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BY THE COMPTROLLER GENERAL

Report To The Honorable Max Baucus United States Senate

OF THE UNITED STATES

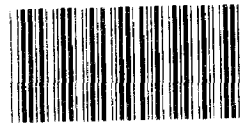
RELEASED

Potential Of Ethanol As A Motor Vehicle Fuel

GAO reviewed selected aspects of ethyl alcohol's (ethanol's) potential for widespread use as a motor vehicle fuel and focused on Federal and other efforts to assess that potential.

GAO found that, even considering constraints on the availability of feedstocks for producing ethanol, it appears entirely feasible for the Nation's vehicle fleet to be operating on a 10-percent ethanol, 90-percent gasoline blend ("gasohol") by the year 2000. A national gasohol program could cut U.S. oil imports by 260 million barrels a year at a savings of over $8 billion, based on current prices for imported oil.

The Department of Energy has taken steps to pull together previously fragmented efforts, but it is too early to evaluate how successful those steps will be. Although much oil industry skepticism remains over ethanol's potential as a widely used motor vehicle fuel, many major oil companies are now marketing gasohol and removing marketing barriers.



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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-198431

The Honorable Max Baucus
United States Senate

Dear Senator Baucus:

Your February 14, 1979, letter requested that we review selected aspects associated with developing ethyl alcohol (ethanol) as a national fuel source and evaluate the efforts undertaken in this area by the Department of Energy (DOE) and other Federal agencies. In your letter you expressed concern that the Federal Government may not be giving sufficient attention to the possible use of ethanol as a major substitute for gasoline in powering motor vehicles and that DOE's work in this area is reportedly in disarray. Pursuant to your request, and as agreed with your office, this report discusses

--technological barriers and other factors that inhibit large-scale reliance on ethanol as fuel for motor vehicles;

--the impacts on fuel consumers, oil imports and related balance of payments, and the domestic agriculture industry that would probably result if the United States were to shift to ethanol as a major fuel source;

--work that has been done by Federal agencies to assess ethanol's potential as a fuel, and our evaluation of that work;

--the oil industry's activities related to the use of ethanol as a fuel; and

--the results of State and private efforts to assess ethanol's potential as a fuel.

At the time of your request, a number of Federal, State, and private efforts to examine ethanol's potential were either recently completed or underway. Included among these were efforts by the congressional Office of Technology Assessment (OTA), DOE, and other Federal agencies. We closely coordinated our work with OTA's efforts and drew upon the results

of those and other Federal, State, and private efforts, as appropriate, in responding to this request. In addition, during our review we interviewed officials from DOE and other Federal agencies as well as various industry representatives. We also contacted several individual and State proponents of the use of ethanol as fuel and reviewed information obtained for us by the U.S. Embassy in Brazil concerning the Brazilian alcohol program. The details of our review are discussed in appendix I to this letter, and the results highlighted below.

Our review showed that ethanol cannot meet all of the Nation's motor vehicle fuel needs. Limited raw materials such as grains, sugar crops, and agricultural processing wastes preclude the production of sufficient ethanol to totally replace the 110 billion gallons of gasoline used annually. Notwithstanding such feedstock constraints, however, it appears entirely feasible that the Nation's vehicle fleet could be operating on a blend of 10 percent ethanol, 90 percent unleaded gasoline--a blend commonly known as "gasohol"--by the year 2000. Thus, ethanol represents an important partial solution which, in conjunction with methyl alcohol (methanol) and other synthetic fuels, merits a key role in the Nation's overall strategy for solving its liquid fuel supply problems.

Achieving ethanol production levels sufficient to meet the demands of a nationwide gasohol program might, however, depend on full development of ethanol from cellulose feedstocks. The extent to which cellulose feedstocks will actually be used for ethanol production, however, is an open question. The use of these feedstocks for ethanol production may have to compete with their use for producing methanol, which can also be used as an alternative motor vehicle fuel. Considerably more methanol than ethanol can be produced from the same amount of cellulose. If these feedstocks are used for methanol production, their availability for producing ethanol would be limited. Based on our analysis of the comparative potential of these two alcohols, this seems highly possible. In addition to being producible from cellulose, methanol can be made from coal, using existing technology. Considering feedstock availability for methanol production, methanol could ultimately replace gasoline as a motor vehicle fuel. Further, available cost estimates show that methanol produced from coal could be much cheaper than ethanol produced from corn and other feedstocks.

Our review further showed that the impact on the fuel consumer, as represented by the price at the service station pump, could be slight. Although the plant price of ethanol is currently as high as $1.80 a gallon, there are indications that a considerable amount of profit-taking is occurring at

these prices due to an excess of demand over supply. As new, more efficient distilleries are put into use and if sufficient quantities of relatively inexpensive feedstocks such as corn, milo, and possibly cellulose are available, the price of ethanol could decline to the point where its use in a 10-percent blend will have a negligible economic impact on the fuel consumer.

The impact on oil imports, the U.S. balance of payments, and the domestic agriculture industry resulting from large-scale reliance on ethanol as a motor vehicle fuel is considerably less clear. The potential impact on oil imports depends on two primary factors: (1) how much oil-based fuels and chemicals are used to produce the ethanol and (2) how much oil the refineries could save by using ethanol as an octane enhancer. Depending on the various assumptions made, our review indicates that if a nationwide gasohol program were in place today, annual oil imports, which now total about 3 billion barrels, could conceivably be cut by about 260 million barrels. With the price of imported oil currently averaging about $32 a barrel, such a program could result in reducing the payments for imported oil by over $8 billion. The overall effect on the U.S. merchandise trade account (an integral component of U.S. balance of payments) would probably be less, but the exact effect cannot be determined. According to the Department of Commerce, the U.S. merchandise trade account ran a deficit of nearly $30 billion for 1979.

The implications of a nationwide gasohol program on domestic agriculture cannot be determined with any degree of certainty at this time. The many different variables that could come into play in going to such a program could change the implications significantly. For example, a January 1978 study by the U.S. Department of Agriculture concluded, in part, that such a program, if based on food and feed commodities as feedstocks for ethanol production, (1) would result in sharply increased food and feed prices and a decline in aggregate livestock production and (2) would largely supplant the existing U.S. soybean crushing industry. These effects, however, could be largely ameliorated under different circumstances. According to a Department official, the agriculture industry, if allowed time to adjust, could probably supply enough grain to produce 5 billion gallons of ethanol annually without significantly disrupting the industry. This level would be sufficient to replace about 5 percent of the current U.S. gasoline consumption and could be achieved well before the year 2000. The official added that the Nation will probably need to look to ethanol produced from cellulose feedstocks for production beyond this amount.

Federal efforts to assess the potential of ethanol until the past year have been fragmented. DOE's alcohol fuels policy review which was completed in mid-1979, however, was a significant step toward pulling together the results of past efforts into a comprehensive study of ethanol's potential. DOE has also taken a number of other steps, including the creation of an Office of Alcohol Fuels, to achieve greater coordination of Federal efforts. The extent to which these steps will ultimately result in effectively assembling a comprehensive Federal program on alcohol fuels remains an open question.

