THE GASOHOL MOTOR FUEL ACT OF 1978

HEARINGS

BEFORE THE

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

NINETY-FIFTH CONGRESS

SECOND SESSION

ON

S. 2533

A BILL TO PROVIDE FOR THE USE OF ALCOHOL PRODUCED FROM RENEWABLE RESOURCES AS A MOTOR VEHICLE FUEL

AUGUST 7 AND 8, 1978

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THE GASOHOL MOTOR FUEL ACT OF 1978

MONDAY, AUGUST 7, 1978

U.S. Senate,
Subcommittee on Energy Research and Development,
of the Committee on Energy and Natural Resources,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m., in room 3110, Dirksen Office Building, Hon. Frank Church, presiding.

Present: Senators Church and Hansen.

Also present: Pete Smith, professional staff member.

OPENING STATEMENT OF HON. FRANK CHURCH, A U.S. SENATOR FROM THE STATE OF IDAHO

Senator Church. The hearing will please come to order. This morning is the first of 2 days of hearings before the Subcommittee on Energy Research and Development on S. 2533, the Gasohol Motor Fuel Act of 1978. The purpose of this bill is to establish a national requirement that is based on alcohol produced from renewable resources. Under the terms of the bill, a 10 percent alcohol-90 percent gasoline blend must be sold for use in automobiles by 1990. In other words, this bill requires the sale of gasohol.

This proposed national requirement is a straightforward and, I believe, realizable directive to the oil industry. Under the bill, all refiners must sell motor fuel with at least a 1 percent blend of alcohol by 1981. This percentage increases to 5 percent in 1985, and by 1990, only gasohol, that is, 10-percent alcohol fuels, can be legally sold as a motor fuel.

There are extremely good reasons why a national requirement should exist. The first reason comes directly from the observation that the Nation's vast transportation network is totally dependent on a dwindling supply of domestic petroleum. The specter of dwindling supplies of domestic petroleum, inevitably higher prices, and of another possible embargo, coupled with the inescapable balance-of-trade deficit all point dramatically to a major transportation problem and a disturbing economic outlook.

Moreover, it seems imperative to me that the economic hard times of our farmers demand attention. Crop surpluses abound. These crop surpluses, along with crop and wood wastes, should be put to use to help fuel our automobiles, and thus create needed markets for farm products. We can grow part of our fuel and replenish each year from the land.

When I introduced S. 2533, I had several important facts in mind. When these facts are put together, they make it clear that gasohol could be marketed nationwide, and not sometime in the distant future. For example, biomass resources in the form of grains, sugar beets, waste wood, refuse, and many other cellulose materials are not only renewable, but they are plentiful.

More importantly, all of these biomass resources can be converted to alcohol now, without any additional technology development. And alcohol mixed in proper proportion with gasoline makes a clean, higher quality motor fuel.

Consequently, we have the renewable resources, we can make the alcohol, and we can use gasohol in our cars. These are the relevant facts, which when coupled to the farm and grain problem, force me to conclude that gasohol at every pump is in our national interest.

At this point I will insert in the record the text of S. 2533.

[The text of S. 2533 follows:]

95TH CONGRESS
2D SESSION

S. 2533

IN THE SENATE OF THE UNITED STATES

FEBRUARY 10 (legislative day, FEBRUARY 6), 1978

Mr. CHURCH introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

A BILL

To provide for the use of alcohol produced from renewable resources as a motor vehicle fuel.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "Gasohol Motor Fuel Act of 1978".

FINDINGS

SEC. 2. (a) The United States is currently importing large quantities of crude oil.

(b) A substantial portion of this crude oil is needed for the production of gasoline sold in interstate commerce.

(c) Renewable resources in the United States can

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provide a sufficient source of alcohol suitable for blending with gasoline to decrease the need for imported oil.

DEFINITIONS

SEC. 3. As used in this Act, the term—

(1) "alcohol" means methanol, ethanol, or any other alcohol which is produced from renewable resources and which is suitable for use by itself or in combination with other fuels as a motor fuel;

(2) "alcohol-blended fuel" means any fuel consisting of a mixture of gasoline and alcohol motor fuel;

(3) "alcohol motor fuel" means alcohol produced for use as a motor fuel;

(4) "commerce" means any trade, traffic, transportation, exchange, or other commerce—

(A) between any State and any place outside of such State; or,

(B) which affects any trade, traffic, transportation, exchange, or other commerce described in subparagraph (A).

(5) "motor fuel" means any substance suitable as a fuel for self-propelled vehicles designed primarily for use on public streets, roads, and highways;

(6) "refiner" means, for purposes of this Act, any person engaged in the refining of crude oil to produce

motor fuel, including any affiliate of such person, or any importer of gasoline for use as a motor fuel;

(7) "Secretary" means the Secretary of Energy;

(8) "United States" means each State of the several States and the District of Columbia;

(9) "ultimate purchaser" means, with respect to any item, the first person who purchases that item for purposes other than resale;

(10) "renewable resource" means any substance which is a source of energy, and which is available in an inexhaustible supply in the foreseeable future.

PROGRAM

SEC. 4. The Secretary shall establish pursuant to this Act a program to promote the use of alcohol-blended fuels in the United States. The purpose of the program shall be to replace gasoline used as a motor fuel with an alcohol-blended fuel containing the maximum percentage of alcohol motor fuel as is economically and technically feasible for use as a motor fuel.

STUDY

SEC. 5. (a) The Secretary, in consultation with the Secretary of Transportation, the Secretary of Agriculture, the Secretary of Commerce, and other appropriate agencies, shall conduct a study to determine—

(1) the most suitable raw materials, other than petroleum or natural gas, for the production of alcohol motor fuel; and

(2) the nature of the alcohol motor fuel distribution systems and the various production processes, using feedstock other than petroleum and natural gas;

that will be necessary for the rapid development of an alcohol motor fuel industry. Such study shall identify ways to encourage the development of a reliable alcohol motor fuel industry and shall identify the technical, economic, and institutional barriers to such development, and shall include an estimation of the production capacity of alcohol motor fuel needed to implement the provisions of this Act.

(b) The Secretary shall report to the Congress not later than six months after the date of enactment of this Act on the results of the study described in subsection (a), together with such legislative recommendations as may be appropriate to further the purposes of this Act.

PRODUCTION GOALS

SEC. 6. The Secretary, by rule, within six months after the completion of the study in section 5, set production goals for the production of alcohol motor fuel in the United States in each of the calendar years 1981 through 1990. In setting such goals, the Secretary shall take into account the availability of reliable sources of alcohol produced from renewable resources. The production goal for alcohol motor fuel for calendar year 1981 shall be not less than 1 percent by volume of the projected consumption of gasoline used as a motor fuel in the United States for that year. The production goal for alcohol motor fuel for calender year 1985 shall be not less than 5 percent by volume of the projected consumption of gasoline used as a motor fuel in the United States for that year. The production goal for alcohol motor fuel for calendar year 1990 shall be not less than 10 percent by volume of the projected consumption of gasoline used as a motor fuel in the United States for that year.

ALCOHOL-BLENDED FUEL REQUIREMENTS

SEC. 7. (a) The total quantity of gasoline sold annually in commerce in the United States by any refiner for use as motor fuel shall contain, on the average, not less than the percentage alcohol motor fuel by volume set forth for the calendar years shown in the following table:

Calendar year:	Percentage alcohol motor fuel by volume
1981	1 percent.
1982	Determined by the Secretary under subsection (b) of this section.
1983	Determined by the Secretary under subsection (b) of this section.
1984	Determined by the Secretary under subsection (b) of this section.
1985	5 percent.
1986	Determined by the Secretary under subsection (b) of this section.
1987	Determined by the Secretary under subsection (b) of this section.
1988	Determined by the Secretary under subsection (b) of this section.
1989	Determined by the Secretary under subsection (b) of this section.
1990	10 percent.

(b) Not later than July 1, 1980, the Secretary shall prescribe, by rule, the percentage alcohol motor fuel by volume required to be contained, on the average, in the total quantity of gasoline sold annually in commerce in the United States in calendar years 1982 through 1984 and 1986 through 1989 by any refiner for use as a motor fuel. Such percentage shall apply to each refiner, and shall be set for each such calendar year at a level which the Secretary determines (A) is technically and economically feasible, and (B) will result in steady progress toward meeting the percentage alcohol motor fuel by volume required pursuant to this section for calendar year 1990.

(c) Each refiner shall report annually to the Secretary the percentage alcohol motor fuel by volume contained on the average in the total quantity of gasoline for use as a motor fuel that refiner sold during the preceding calendar year.

ENFORCEMENT BY THE SECRETARY

SEC. 8. (a) Any person who violates any requirement of section 7 (a) is subject to a civil penalty of not more than $1 per gallon for each gallon of fuel sold that is not in compliance with section 7 (a). Such penalties shall be assessed by the Secretary.

(b) (1) Before issuing an order assessing a civil penalty against any person under this section, the Secretary shall provide to such person notice of the proposed penalty. Such notice shall inform such person of his opportunity to elect within 30 days after the date of such notice to have the procedures of paragraph (3) (in lieu of those of paragraph (2)) apply with respect to such assessment.

(2) (A) Unless an election is made within thirty calendar days after receipt of notice under paragraph (1) to have paragraph (3) apply with respect to such penalty, the Secretary shall assess the penalty, or order, after a determination of violation has been made on the record after an opportunity for an agency hearing pursuant to section 554 of title 5, United States Code, before a hearing examiner appointed under section 3105 of such title 5. Such assessment order shall include the hearing examiner's findings and the basis for such assessment.

(B) Any person against whom a penalty is assessed under this paragraph may, within sixty calendar days after the date of the order of the Secretary assessing such penalty, institute an action in the United States court of appeals for the appropriate judicial circuit for judicial review of such order in accordance with chapter 7 of title 5, United States Code. The court shall have jurisdiction to enter a judgment affirming, modifying or setting aside in whole or in part, the order of the Secretary, or the court may remand the proceeding to the Secretary for such further action as the court may direct.

(3) (A) In the case of any civil penalty with respect to which the procedures of this paragraph have been elected, the Secretary shall promptly assess such penalty.

(B) If the civil penalty has not been paid within sixty calendar days after the assessment order has been made under subparagraph (A), the Secretary shall institute an action in the appropriate district court of the United States for an order affirming the assessment of the civil penalty. The court shall have authority to review de novo the law and the facts involved, and shall have jurisdiction to enter a judgment enforcing, modifying, and enforcing as so modified, or setting aside in whole or in part such assessment.

(C) Any election to have this paragraph apply may not be revoked except with the consent of the Secretary.

(4) If any person fails to pay an assessment of a civil penalty after it has become a final and unappealable order under paragraph (2) or after the appropriate district court has entered final judgment in favor of the Secretary under paragraph (3) the Secretary shall recover the amount of such penalty in any appropriate district court of the United States. In such action, the validity and appropriateness of such final assessment order or final judgment shall not be subject to review.

ALCOHOL DISTILLATION FUEL REQUIREMENTS

SEC. 9. (a) Any person constructing a facility to distill alcohol for motor fuel use shall use fuel sources which are renewable.

(b) The Secretary shall, six months after enactment of this Act, promulgate, by rule, procedures for certifying that any facility built for alcohol distillation pursuant to this Act comply with the following priorities of fuel use:

(1) First priority for fuel sources to operate such distillation facilities shall be given to renewable energy resources.

(2) Last priority for fuel sources shall be given to petroleum, petroleum derivatives and natural gas.

(c) The Secretary may by waiver, authorize the use of subsection (b) (2) fuel sources upon finding that it would be economically or technically infeasible to comply with the requirements of subsections (a) and (b), above.

PROCEDURES FOR RULEMAKING

SEC. 10. Any rulemaking by the Secretary pursuant to this Act shall be, unless otherwise provided in this Act, in accordance with section 501 of the Department of Energy Organization Act of 1977.

AUTHORIZATION OF APPROPRIATIONS

SEC. 11. There is authorized to be appropriated to the Secretary to carry out section 5 and section 6 not to exceed $1,000,000 for fiscal year 1979.

Senator CHURCH. We have with us this morning several of my colleagues who also support gasohol, and who have helped to bring gasohol to the attention of the Congress and the American people. Following their testimony, we will hear from two witnesses who have been directly involved with the production of alcohol and the sale of gasohol.

I understand that Senator Javits is in flight to Washington, and his flight has been delayed. He still plans to testify, but he may come in later this morning. When he does come in, we will hear him directly.

Our first witness is Senator Birch Bayh of Indiana, who has been one of the leaders in the Senate in the effort to attract national attention to gasohol; and I want to welcome him to the committee this morning.

STATEMENT OF HON. BIRCH BAYH, A U.S. SENATOR FROM THE STATE OF INDIANA

Senator BAYH. Thank you, Mr. Chairman. Do you have any objection if my staff assistant, who has spent so many hours on this, joins me at the witness table?

Senator CHURCH. That will be fine.

Senator BAYH. Mr. Chairman, I appreciate very much the opportunity to be here, to appear before your committee, the Committee on Energy and Natural Resources. This is a very important issue, as you know, being one of the leaders in this field.

I wonder if perhaps it might not be wise for me to do what I normally dislike, mainly confining myself to the text on which I have given a good deal of thought. You have a number of witnesses, and I think if I just go over this, I can do it in slightly more than 10 minutes.

If I sit here and extemporize, I probably will abbreviate it into 20.

Senator CHURCH. That, also, is a very usual experience with the committee.

Senator BAYH. That is a senatorial trait, so if you have no objection, why don't I stick to the prepared testimony; and I will, of course, be more than happy to yield, or to answer any questions.

Senator CHURCH. That will be fine.

Senator BAYH. I want to compliment you, Mr. Chairman, for the fact that the committee has set aside time to explore the potential of alcohol fuel for supplementing our Nation's diminishing supplies of fossil fuels.

Certainly, I want to associate myself with your opening remarks. I think you hit the nail right on the head in the interest and support that you, as chairman, and virtually—really, virtually every member of your committee has given to this important area.

It has been very encouraging, and I predict will be very helpful in accomplishing the goals that we all seek. I would also like to express my personal appreciation for the committee's adoption of my proposal S. 2400, the National Alcohol Fuels Commission Act, as part of the DOE authorization bill.

I think this is an important step. I have testified on this bill before your companion committee on the House side, the Science and Technology Committee, and I am most optimistic that it will be retained in conference and included in the bill we send to the President for his signature.

I think this will short circuit the normal, sometimes laborious legislative process, and get us into the business a lot quicker as far as additional information is concerned.

I know that none of us would be here today if we did not share the concern, which I have had for some time, about the need to reduce America's dependence on imported energy supplies and avert projected energy shortages in the future. Projections of a liquid fuels crunch in the 1980's, and the recollections of the Arab oil embargo of 1973, and the natural gas shortages of 1977, make us all painfully aware that energy is a limited and precious commodity which is the lifeblood of our society.

It heats our homes, fuels our cars and trucks, grows our crops, and runs our factories. This we know; America must come to grips with the fact that adequate energy supplies cannot be taken for granted. We must reduce our dependence on foreign supplies, become more energy efficient, make greater use of our vast coal reserves, and accelerate the development of alternative energy sources.

As we look to the future, Mr. Chairman, I think it is clear to most of us that there is not going to be any one answer to our energy problems, but that future supplies will come from a number of diverse sources. Those of us with responsibility for developing Government policy owe it to the Nation to explore every option available to us as thoroughly as possible.

I am convinced, Mr. Chairman, that fuels from renewable resources are one important option that have not received the attention they merit. Although alcohol fuels were used in this country during World War II, as part of our synthetic rubber production efforts, interest in their development as a source of future energy supplies has only been revived in the last year. Neither Federal dollars nor private sector capital have been committed to the development of alcohol fuels, as has been the case with some of the more capital-intensive and large-scale centralized technologies for oil shale production, coal liquefaction, and coal gasification. The oil companies are not interested in developing alcohol fuels. The Department of Energy has meager expertise in this area, and it currently employs only a handful of people in its biomass program. I think the DOE biomass program has three lost souls down there, and if you try to fight a battle for survival, that is hardly the kind of force to raise on the battle field.

Senator CHURCH. I think, Senator Bayh, that these hearings will evidence that private industry is way out ahead of the Government, and DOE is not in the lead at all. It can hardly be provoked into even taking an interest; and the plan for a pilot program is trivial compared to what is already being done by private companies. The question is raised in my mind whether DOE is, in fact, trying to solve the energy problem, or is becoming largely an impediment in its solution.

Senator BAYH. I am sure that these hearings, along with some of the others that you and some of the rest of us have held, will succeed in getting a larger share of DOE's attention. I can only hope the results will be positive.

Senator CHURCH. Let's hope so.

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Senator BAYH. I am confident, Mr. Chairman, that a relatively small investment and application of our best technology to this effort will yield payoffs that can be potentially momentous.

I freely acknowledge that barriers currently exist that have prevented widespread introduction of alcohol and other renewable energy sources into our energy mix. While I would be glad to discuss these considerations if members of the committee have questions on them, I would also point out, Mr. Chairman, that none of these so-called barriers present major problems, and I am confident that they can be overcome relatively quickly if we can just clarify our goals and get on with the job.

This country did not grow and prosper by approaching problems timidly. As a nation, and as individual citizens, Americans have always set our goals and then looked at existing obstacles as challenges rather than insurmountable barriers. This is the kind of effort we must make today as we move to harness our abundant and renewable resources.

Technical and economic barriers exist for every synthetic fuel being seriously considered today. And it is ironic that equally, if not more, complex problems than those faced by alcohol fuels existed when the petroleum industry was in its infancy.

And, Mr. Chairman, I think this is something a lot of people lose sight of. The idea of drilling holes thousands of feet in the ground and transporting oil all around the globe struck some people as absurd. But Washington was more than generous in the supports provided the oil companies.

The industry enjoyed import quotas, depletion allowances, intangible drilling deductions, and foreign tax credits. In fact, oil companies still derive some of their profits from these hidden subsidies.

I point this out not to be critical, Mr. Chairman, but to illustrate that in the past, when the Government has established a goal, it has been willing to act to accomplish its goal. It is only fair to suggest that we do the same with renewable resources.

Having set this context, I would like to focus this committee's attention, if I may, on the advantages offered by alcohol fuels and respond to your request for comments on S. 2533, the Gasohol Motor Fuels Act of 1978.

Alcohol fuels work. That is the place to start, Mr. Chairman. There is no question about that. The Department of Energy, the Ford Motor Co., General Motors, and Volkswagen all submitted testimony to the Senate Appropriations Committee at hearings I chaired in January, indicating that alcohol is a versatile fuel suitable for use in automobiles, gas turbine peaking units, utility boilers, industrial heating units, and fuel cells.

Alcohol fuels are a domestic energy source, a domestic energy source made from diverse renewable resources, available in meaningful quantities in every region of this country. Using them as an energy supplement can help solve our energy supply problems while giving a boost to depressed economies and bankrupt farmers all over this Nation and relieving the drain on urban budgets caused by waste disposal problems.

Alcohol fuels can reduce the cost of farm subsidies, an irritant to city people and farmers alike, and put idle land to good use by growing energy crops on set-aside acreage and marginal lands.

Mr. Chairman, and my distinguished friend and colleague, Senator Hansen, I envision the use of renewable resources grown from our farmland, as similar in impact on the economy as development of the soybean. Farmers don't like to have to be subsidized. The country doesn't like to have to pay subsidies. So why don't we plant a fence post by providing another market for the acres that are now are idle, or for which the return is not sufficient to pay the payments on the mortgage?

Alcohol fuels can reduce our dependence on imported oil, relieving our trade deficit and pressure on the dollar, while removing oil supplies as consideration in our foreign policy decisions.

Alcohol fuel facilities are comparatively inexpensive, without serious environmental problems, and can be built quickly. Alcohol fuels can be available in the near future, when we need them; because production technology is available, and the leadtime for construction of facilities is relatively short.

Alcohol prices are not prohibitive in the short run, and in my judgment, can be brought down significantly in the long run. Gasohol opponents claim that the addition of ethanol to gasoline in 10-percent quantities will increase prices. Every indication we have is that this is not true.

Because it is an octane booster, and offers increased mileage per gallon, gasohol is competitive with premium gasoline. Use of alcohol fuels for other applications is likely to reveal the same benefits. The recent granting of entitlements treatment to fuels from biomass will further increase its competitiveness.

Finally, if we look specifically at the dollar and cents standpoint, Mr. Chairman, alcohol production costs can be brought down in the near term. The Department of Energy currently cites a 13 to 17 per million Btu figure for ethanol production, which translates into $1.20 to $1.60 per gallon, if one considers only the economic costs of production and the distribution.

This estimate is based on production of alcohol from $2.50 to $3 per bushel corn, using traditional technologies developed to compete in nonenergy markets—I want to emphasize that, Mr. Chairman, traditional technologies developed to compete in nonenergy markets.

A process developed at Purdue University by Prof. George Tsao uses diverse, inexpensive cellulosic wastes as feedstocks—such as cornstalks, pulp bagasses from sugar mills, sawmill wastes and small limbs and tree branches, and industrial wastes and trash—cellulosic wastes, across the board, and treats them with a solvent that gives a 100-percent yield of glucose from available cellulose at a very low cost.

Estimates of the cost of ethanol produced by this process range from 40 cents per gallon to 75 cents per gallon, depending on the feedstock used and the value of the byproducts. This is one-third to one-half the cost that DOE and the major oil companies typically cite for ethanol at the refinery gate.

Similarly, research by Battelle Labs of Ohio for the Ohio Farm Bureau indicates that ethanol from sweet sorghum costs half the amount of ethanol from corn. I am sure that close examination of other feedstocks, and energy crops our plant geneticists could develop if given the go-ahead, would reveal the same economics.

In short, I think as far as economics are concerned, we have just started, and the future is a bright one.

Mr. Chairman, I submit to this committee that development of fuels from our farmlands and forests is too exciting a possibility to put off any longer. It is time for this Congress and this Nation to get off the dime and develop a comprehensive national alcohol fuels policy.

I know you share my impatience, Mr. Chairman. This is evidenced by your introduction of S. 2533, the Gasohol Motor Fuel Act. This legislation would impose deadlines on refiners for blending alcohol from renewable resources with motor fuels. By 1990, it would mandate a 10-percent alcohol, 90-percent gasoline, blend nationwide.

This legislative approach is one that has considerable appeal.

Right now, highway vehicles alone consume close to half of the petroleum used in this country. Despite increasingly fuel-efficient cars and trucks, and growth in mass transit services, transportation needs will continue to make a major claim on our liquid energy supplies. This reality highlights the attractiveness of transportation as a logical end use application for alcohol fuels.

In addition, Mr. Chairman, specific target amounts, and a date certain for meeting them, has the appeal of insuring that our goals will be met. It is a direct requirement, and does not depend on the vagaries of marketplace incentives to stimulate early alcohol fuel use.

As I am sure you know, other approaches for stimulating alcohol use have been suggested. DOE currently has the authority to guarantee loans for biomass facilities, and I understand they will begin implementing this program soon. The Senate passed a Federal excise tax exemption for gasohol last year, during consideration of the energy tax bill, which is now pending in conference.

Several States have granted similar exemptions from State taxes. Additional possibilities are low-interest loans or repayable grants for construction of small-scale regional facilities; the granting of investment tax credits or special tax allowances for earned income; guaranteed prices or mandatory Federal purchases; and changes in farm policy that would result in higher farm income and increased acreage for energy crops.

