over the longer term, a carefully designed alcohol fuel program based on forest products and cellulosic materials of agricultural origin could become an important source of fuel, one that would not compete with food production. Liquid fuel from plants, whether in the form of alcohol or as direct hydrocarbon extracts, is an energy source that needs to be aggressively exploited everywhere. At issue is whether governments can encourage the production of alcohol fuel without inadvertently launching an industry that competes directly with food production.

If the potentially adverse effects of current programs to produce fuel from crops are to be minimized, several steps must be taken imme-
38 diately. The governments launching these programs need to warn food-deficit countries of the potential reduction in exportable food surpluses so that they can adjust their agricultural and population policies accordingly. Secondly, the move toward energy crops reinforces the need for an internationally coordinated effort to arrest the excessive erosion of topsoil. Without such an initiative, the widespread planting of energy crops will accelerate the deterioration of the world's cropland base. Where agricultural fuel programs are launched, priority in the use of fuel should be given to tractors and other farm uses over automobiles. And finally, a global food-price monitoring system that would be sensitive to the impact of alcohol fuel programs is needed. Such a system is essential if political leaders are to assess the worldwide impact of national energy crops initiatives on food prices.

Within the food-exporting countries, the short-run attractions of converting exportable food surpluses into alcohol fuel are undeniable. Whether the longer term political effects will be as attractive is less clear. In a world that no longer has any excess food production capacity, the decision to channel foodstuffs into the production of automotive fuel will inevitably drive food prices upward. For the world's affluent, such rises in food prices may lead to belt tightening; but for the several hundred million who are already spending most of their meager incomes on food, continually rising food prices will further narrow the thin margin of survival.

Notes

1. U.S. Department of Energy, *The Report of the Alcohol Fuels Policy Review* (Washington, D.C.: 1979); U.S. Office of Technology Assessment, *Gasohol, A Technical Memorandum* (Washington, D.C.: September 1979); "Production of Fuel-Grade Ethanol From Grain," statement by Bob Bergland, Secretary of Agriculture, before the Subcommittee on Energy Development and Applications, Committee on Science and Technology, U.S. House of Representatives, May 4, 1979.

2. Lester R. Brown, *The Worldwide Loss of Cropland* (Washington, D.C.: Worldwatch Institute, October 1978), *World Population Data Sheet 1979* (Washington, D.C.: Population Reference Bureau, 1979).

3. The notion that liquid fuels could be extracted directly from plants has received serious attention only recently. Melvin Calvin of the University of California has been leading the research effort to identify plants that might serve as future fuel sources. One family, the euphorbia group, is particularly high in hydrocarbons. One representative of this group, *euphorbia lathyris*, grows naturally in Mexico and parts of the American Southwest and is well-adapted to semiarid growing conditions. Calvin believes that cultivation of this plant could yield on a sustained basis the equivalent of 6.5 barrels per acre of oil. The "copaiba" tree, discovered by Calvin in the Amazon, can be tapped like a rubber tree. The liquid it yields can be used in place of diesel fuel without refinement or processing. Although these crops have a long-term potential and merit further research, they are not likely to exert a significant claim on cropland before the early nineties, if ever. Melvin Calvin and Genevieve Calvin, "Fuel from Plants," *New York Times*, August 11, 1979; "Unlike Money, Diesel Fuel Grows on Trees," *Science*, October 26, 1979.

4. Bell quote in Department of Energy, *Alcohol Fuels Policy Review*.

5. Richard A. Nathan, *Fuels From Sugar Crops* (Washington, D.C.: Battelle Institute for U.S. Department of Energy, 1978).

6. For alcohol yields from grain, see Department of Energy, *Alcohol Fuels Policy Review*, for crop yields, see Food and Agriculture Organization, *FAO Production Yearbook 1977* (Rome, 1978).

7. Leon G. Mears, "The Brazilian Experiment," *Environment*, December 1978, Leon G. Mears, "Brazil's Agricultural Program Moving Ahead," *Foreign Agriculture*, July 17, 1978.

8. Office of Technology Assessment, *Gasohol, A Technical Memorandum*; William Holmberg, Office of Consumer Affairs, U.S. Department of Energy, Washington, D.C., private communication, February 9, 1980.

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