With respect to the oil industry's activities relative to ethanol's use as a motor vehicle fuel, the industry appears to be in a state of rapid evolution. The industry's position has evolved from one of opposition to ethanol/gasoline fuels in past years, to a current position of supporting, at least on a limited basis, the marketing of these fuels. This shift, however, should not be interpreted as a blanket industry endorsement of these fuels. Representatives of the major oil companies continue to express skepticism about gasohol's value, and marketing barriers still exist. Considering the solid popular and political support for gasohol, it would appear that the domestic oil industry's position is more in the nature of reluctant acceptance.

Your February 14, 1979, letter requested that we report on the administration's policy with regard to ethanol. At the time of your request, there was no clear statement of the administration's policy on ethanol. During the course of our work, however, DOE completed a review of alcohol's potential and, according to a DOE official, a statement of the administration's policy is contained in the resulting report entitled "The Report of the Alcohol Fuels Policy Review," June 1979. The report under the section "Policy Initiatives" states in part: "The Department of Energy is committed to helping alcohol fuels achieve their potential in the Nation's energy future." The time frame, cost, and methodology used by DOE in carrying out its review are discussed in appendix I under the caption "Federal Efforts to Assess Ethanol's Potential as a Fuel." Operating under this broad policy statement, the President announced in his January 1980 alcohol fuels message that the administration's goal is to achieve an annual ethanol production level of 500 million gallons by the end of 1981. According to a DOE official, the goal has been further extended to between 2 and 3 billion gallons annually in 1985.

Your letter also asked us to identify State and private studies that assess ethanol's potential and to summarize their results. We identified dozens of such studies covering a wide

range of topics. Among the most frequently discussed topics was the net energy of ethanol production. For several reasons, however, we believe net energy analyses have been overemphasized. Net energy analysis is not an exact science and hence, using different assumptions, computations have been made by both proponents and opponents of ethanol to support their respective viewpoints. Moreover, the emphasis on net energy obscures the real objective: producing usable liquid fuels. Thus, the ethanol production process can be considered analogous to using coal, oil, or gas to produce electricity, or using coal and oil shale to produce syncrude--both of which result in energy in more usable forms.

Finally, your letter requested that we provide any recommendations on the use of ethanol as a motor vehicle fuel. As you know, at the time of your request we were conducting an overall review of alcohol fuels, including both ethanol and methanol. We are now preparing a report that sets forth our concerns and recommendations relative to alcohol fuels development, and as agreed with your office, we will provide you a copy of that report as soon as it is finalized.

As requested by your office, we did not obtain official comments from DOE on this report. Unless you publicly announce its contents earlier, we plan no further distribution of this report until 15 days from the date of its issuance. At that time we will send copies to interested parties and make copies available to others upon request.

Sincerely yours,

Comptroller General
of the United States

Contents

ABBREVIATIONS

API	American Petroleum Institute
DOE	Department of Energy
EPA	Environmental Protection Agency
GAO	General Accounting Office
OTA	Office of Technology Assessment
TVA	Tennessee Valley Authority
USDA	U.S. Department of Agriculture

APPENDIX I

GAO OBSERVATIONS RELATIVE TO SELECTED ASPECTS OF ETHANOL'S USE AS A MOTOR VEHICLE FUEL

Current U.S. ethanol production amounts to about 300 million gallons annually. Of this amount, more than half is made from ethylene derived from either oil or natural gas and used in the cosmetics and chemical industries. The remainder is made from fermentable crops and used primarily in the beverage industry and as fuel in motor vehicles. By the end of 1979, ethanol was being produced at an annual rate of nearly 80 million gallons for use as fuel in a blend commonly called "gasohol," consisting of 10 percent ethanol and 90 percent unleaded gasoline.

The Nation's vehicle fleet currently consumes about 110 billion gallons of gasoline each year. Thus, current production of ethanol for fuel represents less than one-tenth of 1 percent of current gasoline use. A national gasohol program would require an annual ethanol production level of about 11 billion gallons. To totally replace gasoline with ethanol, at least 110 billion gallons would have to be produced each year. The likelihood of achieving such production is highly remote, however.

By letter dated February 14, 1979, Senator Max Baucus requested that we review certain aspects of ethanol's potential use as a motor vehicle fuel and evaluate Federal efforts to assess that potential. Pursuant to that request and as agreed with Senator Baucus' office, this appendix discusses

--technological barriers and other factors that inhibit large-scale reliance on ethanol as fuel for motor vehicles;

--the impacts on fuel consumers, oil imports and related balance of payments, and the domestic agriculture industry that would probably result if the United States were to shift to ethanol as a major fuel source;

--work that has been done by Federal agencies to assess ethanol's potential as a fuel, and our evaluation of that work;

--the oil industry's activities related to the use of ethanol as a fuel; and

--the results of State and private efforts to assess ethanol's potential as a fuel.

At the time of Senator Baucus' request, a number of Federal, State, and private efforts to examine ethanol's potential were either recently completed or underway. Included among these were efforts by the congressional Office of Technology Assessment (OTA), the Department of Energy (DOE), and other Federal agencies. We closely coordinated our work with OTA's efforts and drew upon the results of those and other Federal, State, and private efforts, as appropriate, in responding to this request. In addition, during our review we interviewed DOE officials and contractor representatives; officials within the Environmental Protection Agency and the Departments of Agriculture, Commerce, Transportation, and Treasury; and representatives of major domestic and foreign automobile manufacturers, alcohol plant engineering firms, several domestic oil companies, electric utilities, ethanol distillers, and distributors of alcohol/gasoline blends. We also contacted several individual and State proponents of the use of ethanol as fuel and reviewed information obtained for us by the U.S. Embassy in Brazil concerning the Brazilian alcohol program.

TECHNOLOGICAL BARRIERS AND OTHER INHIBITING FACTORS

In reviewing the technological barriers and other factors that inhibit large-scale reliance on ethanol as fuel for motor vehicles, we examined the backup material for DOE's policy review completed in June 1979 1/ and compared its findings with those contained in other reports by Federal, State, and private organizations. 2/ We also interviewed officials involved in making these studies and discussed DOE's findings and conclusions with representatives of the chemical, oil, and automobile industries.

Overall, our review showed that limited feedstocks for producing ethanol, perhaps more than technological barriers, inhibit large-scale reliance on ethanol as fuel for motor vehicles. The consensus of the studies we reviewed is that

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1/DOE's policy review resulted in a report entitled, "Report of the Alcohol Fuels Policy Review," June 1979.

2/A listing of State and private studies that we reviewed is included as appendix II.

APPENDIX I

ethanol's production potential is substantially less than required to totally replace gasoline. However, notwithstanding these feedstock constraints, it appears entirely feasible for ethanol to replace 10 percent of the Nation's gasoline consumption by the year 2000.

Based on existing technology, the feedstocks widely recognized as having potential for contributing to greater ethanol production are grains, sugar crops, and food processing wastes. As discussed in the following sections, there is a limit to the Nation's ability to expand ethanol production using these feedstocks, and research is underway to develop technology for producing ethanol from cellulose. Also discussed are motor vehicle engine modifications that could be needed under a program of large-scale reliance on ethanol as fuel for motor vehicles.