The thread that binds all of these proposals together is the judgment that it is in the national interest to begin to tap our abundant store of renewable resources for energy production. I know the committee will examine the pros and cons of each approach carefully, and I will not attempt to weigh each of them now.

But in response to the committee's request, I would like to make a few general points relevant to any of these legislative approaches. Then I would be glad to answer any questions you might have.

Because the goal of a program of this nature is to replace fossil fuels with those produced from renewable resources, I think it is important that the term "alcohol" be defined in a very generic sense. I would encompass not only what most of us have thought of as alcohols, liquid fuels from grain or wood, but also include any sort of hydrocarbon or chemical produced from a renewable resource that can substitute for a fossil fuel somewhere in the production, end use chain.

Further, any legislation passed in this area should be tailored to take into account the dramatic regional differences of this county, which have so frequently been our saving grace.

One of the most intriguing aspects of increased reliance on renewable energy sources is that we have a multitude of feedstocks that can be converted into a range of fuels suitable for varying needs around the country. Ethanol can be produced from such diverse sources as corn, wheat, milo, sweet sorghum, sugar beets, sugarcane, potatoes, algae, distressed crops, and crop residues, as well as numerous other energy crops that our plant geneticists could develop if given the go-ahead.

Methanol can be produced from newsprint, forestry products, crop residues, wood, and municipal wastes and coal. Methane can be produced from animal wastes, wood, or garbage; and so on.

In addition to considering these diverse supplies, it is important to address ourselves to varying regional needs for fuels or energy-intensive products. Industry uses vast amounts of energy for process and boiler uses. Rural areas need fuels for a variety of on-farm uses. Utilities need liquid or gaseous fuels for their peaking units.

To my mind, Mr. Chairman, one of the most attractive aspects of tapping our renewable energy resources is the possibility of tailoring their development to the needs of local communities. If developed wisely, I can imagine a time when both urban and rural communities can go far toward being energy self-sufficient by using locally available resources to produce energy and byproducts suitable for local needs.

In my own State right now, studies are underway regarding several facilities aimed at this goal. One facility would convert municipal waste, whose disposal is now a problem and expense, into methane, to meet local users' needs for secure gas supplies.

Others would convert a variety of Hoosier agriculture products and wastes into alcohols and other hydrocarbons, usable by farmers and industry in Indiana.

The attractiveness of this regional perspective leads me to one last observation, Mr. Chairman, and that is the importance of local people making decisions about how to best develop local resources, and the danger that once this revolution is set in motion, the oil companies or other major, large, international corporations will jump on the bandwagon and establish the same stranglehold on the production and distribution of renewable energy resources as has been the case for oil. To the extent it is advantageous to draw on the resources of large corportions in this adventure—and, indeed, it is advantageous—we must do so without permitting the development of a vertically integrated structure, with all its possible abuses. Should we not take this precaution, we will deny our farmers and small business concerns the many benefits possible from these developments, and probably sacrifice many of the gains to be had by freeing up the ingenuity of the American people.

Mr. Chairman, that is the end of my prepared text, I will be glad to yield to you, or to my distinguished colleague, for any questions you might have.

Senator CHURCH. Thank you very much, Senator Bayh, for your excellent statement. It shows the amount of thought that you have given to the subject. When the bill that is before us was first introduced, I asked the Secretary of the Department of Energy, Mr. Schlesinger, about gasohol, and he testified in the early part of this year that the economics were such as to suggest that the alcohol would probably have to be produced from coal, that coal looked like by far the cheapest way to do it.

Your testimony is quite different, and appears to be based upon a new process developed at Purdue University which could use almost anything which you have mentioned here—cornstalks, pulp, sawmill waste, sugar beet waste, small limbs, tree branches, industrial waste, trash—and, with the use of a solvent that gives 100 percent yield of glucose, brings the cost down to a price range of between 40 cents a gallon to 75 cents a gallon. These prices are not only competitive with gasoline, but, if they are accurate, they suggest that alcohol could be mixed with gasoline without even raising the price. Your testimony in this regard is quite different from that we received from the Department of Energy and Secretary Schlesinger.

I know that the oil companies are not enthusiastic about gasohol, and I know that many oil companies, also maintain large coal properties. Therefore, if they must produce gasohol, I suppose they would prefer to produce it from coal, so they would have control of both the coal and the oil.

You testimony gives us figures that changed the picture dramatically from the kind of picture presented to the committee a few months ago by the Secretary of Energy, and that is very significant. Have you been able to check these figures carefully for accuracy?

Senator BAYH. To the best of my ability, I have. Although I think the Tsao process is the most recent and most innovative of the new technologies, this Tsao process—George Tsao is the professor at Purdue who conducted this research with Federal grant or seed money—is just the beginning.

Secretary Schlesinger is presiding over a new department, composed of employees from the old agencies that were folded into the Energy Department. The fact that there has been nothing done recently in the alcohol area means that there aren't very many people down there advising him about the potential of alcohol or gasohol, so I think his reaction is to be expected.

I don't want to start a filibuster on this, but I get pretty well turned on over this subject. We talk about cost. You have to talk about more than just the laboratory cost. You have to talk about more than just the cost of industrial production.

What is the cost to our society of what has happened to the value of the dollar? What is the cost to our society of its continued reliance on foreign products which contribute to our trade deficit? What is the cost when we debate whether to sell jets to one nation or another, and in the back of our mind, we are worried about our oil being cut?

What are those costs? There is no way of putting a price tag on those, Mr. Chairman. In looking at the economics, Mr. Chairman, you have to consider—and nobody really has—the value of the by-products. You know, in rural America, we are very familiar—all three of us—we talk about butchering the hog. These days they sell everything but the squeal, but that wasn't always true. And so it will be with the alcohol process.

We are here to talk about alcohol, as a combustible product: but the high value protein that is a by-product of alcohol production is going to have a significant value also. I guess I have said enough on this, but when I think about the people who gnash their teeth and talk about the economics of gasohol, I am glad they weren't at Kitty Hawk talking to the Wright brothers. They would have said, "Well, Mr. Wright, the plane may fly, but it will never be economically feasible."

With respect to alcohols as fuels, we are a generation or two ahead of Kitty Hawk, but we are a long way from the jet transport.

Senator CHURCH. You know, at that time, it was up to the Wright Brothers to get on with the development of the airplane, it wasn't up to the Government. And, more and more we have tended toward making it a governmental responsibility, as we have done with the $10 or $11 billion we have appropriated this year for the Department of Energy to solve the problem; and that is really the approach I am trying to get away from in this bill.

Six years ago, even before the Department of Energy came along, we started to build a pilot plant in Idaho for geothermal energy to demonstrate the feasibility of generating electricity with natural hot water.

From the beginning, the engineers have all said it is perfectly feasible to do it; we have the resource. We are still trying to get the plant built. I think, maybe by the end of the decade, we will get it built; and then we will employ Federal people to watch it for another decade, and we will report back to the Congress on how well it is functioning, and we will colonize that little problem and keep it colonized, maybe till the end of the century.

And we can colonize gasohol, too, depending on the approach we take: we can capture it, colonize it, and hold it up until the end of the century with various governmental experiments and pilot plants, all shepherded by the Department of Energy.

Or we can just say, "Let's do it," to the industry, to the country, and set up a requirement. The technology is known; it is perfectly feasible; we will give industry a reasonable amount of time to tool up to it, with them a set of obtainable goals. My bill is very generous; it gives them till 1990, which I think is longer than necessary, but I have tried to accommodate any possible difficulty that might occur in turning the country in this direction. I think it is the only way of getting it done. I think the other route would prove as disastrous as my experience with geothermal pilot plants in the State of Idaho, and that experience is typical. I look in vain today for anything that has been built by the Department, anything that is on the line, anything that is producing.

Therefore, in my view, if you want to get there, you lay down the requirement and leave it to industry to meet that requirement. They will find 100 different ways to do it, in 100 different regions of the country, and they might get it done without the help of a single Federal employee, if we mandate it.

What is your opinion on that particular subject?

Senator BAYH. One thing that your approach accomplishes is to get around the chicken-or-egg excuse that one is confronted with every time you try to say, "Well, let's go." The argument is, "Well, we are not going to be able to develop the product until you have a market."

On the other hand, the marketers say, "Well, we can't market it until we have a product," so you are on the horns of a dilemma there. I think a requirement is that there will be a way to create a market.

I would hope that in the process we would not overlook, with regard to alcohol fuels, the potential for small businesses. Although getting gasohol into the fuel tanker is one of the major goals, we should handle this in such a way so that we would not permit the whole process to be monopolized by a few multinational giants, who take away the individual opportunity for companies.

As I said in my testimony, where you come from, timber products hold a great deal of hope. Cornstalks sugar-refined products, and other things that come from the Midwest also hold a great deal of hope. I can just envision, in time, that a rancher, like Senator Hansen, will coop up about 300 of those cows of his and they will produce enough energy to run his whole ranch.

Senator HANSEN. The bank has been in charge of my operation lately.

Senator BAYH. The bank? Well, that has happened to a lot of people, unfortunately. But, seriously, I had a lengthy conversation with several scientists that really did not have any Federal money; but they put a biomass project together using cow manure to generate methane, and it was a very good project.

Now, some of these projects are going to be pipe dreams, but so was the airplane, and so really was the first bubbling oil that was discovered in Pennsylvania, compared to where we are right now. I want those oil companies to discover all the oil they can; and God bless them—we want to help them, but that isn't going to be the answer to our problem. I think we all know that, and I think renewable resources should be developed post haste.

Senator CHURCH. Well, I agree with what you say. I think that if we want to create a market quickly, we should lay down a requirement to start blending alcohol with gasoline. Markets will appear overnight, and all of these small communities and small businesses as well as the big oil companies would engage in the production of alcohol.

I think that when new technologies involve a large risk or a large capital expenditure, so that private industry is unwilling to take the risk, then there is a role for Government to play. But the technology exists, it seems to me that the best way to facilitate market growth is to set a requirement now.

Senator BAYH. I don't know what the time frame is, Mr. Chairman, but we have only recently begun to research alcohol production; and I would think that in the new term, we are going to have some major breakthroughs in technology like the Tsao process, and maybe the second and third version of the Tsao process. These breakthroughs would significantly change the economics, if one is contemplating a national requirement.

I would hope that whatever that time frame is, if we are going to invest significant amounts of capital in developing alcohol, that we have a time frame that would permit the development of the second generation instead of the first generation of technology, so that we would have a greater return on the investment for the investors.

Senator CHURCH. That is why in this bill the time frame is extended to 1990, which would give ample opportunity for new technology to come on line.

Senator BAYH. You might want to think—and I haven't had a chance to confirm in my own mind—the 1990 time frame. A 10-percent requirement, might be acceptable and cause very little damage; whereas, in 1981, the requirement of 1 percent might create problems.

In other words, I don't know where or how long it is going to take to commercialize the Tsao process. If there were some similar process already industrialized—whatever it might be—then we could easily make the 10 percent by 1990, but the 1-percent factor might be much harder to reach.

I don't know, but I am sure the committee will look into that problem.

Senator CHURCH. We will certainly put that question to some of the experts who will testify here in the next day or two.

Your testimony has been very helpful. It makes an excellent opening statement for us, and we appreciate your interest in helping to make gasohol a reality.

Senator Hansen, do you have questions you would like to ask?

Senator HANSEN. First, let me compliment our distinguished colleague from Indiana for his interesting and excellent testimony here this morning. I am intrigued with the prospect that you spoke about. The cow manure is an interesting example; you know, because there are some big feedlots in this country, right today, and EPA has been causing them some headaches for reasons that are known to everyone. And they have determined that the management of big livestock feeding operations can't be continued as they have been in the past. Converting manure to gas provides an opportunity. Of course, manure isn't a total waste, by any means, but not full utilization is made of it.

I think that the cities of America are a classic example that cries out for better utilization and better disposal of waste products. I have traveled to New York City on the Metro, and when you pass that sea of flying papers and the area that is being consumed with landfill operations now, you can certainly understand that we can't continue very long with that sort of land use.

I think there is an exciting future that could very well solve two problems: one, the management of waste products; and, second, a significant addition to our overall energy supplies. I do have a concern about mandating the amount of motor fuel that shall come from gasohol.

I think that there may be better ways of approaching a very desirable end than approach, but I am open minded about it. I don't have any alternative to suggest necessarily. You spoke about the various things that the Congress has done to give encouragement to the oil companies, including import quotas, depletion allowances intangible drilling productions and foreign tax credits.

I should think that maybe to explore this kind of aid might be a better mechanism than simply mandating that a certain percentage of our total motor fuel come from a particular source. I think it has been axiomatic in the past, in the free enterprise economy, that we will invariably develop our cheapest resources first.

I have heard a statement made a number of times—one which I agree with—that we will never pop our last barrel of oil; and we won't for one very good reason. Before we get the last barrel of oil out of the ground that can be gotten out of the ground, we will have come up with a cheaper form of energy. It will be uneconomic to get that last barrel of oil out of the ground.

So, I want to compliment you for your testimony, and to assure you of my real interest. It is an exciting thing in those parts of the country that depend significantly upon agriculture, as do your State, and mine, as well. I hope that out of the hearings this morning there comes some thoughtful legislation, which will enable us to take advantage of wastes that we have tolerated all too long.

Thank you very much, Senator.

Senator BAYH. Thank you, Senator Hansen. I am glad to see that this problem is in such good hands as yours and the distinguished chairman. The question of mandating or not mandating is a difficult one to resolve, but it is a chicken-or-an-egg situation. You have certain corporations that have a real interest in continuing to develop the investments that they presently have. It is quite understandable. It seems to me that we must find a way to get around that reticence and to get involved, because I think gasohol holds a great deal of promise.

I am looking forward to working with all of you. I think we can not only deal with our energy problem and with the waste problem, but provide another source of farm income; so we are really talking about three opportunities, instead of three problems.

Senator HANSEN. Thank you very much.

Senator CHURCH. Senator Javits, I am told, is still aboard his plane en route to Washington; and Senator Morgan has been called to the floor of the Senate to discuss the HUD appropriations bill.

So our next witness will be Mr. F. Al Mavis, the energy coordinator, Bureau of Soil and Water Conservation, of the Illinois State Department of Agriculture.

Mr. Mavis, we are happy to have you here this morning.

STATEMENT OF F. AL MAVIS, ENERGY COORDINATOR, BUREAU OF SOIL AND WATER CONSERVATION, ILLINOIS STATE DEPARTMENT OF AGRICULTURE, SPRINGFIELD, ILL.

Mr. MAVIS. Good morning, Senator. It is a real pleasure for me to represent Illinois in this very appropriate meeting. I would kind of like to lay to rest the 1 percent mandate, because I, being a country boy, have never believed in mandates, but I think what Senator Church is trying to do is to help get the Government off the back of a new energy and to encourage some operation that will make this thing succeed.

I suspect—I am like Senator Bayh—I had best read from my notes, so I don't get too far from the printed matter. I brought some library material I left with the staff, so if there is some future question about some of these things, the staff has the material, and we at the Energy Section at the Department of Agriculture are always at your back and call to simply do what we can to encourage the implementation of the new alternate fuel system.

It is indeed a privilege and an honor for me to appear before this esteemed committee and present the Illinois case for alcohol blends of gasoline.

My talk will be primarily about agriculturally derived ethanol. We recognize, of course, there are many other sources that American ingenuity will bring on the line very rapidly in probably large amounts.

When 10 percent is blended into 90 parts of unleaded fuel, it is to be called "gasohol."

We in agriculture are seeking the support of the petroleum industry in the use of ethanol as the "fuel extender" we need while other sources of liquid fuel are being developed.

Why is agriculture so vitally interested in America developing a viable, alternate fuel source? It is quite simple. Farmers must have liquid fuels. They can't put a coal bucket on the tractor; they can't use electricity. Geothermal won't work. It is just this simple—agriculture must have readily available liquid fuels.

Without fuel, there will be no food; and vice versa, without food, there is not immediate renewable alternate fuel available.

Agriculture production only uses 3 percent of the energy consumed in America. With this small amount of fuel, agriculture produces enough food and fiber to keep 220 million people fat and sassy, enough extra production to send ag exports overseas to pay for one-half of all the oil America imports, and surpluses enough to break their markets below production costs.

Agriculture has taken a hard look at conservation and is rapidly moving into reduced and zero-tillage programs. In Illinois we ask, "Is this trip necessary?" Saving a trip saves energy, soil, water, time, and a dollar. Illinois has 24 million acres under cultivation. We save about 24 million gallons of nonrenewable fuel each time we get Illinois farmers to save a trip. An intense program of soil testing is encouraged to assure that the fertilizers applied are properly used.

Diesel power units versus gas: Oil folks tell us when American runs out of gas, it will run out of diesel. Conservation programs are great, but very limited in effort. If America is to reduce its energy consumption, it must be careful that it doesn't result in bringing the American way of life and American industry to a halt.

Early in our conservation program, it was quite obvious the weatherman, insects, and time have a lot to do with trips reduced and chemicals used. It was obvious we could attain conservation of nonrenewable fuels by the substitution of renewable, alternate fuels.

In addition to agriculture, this substitution would also fit cars and most trucks being used on U.S. highways. We are looking forward toward a 7 percent saving by conservation before 1985.

Senator CHURCH. It is interesting that we talk so much about conservation. Everybody favors it, and yet the projections are perhaps a saving of 7 percent through all kinds of conservation measures. We could save 10 percent if we could mix alcohol into gasoline. This comparison illustrates, I think, the importance of gasohol and the significant contribution it could make. Gasohol presents a real opportunity which the Nation badly needs.

We ought to look beyond the vested interest of certain private groups and take advantage of this opportunity.

Mr. MAVIS. I think you recognize the very fact we talk about we can get conservation—we see a field out here that is almost unlimited on the other side, and that is substitution.

With America importing half of its oil, with cars in America burning half of all the oil used each day, it is quite obvious that all the oil that we import is being consumed by the American driver, about $5 million an hour, every hour, every day of the year.

Ethanol has been recognized as a good fuel for years, its early advocates being Henry Ford and Edison. It was extensively used during the war, and now all this has been reconfirmed and documented by recent Nebraska gasohol studies. A grass roots movement in Illnois led to gasohol commercialization.

In October 1977, Congressman Paul Findley requested his administrative assistant to have some testing done with his mobile office and a pickup truck. The first over-the-road test carried with it a set of extra tanks for switching fuels and an EPA emissions tester.

Needless to say, this tour through the 20th District was a success, and it became the catalyst to get ethanol moving into the fuel systems of Illinois.

In November 1977, Adeline Geo-Karis and Joe Lucco, two members of the Illinois House of Representatives, and members of the Illinois Energy Resources Commission, held energy meetings, at which time they poured ethanol derived from cheese whey into their own car and drove off into the sunset.

At this same time, Representative Geo-Karis asked one of her constituents to open commercial sales. From that mere beginning, Illinois now has outlets throughout the State. These stations are selling gasohol for what it is, a premium no-lead, without any subsidy.

During this period of time, the Department of Administrative Services tested 11 State cars on an "as-was basis". This test again confirmed what Nebraska and Germany reported, less pollution, and increased mileage.

Early in October of 1977, a request was made to Earle Gavett, an economic advisor of the USDA, to obtain answers to the following questions:

One: Value of having the agricultural community in full production?

Two: Value of eliminating Federal payments for nonproduction?

Three: Value of renewable energy sources versus deficit dollar purchase of foreign oil?

Four: Value of increased spending by agricultural communities when agricultural production is profitable?

Early in January, a copy of the USDA publication, "Gasohol from Grain—the Economic Issues", was received as the answer to these questions. There was absolutely no connection. To simplify it, this report said, "It was based on 'secondary information' and it only covered 'grains' ".

At this time, and to this date, most of the ethanol is coming from sugar and starch streams that result from primary processing of timber, grain, and milk. At the time this report was written, only ethanol from the paper industry and cheese whey plants were available. In the same report the $10 billion subsidy to get gasohol used in America, which would be about 10 cents a gallon—I would sure like to have 4, Senator.

Ethanol is here now. It is a clean burning, renewable, viable fuel, whose raw products are available in every corner of this United States of America, and in large, storable, renewable quantities. Many of these are receiving huge Government payments for subsidy, storage, and disposal, such as molasses, dried milk, sugar, corn, wheat, and milo.

In this kit that I left your staff, Mr. Chairman, are some figures that came down, just as the Government has in store, 568 million tons of nonfat dried milk that we paid $714 million subsidy on last year to store and handle it. If this figure is true, that 568 million tons is enough milk to produce enough alcohol to put 10 percent in every car in America for 13½ years. We may not need any doctors—we may just need a dairyman.

Senator CHURCH. We will have to check those figures.

Mr. MAVIS. Yes, sir, well, I enclosed in your file a letter that came down from Congressman Findley's office that the gentleman in the Commodity Press cornered, so it is in your text.

From the one-limited source, milk ethanol from Milbrew of Wisconsin and wood ethanol from Georgia Pacific of Bellingham, Washington, we now have Archer-Daniels Midland of Decatur, Illinois, Grain Processing of Muscatine, Iowa, and Anheuser-Busch of California, who are producing ethanol that is available for fuel.

Currently, 1 gallon of ethanol costs more than $1. The sad situation is that current distillation processes turn this alcohol out in its best beverage quality. Then, in turn, it must be poisoned before entering the fuel systems. There is a general feeling of those distilling ethanol that "rotgut alky" will burn as well and be easier and cheaper to produce.

Here is where the Department of Energy could be spending some of its $10 billion. We are denaturing with methanol, the other alcohol. Here is an easy way to use methanol without having it give motorists the problems of phasing, hard start, et cetera.

Current plants are in pilot stages, and we have yet to see the economic impact of competition or American ingenuity. Even though the alcohol is higher priced than gasoline, as a gasohol blend, it becomes a premium no-lead and is priced and selling in this market.

Quite often you have heard, or you have read, that it takes more Btu's to produce ethanol than the Btu's it produces. Let's really look at the facts:

One: First, America is not short Btu's. It is short liquid fuel.

Two: Energy inputs used in these studies include raw production energy, part of which is the energy used to manufacture the tractor and its implements. If we use this basis for ethanol, we should, in turn, charge all the same proportionate share of energy used to build the drilling rigs, the tankers, the refineries, the pipelines, et cetera, to each gallon of oil.

Where do we put these charges when we export the products? When exporting, we ship the carbon, hydrogen, oxygen, rainfall, and sunshine, as well as the nitrogen, phosphorous, potassium, and microorganisms overseas. All these need total replacement. Ethanol production consumes only the renewable.

Three: What charge shall we place on the word "nonrenewable" versus "renewable"?

Four: How do electricity, nuclear, et cetera, compare, using the same basis as they choose for ethanol? We are not technical people, but we do know we can use ethanol in gasoline on a 1-to-1 basis and improve emissions and performance. Electric generation is only about 30 percent efficient.

One of the top ethanol experts in Government is Dwight Miller, USDA Regional Lab, Peoria, Ill. His letter of July 24, 1978, says 1 gallon of ethanol replaces more than 1 gallon of foreign oil.

How about the economics of production? Here we need to do a study of the DOE release, "Alcohol Fuels Program Plan," DOE/US—001/2, March 1979.

I will cite a couple of items from this report. Pages 1 through 5 says, "The limiting factor to alcohol fuels utilization through the year 2000 is the availability of fuel producing plants." What is wrong with DOE getting plant construction underway?

On this same page it says, "Ten plants could be built for $500 million." This is just 5 days of deficit dollars going overseas for foreign oil. This 300 million gallons of ethanol has an American retail value of $360 million.

Retail amount—$360 million.

Will replace equal amount of foreign oil—$90 million.

Net value—$450 million.

Without any value to the American economy, no value for all the other products produced in the process, no value on freezing OPEC price rises because of competition, the return in 1 year is about $1 for each $1 of plant cost.

The figures I use for Illinois corn set-aside program will have the same relationship to every State in which set-aside for wheat and grain being used.

Previous 3-year Illinois corn production average—1.2 billion bushels.

Previous 3-year Illinois acres planted, average—12 million acres.

Twenty percent set-aside, 240 million bushels.

Twenty percent set-aside, 2.4 million acres.

Two hundred forty million bushels—600 million gallons of ethanol at $1.20—$720 million.

One hundred dollars per acre set-aside payment, 2.4 million acres—$240 million.

Six billion gallons foreign oil not needed at 40 cents—$240 million

Net wealth for Illinois and America—$1.2 billion.

Again, we haven't placed any value on the general economic value of taking the farmers off the tax recipient role, the value of all other products in the processing of products for ethanol, the value of all services being able to operate at 100-percent capacity—all have positive values. The set-aside was not achieved in Illinois, but was highly promoted and advertised.

Federal help with ethanol is almost nonexistent. In the USDA program, $24 million for research was written into section 1419. Several Illinois universities and colleges filed applications, only to find this section was not funded. Section 1420, that contains loan guarantees, has all of America excited, but those loans appear to be months, perhaps years, away.

DOE has poured millions into new solar research, while almost totally avoiding the solar programs that are now working. The American farmer, whether he grows trees or milks cows, is the best "solar-engineer in America." Why hasn't DOE funded ethanol research programs that will lead to improved techniques in fermentation, distillation, and commercialization of ethanol? Ethanol is a known and operating solar energy recovery program. Brazil says, "Alcohol is solar energy in liquid form."

Why haven't the same tests on ethanol been completed at the test centers as has been done with methanol? The American Automobile Association demonstration here in Washington, that many of you participated in, is the best example of the simplicity of ethanol and the quality of fuel it makes when blended with gasoline.

In a recent press release, Congressman Paul Findley, of our State of Illinois, reported 87 percent of those who answered the survey they received when they fueled up with gasohol at Capitol Hill, told of improved operation and mileage. This is typical of the stories heard from Iowa, Nebraska, Pennsylvania, New York, Montana, and Illinois.

Senator CHURCH. Incidentally, I had my tank filled with gasohol that day. I didn't check my mileage, but I do know that the balance of the week the car operated splendidly.

Mr. MAVIS. Thank you.

I think the real big breakthrough there, Senator, is the fact that people find that even though we will only have gasohol in limited areas, you can drive and use it while you can, because it is a better fuel. When you run down the road and you can't buy it, you go ahead back to your usual fuel system without any modification of the automobile's system. So, a lot of these reports we have read have not been true.

In closing, here are some things that need immediate attention. If America is to break the stranglehold OPEC has on this Nation and its people, it must:

One: Promote the substitution of renewable alternate fuel—ethanol—as the number one way to get conservation of nonrenewable fossil fuels.

Two: The 4 cents Federal tax needs to be removed immediately. We agree with many of you, it is worth more than 4 cents a gallon to keep the American dollar home. A 10 percent reduction in imports is $4.5 billion. This money stays home, as well as the new wealth and taxes generated by industry and agriculture.

All or parts of this can be transferred to the road trust funds to make certain our highways are kept in first class condition. The 4 cents tax on 100 billion gallons of gasoline consumed in 1 year is just $4 billion.

Three: A finance program on the original Rural Electrification Act, which gives low interest, long-term repayable financing for production and distribution of ethanol. This program should be used only if raw products used are renewable.

Four: Immediate funding of Section 1419 of the USDA program.

Five: DOE grants and loans to alcohol producers to establish, as soon as possible, the feasibility of removing the alcohol before it reaches beverage quality.

Six: Immediate implementation of fleet program, using gasohol for Government vehicles, Postal, General Services, Army, Navy, et cetera. Every gallon of ethanol saves one gallon of nonrenewable fossil oil.

Seven: A test program of vehicles, with all pollution equipment removed, operating on gasohol with various amounts of ethanol: 5, 10, 15, and 25 percent. At the same time, monitor like vehicles, with and without pollution equipment, on standard gasoline. The elimination of the equipment could lead to reduced car costs, as well as increased mileage.

Eight: Immediate funding of research on ethanol and diesel combinations. Early research documents 10 percent ethanol sharply reduces smoking of diesel. This should be of primary interest to the Department of Defense to eliminate smoke with their tanks and to EPA to clean up the air.

Nine: Order elimination of gas with the toxic tetraethyl lead. This will eliminate regular gasoline. Replace it with clean-burning gasohol. Gasohol appears to be the one fuel that could fuel all cars effectively. Service stations could now have one pump. This eliminates the Government's worry of people filling their no-lead cars with regular gasoline in the self-service stations.

Ten: Tax incentives for companies who manufacture ethanol from by-product sources or Government surpluses.

Eleven: A positive, honest, public relations approach to the uses and benefits of the clean-burning, renewable fuel, ethanol. Fund the American Auto Association to do acceptance programs throughout these United States. Shopping-center-oriented dispersal is easy to attain with AAA's program.

Not since Pearl Harbor has America had any one thing to rally around that will benefit them all. This is the first thing in my lifetime that all the farm organizations can be for without jeopardizing their private whims.

This is probably the first thing that EPA could find that doesn't cause cancer. Cleaner cities, roadsides, and waterways will result. A new capital investment and employment program, good for all America, will also result.

The reversal of the flow of deficit dollars, retaining these dollars in the U.S. Treasury to be joined by the taxes the new industry creates.

Please, gentlemen, take whatever steps necessary to implement a national gasohol program now.

Thank you very much.

Senator CHURCH. That was an excellent statement.

Tell me, Mr. Mavis, in the State of Illinois, how many gas stations are selling gasohol?

Mr. MAVIS. Thirty-three commercial stations, on the line.

I think our last big breakthrough—you might be interested in—was Continental Oil distributor, right in the Wood River area—just took on a station. He distributes Continental Oil in the southern State.

Senator CHURCH. It has often been said that one of the difficulties of getting gasohol on the market has been the lack of availability of the product. Where does the gasohol come from that is being marketed through these 33 stations in Illinois?

Mr. MAVIS. Let me give you a little history, Senator.

Last November, when Illinois decided we were going to commercially implement gasohol, our first and only source at that time was the cheese industry in Wisconsin. At that same time, Nebraska had been successful in getting some wood sugar alcohol from Washington. So those two sites were the only sites, and the alcohol we could get our hands on—it was only 192; and everything that we had read in the library, and everything that everybody had told us, it had to be 200.

But, again, because agriculture was sick, and Illinois produces one-sixth of all the corn in America, and we have stored in Illinois almost a year's crop, these things are serious with us. We are producing probably this year the largest crop we have seen, and without any change and frost; and even though we have had a cutback in acreage, we weren't able to get the larger people interested in what we were doing, because they had read so many "anti" articles. The press had been very bad—primarily not that they were bad, but that they were misinformed. They mixed up methanol with ethanol, and they mixed tank costs with alcohol costs or gasoline costs.

So we got together with the Illinois Petroleum Markets, a very fine agency that represents a lot of petroleum people, and with them we had a joint meeting of the oil people. We brought in waste people and pump people, and sat down and looked at that time the tankloads of unleaded fuel and the cost in Illinois of about 40 cents; so, without tax, nine gallons of 40-cent fuel is $3.60 and a gallon of alcohol is $1.44. So, right quick, we knew what our costs were. We were up to $3.60; we were 49.4 cents without tax. And we had in Illinois a Federal tax of 11.5 cents, so, right quick, we were up to 60.9—and that is what the fuel is going to cost, other than the limited amount of States sales tax, 5 percent on the original 40, and a profit.

We went on the line with the first alcohol fuels at 69.9, and based on where it is, it still ranges from 69.9 to 77.9; so it gives the station money for their State sales tax, and a profit that ranges from 9 to 17 cents. Some of the taxes I am not familiar with—

Senator CHURCH. How does that compare with the price of premium gasoline?

Mr. MAVIS. It is under premium gasoline. It is within the price of no-lead in our country. Amoco premium no-lead gasoline sells in Springfield at 78.9, and we can buy gasohol at 75.9. So it is a little under; it is a no-lead price more than premium lead.

The thing about it is in the breakthrough we use 190, the cheaper alcohol, the one that every beverage company can make; and we think that led to some of the breakthroughs that have taken place. After 4 months of visiting over the phone with these people, they invited us to come and spend a day with them and talk about it; and when we left them, they told us they would come on the line with the first anhydrous alcohol plant, and the plant indicator is the first anhydrous alcohol plant in the world that makes anhydrous alcohol out of wet alcohol.

Previously, we have always gotten it from the petroleum industry, but this is a country-based, 200-proof alcohol. So for those people who feel like they have to have 200, there is some available. But we are selling the 190, too.

Senator CHURCH. Isn't 200 proof drinkable?

Mr. MAVIS. The 190 is drinkable, too, sir. Both of them are drinkable. but 200 has absolutely no water.

Senator CHURCH. I see.

Mr. MAVIS. But the 190 is also drinkable until we put in the denaturant of methyl and some of the other poisons to keep the people from making it drinkable; and you might point out that we have seen some price breaks, as I told you. The first alcohol we bought was $1.34. A tank float now, or tanker lots, is $1.17. We have been in search of a way to get freight rates involved in this thing, and we find two or three things that are disturbing.

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First, the smallest car that we can get to ship it in is 29,000 gallons. That takes a very large petroleum distributor to take that. It is a long time in moving it. He has got his money tied some time. But at that price, had we been able to put the freight rate together, it was $1.12.

So, competition within 9 months, ingenuity within 9 months, has reduced the cost of the fuel on the basic alcohol considerably, and we look for sharply lower prices as the industry really moves its waste product into the fuel system.

Senator CHURCH. Well, I think that your experience, even with the conventional method of distilling the alcohol, shows that it can be marketed.

Mr. MAVIS. Yes, sir. It is very viable.

Senator CHURCH. Experts vehemently deny that gasohol can be economically marketed, yet you are doing it. It would seem to me that this is the best evidence that it can be done.

Mr. MAVIS. I go back to this thing of honesty in reporting. That disturbs us no end. Some of the oil companies have been successful in getting letters to the editor in every paper in the country, in which they have told about the nondrivability of gasohol, and the cars clicking, and needing new fuel systems. These are things that we have got to stop some way, because they are not the facts.

It is a very, very simple fuel. I travel in a State car, and away from the garages—we have seven garages in the State that we can put it in—but when I go away from there, I carry a 2-gallon can with me and put in 2 gallons of alcohol and ask for 18 gallons of unleaded, so that we can monitor the cars and keep the records that we are keeping.

So, there have been a lot of poor reports written.

Senator CHURCH. You have been experimenting with gasohol in the State cars and monitoring their performance?

Mr. MAVIS. Yes, sir.

Senator CHURCH. How long has this been going on?

Mr. MAVIS. We put the first alcohol in State cars in November, and we now have seven State garages that are actively furnishing every car that pulls in there. Every car, whether it is a State police car, department of law enforcement, education; everybody gets gasohol.

And, to this day, Senator, the only complaint we have ever seen—we had one truck at the fairground that quit, and we discovered—that was a good discovery, because we thought it was a scavenger. If you put gasohol in a car that has been rusty and has sediment in it, it will wash it all down right now and it will plug up the pipes.

We have learned to be very careful with rusty tanks.

Senator CHURCH. Aside from the rusty tank problem, what is your monitoring showing on the State cars?

Mr. MAVIS. It showed a 6.1 percentage increase in mileage, a 30-percent reduction in hydrocarbon, and 6-percent reduction in carbon monoxide. It will benefit in every way, sir. We, in Illinois, use 14 million gallons of gasoline a year; so if we get a 6-percent increase in mileage, we save the State a considerable amount of money.

Or the consumer might look at it like this—if fuel is worth 75 cents, and you get 6 percent greater mileage, you are driving 70-cent fuel. There are lots of ways of looking at it.

Senator CHURCH. You have used cheese whey. You said that was the original source of your ethanol. You have already testified about the surplus dry milk. What other sources would you think would prove highly attractive?

Mr. MAVIS. Almost unlimited. The Idaho potato farmer has got to be concerned real fast, because the little potatoes that have been left for years—I have a close friend in Georgia who used to grow sweet potatoes, and the sweet potato market went sick. He is now growing soybeans in competition with me, not that he likes to grow soybeans; so the sooner he gets an alcohol plant in Georgia that will make alcohol from sweet potatoes, the better off I will be.

I see all the slipstreams, you know, the grain processing. If we are able to take and convert 50,000 gallons of alcohol out of the waste streams in 1 plant, we have got 11 others that probably have the same problem. So, there are lots and lots of sources. It is almost unlimited—wood sugar, out of every wood plant.

Senator CHURCH. Senator Hansen, do you have any questions?

Senator HANSEN. Mr. Mavis, thank you very much for your testimony.

I have a letter written to the Washington Post by Joe E. Pennik, president of Mobile Research and Development Corp. I think this was in—I am not certain what day—it must have been around the second of June. I just want to read a couple of statements from that letter.

He is commenting upon a column by Jack Anderson and says:

> Even the high price between the alcohol, three times the price of gasoline, wholesale, could be offset at taxpayers' expense, of gasohol, it would really reduce the outpouring of dollars to the oil potentates.

Mr. Anderson asserts:

> But it would not. Imports would go up, not down, because the process of growing, fermenting, and distilling grain, consumes more energy than it produces.

A new Department of Agriculture report put it this way:

> Converting corn energy into automobile fuel results in a negative energy balance. Agriculturists calculate that it takes twice as much energy in the form of diesel fuel, gasoline, and fertilizer fuel oil, et cetera, to grow the corn and operate the distilleries than is contained in the final product.

Would you care to comment on that?

Mr. MAVIS. I would love to comment on that. That is the kind of press that it has been hard to handle. The people are misinformed. I said in my statement, if we are going to put the charges on the energy it takes to produce the crop into the alcohol, then we ought to charge the value of the nonrenewable coal. We ought to take the energy it takes to build a refinery and charge it back. We ought to take the energy to build a tanker and pipeline, because what they are doing, they are charging a product of value to the cost of the alcohol that is going to be used, even if we ship that grain overseas.

And the $2 sale—the sale which the Government has under Public Law 480, where we send those products over, we send all that energy and all that fertilizer overseas—but where we convert into alcohol, in America, all we take out is the carbon, hydrogen, oxygen, rainfall and sunshine, and we have got the other left, either for food for animal or man, or it is returned to the soil. So, Mr. Pennik's figures are not true. Had they been true, there would have been a lot of people in the alcohol business quit. We wouldn't be seeing them making fuel out of waste streams.

Anheuser-Busch wouldn't be having a plant where they could make their waste streams, because all of a sudden everybody wants to charge all the fuel costs to the cost of that corn. A bushel of corn gets two and a half gallons of alcohol, but it gets 18 pounds of high quality protein. They play with these figures, sir. They are misleading.

Senator CHURCH. Our next witnesses might have something to say about the processes they are using in this connection, and we certainly want to follow up on that issue.

Senator HANSEN. I don't mean at all to leave the impression that we are trying to defend the oil companies. I just want to get your comments. I would ask you this, though. In the case of the drilling and refining and transportation facilities that an oil company uses, wouldn't they have to amortize those costs in with other costs in determining when they can profitably sell a gallon of gasoline.

Mr. MAVIS. You can amortize our production costs into per bushel costs, too, sir.

Senator HANSEN. Your point is that these figures do not reflect the same accounting procedure?

Mr. MAVIS. No, sir, and we were about a one-to-one, if you stop and figure we get back per energy put in even with production costs, we get back an energy unit of alcohol. But we are overlooking, I think, the important impact of the thing. It is totally renewable every time the sun shines somewhere in America somewhere.

Thank you.

Senator HANSEN. Thank you, Mr. Mavis.

Senator CHURCH. Mr. Mavis, would you come back and answer one question I meant to ask directly, and I failed to ask?

Mr. MAVIS. Yes, sir.

Senator CHURCH. Based on your experience, at what point in the distribution chain should alcohol be added to gasoline to create gasohol? From a technical and regulatory standpoint, is it better to add alcohol at the refinery level, distributor's level, or the retail level?

Mr. MAVIS. At the distributor's sir. It is very, very easy to handle there, because a tanker comes in and at the station it would be some time before we are looking down the road at one fuel, as we talked about—so a tanker going out to an area can take some no-lead, and premium lead, and some gasohol, as long as it is in the present petroleum system.

Senator CHURCH. Then there isn't any question in your mind that the most efficient way to get gasohol into the market is through the present fuel distribution center.

Mr. MAVIS. That is what we have never been able to understand, because we have encouraged the oil people to join hands with us. We have led the oil people to the alcohol people, and saying, "All we are doing is helping you with 10 percent more stuff to sell."

Senator CHURCH. Thank you very much. Our next witness this morning is Senator Morgan.

STATEMENT OF HON. ROBERT B. MORGAN, A U.S. SENATOR FROM THE STATE OF NORTH CAROLINA

Senator MORGAN. Thank you, Mr. Chairman.

I apologize for not being here at my allotted time. I had 7 minutes I had to use on the floor.

Senator CHURCH. Perfectly all right.

Senator MORGAN. Gentlemen, I have a statement I would like to submit for the record, because I think it is rather interesting and more in detail.

But for the purpose of discussing the two points that I want to raise with you, I will speak from my talking paper. I am sure that from the previous testimony that you have already heard this morning, there is a great deal of support and praise for alcohol fuels.

And I, of course, want to join with that. I think that it offers a real possibility for the future, and I might say, as an aside, that coming from a particular area of my State, that I do—my particular county, we have had right much experience in manufacturing alcohol in the past, not altogether legal, but it has been—well, some of my clients were rather successful at it, and we might be able to call on them for their expertise.

There are two unrelated points that I would like to mention. One is that an alcohol fuel might finally be the solution, or present us a solution, to a very serious problem that the southeastern part of the United States has experienced in recent years with regard to aflatoxins in corn.

Senator HANSEN. In regard to what?

Senator MORGAN. Aflatoxin; it is a mold that infects corn if there are more than 20 parts per billion. It cannot—it is alleged to be carcinogenic, and last year, out of 198 million bushels of corn grown in the southeastern part of the United States, 111 million bushels were found to contain more than 20 parts per billion of this "mold," I guess you call it.

And it causes a real problem in North Carolina, because if the corn is bound into container mode, you can't use it for human consumption, and you can't use it for livestock. Now, the North Carolina Department of Agriculture has a very effective enforcement division, and because of that, we had quite a crisis in and among our corn growers last year.

Many of the farmers, of course, I am sure fed it to livestock anyway, fed it to the livestock that did not cross State lines. And I am sure that more of it got into interstate commerce, but it is a very, very serious problem.

Now, this past year is the worst year that we have had in a long time, but it does present a real problem. About 40 percent of the corn crop in North Carolina was contaminated with this highly carcinogenic mold. So, as a result, large volumes of corn were destroyed by burning.

Some farmers were required to bury the corn. Much of it was dumped in the ocean. And these crops, could have been converted into alcohol fuels at a very low cost, since the corn had no value for other purposes.

I suspect—I notice the somewhat surprised look on the committee's face—I had never heard of the mold either until last year, until my farmers descended on me.

Senator CHURCH. I suppose you have heard very little else since.

Senator MORGAN. This is one area where we think it could be used and isolated now. I am sure that there are other crops that are grown that would be in a similar situation. But a second unrelated point, which I want to mention—and I address these more thoroughly in my paper—is that of the tens of thousands of plant species in the world, we rely only on about 20 for the overwhelming bulk of our food industry in this country.

And it would be a remarkable coincidence if the plants that we use for food are also those best suited for producing alcohol fuels. So, what I suggest in my paper is something along the lines of a fuel farm research act. It could follow along the lines of, or in the steps of, the highly successful National Science Foundation efforts to catalog rare plants with commercial application; and I am sure that both of you are familiar with some of those successes.

Perhaps the most famous and successful discovery was the flying bean, a plant which has potential for raising the consumption of protein in the underdeveloped world; and I could name many others, but suppose for instance this farm research developed that some of the fast growing plants in the world were just as suitable, or maybe more suitable for producing alcohol—how beneficial it could be, and it might be more economical.

When I was going over this, the thought occurred to me that if we could just find some way to convert kudzu into alcohol.

I saw the quizzical look on Senator Hansen's face when I mentioned the word "kudzu"; have you heard of it?

Senator HANSEN. No.

Senator MORGAN. Let me tell you about it. It is a plant that was introduced back in the Depression days by the Conservation Corps, the CCC—I have forgotten the exact initial—the Civilian Conservation Corps. In their work, you know, they cleaned out gullies, and kudzu was supposed to help prevent erosion.

It prevented erosion of the gullies, but it also ate up the farmers. It is the fastest growing vine that you have ever seen. You drive along in the South, and I am sure in other parts of the country, you can just see fields and fields of green vine with leaves about this big. It is so thick that you can't walk in it.

The roots will eventually get this big; and until the last few years there was no way of killing it except by continually cutting it up in the wintertime when there were hard freezes.

Or you could do it in the summertime, when it was hot. But recently they have come forth with some kind of a spray chemical that will kill it. Now, I have one whole farm that CCC did for my father back in the 1930's, and it just ate the farm up.

Well, I probably could have stopped it years ago, but up until the last few years, cleared land wasn't that valuable in the South, so I let it go. It can be done now with chemicals. Suppose we were to find that some fast growing vine such as this—it grows with almost no expense except the use of the land—could be converted into alcohol.

So, what I propose, or what I suggest, is that I think we want to consider a program for alcohol fuels as a viable alternative for some of our problems in energy, and certainly, in these two respects. It could be of interest to the whole Nation.

[The prepared statement of Senator Morgan follows:]

Statement of Hon. Robert B. Morgan, a U.S. Senator From the State of North Carolina

In my testimony today I would like to address two somewhat unrelated matters. First, I would like to describe the potential in the Southeast for brewing alcohol from corn contaminated with aflatoxin, a widespread and extremely carcinogenic mold residue. Second, I would like to recommend several research initiatives that I think will have a particularly high pay-off value.

There has been a great deal of general discussion of the values and virtues of alcohol fuels. I would like to focus my testimony on a very specific opportunity that the Southeast, and North Carolina in particular, have to help solve the energy problem and at the same time to eliminate a major health and economic distress.

Throughout the Southeast corn crops are regularly plagued with a mold that produces one of the most potent carcinogens known to man. This mold leaves a residue called aflatoxin. The Food and Drug Administration outlaws the sale or use of corn with concentrations of more than 20 parts per billion. Aflatoxin is the most potent liver carcinogen known to man. It is roughly 10 million times as carcinogenic as saccharin. Almost every year a sizeable percentage of the corn crops in the Southeast are contaminated by aflatoxin mold.

This contamination is not an isolated phenomenon. Last year, of the roughly 198 million bushels of corn grown in the Southeast, 111 million bushels contained aflatoxin in concentrations exceeding 20 parts per billion. More than half the corn produced in the Southeast was rendered unfit for human or animal use by the aflatoxin mold. Although 1977 was a particularly bad year for aflatoxin, this mold causes great losses even in the best of years.