Limited production from grains, sugar crops, and food processing wastes

The potential for grains, sugar crops, and food processing wastes to serve as abundant feedstocks for ethanol production depends on a number of factors, such as the quantity of these feedstocks that can be grown and the yield of ethanol from such feedstocks. Other factors, including domestic food and feed demands as well as export requirements, also affect the potential use of these feedstocks for ethanol production.

A number of studies have been made which examine the potential for increasing the availability of these feedstocks for ethanol production, taking the above factors into consideration. DOE studied this issue as part of its overall review of alcohol fuels policy which was completed in June 1979. Based on that study, DOE projected that about 11.5 billion gallons was the maximum practical amount of ethanol that could be produced from these feedstocks annually by the year 2000, as follows:

Feedstocks	Annual production of ethanol by the year 2000 (billions of gallons)
Grains	1.9
Sugar crops	9.0
Food processing wastes	.6
Total	11.5

DOE recognized that achieving this level of production would be difficult and would require developing additional land to grow crops. If this level could be achieved, ethanol could replace 10 percent of current gasoline consumption (enough for a nationwide gasohol program) by the year 2000.

In order to test the reasonableness of DOE's projection, we examined the backup material for the study and interviewed officials involved in making the study. We also discussed DOE's projection with officials of the U.S. Department of Agriculture (USDA). A discussion of each component of the DOE projection follows.

Grains

The primary grains considered in most studies as having potential for ethanol production are corn, milo, and wheat. At first glance, DOE's projection of 1.9 billion gallons of ethanol production from grain in the year 2000 appears low when compared to the amount of ethanol that could be produced from grains harvested in the United States. For example, in 1978 the U.S. corn, milo, and wheat harvest was sufficient to produce about 25 billion gallons of ethanol. While DOE's projection assumed increased grain yields per acre and use of set-aside lands, it did not include corn. The projection included 1.7 billion gallons of ethanol from wheat and 0.2 billion gallons from milo.

Corn was not included in the projection because DOE assumed that any land that could be used to grow corn for ethanol production would be used instead for growing sweet sorghum, which yields significantly more ethanol production per acre of land. However, grains are more easily stored than sugar crops, and ethanol plants using grains could be kept at peak production levels during poor crop years by using stored grains as feedstocks. This would not be the case for plants using sugar crops as feedstocks. In view of this, we estimated the amount of corn that might be grown on the land DOE projected for growing sweet sorghum and concluded that it would probably be sufficient to produce about 3.5 billion gallons of ethanol annually. This would bring the potential annual production of ethanol from grain in the year 2000 to 5.4 billion gallons.

Sugar crops

To put in perspective the extent to which sugar crops could contribute to greater ethanol production, the Nation's entire 1978 domestic sugar crops would have yielded only about 1 billion gallons of ethanol--about 0.6 billion gallons from

sugar beets, 0.4 billion gallons from sugar cane, and a negligible amount from sweet sorghum. Relatively, the DOE projection of 9 billion gallons of ethanol from sugar crops in the year 2000 appears quite high. It included 8.3 billion gallons from sweet sorghum and 0.7 billion gallons from sugar cane. The projection did not include sugar beets because it was assumed they would be used to produce sugar for domestic use.

The projected 9-billion-gallon capacity was based on a recent study prepared for DOE by Battelle Columbus Laboratories. Regarding sweet sorghum, the study pointed out that very little sweet sorghum is grown in the United States at the present time. According to the study, to obtain the quantities of ethanol from sweet sorghum projected by DOE, sweet sorghum would need to be grown in 7 of the 10 USDA farm production regions of the country, and varieties of sweet sorghum would need to be developed for each of these regions. Farmers would need to adopt sweet sorghum as a cash crop and adopt narrow row spacing of sweet sorghum crops. In addition, sweet sorghum harvesting equipment would need to be developed by 1990.

These tasks, especially obtaining the additional land for sweet sorghum production, appear to be formidable. Obtaining the necessary land was based on the assumption that the Government would take steps to stimulate the development of the required acreage. In this connection, the projection assumed that 14 million acres of sweet sorghum would be planted annually by the year 2000. Battelle estimates that no more than 20,000 acres of sweet sorghum are currently planted in the United States each year. Expanding this acreage for sweet sorghum production would require that some of this land be cleared and drained, some would need to be irrigated, and some would have to be diverted from production of corn and other existing crops.

One USDA official, however, has a different view concerning the formidability of these tasks. The official pointed out that expansion and diversion of agricultural lands for new crops and other uses is a rather continuing process. This official also felt that it would be reasonable to expect the acreage needed to meet DOE's projection of ethanol production from sweet sorghum to be achieved by the year 2000. He also believed that there was ample time to develop optimum varieties of seeds for different growing regions in the country. He added that farmers would readily take advantage of the opportunity to pursue sweet sorghum as a cash crop if the demand existed. He further believed that the farm equipment manufacturing industry could respond by producing the

necessary sweet sorghum harvesting equipment in the time frame needed.

Food processing wastes

DOE contends that the annual production of ethanol from food processing wastes (e.g., cheese whey and wastes from processing citrus fruits, potatoes, and corn) would be about 0.6 billion gallons in the year 2000.

DOE's projection is described as "maximum practical" and does not include all the wastes that might be available for ethanol. In this connection, DOE's Report of the Alcohol Fuels Policy Review points out that a total of 0.9 billion gallons could be produced from these same wastes. DOE's projection recognized that high collection costs would preclude using all such wastes for ethanol production. Most food processing wastes have a high moisture content, and when these wastes are widely dispersed geographically, they become expensive to transport. DOE's projection, therefore, assumed that the more costly wastes would not be used for ethanol production. However, even this projection may be optimistic. We found that the majority of food processing wastes are currently being used as an animal feed supplement and may not be available for ethanol production.

Commercial production of ethanol from cellulose not available

The largest quantity of feedstock that could potentially be used for ethanol production is the cellulose contained in wood, agricultural residues, and municipal solid waste. Producing ethanol from this cellulose, however, will require advances in the state-of-the-art. The process of producing ethanol from cellulose involves first converting the cellulose to glucose or other sugars and then converting these sugars to ethanol. DOE is funding research on methods by which this production process could be carried out, namely, chemical conversion by means of acid hydrolysis, and biological or enzymatic conversion. In addition, Gulf Oil Chemicals Company (a subsidiary of the Gulf Oil Corporation) has done work in this area and has developed a process involving enzymatic conversion of cellulose. Gulf representatives told us that their process needs further refinement but is expected to be cost competitive with production of ethanol from grain.

As part of its alcohol fuels policy review, DOE studied the potential for producing ethanol from cellulose. Based on its study, DOE projected that 41.8 billion gallons of ethanol

could be produced annually from cellulose by the year 2000, if either the chemical or the biological process were commercialized. The projected quantities from various cellulose feedstocks are as follows:

Feedstocks	Annual production of ethanol by the year 2000 (billions of gallons)
Wood	25.8
Agricultural residues	13.1
Municipal solid waste	2.9
Total	41.8

In making these projections, DOE made the following assumptions:

--Nearly 50 percent of the wood will come from silviculture "energy farms" which would become fully operational in the 1990s.