Farmers who have their crop contaminated by aflatoxin are restrained from using this corn by a variety of state and federal regulations. Enforcement of these regulations is in many states lax, although I am proud to say that the state of North Carolina has an enforcement program that is generally recognized to be the most extensive and effective in the region. Farmers are understandably reluctant to throw away their crops and many of them are reluctant even to have their crops tested for aflatoxin. Despite the best efforts of the public health officials, a public health problem of sizeable proportions remains.

Farmers suffer a substantial loss because of aflatoxin. In North Carolina alone, farmers lost over $30 million in income from aflatoxin. Condemned corn is often burned, or buried, thus providing no benefit to anyone.

If we could take this contaminated corn and brew alcohol fuels, farmers would be saved millions of dollars, the public would be protected from a major health hazard, and the nation would have to rely less upon imported oil. Corn contaminated by aflatoxin can be brewed into alcohol than contains not a trace of aflatoxin. The process of fermentation effectively removes aflatoxin.

I hope that as this subcommittee considers the development of alcohol fuels this pressing problem of the Southeast will be given the attention it deserves. Since the corn contaminated with aflatoxin is worth nothing, it costs nothing. Brewing alcohol from aflatoxinated corn should thus be economical long before alcohol brewed from unspoiled crops. I think the construction of an alcohol brewing center in the Southeast for contaminated corn should be a priority in our national effort to encourage alcohol fuels. Here is an opportunity to brew alcohol from an essentially free source, to work out the bugs in commercial size plants, and to show the public the great potential of alcohol fuels.

The second topic I wish to address concerns what I feel is the weak link in our efforts to develop alcohol fuels from crops: primary agricultural research. Today mankind derives almost all food and fiber from only 20 crops. There are however, tens of thousands of plant species that we know little about or that we don't use. It would be a coincidence of great unlikelihood if those crops currently consumed by people were at the same time the most suitable for brewing alcohol fuels. Somewhere among all the plants growing wild there could be a plant truely capable of bringing fuel farms into reality.

Recently the National Academy of Sciences completed a study into those wild or unused plant species that could be put to human use. This effort was oriented toward finding plants that could meet basic human needs in the underdeveloped world. We need a similar study of the plants of the world to identify those which can be used to brew alcohol fuels most economically. We are not so developed that we couldn't benefit enormously from an innovation at the level of basic of agriculture.

A look at some of the plants discovered by the National Academy of Sciences researchers suggests the rich potential here. Perhaps the most famous discovery of this study was the flying bean, a plant with the potential for raising the consumption of protein in the underdeveloped world. The recent increase in the price of oil, and hence of petroleum based synthetic rubber has brought the native North American rubber bush, guayule, back to the margins of economic feasibility. Recently the Senate passed the Guayule Research Act to accelerate the commercial development of this plant which only a few years ago was little more than another desert bush. Similarly, the rapid rise in the price of sperm whale oil has given impetus to the cultivation of jojoba. Growing wild in the deserts of the Southwest, jojoba promises to be a major source of high grade oils and lubricants in the future.

I mention these examples because I think there is a great potential for similar discoveries of plants uniquely suited for the brewing of alcohol fuels. I think we would be wise to make the extremely small investment in a comprehensive research program to identify those plants that could be adopted for use on fuel farms. We must limit such a research to our own shores. Plants from other countries could be brought to this country just as many were when the Europeans first came to the shores of the new world. These so-called plant migrations have proven to be enormously beneficial to mankind, opening up regions for agricultural production that would otherwise remain unproductive.

An adequate cataloging of the plants suitable for fuel production could also greatly benefit those poorer countries that are so hard pressed to meet the burdens of the high price of oil in the world market. Tropical nations contain vast areas not currently under cultivation. Tropical countries receive much greater quantities of sunlight than do the temperate regions and in the long run they may be best suited for large-scale fuel farming.

Our search for plants appropriate for alcohol brewing should not stop at the water's edge. Many aquatic plants have awesome rates of growth, and could be converted to fuels without the use of increasingly scarce land. In this regard, I think we would be smart to look at those plants that can grow in salt water since fresh water is in such short supply or altogether unavailable in many regions of our nation. In approaching the search for fuel crops we must not be bound by the canons of what is palatable to man or animal since neither man nor animal will have to eat the products of these farms.

The use of non-food crops for the production of alcohol fuels should alter the economics of alcohol fuels quite dramatically. The recent study on gasohol from grain prepared by the Economics, Statistics, and Cooperatives Service of USDA shows that the economic viability of gasohol is highly sensitive to the price of grains. This is quite understandable if only grains are considered. However, if you consider crops that aren't in demand for food or feed, then I think the picture will change dramatically.

The use of non-food or non-feed crops for fuel can complement not supplant, the cultivation of fuel crops. Fuel crops could be grown on marginal land, on set-aside land, or even between rows of food crops. In many cases fuel crops growing side-by-side with crops may enhance the ecological balance and preserve the soil better than a single-crop planting can.

In closing I would like to air one caveat about our move to alcohol fuels. We must be careful not to forget that agriculture—a renewable resource—is based on a nonrenewable resource—the soil. We must not allow our pressing need to find replacements for nonrenewable fossil fuels to deplete our far more valuable natural resource of the soil. Long after the deserts of Arabia have given up their last barrel of oil, the farmlands of America will be just as productive as today—if we take care of them. Alcohol fuels promise to inject new life and vigor into the agricultural sector of the economy. We must guard against this becoming a short-term boom that will exhaust the soil, our most valuable non-renewable resource.

I do not mean these remarks to suggest that we need anything other than a national effort to bring alcohol fuels on line. But the transition to alcohol fuels could be made less expensive, and more rapid if we pursue a research program into plants we aren't now cultivating. This program should be part of the same effort in basic agricultural science that has made American agriculture the most productive in the world.

Senator CHURCH. I think in that connection it might be well to introduce into the record an article by Hugh Wray McCann, a free-lance writer from Detroit, which appeared in the Washington Post on Sunday, July 16, 1978. The article is entitled "Striking Oil in Weeds," and it is very interesting.

I might read one or two paragraphs of the article, because it is in line with the general direction that your testimony takes:

If it were anyone but Melvin Calvin claiming that American farmers could be growing oil as a major cash crop before the year 2000, you'd suspect him of spending too much time in the hot California sun, fussing with his strange weeds.

Calvin, a Nobel Prize-winning chemist and a member of the President's Office of Science and Technology, has been experimenting with a poinsettia-like bush which, he says, produces oil.

On a few small plots, he has reaped man's first crop of crude oil at a commercially prohibitive yet encouraging price of $20 per barrel. Oil from Saudi Arabia costs around $10 a barrel.

Calvin is betting his Priestley Medal, the American Chemical Society's highest award which he won this year, that he can double his yield in 1978 and cut the cost to $10 a barrel.

Here is a plant, which apparently produces oil, that might become a very important crop for farmers, and it certainly bears out your point. It would be coincidental, indeed, if the kinds of plants that we have cultivated through the years for our own food supply would be the best plants for fuel oil. It is time that we looked at the other possibilities.

[The article follows:]

[From the Washington Post, July 16, 1978]

STRIKING OIL IN WEEDS

(By Hugh Wray McCann*)

If it were anyone but Melvin Calvin claiming that American farmers could be growing oil as a major cash crop before the year 2000, you'd suspect him of spending too much time in the hot California sun, fussing with his strange weeds.

Calvin, a Nobel Prize-winning chemist and a member of the President's Office of Science and Technology, has been experimenting with a poinsettia-like bush which, he says, produces oil.

On a few small plots, he has reaped man's first crop of crude oil at a commercially prohibitive yet encouraging price of $20 a barrel. Oil from Saudi Arabia costs around $10 a barrel.

Calvin is betting his Priestley Medal, the American Chemical Society's highest award, which he won this year, that he can double his yield in 1978 and cut the cost to $10 a barrel.

If he's right, then his discovery of use for a wild plant, until now little more than a botanical curiosity, could be as significant for society as the atomic bomb, which he helped develop during World War II.

Calvin also sees this weed as the solution to the so-called "greenhouse" effect, the ominous buildup of carbon dioxide in the atmosphere from 200 years of burning fossil fuels (coal, oil and natural gas), causing the planet to overheat.

The project, currently in its second growing season, is under the aegis of the Laboratory of Chemical Biodynamics at the University of California (Berkeley), where the 67-year-old Calvin heads the laboratory and teaches chemistry.

*McCann is a free-lance writer based in Detroit.

He says that at least two major multinational corporations, one of them an oil producer, have promised money for the research, which at this point is still a small university project. He feels the road to the commercial exploitation of oil plantations will open up "when the individual corporation says it's willing to spend one or two million dollars to get this thing going."

GROWS ON POOR LAND

The bush causing the excitement is the *euphorbia Lathyris*, a relative of the poinsettia. More commonly known as the caper spurge, or mole or gopher plant, its leaves contain a milky latex, which is a mixture of hydrocarbons and water.

There are about 2,000 varieties of *euphorbia* around the world. The *Lathyris* species, which reaches 4 feet in height in seven months, grows primarily in hot, dry areas unsuitable for normal agriculture. One of the places where Calvin found the bush, with its long, lance-like leaves, was on his ranch, near Healdsburg, in northern California.

Calvin won his Nobel Prize in 1961 for his work on photosynthesis, the process by which plants turn sunlight into other forms of energy. Through photosynthesis, he saw "the green plant captures the carbon dioxide from the atmosphere and, with the aid of sunshine, separates hydrogen from the water." This turns it into carbohydrate, such as a sugar, "in which there is only one oxygen atom on each carbon atom.

"Eventually some plants can take the carbohydate and reduce it all the way to hydrocarbons, with no oxygen at all on the carbon atoms.

"This is essentially what petroleum is."

Calvin began his experiment modestly by cultivating around 800 *euphorbia Lathyris* bushes and checking the effects of water and fertilizer.

"It's as if we were back in the Stone Age," he says, "learning how to domesticate wild plants."

When the first crop was harvested, the bushes were crushed, which released the latex, and mixed with acetone as a solvent. The result was "black oil—just like crude oil."

It cost $10 a barrel to cultivate and $10 a barrel to process.

"But this [price] doesn't allow for the improvements which I have absolutely no doubt we can make," he says. "We know every single enzyme that is required to convert carbon dioxide into hydrocarbons. This means we cannot only improve the yield by ordinary classical seed selection and cloning; we can do genetic engineering on the single cells to change the nature of the hydrocarbon yield, then take those single cells and regenerate a whole [new] plant."

The regeneration of new plants from genetically reengineered single cells has been done, he says, to the carrot, tobacco, Southern palm, Douglas fir and sugar plants.

From three or four small plots in th first season, the nation's first experimental oil plantation is now on a 10-acre site. Calvin visualizes *euphorbia Lathyris* plantations "on land which is the least productive for human use—western Texas, most of Arizona and New Mexico"—and where the sun's energy is at its maximum.

"On the basis of this experiment," Calvin says, "we know how much oil we can get per acre this year." From 43,500 plants containing 8 to 12 percent oil, "we calculate at this point about 10 barrels per acre in seven months."

BEGAN WITH EMBARGO

Calvin began searching for alternative energy sources in 1973, during the Arab oil embargo. He was one of millions of Americans who got their first, bitter taste that winter of queueing up at gas stations. "It was during those 1½- and 2-hour periods of quiet," he recalls, that he would ponder the questions of "how plants collect the energy of the sun and store it in the form of chemicals."

During his reflection, he continues, several "messages" came through. One was that the nation's supply of fossil fuels, "which were placed in the ground millions of years ago," are running out.

Another "message" had to do with the carbon dioxide danger.

Since the Industrial Revolution of the mid-1800's, the amount of carbon dioxide in the atmosphere has reached critical proportions. Normally it is a harmless gas which is absorbed by lakes and oceans and changed into oxygen by the leaves of green plants.

However, as industrialized societies turned away from burning wood to coal, oil and gas, they began to pump increasing quantities of carbon dioxide into the atmosphere at a faster rate than plants could change it back into oxygen or lakes and oceans could absorb it, says Calvin.

Scientists explain that around the earth there is a carbon dioxide blanket that allows in the ultraviolet radiation of the sun but prevents the infrared radiation reflected from the earth from escaping. The result, they say, is that the earth has been gradually heating up since man started burning fossil fuels.

"Some meteorologists have suggested that a consequence will be the melting of the Antarctic ice sheet and the rise of ocean levels," he says, adding that the heat would have a "disastrous" effect on agriculture and on society in general.

Fuel derived from *euphorbia lathyris*, when burned, would not add to the carbon-dioxide blanket. "If we use plants as a source of [energy] material," he explains, "the plants get most of the carbon dioxide out of the atmosphere in the first place."

Calvin thinks that the first commercially viable oil plantation is about 10 years away. "In the longer reach, however," he says, "we should learn how the plant captures the sunlight in the first place * * * I know a good bit about how, but I don't know [exactly] how."

Senator MORGAN. Mr. Chairman, I don't see how we can afford not to make the commitment in this case, because we know it can be done. It is a question of how we want to make it economically feasible. We know that with the proper care of our soil and our land in this country, which we are going to do, we can be growing this sort of plant long after the sands of Saudi Arabia and other places are dry.

I hope that the committee will move forward with a strong effort in this direction.

Senator CHURCH. Thank you so much.

Do you have questions, Senator Hansen?

Senator HANSEN. Well, just a word or two, Mr. Chairman. First, I am impressed with this particular vine that Senator Morgan spoke about. It occurs to me that if we really make the breakthrough that everyone is hoping will come about, we will probably use, first, waste products and plants that are not now being put to use.

I suspect that one does not need to challenge Mr. Pennik's statement that, at the present time, it doesn't pay to raise corn or wheat and try to convert them directly into alcohol.

But if you take the waste products that result from the distillation of those crops, say, by Anheuser-Busch—I am glad to mention that name, because one of the members of the family is a good neighbor of mine in Jackson, Wyo.—perhaps alcohol production will be more economical. We should think about the point mentioned earlier by Senator Bayh of the possibility that manure can be utilized. We have already raised the beef and we have raised the grain, and we have fattened the cattle, and we should take advantage of the waste products too.

It seems to me that we might indeed move this technology forward far more rapidly than we have in the past.

I thank you, Senator Morgan, for calling attention to this particular vine, which I understood was first introduced into your part of the country in order to bring about some measure of erosion and gully control. Now that we know how well it responds to the warm wind and sunshine and rain of North Carolina, and to the development of farms, including yours, it is possible that technology could be developed which would take advantage of such prolific growth and would provide a large resource for alcohol production.

I should think that we would be moving science ahead very rapidly.

Thank you.

Senator MORGAN. Thank you.

Senator CHURCH. Thank you very much.

Our next witness is Dr. George F. Huff, vice president in charge of research and development, Gulf Oil Chemicals Co., from Houston Tex.; and he is accompanied by Dr. George Emert, director of biochemical technology, for the Gulf Oil Corp., and by Dr. Raphael Katzen, who is a consultant.

Gentlemen, we appreciate your coming this morning.

STATEMENT OF DR. GEORGE F. HUFF, VICE PRESIDENT OF RESEARCH AND DEVELOPMENT, GULF OIL CHEMICALS CO., HOUSTON, TEX., ACCOMPANIED BY DR. GEORGE H. EMERT, DIRECTOR OF BIOCHEMICAL TECHNOLOGY, GULF OIL CORP., SHAWNEE MISSION, KANS., AND DR. RAPHAEL KATZEN, CONSULTANT

Dr. HUFF. Thank you. We are happy to be here.

My name is George F. Huff. I am vice president of research and development for Gulf Oil Chemicals Co. Accompanying me today is Dr. George Emert, who is our director of biochemical technology. Also with me is Dr. Raphael Katzen, of Katzen Associates of Cincinnati, who is an internationally known expert in the field of the fermentation process engineering.

Dr. Katzen is currently cosulting on our project in order to evaluate our process and to validate our initial economic assessment.

Our presentation today consists of this executive summary along with a detailed presentation of the Gulf ethanol process, which is complemented by a set of 46 color reproductions, graphs, charts, and tables.

Rather than take the subcommittee's time, I would ask, Mr. Chairman, that this detailed presentation be made part of your hearing record.

Senator CHURCH. Without objection, it will be so ordered.

Dr. HUFF. Then I will simply go over this summary.

Gulf's biochemical research program began in 1971 with a search for alternate feedstocks for our petrochemicals business. Practically all of the organic chemicals industry relies on chemicals derived from fossil fuels: petroleum, natural gas, or coal.

Some of us had become concerned, even before the Arab embargo, that increasing prices of petroleum and consequently of petroleum feedstocks would eventually make many of the materials supplied by the modern chemicals industry too expensive for general use.

From an economic standpoint alone, it is becoming imperative to have alternate feedstocks available.

As a result of this concern over feedstock availability, and based on the research work which Gulf has done, construction was undertaken in August of 1975 of a cellulose to ethanol pilot plant facility at our Jayhawk Plant in Pittsburg, Kans. This pilot plant is of a 1-ton-per-day feedstock input size and has been testing various cellulosic feedstocks since January 1976.

Our work in the bioconversion field, and specifically, the knowledge we have gained from direct operation of the pilot plant facility, provides us the basis on which to provide this Subcommittee the following preliminary conclusions and estimates:

U.S. production of available cellulosic material amount to huge tonnages on a daily basis; however, the key to utilization of these materials is to have them collected to a central location in commercial quantities at a reasonable cost. Our investigations have also purposely avoided feedstocks, which are now directly part of the food chain, as the value of waste biomass has greater potential for upgrading.

Our plans for this technology in the very near future include the process design of a demonstration plant, demonstration plant size being 50 tons of cellulosic waste per day, or approximately 2,000 gallons per day of ethyl alcohol. A very ambitious, but possible, schedule would call for engineering, procurement, and construction of the demonstration plant, beginning about mid-1979, with completion expected by the end of 1980.

During 1980, with the information we have gained through the operation of the pilot facility at Jayhawk, and work that has been done to that point on the demonstration plant, we could begin design of a commercial scale plant which is on the order of 25 million gallons of ethyl alcohol produced per year, utilizing an input of 1,000 tons of waste per day.

Such a condensed schedule could lead to the operation of the first commercial-size cellulose to ethanol facility in mid-1983.

A conservative estimate of capital costs for 1981 construction would be $65 million for a 25 million gallon per year plant. Considering fixed charges, raw materials, chemicals, energy, labor, freight, a feed credit, and Federal and State taxes, a conservative estimate of the 1983 alcohol selling price is approximately $1.73 per gallon.

This compares with a Gulf estimate for the 1983 projected selling price of ethylene-derived ethyl alcohol, or synthetic alcohol, of approximately $2 per gallon.

The overall net energy efficiency of Gulf's direct ethanol from cellulosics process is estimated at the commercial plant level of 59 percent.

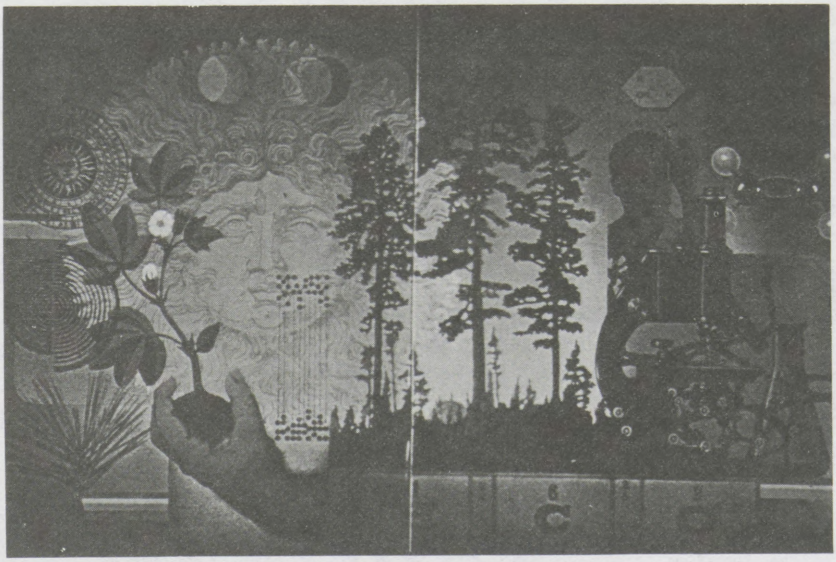
I would like to conclude this testimony by summarizing the characteristics of the direct ethanol from cellulose program. It first addresses two important national problems: One, the removal or decrease in volume of solid waste. Two, the production of ethyl alcohol, which can be utilized as a chemical or in some local or regional situations, as a fuel.

Commodity chemicals can be produced, especially those which we now obtain from fossil fuels.

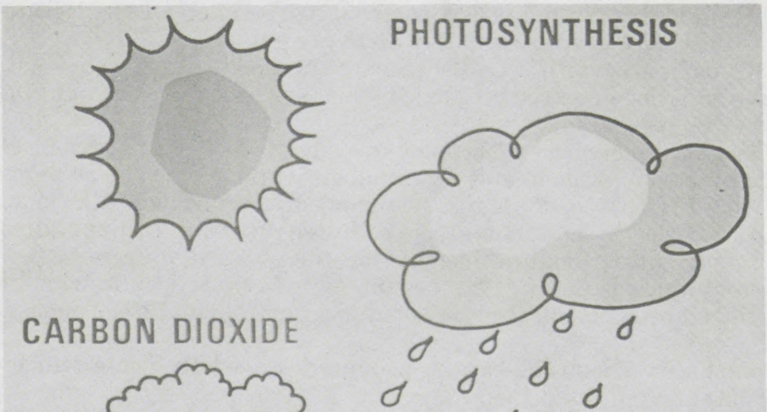
Gulf Chemicals is now pursuing two major objectives: One is defining feedstock availability in the amounts necessary to support commercial-scale facilities; and, two, we are seeking markets for the ethyl alcohol, which we can produce through our technology from these feedstocks.

Thank you, gentlemen. We will now do our best to respond to your questions.

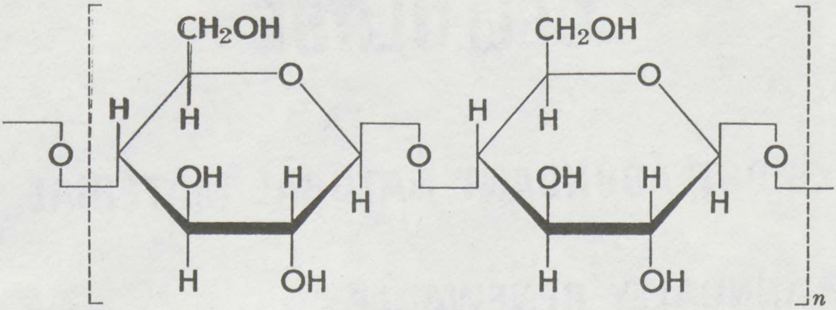
[The material submitted by Dr. Huff follows:]



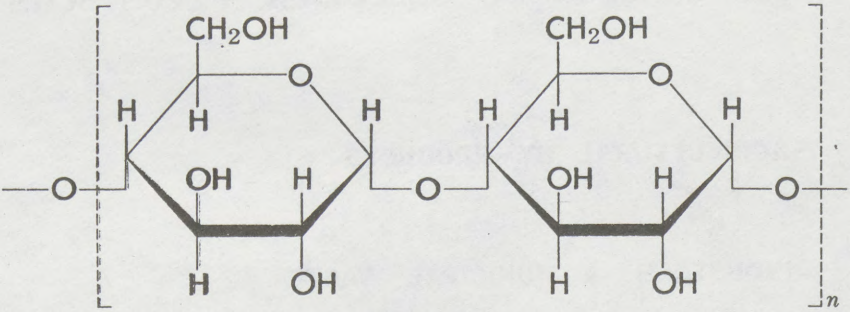
Slide 1.—in 1971 Gulf Oil Chemicals Co. conceptualized the need for alternate sorces of carbon/carbon bonds other than fossil fuels. Their search led them to recognize that renewable resources in the form of hydrocarbons or carbohydrates would be an excellent future source for chemicals.