--Techniques would be developed for economically collecting agricultural residues.

--The amount of crop residues left on the land to maintain soil conditions would be reduced from the current 75-percent level to a projected 35-percent level.

--Municipal solid waste would be used only for ethanol production as opposed to direct burning and other possible uses.

It would appear from these assumptions that achieving the projected 41.8 billion gallons of ethanol from cellulose feedstocks would be a formidable task. However, in commenting on the production from wood and agricultural residues (representing over 90 percent of the total), USDA officials told us that the projected quantities are achievable and that a number of efforts are either underway or could be initiated that could help reach these projected amounts. For example, an official of USDA's Forest Service told us that silviculture energy farms could be started almost anytime and it would not be difficult to have them fully operational in the 1990s. He said, however, that obtaining from these farms the quantities of wood necessary for nearly 50 percent of the projected 25.8

billion gallons of ethanol in the year 2000, while entirely possible, would be extremely difficult.

Our review has shown, however, that there may be even a more significant constraint to using these feedstocks for ethanol production. That constraint relates to the fact that these same cellulose feedstocks can be used to produce significantly greater quantities of another type of alcohol--methanol--which is also an alternative motor vehicle fuel. According to DOE's alcohol fuels policy review, these same feedstocks can be used for producing about 155 billion gallons of methanol as opposed to the nearly 42 billion gallons of ethanol shown in the table on page 7. Thus, the use of cellulose feedstocks for methanol production would limit their availability for ethanol.

Possible modifications to motor vehicle engines

Aside from the constraints relative to limited feedstocks for producing ethanol, there are other factors affecting large-scale reliance on ethanol as a motor vehicle fuel. These factors primarily relate to the performance characteristics of ethanol when used in motor vehicle engines. A gasohol mixture containing ethanol in quantities significantly higher than 10 percent would require making adjustments to automobile engines to permit their efficient operation. New, or at least significantly modified, engines would be required to use straight ethanol.

Ten-percent ethanol blends are being widely used in the United States without major problems in unmodified automobile engines. Fuel consumers may experience some problems when first using these blends if water is present in their gas tanks or if their fuel lines are dirty. The problems will not continue once the water has been absorbed by the alcohol and run through the engine, the fuel line dirt is cleansed by the alcohol, and the fuel filter replaced.

Existing engines would have to be altered to use significantly higher percentages of ethanol or to use it straight, since ethanol has only two-thirds the energy of gasoline and, unlike gasoline, contains oxygen. As the percentage of ethanol increases in the blend with gasoline, the resulting fuel characteristics differ to an increasing extent from gasoline's. Current engines, built and adjusted to burn gasoline would, at a very high blend level, require carburetor modification to adjust for these differing fuel characteristics. Fuel flow would have to be increased to adjust for ethanol's lower energy content and air flow would have to be reduced to

compensate for ethanol's oxygen content. These modifications could be readily made to new vehicles at the factory. A nationwide retrofitting program for vehicles now on the road would, however, be a major undertaking.

In addition to changes in carburetion, more substantial modifications would be required to efficiently use straight ethanol. The primary value of ethanol as a motor vehicle fuel is its very high octane. To take full advantage of this characteristic, engines would have to be built with higher compression ratios. In addition, straight ethanol requires a higher temperature to ignite than gasoline. Therefore, some engine modification would be required to start the engine, particularly in cold weather. Auto makers told us that the technology necessary to make these changes exists today. In Brazil, a number of U.S. and European auto makers have begun production of automobiles that run on straight ethanol.

PROBABLE ECONOMIC CONSEQUENCES

Considering feedstock supplies and economics, it is questionable whether more than 10 percent of the Nation's gasoline consumption will be replaced by ethanol. This is based on the assumption that ethanol will most likely have to compete with methanol as a motor vehicle fuel. In this connection, methanol can be made from cellulose and coal, and projected costs of methanol from coal are considerably less than ethanol from corn and other feedstocks. The studies we reviewed showed that methanol performs at least as well as ethanol in straight use, and can also be blended with gasoline, albeit in smaller quantities.

Accordingly, our discussion of the probable economic consequences of the United States shifting to ethanol as a major fuel source is based on 10 percent of the Nation's current gasoline consumption, or 11 billion gallons of ethanol a year. We considered the

--price U.S. fuel consumers would likely have to pay for the fuel;

--impact on oil imports and associated U.S. balance of payments; and

--implications for the domestic agriculture industry.

Price consequences for fuel consumers

Overall, our review showed that consequences for fuel consumers resulting from a national gasohol program could be slight. Automobiles get nearly the same mileage with gasohol as they do with gasoline. Hence, the primary factor in determining the effect of a gasohol program on fuel consumers is the price of the fuel. Depending to a great extent on the type of feedstock used and at least in the near-term, whether supply can keep up with demand, gasohol prices may not differ substantially from unleaded gasoline.

Ethanol is currently selling at a price of about 80 cents a gallon higher than the average refinery price of unleaded gasoline. The plant price of ethanol is about $1.80 a gallon, and the average refinery unleaded gasoline price is nearing $1.00 a gallon. Based on this difference alone, the price of gasohol would be about 8 cents a gallon higher than unleaded gasoline's.

We found, however, that this price difference could be substantially reduced in the future as a result of expected gasoline price increases and possible ethanol price reductions. The price of gasoline is expected to increase as a result of the decontrol of domestic oil prices and the recently imposed oil import fee. For example, if the price of domestic oil increases to the current average price of imported oil--about $32 a barrel--we estimate that the refinery price of regular unleaded gasoline will increase to about $1.25 a gallon. 1/ The oil import fee imposed by the President in March 1980 2/ is expected to increase this price by an additional 10 cents. Finally, as world oil prices continue to rise, gasoline prices will be further increased.

On the other hand, there are indications that the price of ethanol could decline as ethanol supply comes into closer

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1/Based on the relationship between the refinery price of regular unleaded gasoline and the crude oil acquisition price contained in a report by OTA entitled, "Gasohol--A Technical Memorandum," dated September 1979.

2/While this report was being finalized, the U.S. District Court ruled against the fee and its imposition has been delayed. The administration has appealed the ruling but the fee's ultimate imposition is now in doubt.

balance with ethanol demand and new, more efficient distilleries are put into production. The current ethanol price of $1.80 a gallon is greatly influenced by the fact that demand now exceeds supply and that considerable profit-taking may be occurring as a result. Most studies we reviewed indicate that if new, efficient plants were on line, ethanol producers could sell ethanol today at about $1.30 a gallon and still make a reasonable profit. At this price, assuming the same distribution costs for gasohol as for gasoline, the effect on the fuel consumer could be slight.

Maintaining such a price level would be more difficult at higher levels of production. The major portion of the cost of producing ethanol is the cost of the feedstock. As ethanol production increases toward a level necessary for a national gasohol program, there will undoubtedly be upward pressure on ethanol feedstock prices and hence upward pressure on ethanol prices. Nonetheless, there is evidence that even at such a vastly increased production level, ethanol prices may still decrease.