Slide 2.—These carbon/carbon bonds are formed through a unique process called photosynthesis whereby solar energy is converted through the action of plants, along with carbon dioxide, water and inorganic nutrients to chemical energy.



CELLULOSE



STARCH

SLIDE 3.—The two major forms of carbohydrate chemical energy are those represented by the molecules, cellulose, and starch. Starch is found in corn, sugarcane, potatoes, et cetera, and is characterized by a unique linkage between glucose molecules called an α-1,4 linkage. This linkage is readily broken by enzyme systems found in man and almost every other form of life. Its counterpart, cellulose, differs only in the configuration of the bonding between the two glucose molecules called a β-1,4 linkage, not as many life forms have the enzyme system necessary to break down this bond. Thus, this material is readily available in nature. Bacterial systems, fungal systems and some invertebrate systems have the enzyme systems necessary. Starch, being easily degradable by man and other animals is a foodstuff whereby cellulose, not being degradable in man or other animals consumed by man, is not considered a foodstuff. It is only necessary because of its fibrous nature with respect to certain physiological movements in the digestive systems of these animals.

CELLULOSE

- MOST ABUNDANT NATURAL MATERIAL
- ANNUALLY RENEWABLE
- NOT DIRECTLY USEFUL AS A FOODSTUFF

Slide 4.—Cellulose is the most abundant natural material. It is annually renewable and not directly useful as a foodstuff.

THREE CLASSES OF CELLULOSE FEEDSTOCKS

AGRICULTURAL BY-PRODUCTS

INDUSTRIAL & MUNICIPAL WASTE

SPECIAL CROPS

Slide 5.—There are three classes of cellulose feedstocks. One is agricultural byproducts such as cotton gin trash, bagasse (the material left over after squeezing the sugar syrups from sugarcane), cannery byproducts, and corn stover. The second class of cellulose feedstocks is industrial and municipal wastes, of which there is considerable as you will see later; and third are special crops such as poplar trees, aspen, grasses, et cetera.

TOTAL U.S. PRODUCTION OF CELLULOSIC FEEDSTOCKS

FEEDSTOCK	TONS/DAY *
municipal solid waste	680,000
total terrestrial plant biomass	820,000
straws	390,000
cotton gin trash	10,959
yellow poplar	4,811
other hardwoods	30,142

* 365 day year

SLIDE 6.—The total U.S. production of available cellulosic feedstocks amount to huge tonnages on a daily basis. The key to utilization of these materials is to have them collected to a central location in commercial quantities at a reasonable cost.

AVAILABILITY OF MUNICIPAL SOLID WASTE (CELLULOSICS)

METROPOLITAN AREA	TONS/YEAR	NO. OF ALCOHOL PLANTS
New York	8,818,000	27
Philadelphia	4,330,000	13
Los Angeles	6,602,000	20
Chicago	6,350,000	19
Houston	2,158,000	7
Pittsburgh	2,145,000	7
Kansas City	1,157,000	3

SLIDE 7.—The cellulosic fraction of municipal solid waste is an acceptable feedstock for producing chemicals, especially ethyl alcohol. Tonnage estimates of MSW for the city of New York enable projections of 27 commercial scale alcohol plants (1,000 tpd feedstock to produce 25 million gallons ETOH).

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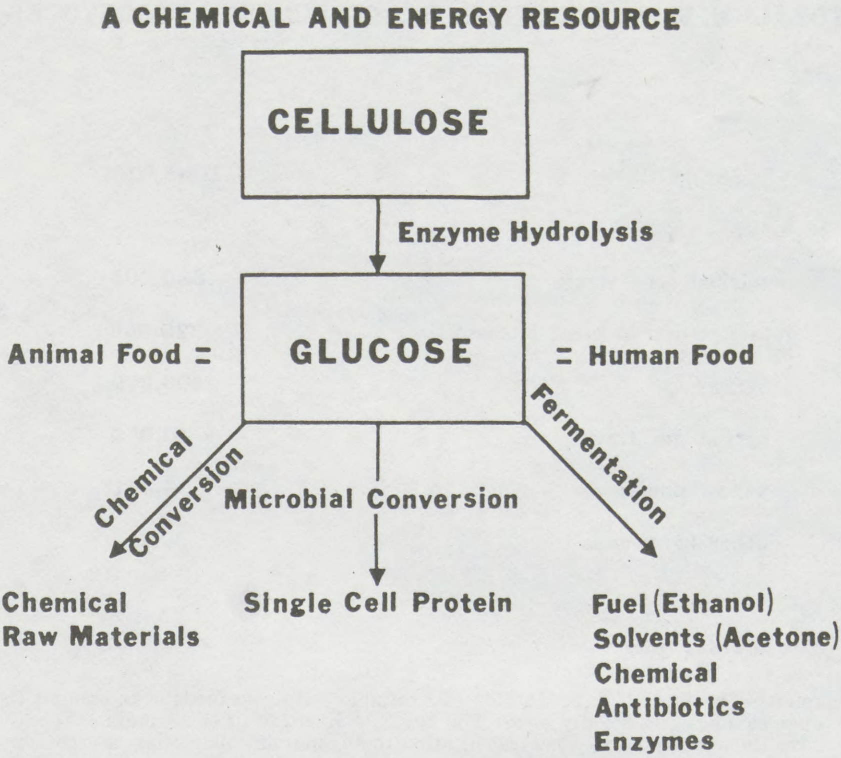
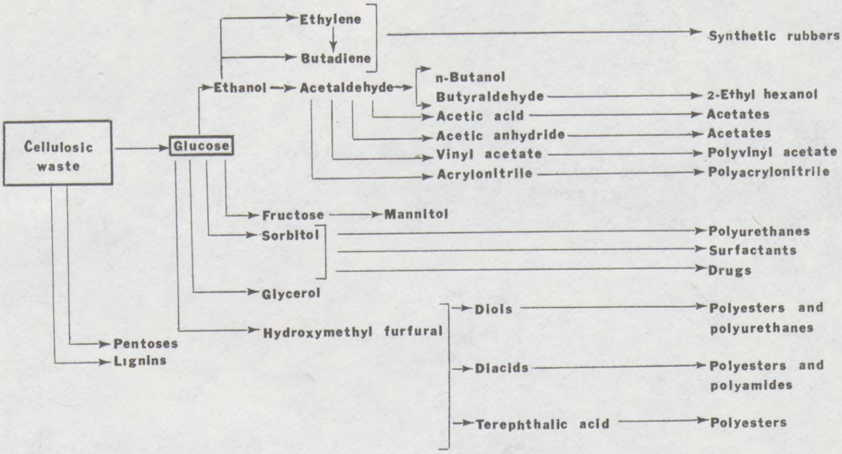


SLIDE 8.—Cellulose is a biomass which is a great potential chemical and energy resource. There are a number of things which you can do with it. Obviously you can burn it. Through enzyme hydrolysis or acid hydrolysis you can convert the material to glucose which can be utilized directly as an animal food or human food and it can be chemically converted to a number of other raw materials for chemicals. Additionally, you can convert the glucose through microbial action to single cell protein or you can ferment the glucose, again through microbial or yeast action, to ethyl alcohol which could be utilized as a fuel or solvent, acetone, antibiotics or other enzymes.

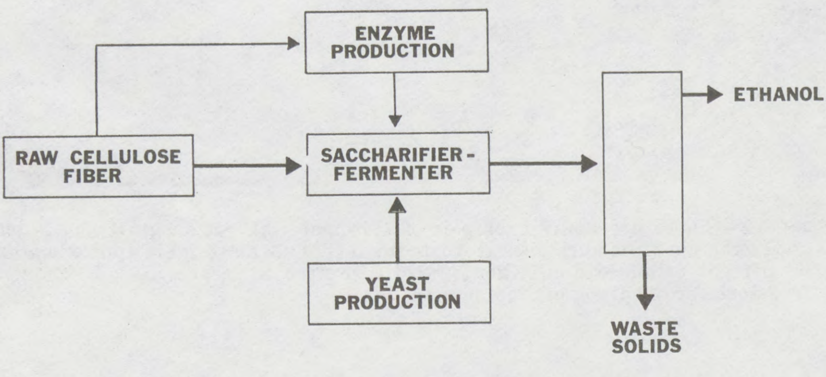
ROUTES FROM CELLULOSE TO PETROCHEMICALS

ARE MANY AND VARIED

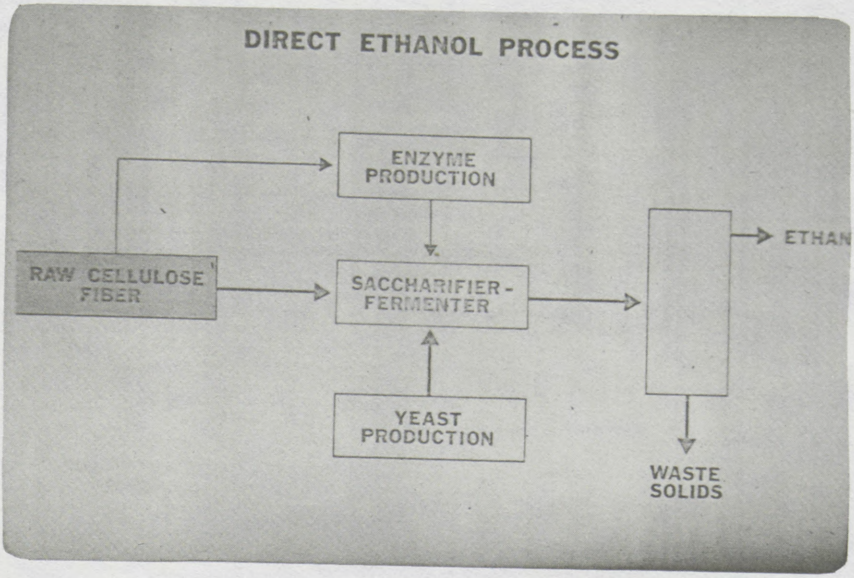


SLIDE 9.—Let's assume for the moment that we want to make chemicals and imagine what we can do with cellulosic waste material if we can convert it to glucose. Once cellulosic wastes are converted to glucose, one can very easily obtain 95 percent of theoretical ethanol yield. There is technology available to convert ethanol to ethylene or butadiene, from which synthetic rubbers can be made. Additionally, ethanol can be converted to acetaldehyde from which you can obtain acetates, including polyvinyl acetate, polyacrylonitrile and other chemicals. The glucose can be converted directly to fructose, sorbitol, and glycerol. These are precursors for polyurethanes, surfactants, and some drugs. In addition to the glucose in cellulosic wastes, there are five carbon sugars called pentoses and a polyphenolic, amorphous material called lignin. The pentoses can yield furfural or xylitol. The lignins could yield cumene, phenol, vanillin, and other aromatics. The point is, there are many routes from cellulose containing materials to chemicals we now derive from fossil fuels. Let's examine the case of ethyl alcohol.

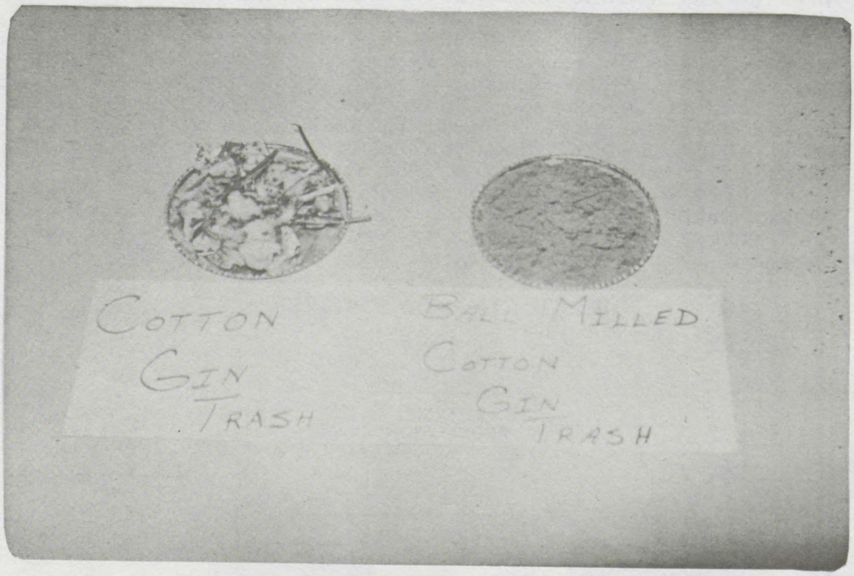
DIRECT ETHANOL PROCESS



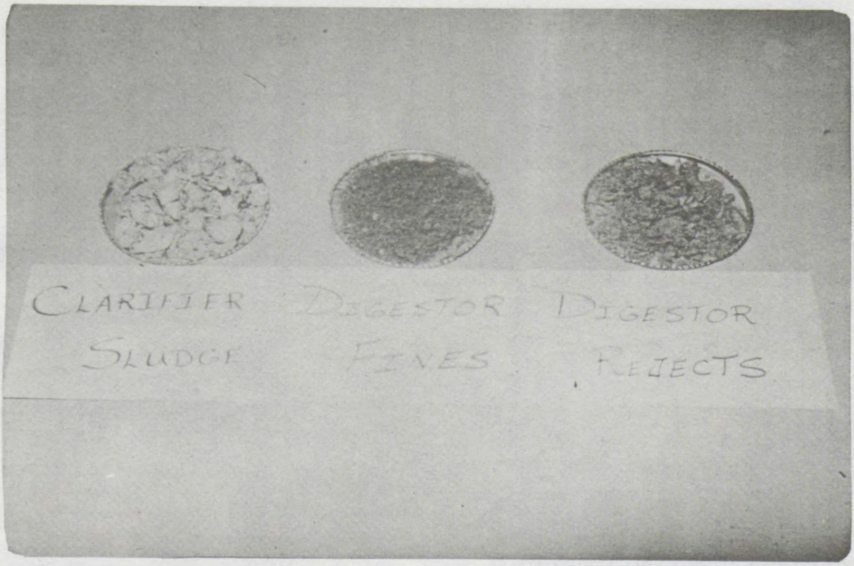
SLIDE 10.—Gulf Oil Chemicals Co. has a direct ethanol process whereby raw cellulose fiber is converted to ethanol.



SLIDE 11.—Let's first talk about raw cellulose fiber.

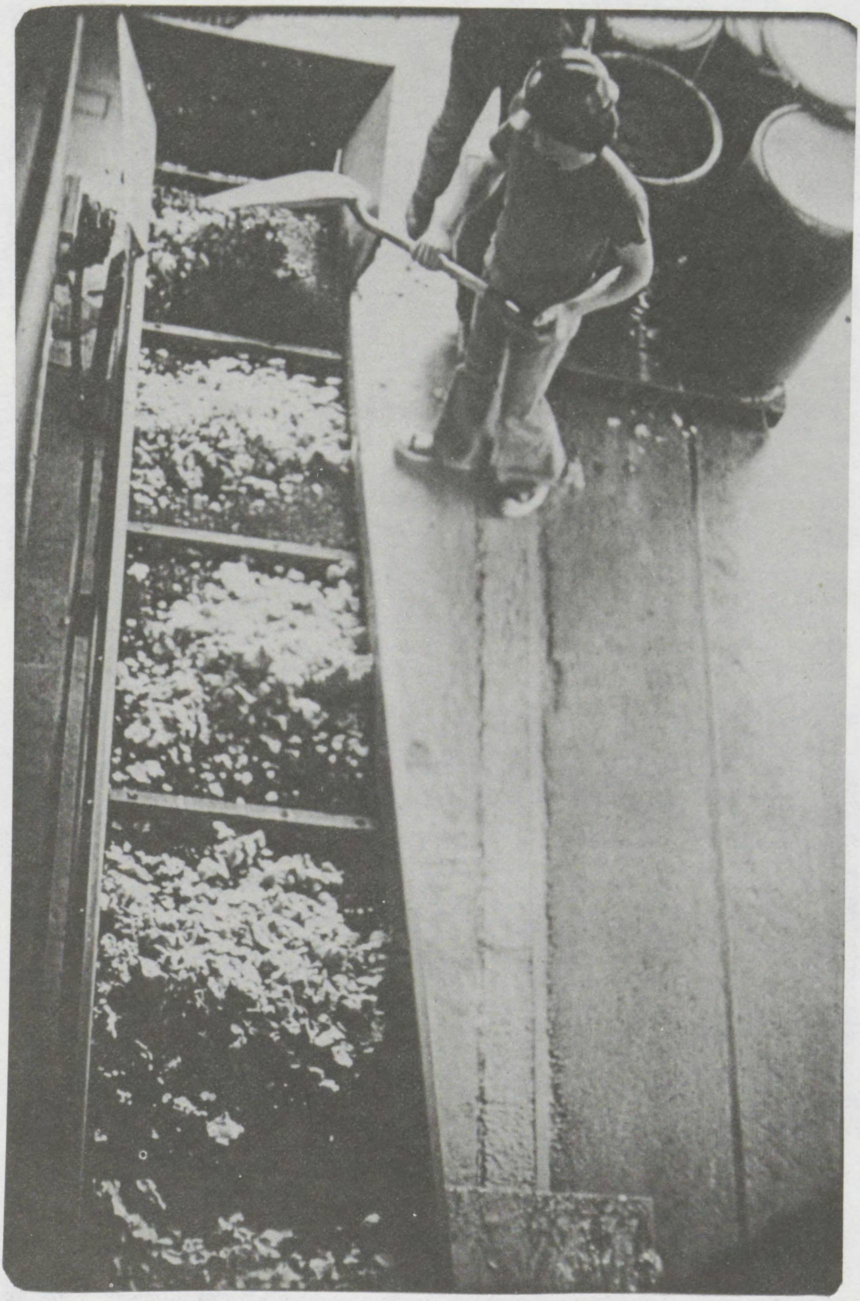


SLIDE 12.—There are many examples of this material, cotton gin trash is one good example of an agricultural waste product. This material is approximately 60 percent cellulose and, when properly pretreated, serves as an excellent feedstock for the direct ethanol process.

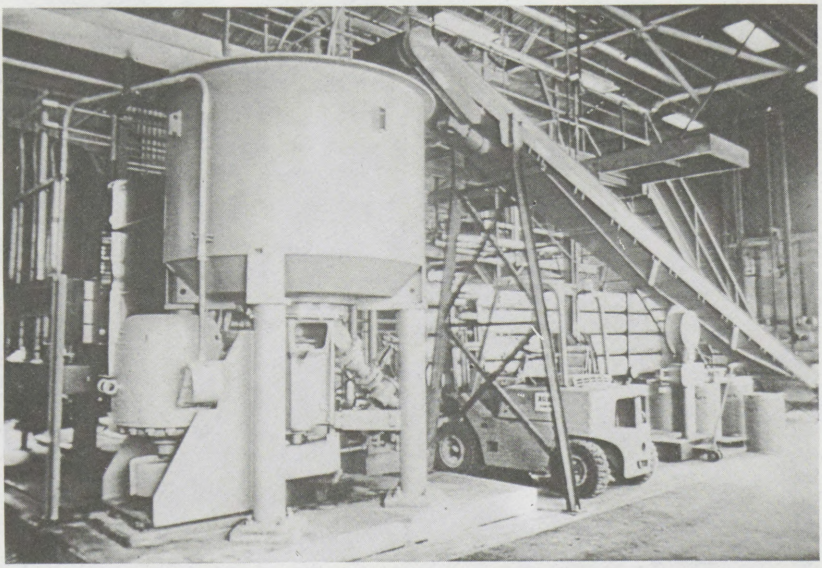


SLIDE 13.—Pulp and paper wastes are also excellent feedstocks. As you know, many such wastes, including clarifier sludges, digester fines and digester rejects are currently landfilled and in some cases even dumped in ponds and rivers. These materials are particularly excellent feedstocks for this process.

SLIDE 14.—One of the biggest problem areas on which we are intensely working now and have been working for a number of years is the handling and pretreatment of cellulosics for this process. At our pilot facility we use a forklift to raise 40 gallon barrels of pulp waste to move into the pilot facility building.

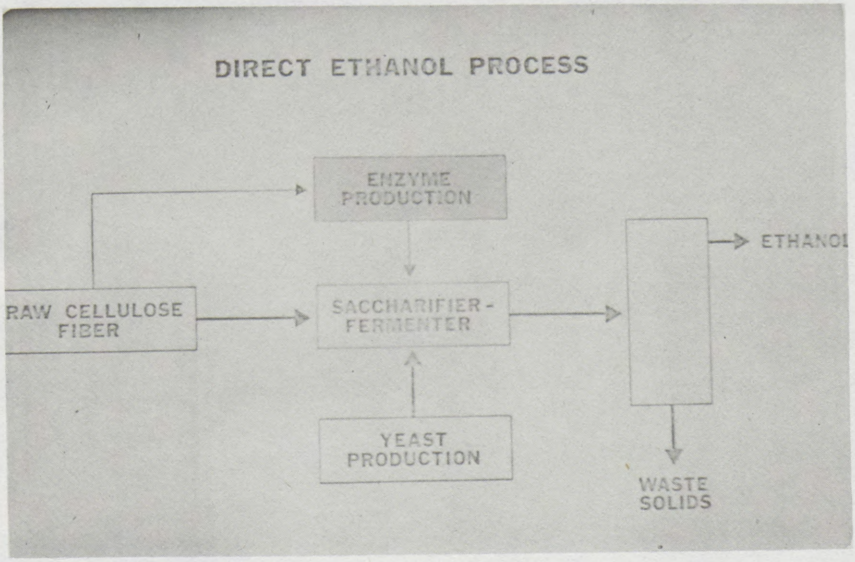


SLIDE 15.—The material then is manually shoveled onto a conveyer belt which carries it up to a height where it can be dropped into a piece of equipment similar to a Waring blender.

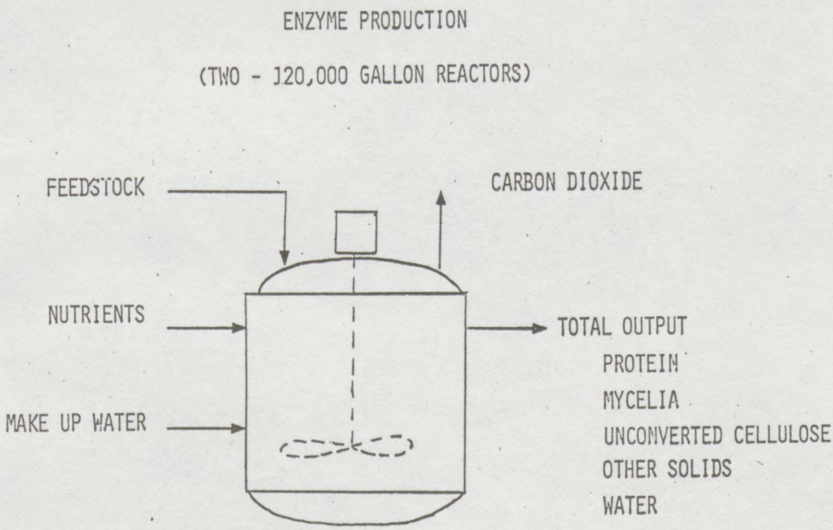


SLIDE 16.—The only difference is it is approximately 1,500 gallons capacity. The purpose being simply to mix the material and to moisturize it.

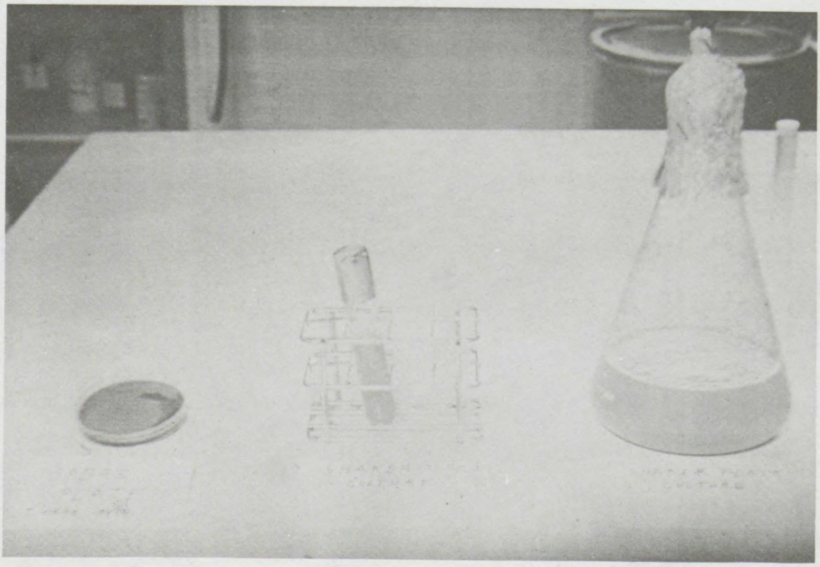
SLIDE 17.—After that is accomplished, the material is pumped through a heat exchanger where it is heated up to a high temperature in order to pasteurize or sterilize the material as is necessary. At this point, the cellulosic feedstock is ready for either of the process operations which follow.



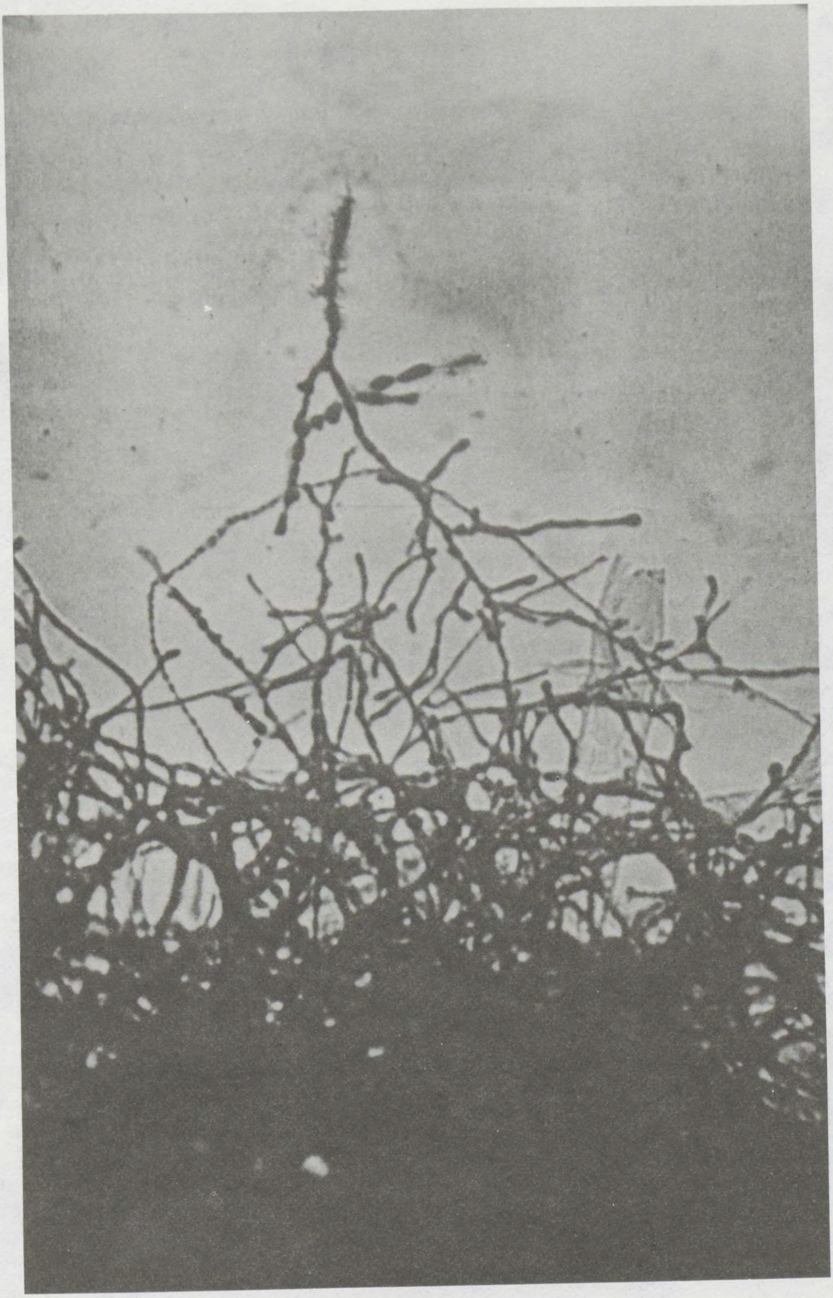
SLIDE 18.—The first one we will talk about is enzyme production. The objective of the enzyme production step in the process is to produce the catalyst which will aid the biodegradation of the cellulose in waste materials.



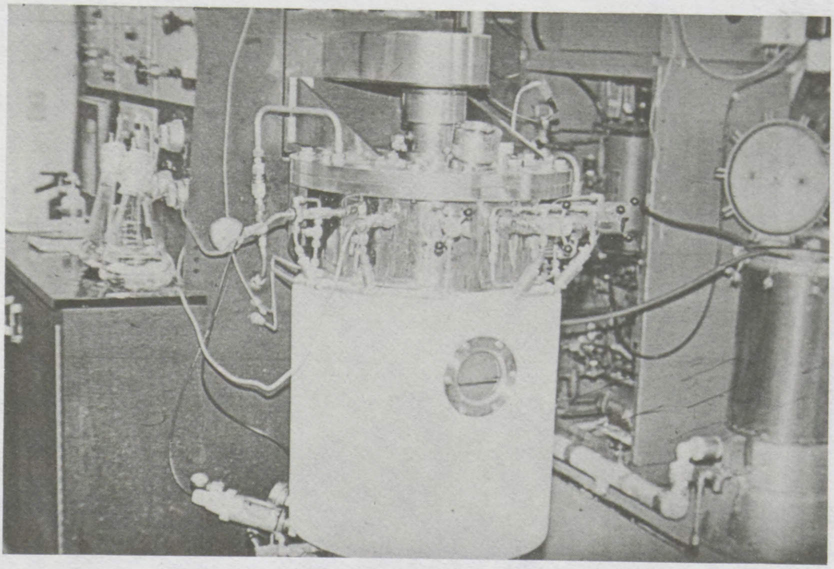
SLIDE 19.—Reactor input is feedstocks, nutrients, make-up water, and air placed into a vessel from which carbon dioxide is given off and protein mycelia, the organism biomass, unconverted cellulose, and other solids are the output. The key output, of course, is protein, which makes up the enzyme or catalyst.

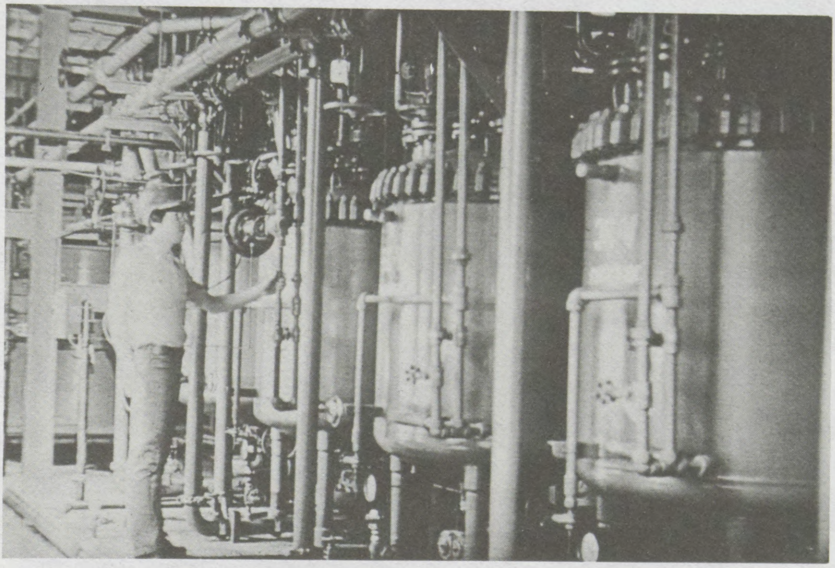


SLIDE 20.—You must start with a spore which is approximately the size of a red blood cell in your body.



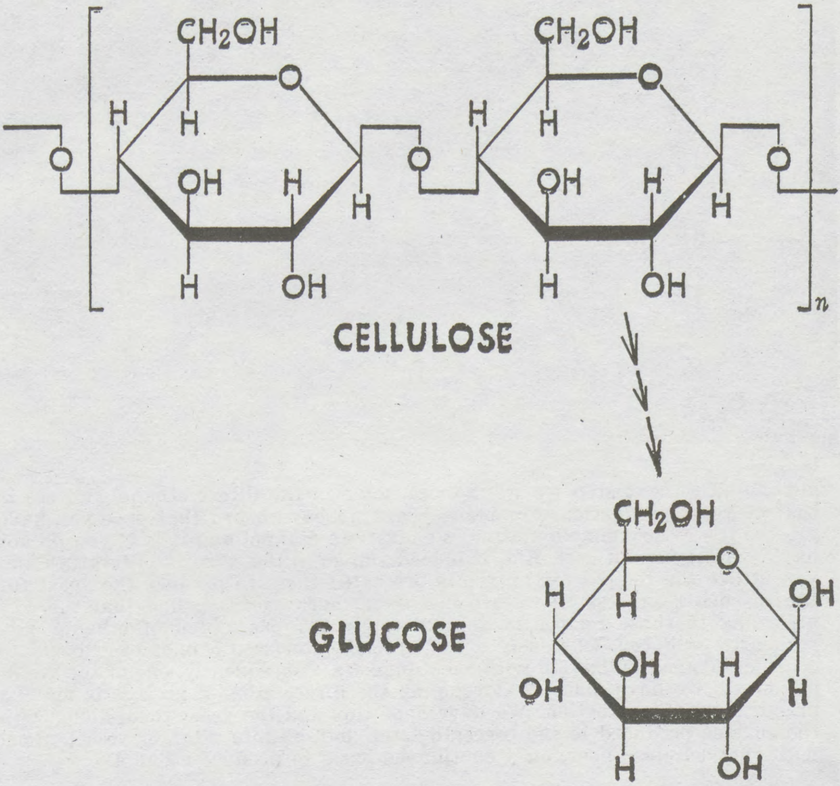
SLIDE 21.—You must then scale up from the spore through growth in flasks to obtain mycelia for subsequent enzyme induction.



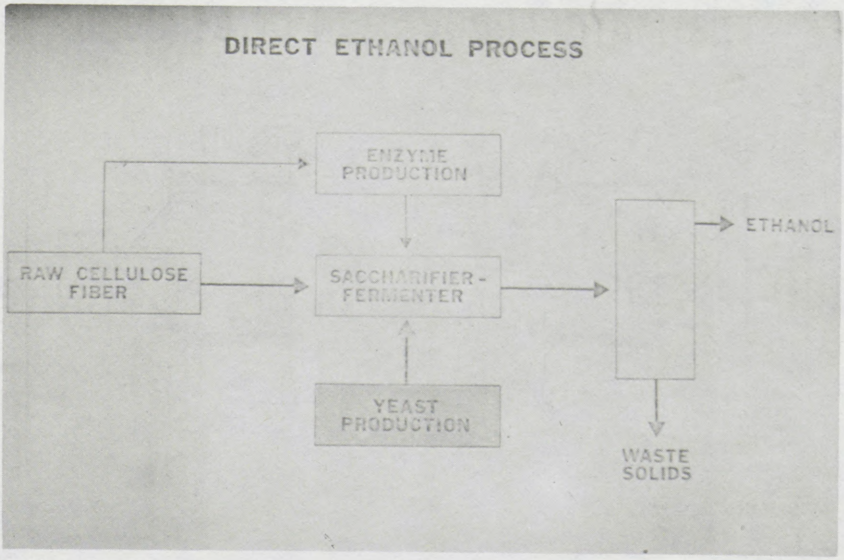


SLIDES 22 and 23.—130 liter fermenter is inoculated through utilizing shake flasks size equipment and the material obtained goes into 300 gallon units at our Jayhawk pilot facility. This is simply to make the enzymes.

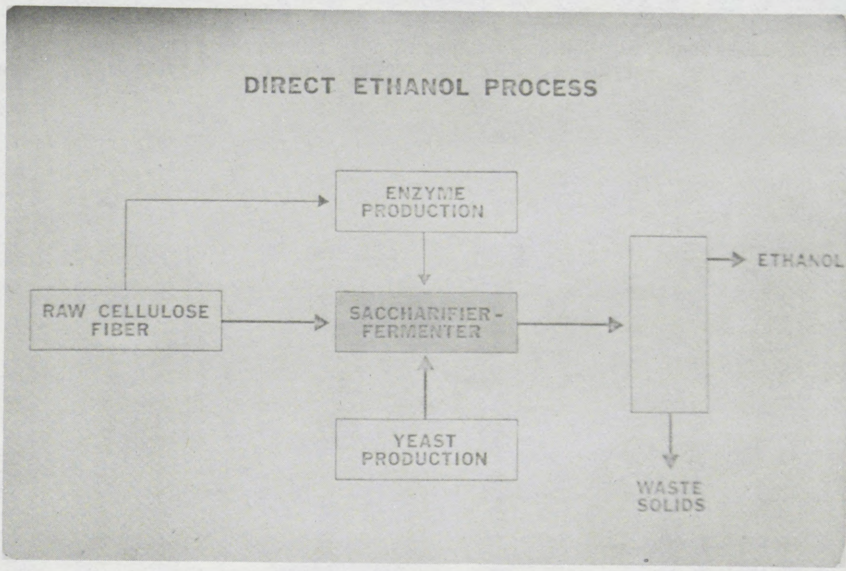
ENZYMATIC PRODUCTION OF GLUCOSE



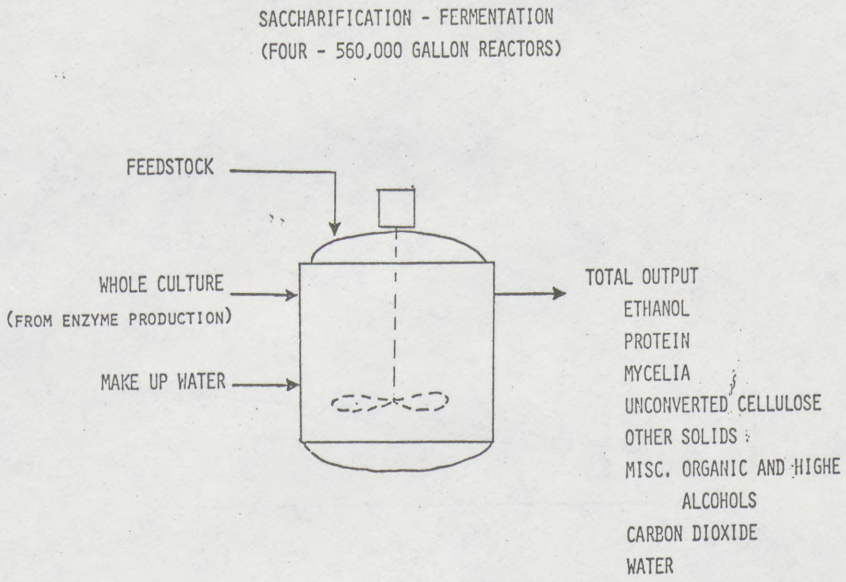
SLIDE 24.—Chemically cellulose is degraded to glucose by the action of three main enzyme activities in the cellulase or enzyme system.



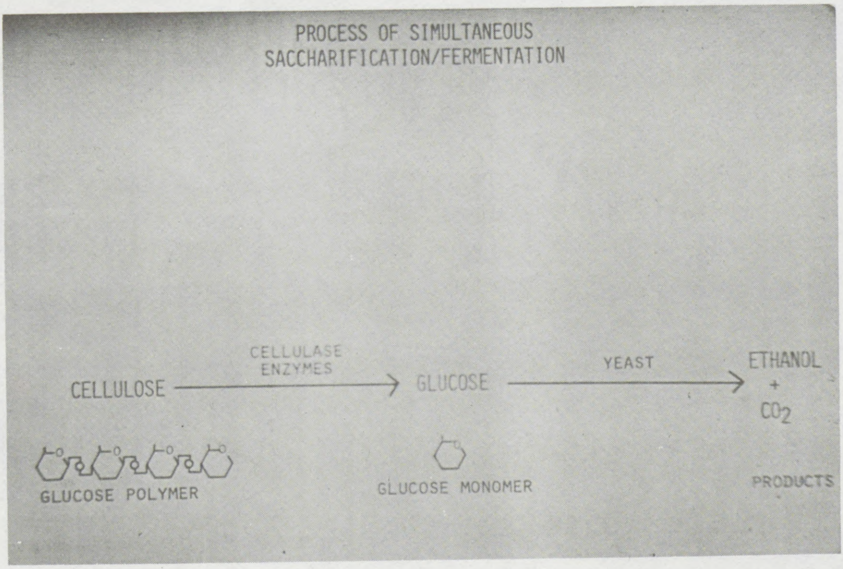
SLIDE 25.—The next step we want to consider in the direct ethanol process is that of yeast production. For many years we have heard that once you have glucose it's a very simple matter to convert to ethanol and it is if you do not have to worry about cost. But, if indeed you go to the scientific literature and you utilize the recipes for nutrients presented there to produce the yeast for use in such a process as we are discussing here, you will find that the cost according to those recipes is approximately $17 per gallon of ethanol subsequently produced. Obviously a commercial enterprise cannot even begin to consider commercialization with such numbers. Consequently, one of the greatest efforts we have made in developing the direct ethanol process is making practical yeast production. We have done this and the yeast then, along with the enzyme produced in the preceding step both go into a larger vessel, along with raw cellulose fiber, on a continuous basis to produce ethanol.



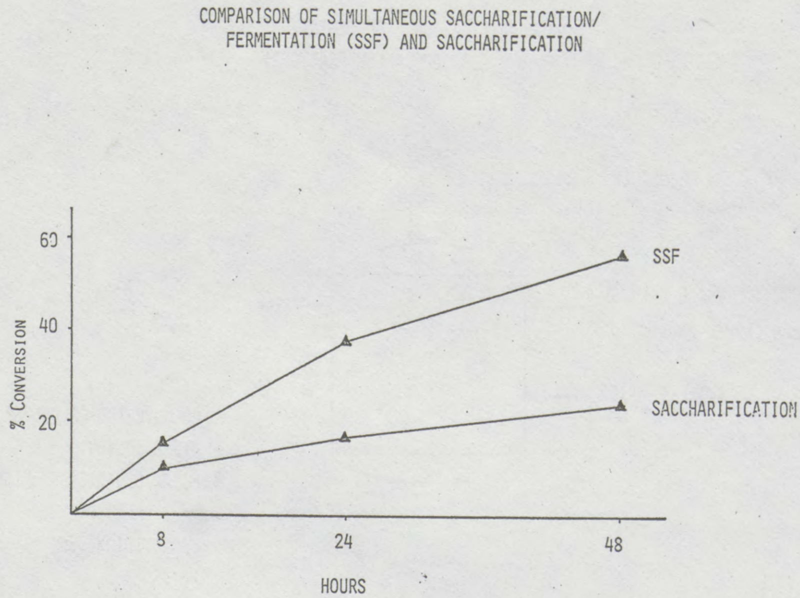
SLIDE 26.—The key step in the direct ethanol production process is the SSF or saccharification fermentation process. Basically saccharaification means production of sugars. Fermentation in this case means production of ethyl alcohol.



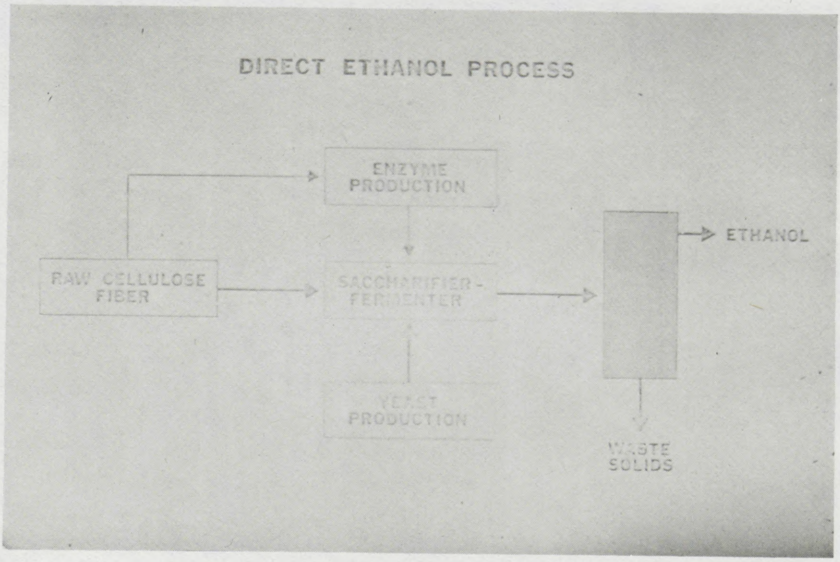
SLIDE 27.—Reactor input is feedstock, the whole culture from enzyme production, yeast, and make-up water. There is no separation of the enzyme. The total output then is ethanol, remaining protein (some of which can be recycled), the mycelia, unconverted cellulose, other solids, miscellaneous organic, and higher alcohols, carbon dioxide, and water.