The studies we reviewed indicate that domestic agriculture could probably supply enough corn and milo for producing about 1 to 2 billion gallons of ethanol a year without creating a significant increase in the price of these feedstocks. Accordingly, ethanol could still be produced in new efficient plants at a plant price of around $1.30 a gallon at today's prices. Some studies claim that it is even possible to reduce the cost of ethanol, especially that produced from grain, if byproducts more valuable than distillers' dried grain were produced, such as corn oil and high-protein food supplements. However, most studies we reviewed indicate that the market could not support the significantly increased quantities of the ethanol byproducts that would result from a large-scale ethanol industry, and the related value of the byproducts as an offset to the cost of producing ethanol would be minimized.

While grains can supply a portion of the ethanol required for a national gasohol program, the majority of this requirement has been projected by DOE to come from sugar crops--particularly sweet sorghum--and cellulose. No definitive data is available on potential prices of ethanol produced from sweet sorghum since so little sweet sorghum is grown today. However, based on information contained in DOE's Report of the Alcohol Fuels Policy Review, ethanol produced from sweet sorghum could ultimately have a selling price of about $1.75 a gallon, once again less than today's selling price.

APPENDIX I

Regarding ethanol produced from cellulose, once again no significant production is occurring today so price projections are difficult to make. However, if the technology for producing ethanol from cellulose were commercialized, large quantities of ethanol could be produced, possibly at less cost than from some other conventional feedstocks. In this connection, officials of Gulf Oil Chemicals Company told us that their process should be able to produce ethanol from municipal solid waste for a price competitive with that of producing ethanol from grain.

The current 4-cents-a-gallon exemption of gasohol from the Federal excise tax on gasoline makes the price competitiveness of ethanol even more attractive when compared to gasoline prices. The continuation of this subsidy, however, should not be counted on. The exemption, which equates to 40 cents for each gallon of ethanol, was authorized by the Energy Tax Act of 1978, and its period of allowability was extended by the recently enacted Crude Oil Windfall Profit Tax Act of 1980 (P.L. 96-223). The extension was allowed through the year 1992, but because it results in lost revenue to the Federal Highway Trust Fund, its continuation beyond 1992 is questionable.

Impact on oil imports and balance of payments

It is difficult to predict the extent to which oil imports and the associated merchandise trade account (an integral component of overall U.S. balance of payments) would be affected under a national gasohol program. Two primary factors affect the potential impact that such a program could have on the Nation's oil imports: (1) how much oil-based fuels and chemicals are used to produce the ethanol and (2) how much oil the refineries could save by using ethanol as an octane enhancer. Although the range of possibilities is large, we estimate that if a national gasohol program were in place today, it conceivably could reduce the Nation's annual oil imports, which now total about 3 billion barrels, by about 260 million barrels. Since the average price of imported crude is about $32 a barrel, a reduction of over $8 billion of the money needed for imported oil would be possible. The overall effect on the merchandise trade account would probably be less, but the exact effect cannot be determined. According to the Department of Commerce, the merchandise trade account ran a deficit of nearly $30 billion in 1979.

Energy to produce ethanol

If ethanol is to reduce the Nation's need for imported oil, it must be produced with a minimum of oil. To produce ethanol, energy is needed to grow and harvest the feedstocks as well as operate the distilleries. The energy used in farm equipment and in the production of fertilizers and pesticides is primarily supplied by oil and natural gas and will probably continue to be supplied by these resources. The amount of oil required in this capacity therefore reduces the amount of oil saved when ethanol replaces gasoline. In addition, most distilleries currently run on oil and natural gas. Distillery energy requirements, however, can be met with coal or renewable resources. For ethanol to provide any substantial oil savings, most studies agree that distilleries will have to use these other fuels.

An offsetting factor that should be considered is the energy savings associated with the byproducts of the fermentation process. By using fermentation byproducts such as distillers' dried grain as an animal feed instead of crops like soybeans, the energy needed to grow and harvest these crops would be saved.

How ethanol is used in gasoline blends

In addition to the factors related to ethanol production, gasohol's oil saving potential is materially affected by how ethanol is used in the gasoline blends produced. For example, OTA concluded in its September 1979 report that each gallon of ethanol produced from corn could save slightly more than half a gallon of oil if the ethanol were simply mixed with existing regular-grade, unleaded gasoline. 1/ In this case each gallon of ethanol would reduce the refiner's regular-grade, unleaded gasoline production requirements by about one gallon, but the oil consumed in the ethanol production process would negate about half of these savings. It is important to note, however, that the resulting gasohol would have a higher octane and hence be more valuable than the regular-grade, unleaded gasoline it displaced.

1/In performing its analysis, OTA assumed that additional energy would be required to grow the corn feedstock because less productive lands would have to be placed into production, and the energy requirements of the distilleries would be met with coal. If feedstocks other than corn were used, the results could differ.

While each gallon of ethanol used in this manner would save only about one-half gallon of oil, it is possible under other circumstances for the Nation to save a gallon or more of oil for every gallon of ethanol produced. This can be achieved in two ways.

First, refiners can reduce the octane quality of the base unleaded gasoline so that when blended with ethanol, the resulting gasohol's octane is the same as that of existing regular-grade, unleaded gasoline. We estimated that if this approach was taken, almost one gallon of oil could be saved for each gallon of ethanol because it takes less oil to produce the lower octane, unleaded gasoline.

Second, an even greater quantity of oil could be saved if refiners' instead used gasohol to replace premium unleaded gasoline. In the production of unleaded gasoline, progressively more oil is needed to raise the octane quality each additional level. Premium-grade, unleaded gasoline therefore requires more oil to produce than regular grade. To the extent that gasohol replaces this more energy-intensive product, additional oil can be saved. Used in this capacity, we estimate that more than one gallon of oil could be saved for each gallon of ethanol produced.

Once again, these two analyses assume the use of corn feedstock in a coal-fired distillery. If other feedstocks were used, the results could differ. Also, it should be noted that the oil savings by substituting gasohol for leaded gasolines would be less than for unleaded gasolines. However, the continued use of lead as an octane enhancer is being phased down in accordance with Clean Air Act and Environmental Protection Agency (EPA) requirements.

Implications for the domestic agriculture industry

The implications for the domestic agriculture industry are not clear. Much of the initial impetus for the current push to use ethanol in blends with gasoline stemmed from the desire to help the economic well-being of the domestic agriculture industry. Although this is one possible implication, the many different variables that could come into play by going to a nationwide gasohol program could have significantly different implications for large segments of the agriculture industry.

If the Nation is to produce enough ethanol for a 10-percent blend with gasoline, one or more of the following must occur:

--More sugar crops will have to be grown.

--Acreage for crop production will have to be expanded.

--Animal feed content will have to be changed.

--Ethanol from cellulose technology will have to be developed and commercialized.

Each of these occurrences would have significant economic consequences for the domestic agriculture industry, but the consequences have not been fully evaluated. DOE's Report of the Alcohol Fuels Policy Review did not address these consequences. OTA's September 1979 report on gasohol discussed some of the problems, but OTA's work was primarily focused on issues other than the economic consequences for agriculture resulting from a large-scale ethanol program.

On January 19, 1978, USDA issued a report on its preliminary economic assessment of introducing a national gasohol program based on ethanol produced from grains. Conclusions regarding the implications of such a program for the domestic agriculture industry were as follows:

--Additional land not now farmed would be needed.