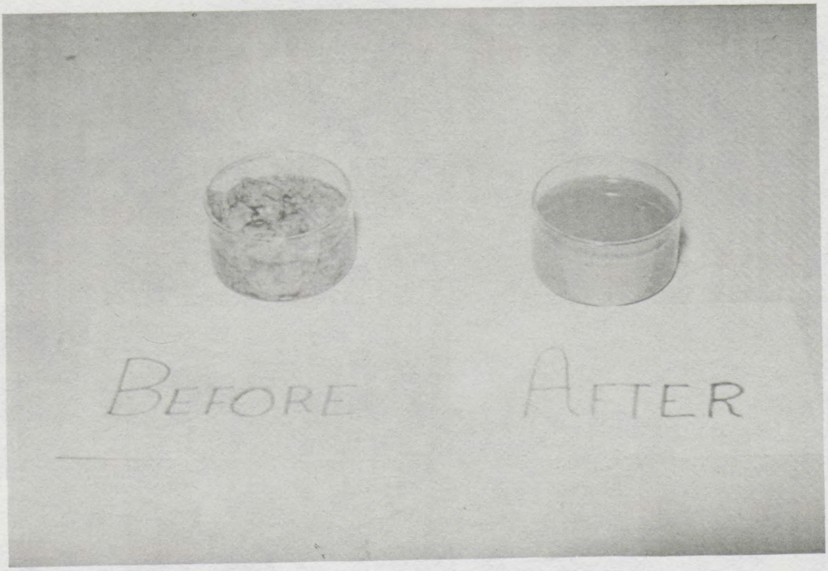
SLIDE 28.—This SSF process is summarized as cellulose, through the aegis of cellulolytic enzymes, being converted to glucose, and glucose, through the action of yeast, being converted to ethanol and CO_2.



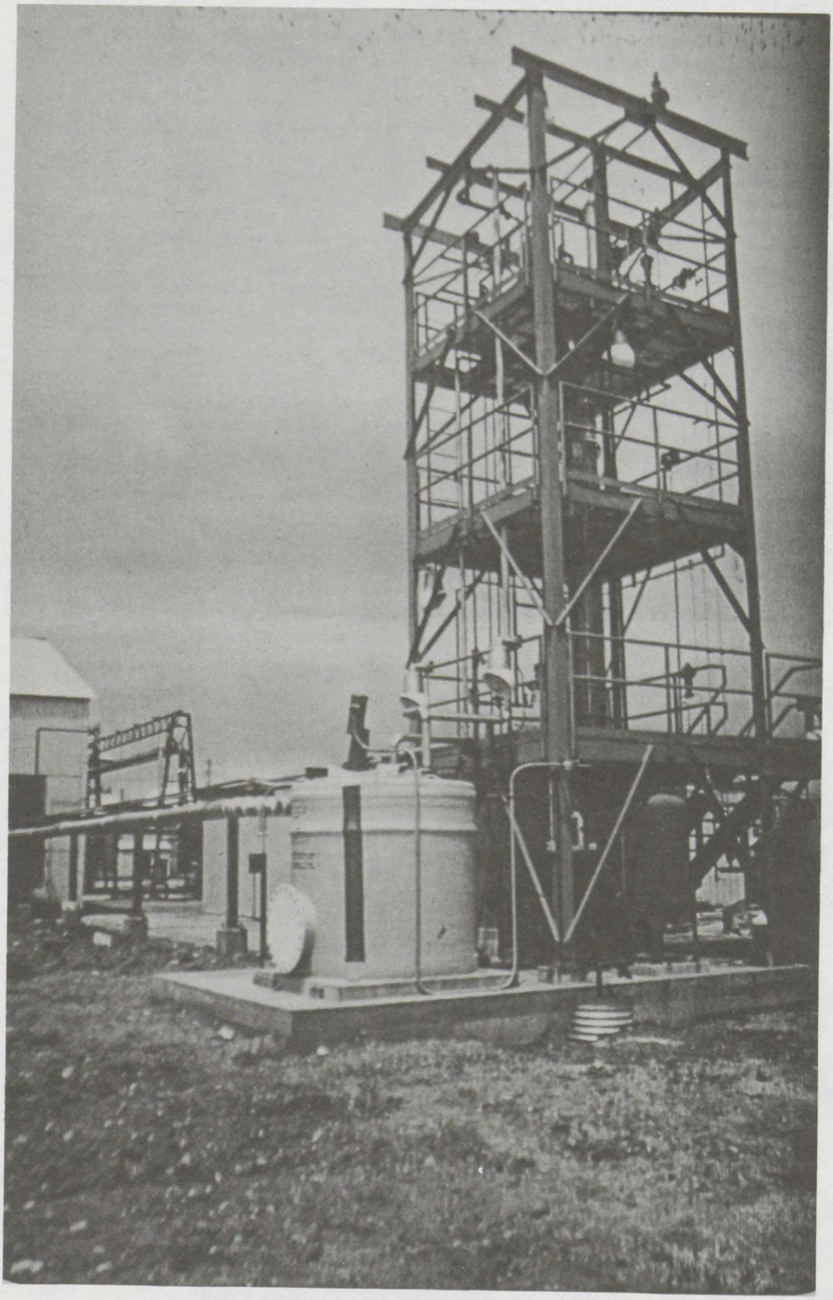
SLIDE 29.—A comparison of simultaneous saccharification fermentation, and saccharification alone, indicates the magnitude of enhancement obtained when the inhibitory products of saccharification are instantaneously removed upon their production by the yeast so that SSF then yields approximately 25–40 percent enhancement over simple saccharification alone.



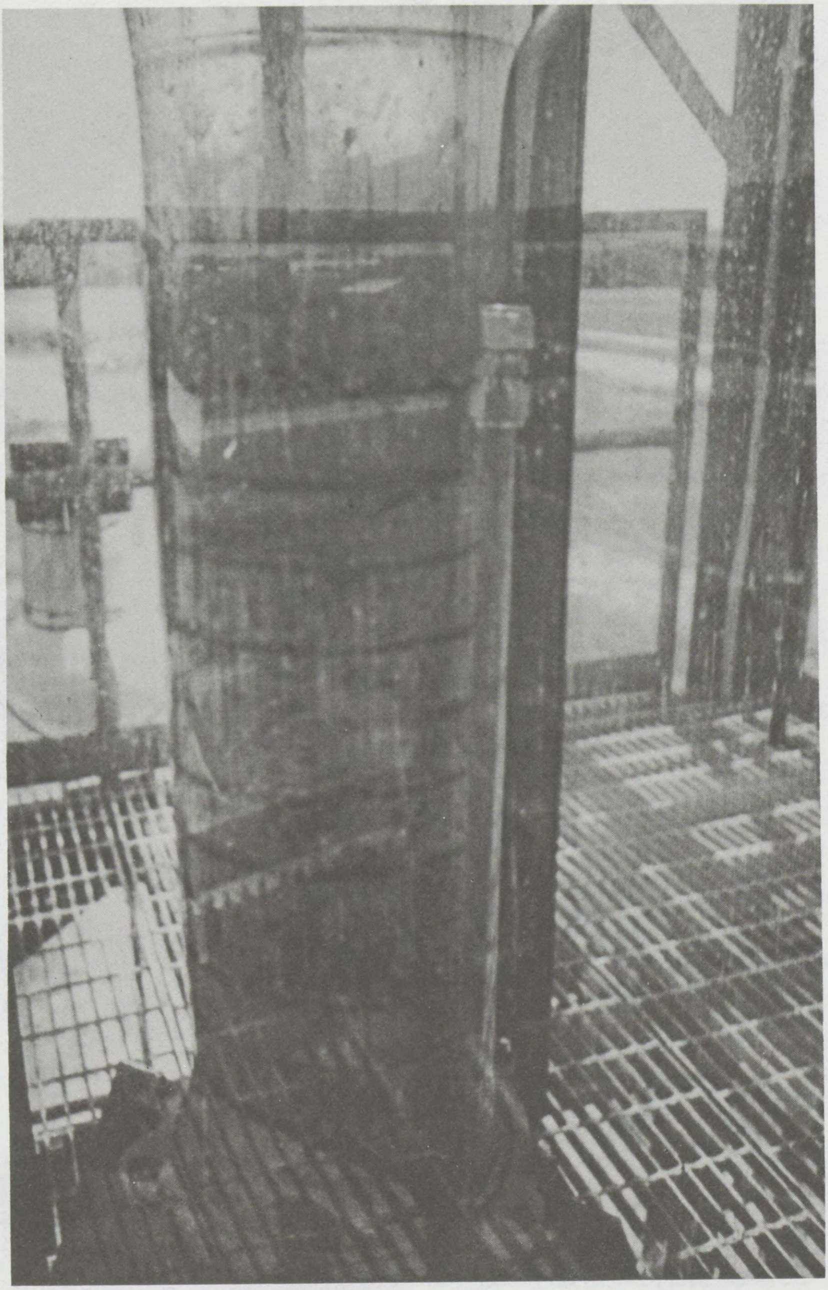
SLIDE 30.—Once you have then a mash containing ethyl alcohol and these other outputs of SSF you must then recover the ethanol.



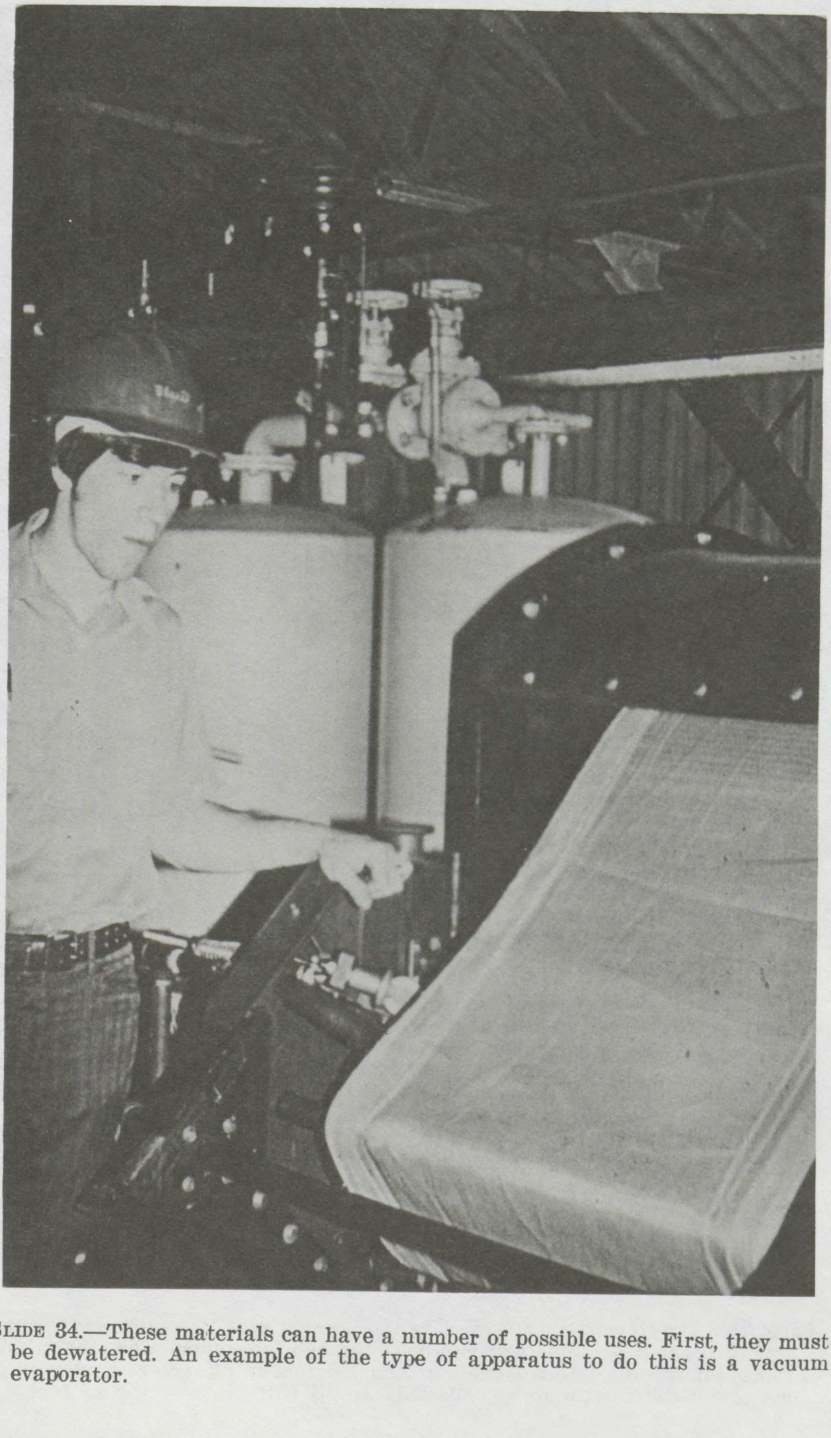
SLIDE 31.—This material, before it goes into SSF, is simply very lumpy and viscous. Through action of the enzymes and yeast it becomes very watery.



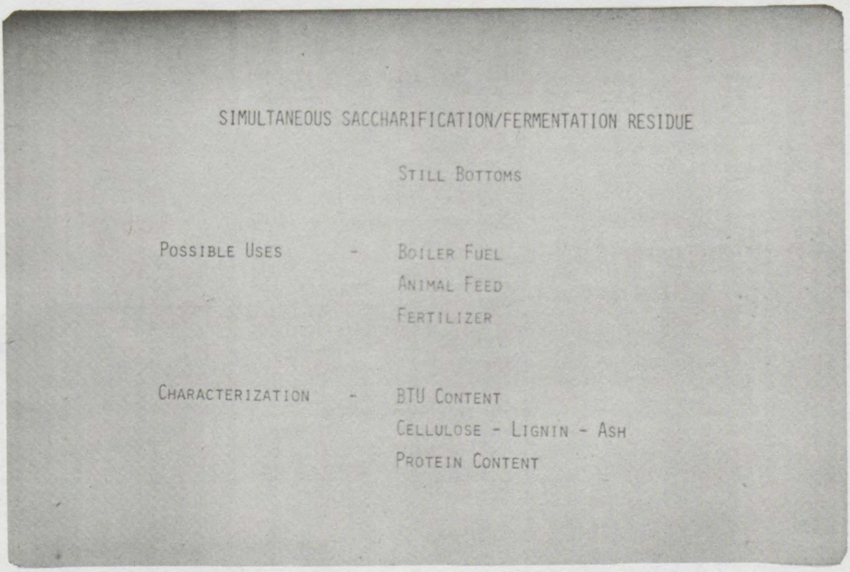
SLIDE 32.—The watery material is what is taken to a slurry stripper. This is basically a 25 foot high reactor, 18 inches in diameter, which has plates arranged so that when this mixture is poured down through the top and steam released up through the bottom, we can separate off the alcohol and collect it in a condenser.



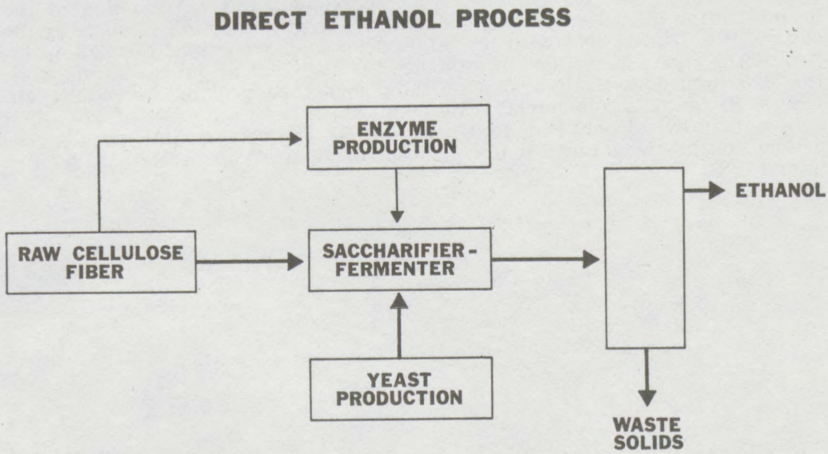
Slide 33.—The column is made of glass and it's very easy to see during the operation of the unit how this material flows through the column. The ethyl alcohol comes off the top into a condenser and the remaining materials stay in the bottom of the reactor to be collected as still bottoms.



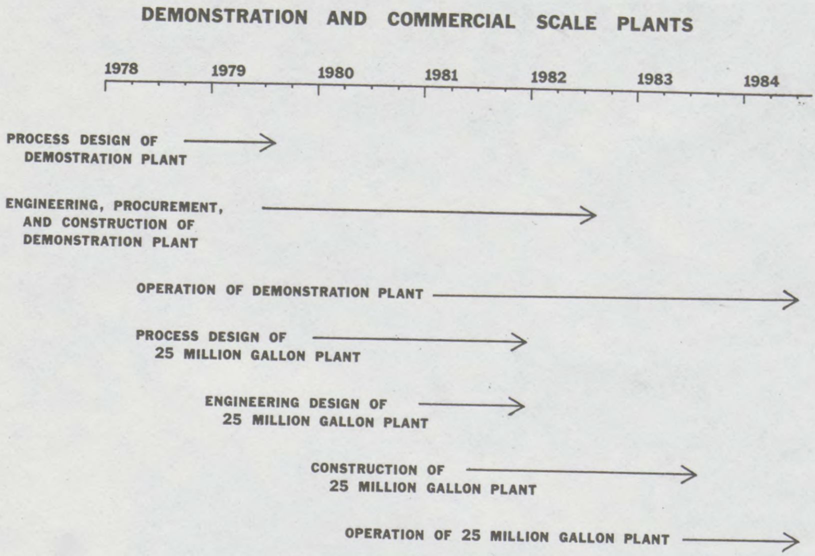
SLIDE 34.—These materials can have a number of possible uses. First, they must be dewatered. An example of the type of apparatus to do this is a vacuum evaporator.



SLIDE 35.—Possible uses for the material are as a boiler fuel (which is our plan in order to provide steam for earlier steps in the process), as an animal feed or as a fertilizer.



SLIDE 36.—Let's compare this direct ethanol process with that which exists for the beverage industry, that of grain fermentation or starch fermentation. The purpose then for this comparison is to show tha ethyl alcohol from cellulose is competitive with ethyl alcohol from grain, which is competitive with ethyl alcohol from the hydration of ethylene. So in the case of grain fermentation, you must receive the raw grain and you must pretreat it. In the case of grain, you must use a disc attritor in order to break up the kernels and make starch available. You must then have an enzyme step, in this case an amylase, to degrade the starch to sugar. There is also a yeast production step. The yeast does the same thing as in the cellulose case; it converts the glucose to ethyl alcohol in a fermentation step. The major process steps are thus very similar when grain is compared with cellulosics. Even now some facilities formerly used to produce beverage alcohol are switching to industrial grade alcohol output. The reason is simply a stronger competitive position with ethylene-derived alcohol.



SLIDE 37.—Our plans for this technology in the very near future for demonstration and commercial scale plants include the process design of a demonstration plant, demonstration plant size being 50 tons of cellulose waste per day, or approximately 2,000 gallons of ethyl alcohol. A very ambitious, but possible schedule would call for engineering, procurement, and construction of the demonstration plant beginning about mid-1979 with completion expected by the end of 1980. During 1980 with the information we have gained through operation of the pilot facility now in existence for 2½ years at Jayhawk, and work that has been done to that point on the demonstration plant, we could begin process design of a commercial scale plant which is on the order of 25 million gallons of ethyl alcohol produced per year. As you can imagine, such a condensed schedule would lead to the operation of the first commercial size facility in mid-1983.

GULF OIL CHEMICALS COMPANY
CELLULOSE ALCOHOL

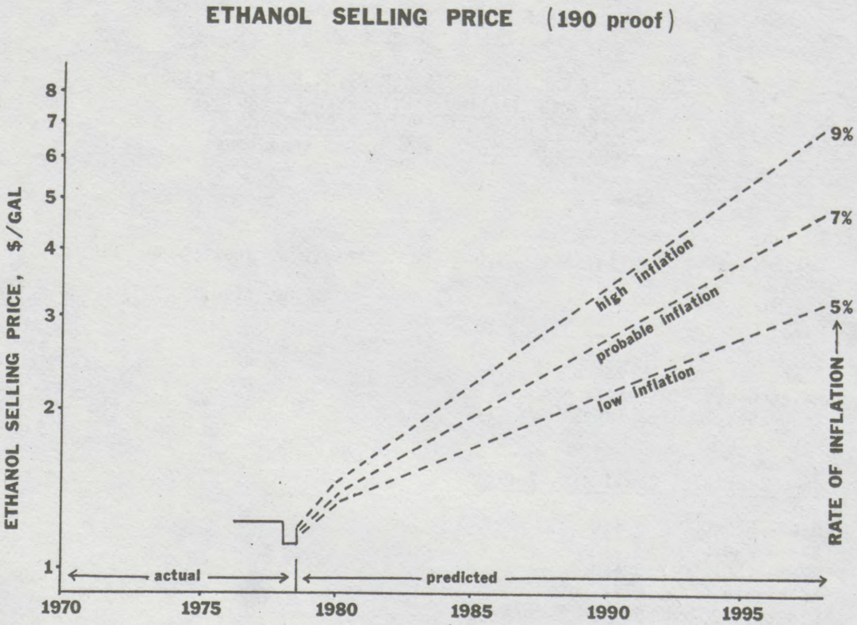
ALCOHOL PRODUCTION COSTS, CREDITS, SELLING PRICE
10 YR AMORTIZATION - WITH FEED BY-PRODUCT
25 MM U.S. GALLONS/YR PRODUCTUION
(50% 190^0 proof - 50% 99.98% anhydrous)

Total Invested Capital $64,000,000 (conservative projection) - 1981 costs

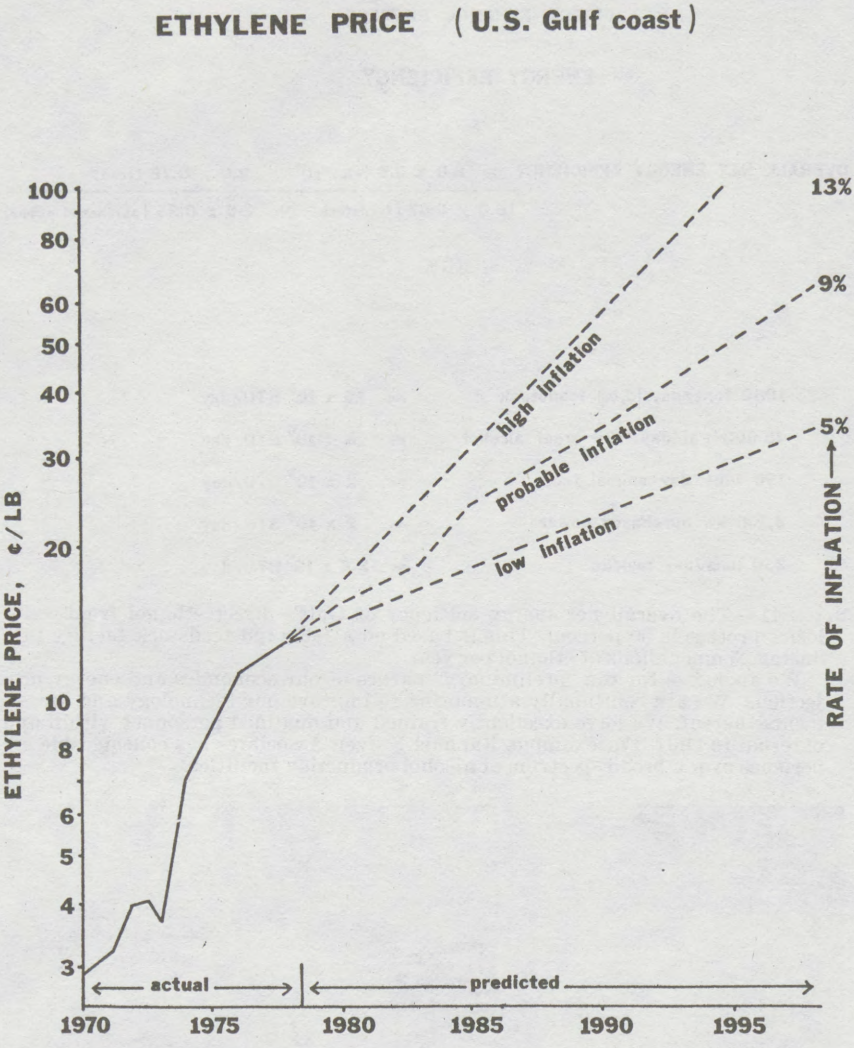
		Annual ($MM)	$ Per Gallon
Fixed Charges			
Amortization - 10 years	6.4		
Maintenance - 4%	2.6		
Insurance local & Taxes - 2%	1.3	10.3	0.412
Raw Materials, Chemicals, Energy			
MSW - 500,000 T @ $10	5.0		
SW - 250,000 T @ $15	3.8		
PMW - 250,000 T @ $10	2.5		
Nutrients, Chemiclas, etc.	2.5		
Electric Power 8000 KW @ 3¢/KwH	1.8	15.6	0.624
Labor & Supervision (including benefits)			
7 - Supervisory staff	0.3		
10 - Office & Lab staff	0.2		
52 - Operators, Laborers	1.0	1.5	0.060
Sales, Freight, G & A 0(10¢/gal)		2.5	0.100
Total Costs		29.9	1.196
Credits			
Annual Feed 50,000 T/yr @ $120/T		-6.0	-0.240
Net Production Cost		23.9	0.956
Additional Charges			
Federal & State Taxes		9.6	0.384
Net Profit		9.6	0.384
Alcohol Selling Price		43.1	1.724

7/31/78

SLIDE 38.—A conservative estimate of capital costs for 1981 construction would be $64 million for a 25 million gal/y plant. Considering fixed charges, raw materials, chemicals, energy, labor, freight, a feed credit, and Federal and State taxes, one could estimate a 1983 alcohol selling price of approximately $1.73 a gallon.