--Prices for food and feed grains would sharply increase.

--The soybean crushing industry would be largely supplanted because distillers' dried grain would be used as an animal feed instead of soybeans.

--Soybeans would be produced mainly for food oil and for export.

--Aggregate livestock production would decline from levels that would otherwise be achieved.

--Net farm income would increase slightly.

USDA later studied the implications for the farms sector resulting from a large ethanol from corn program, and presented its findings on May 4, 1979, to the Subcommittee on Energy Development and Applications, House Committee on Science and Technology. The report pointed out that USDA has emphasized residues as feedstock for fuel production rather than food and feed commodities, and concluded that any commitment to a grain-based ethanol program should probably not exceed 2 billion gallons of ethanol annually. The overall effect that

a large ethanol from corn program would have on agriculture was summarized as follows.

> "In sum, an alcohol fuels industry and agricultural policies would be mutually supportive of one another only in various incidental (or accidental) ways. These interrelationships could be expected to result in additional costs (for increased reserve stocks) as well as benefits (in the form of additional outlets for short-term commodity surpluses), and the net cost/benefit impact would be difficult to determine. Because these related aspects are largely incidental, and their net impact in terms of costs and benefits is indeterminant, they cannot be prudently taken to justify, or militate against, the encouragement of an alcohol fuels industry per se."

In March 1980, we discussed these two studies with the USDA official who prepared the later study, and were told that if sufficient time were given the agriculture industry to adjust, it could probably supply enough grain to produce about 5 billion gallons of ethanol annually without significantly disrupting the industry. This could be achieved well before the year 2000--possibly by 1990. This official added that beyond this amount, the Nation will probably need to look to ethanol produced from cellulose.

FEDERAL EFFORTS TO ASSESS ETHANOL'S POTENTIAL AS A FUEL

As part of this issue, Senator Baucus wanted to know the following:

--What work has been done by DOE and other Federal agencies to assess ethanol's potential?

--Who and what agency has been coordinating this work?

--What is GAO's evaluation of this work?

During the past few years, DOE, the former Energy Research and Development Administration, and a number of other Federal agencies have conducted a large number of studies and research and development activities which touched on ethanol's potential as a motor vehicle fuel. These efforts have generally been fragmented.

The most comprehensive look at ethanol's potential was completed by DOE in 1979 as part of its alcohol fuels policy review. That review, which was carried out over a period of 12 months, effectively pulled together the voluminous data that had been developed as a result of earlier Federal efforts.

Scope of Federal agency activities

During our review, we found that in recent years, many Federal agencies have conducted analyses concerning the potential of alcohol fuels. The largest of these was directed by DOE. In addition to DOE, a number of other Federal departments and agencies such as USDA, EPA, the Tennessee Valley Authority (TVA), and the Office of Minority Business Enterprise within the Department of Commerce, have conducted research or made assessments of ethanol. Of all these efforts to date, however, DOE's alcohol fuels policy review has been the most comprehensive.

DOE has been actively studying aspects of alcohol fuels' potential for several years. In October 1977, a bipartisan group of 27 Senators urged DOE and USDA to undertake immediate and comprehensive efforts to develop alcohol fuels. In response to that initiative, DOE established an alcohol fuels task force in December 1977. In its March 1978 report, 1/ the task force concluded that there was a need to take aggressive action to develop alcohol fuels. Accordingly, it recommended a program

> "* * * to provide the information considered essential for the introduction of alcohol fuels as one means for supplementing and eventually supplanting petroleum-derived fuels."

However, DOE regarded the task force's work as preliminary and, accordingly, did not adopt the recommendation.

Subsequently, in July 1978, DOE began its alcohol fuels policy review to comprehensively assess the potential of alcohol fuels as an alternative source of energy. In June 1979, DOE published its Report of the Alcohol Fuels Policy Review. The report represented the most comprehensive Federal look at

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1/The task force produced its report in the form of an alcohol fuels program plan.

alcohol fuels to date. The report found that ethanol is the only alternative fuel likely to be available, although only in small quantities, before 1985. It also found that methanol could be produced in much greater quantities from commercially available technology by the mid- to late-1980s. The report concluded that although alcohol fuels cannot be a major solution to the Nation's energy needs in the near-term, they do represent an important energy component and building block for the longer term.

Beyond these studies, DOE has undertaken wide-ranging research activities on alcohol fuels over the past several years. We noted that seven different DOE headquarters organizations have been conducting efforts related to ethanol and methanol development. Activities on ethanol have included a reliability fleet testing program, research on improved fermentation and distillation processes and high-yield feedstocks, and research on ethanol production from municipal solid waste and other cellulose materials.

A number of other agencies have also been conducting ethanol fuels research and making alcohol fuels assessments. In addition to conducting related agriculture research, USDA has studied gasohol's potential. It has studied the impact of a large gasohol program on farmer income, farm prices, and agricultural programs. The analyses have concluded that a large gasohol program would raise farm prices but would have a limited impact on net farm income and agricultural programs. USDA also has underway a loan guarantee program to aid small-scale ethanol producers.

EPA, TVA, and the Department of Commerce have also been involved. EPA, in fulfilling its responsibilities under the Clean Air Act, has conducted intensive tests to assess the impact of gasohol on auto emissions. On the basis of these tests and other data, EPA permitted gasohol sales. TVA has conducted, and is continuing, tests using gasohol in its vehicle fleet and other gasoline-burning equipment. The Office of Minority Business Enterprise, within the Department of Commerce, has issued grants to two cooperatives to construct experimental ethanol production facilities.

Two congressional agencies have made alcohol fuels assessments as well. For example, OTA's September 1979 report included gasohol's production potential, its likely production costs, and its probable environmental, social, and food-cycle impacts. OTA noted that:

--gasohol production, in the short-term, will be limited primarily by capacity;

--a nationwide gasohol program could lead to inflationary trends in food and feed markets;

--large increases in corn production as an ethanol feedstock could lead to an increase in soil loss, as well as increases in fertilizer and pesticide use; and

--overall social impacts, particularly those associated with stabilizing rural communities, could be strongly positive.

In October 1979, the Congressional Research Service updated a May 1974 report on issues related to alcohol fuels. That report discussed both ethanol and methanol from the perspectives of usability in automobiles and potential supply capabilities. The report noted that methanol can be derived from coal, wood, and urban wastes in sufficient quantities to make it worthy of consideration as an alternative automotive fuel. As for ethanol derived from grain, the report stated that supply problems appear to make its use on a nationwide basis impossible. In this regard, the report pointed out that the entire U.S. grain harvest could produce only enough ethanol to fill 25 percent of the Nation's automotive fuel needs and that converting the Nation's entire sugar crop would meet only an additional 1 percent of these needs.

Coordination of Federal efforts

For the most part, the activities of the agencies conducting alcohol fuels assessments have been fragmented. DOE established several mechanisms to promote coordination of Federal efforts related to alcohol fuels. It formed an ad hoc interagency group to exchange information on alcohol fuels, instituted several interagency agreements, and recently created within DOE a new Office of Alcohol Fuels. The extent to which these mechanisms will result in effectively assembling a comprehensive Federal program on alcohol fuels remains an open question.

Until recently, the only multiagency organization on alcohol fuels was the Ad Hoc Interagency Committee on Alcohol Fuels. That group was formed by a DOE staff member to exchange information on agencies' alcohol fuels activities. While contributing to more open communications, the meetings were not attended by policy-level personnel from any of the participating agencies, and hence did not serve as an

effective mechanism for a unified and comprehensive Federal strategy. According to a DOE official, with the recent creation of DOE's new Office of Alcohol Fuels, this committee has ceased to function.

In addition, DOE has established a number of bilateral agreements with individual agencies to conduct a variety of specific activities. DOE and USDA developed a memorandum of understanding formalizing a broad policy of cooperation in energy research. Further, DOE and USDA have recently negotiated separate interagency agreements which cover organizational and management responsibilities for conducting wide-ranging biomass research activities, some of which support alcohol fuels. DOE has also established a working relationship with EPA related to DOE's fleet testing program. The two agencies are working together to ensure that emissions measurements taken during the fleet test conform to EPA's data needs. Finally, DOE has two interagency agreements with the Department of the Army: one is to study the effects of alcohol fuel use on engine wear; the other concerns work with ethanol production technology.

DOE's creation of a new Office of Alcohol Fuels could be a further step in achieving greater coordination of alcohol fuels activities in the Federal Government. The new Office, which was created by the Secretary of Energy in February 1980, is responsible, in part, for working with several Federal agencies on alcohol fuels matters. However, because of the recency of its creation, it is too early to evaluate whether the Office will be effective in coordinating Federal alcohol fuels efforts.

GAO's evaluation of efforts by Federal agencies to assess ethanol's potential

As part of his request, Senator Baucus asked us to evaluate Federal efforts to assess ethanol's potential. In this connection, he also asked us to determine the cost of these efforts and the extent to which these efforts have been conducted by agency personnel versus outside contractors and consultants. In responding to this request, we focused our attention on DOE's June 1979 policy review because it was the most comprehensive Federal effort to assess the potential of ethanol as a fuel. Furthermore, developing cost data and in-house versus contractor breakdowns of all the Federal alcohol fuels assessment activities proved to be impractical. The records necessary to develop overall data were not maintained by individual agencies in a manner that would facilitate such a comparison.

DOE's policy review began in July 1978 and was carried out over a 12-month period. The input used to develop the review group's report included public hearings, contractor reports, and internal evaluations. DOE's stated contractor cost for that review was $725,000. A list of the contractors used in the study is contained in appendix III. In addition, DOE told us that it devoted almost 2,100 of its own staff-days to the study.

In evaluating DOE's policy review, we analyzed the extent to which the study's findings and conclusions were supported by reports submitted by DOE's contractors. We also compared the study group's findings with the results of other previous studies, and with information collected during the numerous interviews we held with industry and Government officials.

Overall, the findings presented in the report were supported by DOE contractor analyses. In addition, while we found that opinions varied on almost every technical aspect of alcohol fuel use, the policy review represented a reasonable consensus of those varied viewpoints. As a whole, therefore, we found no reason to dispute the findings set forth in the report. However, we believe the conclusion that alcohol production for fuel would only be 500 million to 600 million gallons a year by 1985 was overly pessimistic. The administration has, however, recognized this weakness, and the President recently set a goal for ethanol production of 500 million gallons annually by the end of 1981. 1/ According to an official of DOE's Office of Alcohol Fuels, the goal has been further extended to between 2 and 3 billion gallons in 1985.

We also noted two factors which affect ethanol's potential that could have received a more thorough treatment. First, DOE's work did not include an indepth analysis of the economic impacts of a widespread ethanol fuel program. Certainly, a clear picture of these impacts should be an integral part of any decisionmaking process leading to the possible commitment to such a program. The second, and perhaps more important factor was DOE's seemingly limited treatment of methanol.

1/President's "Alcohol Fuels Program" message on January 11, 1980.

Our overall review of the potential of alcohol fuels showed that methanol's potential to substitute for gasoline is vastly greater than ethanol's. While the practical limit of ethanol's potential appears to be as a 10-percent substitution, methanol could ultimately replace gasoline entirely. Despite this vast difference in potential, DOE's report focused its attention on ethanol. For example, the report presented a number of policy initiatives designed to expand the production and use of ethanol but offered few for methanol. In view of the comparative potential of the two fuels, we believe such disparate treatment is significant because it could result in an unwarranted bias in Federal alcohol fuels development and commercialization efforts.

OIL INDUSTRY'S ACTIVITIES RELATED TO USE OF ETHANOL AS A MOTOR VEHICLE FUEL

During the course of our review, we found indications of a shifting attitude on the part of the major U.S. oil companies toward the use of ethanol as a motor vehicle fuel. In past years, the domestic oil industry has generally argued against programs to promote widespread gasohol use, both in public statements and through various marketing activities. Recently, this position began changing. A number of companies are actively test-marketing gasohol, and some marketing barriers have been removed. The industry, for the most part, is still taking a cautious approach to widespread gasohol use, and some opposition remains. But recognizing the increasing public attention to the fuel, the oil industry seems to be more supportive of gasohol's use.

During the previous several years of gasohol's development, the domestic oil industry has, in many forums, argued against the widespread use of ethanol as a motor vehicle fuel. The American Petroleum Institute (API), an association which represents the petroleum industry, took the position, in a July 1976 report entitled "Alcohols: A Technical Assessment of their Application as Fuels," that gasohol made little sense on economic or technical grounds. The report stated that alcohols were too expensive for large-scale fuel use. It also stated that alcohols, either straight or in blends, could not be interchanged with gasoline in conventional vehicles without engine and fuel system modifications. On the basis of these and other considerations, API concluded that alcohol/gasoline blends would be the least attractive of several possible fuel uses for available alcohol. These other possible uses include use in turbines for generating electricity and use as straight fuel in captive fleets.

This negative outlook toward gasohol was confirmed in our contacts with 10 major oil companies. Technical representatives told us generally that unattractive economics and several technical problems gave gasohol a bleak future as an automotive fuel. They felt that technical problems, particularly those associated with preventing the ethanol and gasoline mixture from separating and with maintaining constant fuel characteristics, would be expensive to overcome and would sacrifice, to a large extent, the oil-saving potential of ethanol's use.

In addition to this technical viewpoint, we also noted that a number of companies had marketing practices which served as barriers to the increased use of gasohol. Among the reported practices were banning charges of gasohol purchases on company credit cards, and requiring separate storage and pumping facilities for gasohol to be sold at company outlets. Such practices have been important disincentives to expanded gasohol marketing through major oil company outlets.

There are now several indications that this policy of opposition to widespread gasohol use is shifting. Company representatives with whom we spoke continue to have reservations concerning the use of ethanol as a gasoline extender. However, spurred by growing public acceptance and continuing governmental incentives, some companies are beginning to take more supportive actions.

The most significant action may be the initiation of test-marketing campaigns. Led by the Texaco Corporation, with over 1,000 stations now selling gasohol, at least 8 major U.S. oil companies are engaged in, or planning to begin, gasohol test marketing. While the number of stations involved is only a tiny fraction of the over 150,000 gasoline outlets nationwide, such test marketing does represent a significant departure from past opposition.

Additionally, Texaco has announced that, along with CPC International Inc., it is studying the feasibility of producing its own ethanol on a large-scale basis instead of buying it from an ethanol producer. The feasibility study is scheduled for completion by mid-1980. If the study is favorable, a company representative told us production could begin by mid-1981 at a level of up to 60 million gallons a year.

Finally, some companies have reversed previous positions and are now allowing gasohol purchases to be charged on company credit cards. In these instances, at least, a marketing practice that had previously inhibited gasohol sales has been removed.

This shifting position toward gasohol should not be interpreted as an industry endorsement of the fuel. Company representatives continue to voice skepticism about gasohol's value in reducing petroleum imports on both technical and economic grounds. In addition, although steps have been taken to remove discriminatory marketing practices, some still remain. Nonetheless, for a variety of reasons, the domestic oil industry seems to be moving, urged by solid popular and political support, toward a position of reluctant acceptance of gasohol as a fuel.

STATE AND PRIVATE STUDIES AND PILOT PROJECTS

During the past few years, there have been literally dozens of State and private studies and pilot projects which examined certain aspects of ethanol's potential for use as a motor vehicle fuel. The studies have generally covered a wide range of topics, but most include discussions on the economics of ethanol's production, the net energy of ethanol production, and the availability of selected crops and other feedstocks for ethanol production. The studies we reviewed are identified in appendix II.

Although some of the studies reached widely differing conclusions, a number of important observations can be made. With respect to the economics of ethanol production, for example, studies conducted more than a year ago are likely to be out of date. We noted that some studies which showed ethanol production to be uneconomical were using, for comparison purposes, oil at the outdated prices of $10 to $15 per barrel. The currently higher price for imported crude no doubt would show ethanol's use as motor vehicle fuel to be more economical.

With respect to net energy, although some studies show negative results, others show a positive net energy yield. One overall observation we have is that net energy is often used by both proponents and opponents of ethanol to support their respective viewpoints. We believe this is unfortunate. Our work in the area has shown that net energy analysis is not an exact science; therefore, any two or more studies of a particular energy system can yield vastly differing results, depending on the methodologies, approaches, and systems boundaries selected. There is also a tendency to overemphasize net energy aspects of ethanol as a fuel, thereby losing sight of the real objective: producing usable liquid fuels. For example, using coal to fire the distilleries to process grains and other crops into ethanol may, as some studies show, result in a net energy loss. But the process produces a fuel

which is more readily adaptable for certain uses (e.g., motor vehicle fuel). Thus, the process can be considered analogous to using coal, oil, or gas to produce electricity, or using coal and oil shale to produce syncrude--both of which result in energy in more usable forms.

In addition, a number of State and private fleet tests have been conducted and the results published. Nebraska, for example, completed a 2-million-mile road test program using gasohol in State-owned vehicles with impressive results. This program showed, in part, that gasohol is clean burning, results in slightly greater miles per gallon, and improves engine performance. In addition, the States of Illinois and Iowa, as well as the American Automobile Association, have sponsored vehicle testing programs with similarly impressive results.

With respect to the pilot projects that we reviewed, several examined the production of ethanol on a small scale. One observation that can be made from reviewing these projects is that ethanol can be produced inexpensively if low-value feedstocks, such as spoiled grains, are used. These projects have also shown other positive aspects of small-scale operations. For example, small-scale plants may be able to take advantage of inexpensive sources of labor and fuel, such as scrap lumber and residues from forests and crops.

APPENDIX II

STATE AND PRIVATE STUDIES

OF ETHANOL'S POTENTIAL

Alcohol--Its Nature and Potential for Tractor or Automobile Fuel, Robert Y. Ofoli and Bill A. Stout, Michigan State University, January 1978.

Alcohols and Motor Fuels: The Promises and the Problems, Chevron Research Company, December 1977.

Alcohols: A Technical Assessment of Their Application as Fuels, American Petroleum Institute, July 1976.

Consumer Acceptance and Market Potential of Gasohol, Iowa Development Commission, October 1978.

Directions for Alternative Automotive Fuel Programs, General Motors Research Laboratories, April 1979.

Economic Aspects of Using Grain Alcohol as a Motor Fuel, with Emphasis on By-Product Feed Markets, R.N. Wisner and J.O. Gidel, Iowa State University, June 1977.

Economic and Energy Requirements of Ethanol Production, Peter J. Reilly, Iowa State University, January 1978.

Energy and Ethanol, Dr. William A. Scheller, University of Nebraska, April 1978.

Exhaust Emissions, Fuel Economy, and Driveability of Vehicles Fueled with Alcohol-Gasoline Blends, Society of Automotive Engineers, Incorporated, February 1975.

Feasibility of Ethanol from Grain in Montana, Richard Stroup and Thomas Miller, Montana State University, January 1978.

The Feasibility of Gasohol: An Examination of the Issues, Summary report of the University of Idaho committee to study and recommend action relative to the 1977 Farm Bill.

Food or Fuel: New Competition for the World's Cropland, Worldwatch Institute, March 1980.

Gasohol--Current Status and Potential for the Future, Illinois Farm Bureau, February 1978.

Grain Alcohol in Motor Fuels--An Evaluation, James G. Kendrick and Pamela J. Murray, University of Nebraska, April 1978.

APPENDIX II

Grain Alcohol-Process, Price and Economic Information, Dr. William A. Scheller and Brian J. Mohr, University of Nebraska, September 1976.

International Symposium of Alcohol Fuel Technology--Methanol and Ethanol, Papers presented at the symposium held in Wolfsburg, Federal Republic of Germany, November 1977.

Net Energy Analysis of Alcohol Fuels, American Petroleum Institute, November 1979.

Net Energy Analysis of Ethanol Production, Dr. William A. Scheller and Brian J. Mohr, University of Nebraska, April 1976.

Practicality of Alcohols as Motor Fuel, Amoco Oil Company, 1979.

Production and Marketing of Alcohol Motor Fuels from Colorado Agricultural Commodities: A Tentative Description, Colorado Gasohol Task Force, April 1978.

Protein Concentrates from Distillers By-Products, Dr. William A. Scheller and Brian J. Mohr, University of Nebraska, October 1975.

Report on Corn Alcohol as a Fuel Additive, Peter J. Reilly, Iowa State University, October 1977.

Synthetic Fuels Program, California State Legislature, June 1979.

The Use of Ethanol-Gasoline Mixtures for Automotive Fuel, Dr. William A. Scheller, University of Nebraska, January 1977.

APPENDIX III

CONTRACTORS USED BY DOE IN ITS ALCOHOL FUELS POLICY REVIEW

Aerospace Corporation

Argonne National Laboratory

Arthur D. Little and Company

Battelle Columbus Laboratories

Booz Allen and Hamilton, Incorporated

Energy Resources Company, Incorporated

Folke Dovring (consultant)

Midwest Research Institute

Mitre Corporation

Mueller Associates, Incorporated

Pincas Jawetz (consultant)

Raphael Katzen Associates

SRI International (feedstock)

SRI International (production)

TRW, Incorporated

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