SLIDE 39.—A reasonable selling price for ethylene derived ethyl alcohol, including projected inflation, would be approximately $2 a gallon in 1983 when our schedule indicates a commercial facility on stream.



SLIDE 40.—Ethylene prices are projected to be $0.20 plus per pound at that time. Capital investment for a grassroots ethylene hydration plant are nearly prohibitive already. There has been no such facility constructed in the last 10 years in the United States.

DIRECT ETHANOL PROCESS

ENERGY EFFICIENCY

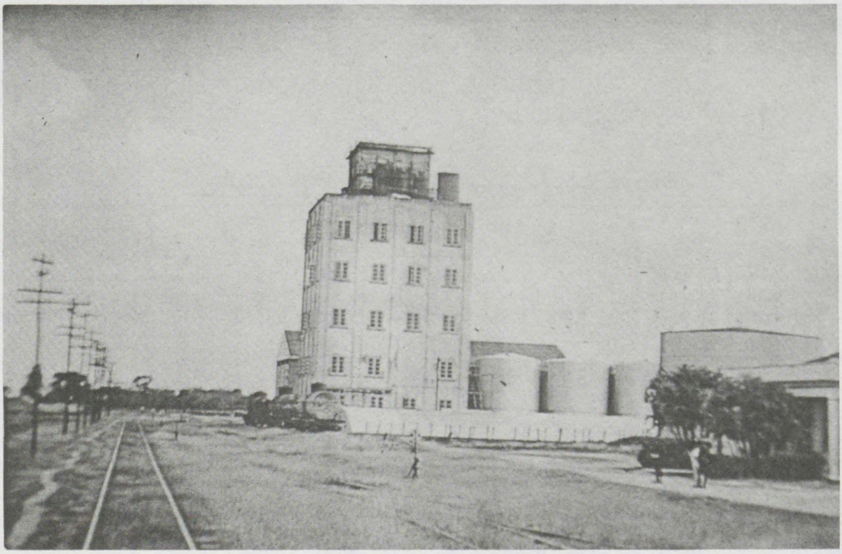
$$\text{OVERALL NET ENERGY EFFICIENCY} = \frac{6.0 \times 0.8 \text{ (alcohol)} + 2.0 \times 0.75 \text{ (feed)}}{15.0 \times 0.67 \text{ (feedstock)} + 2.0 \times 0.35 \text{ (purchased power)}}$$

$$= 59\%$$

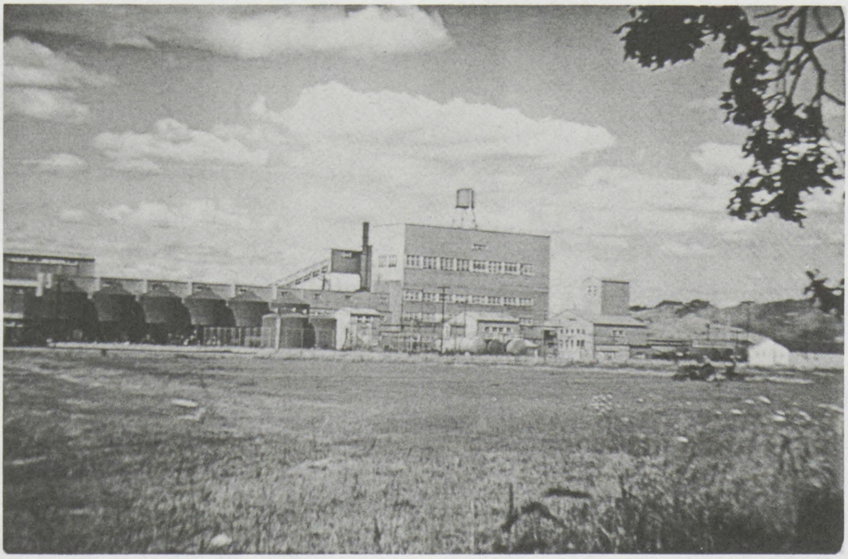
1000 tons/day (d.b.) feedstock	≈	15×10^9 BTU/day
75 000 gal/day 190 proof alcohol	≈	6×10^9 BTU/day
150 tons/day animal feed	≈	2×10^9 BTU/day
8,100 kw purchased power	≈	2×10^9 BTU/day
350 tons/day residue	≈	5.8×10^9 BTU/day

SLIDE 41.—The overall net energy efficiency of Gulf's direct ethanol from cellulosics process is 59 percent. This is based on a 1,000 tpd feedstock facility producing 25 mm gallons of ethanol per year.

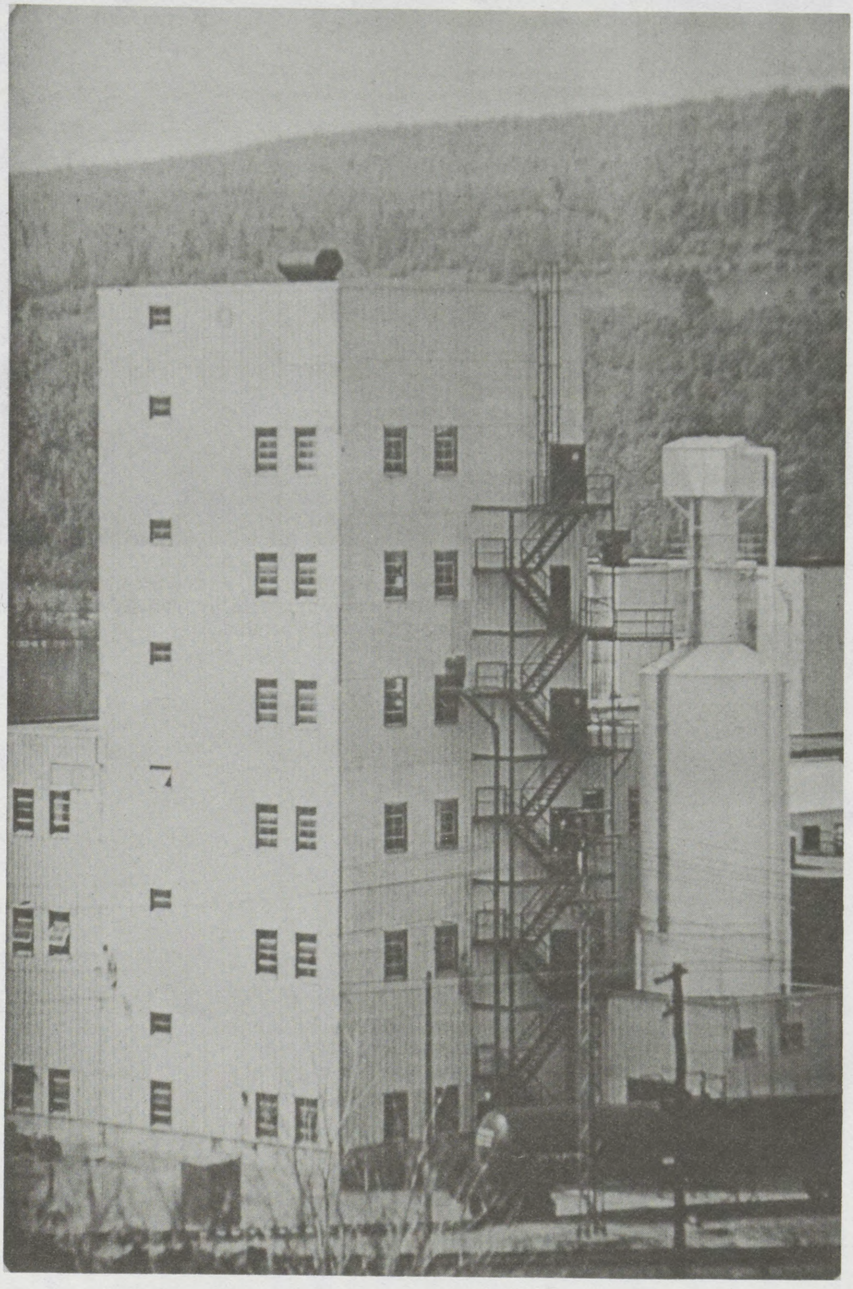
We apologize for the "preliminary" nature of our economics and energy projections. We are continually attempting to improve our technology and assessments thereof. We have excellently trained and qualified personnel within and external to Gulf. For example, Raphael Katzen Associates has considerable experience over a broad spectrum of alcohol production facilities.



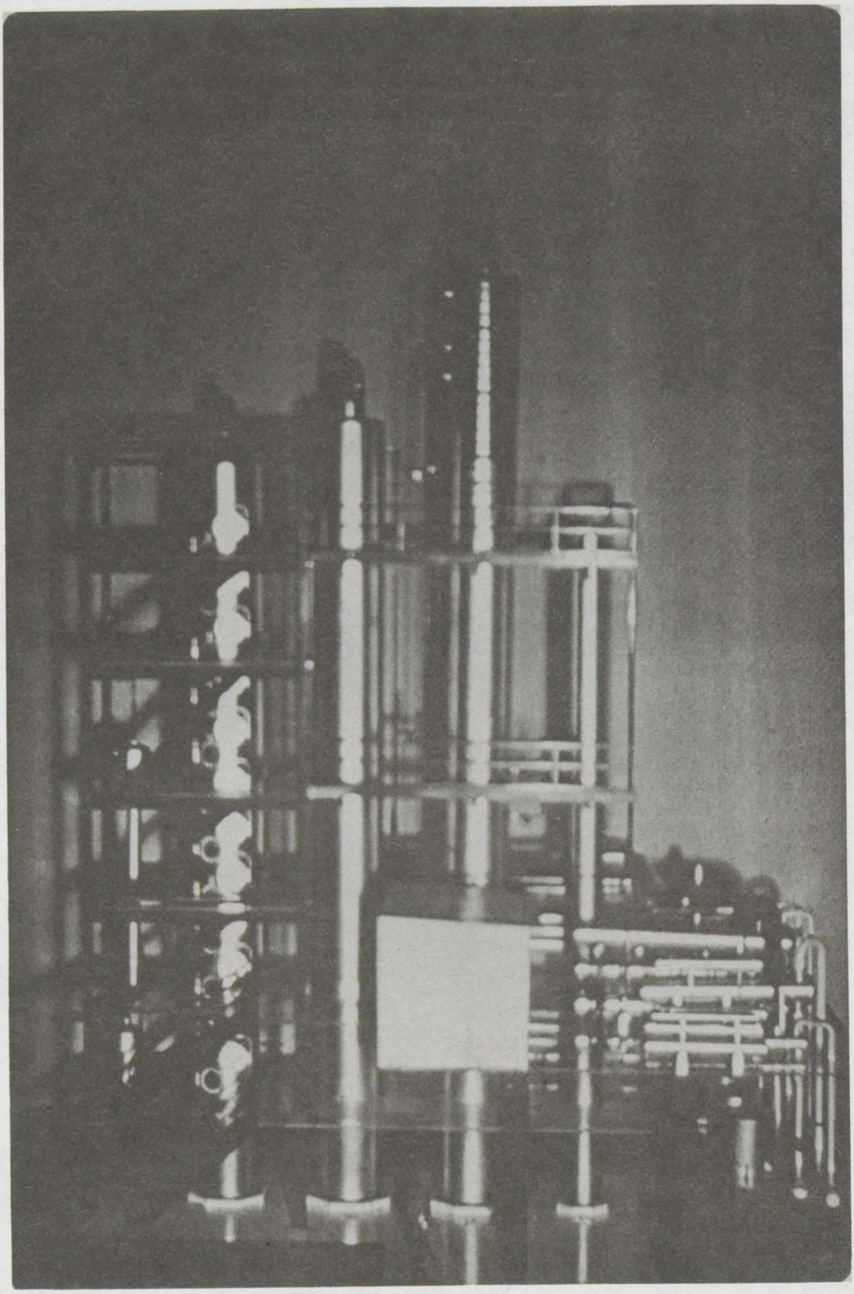
SLIDE 42.—His firm engineered a Cuban gasohol plant in Camaguey, Cuba (1953) where 15,000 gal/d of 99.5 percent absolute ethanol was produced from excess blackstrap molasses. This alcohol was used in 15 percent blend with gasoline.



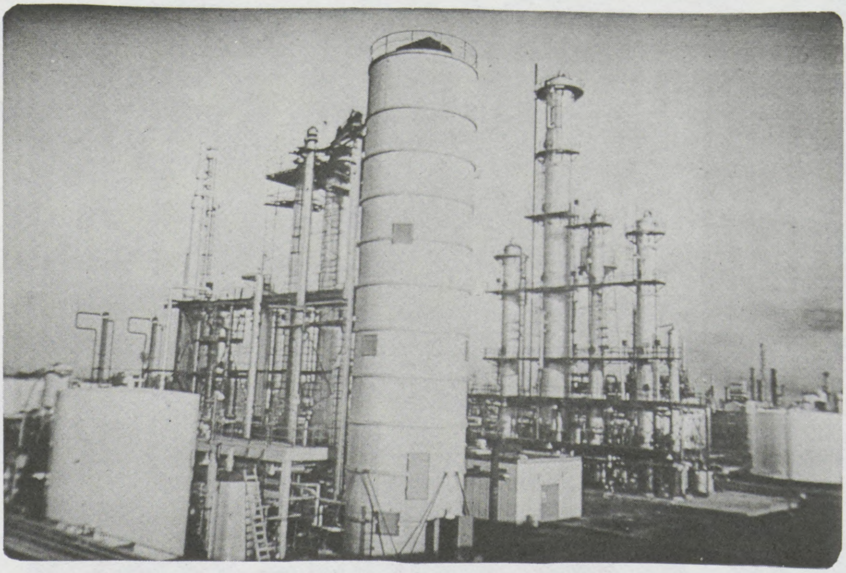
Slide 43.—Dr. Katzen aided the U.S. Defense Plant Corp. with a wood hydrolysis alcohol plant in Springfield, Oreg. (1946). Through acid hydrolysis of sawdust waste, 12,000 gal/d of 190 degree proof alcohol was produced.



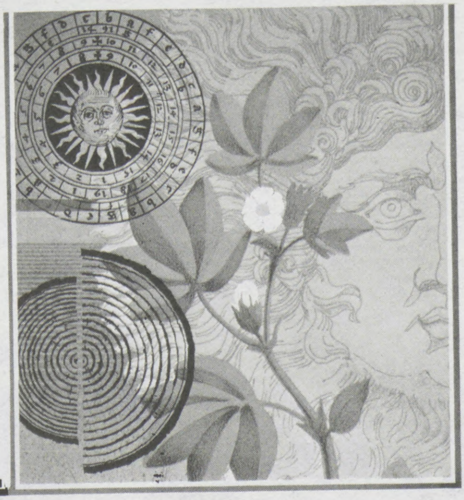
SLIDE 44.—His engineering skills also were used in a Canadian project (1962) where 12,000 gal/d 190 degree proof alcohol was produced from wood pulping sulfite waste liquor.



SLIDE 45.—Grain alcohol experience includes a plant in Kansas (1968) where 18,000 gal/d 190 degree proof beverage and industrial alcohol is produced from milo and other agricultural materials.



SLIDE 46.—RKA has helped engineer a synthetic alcohol plant in Canada (1970) where 60,000 gal/d 192 degree proof industrial alcohol and 99.98 percent anhydrous alcohol for food and pharmaceutical use is produced.



THE CELLULOSE PROJECT

Start with cellulose-containing materials such as waste pulp from a paper mill, or ground-up corn cobs, or trash from a cotton gin; treat it first with a fungus and then with a yeast; and end up with ethyl alcohol or other chemical intermediates and raw materials.

Such a procedure is neither science fiction nor wishful thinking. It is, in effect, what is happening in a pilot plant at Gulf Oil Chemicals Company's Jayhawk Works near Pittsburg, Kansas. GOCHEM researchers are treating cellulosic materials with enzymes produced by a fungus to make glucose, a sugar. This, in turn, is acted upon by other enzymes, produced by a yeast, to convert it to ethyl alcohol, from which can be made a wide variety of other organic chemicals, including ethylene, a basic building block of the chemicals industry.

"We have been operating our pilot plant for more than a year and a half," Dr. George F. Huff, GOCHEM Vice President of Research and Development, said, "and while we still have much to learn, we have progressed to a point where we are beginning engineering studies to design a commercial-scale plant."

Gulf's biochemical research program began in 1971. "What we are looking for are alternate feedstock sources," Dr. Huff said. "Today, practically all of the organic chemicals industry relies on petrochemicals. Some of us had become concerned, even before the Arab embargo, that increasing prices of petroleum and, consequently, of petroleum feedstocks, will eventually make many of the materials supplied by the modern chemicals industry too expensive for general use. From an economic standpoint alone, it is becoming imperative to have alternate feedstocks available."

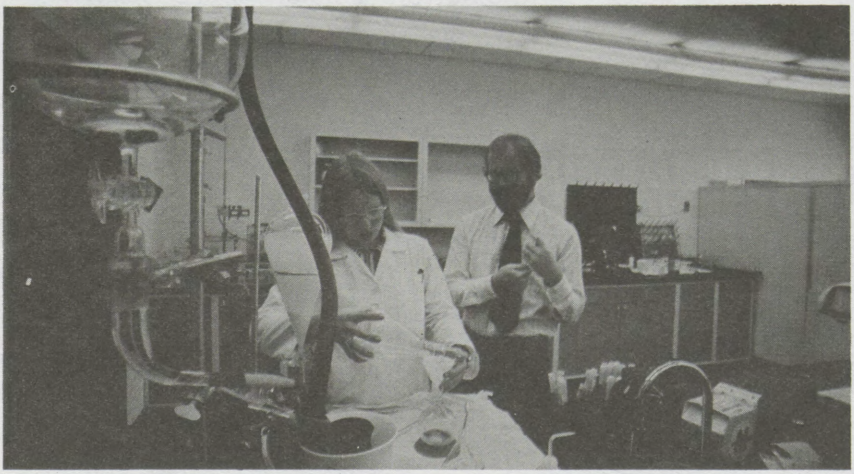
Turning to fermentation processes to produce industrial chemicals is, in a sense, turning back the clock. (Fermentation is a transformation of organic substances catalyzed by the action of microbial enzymes. Enzymes are proteins that act as biological catalysts.) Long before they were able to define or understand the process—from before the beginning of recorded history—humans have been fermenting beer and wine and baking bread. Today, in addition to spirits, baked goods and cheese, fermentation is widely used for the production of antibiotics and vitamins. Before 1930, practically all of the industrial ethanol (along with many other organic chemicals) used in the United States was prepared by fermentation processes. With the rise of the petrochemicals industry, however, an ever increasing amount of the alcohol is made by the hydration of petroleum-derived ethylene. Fermentation as a source for chemicals was becoming a lost art.

"Petrochemicals have enjoyed a tremendous growth over the past half century because of the low cost of petroleum, but since the Arab embargo, low-cost petroleum has become a thing of the past," Dr. Huff said. "When we started our project in 1971, ethylene was selling for about 2.75 cents a pound and sugar was 7 cents a pound; today, ethylene is up to 12.5 cents and sugar is about 11 cents. So already, ethylene has become more expensive than sugar, and the gap will surely become greater. That is a fundamental reason why we are looking back to the old days.

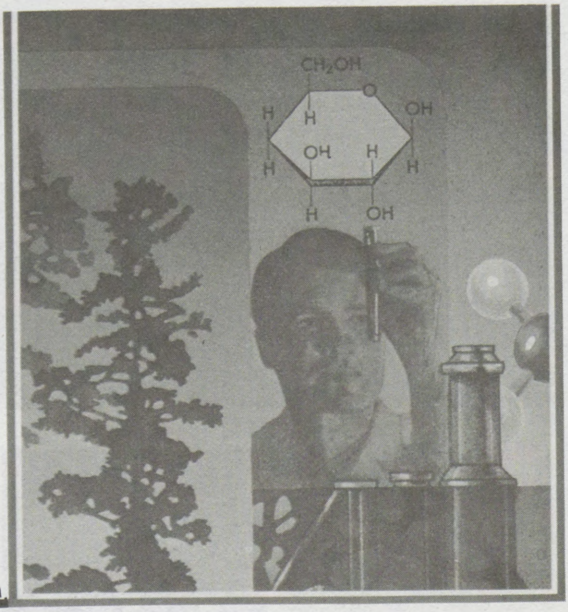
"There is a tremendous difference, however, between those days and the 1970s," he added. "The difference lies in the advances made in biochemistry, particularly in the past 10 years. Great strides have been made in elucidating the manner in which nature makes almost all known organic chemicals efficiently, without pollution, requiring only the energy of the sun."

One of the organic materials that nature makes in great profusion with the aid of the sun, and one that is annually renewable, is cellulose. Cellulose, a product of photosynthesis, is the structural material of all plants. It is the natural starting point in the search for alternate feedstocks. Hundreds of millions of tons of cellulose waste accumulate each year from agriculture and food processing, from lumbering and paper making, and from the nation's municipal wastes.

The basic chemistry of converting cellulose to glucose through the action of microbes is well known. A number of companies and laboratories, including the U. S. Army facility at Natick, Massachusetts, are engaged in research to find ways of applying the technology on a commercial scale. The story is told of how American troops in the South Pacific during World War II were having great difficulty in keeping their cotton gear intact—tents, uniforms, knapsacks, etc. "Jungle rot" was destroying the items in record time. Army scientists succeeded in isolating the culprit on a cartridge belt sent from New Guinea: a mold, *Trichoderma viride*, was converting the cotton (which is largely cellulose) to glucose and then feasting on the sugar.



The GOCHEM laboratory at Merriam, Kansas, offers direct support to the Pilot Plant at Joplin. Additional laboratory work is carried out in Japan and at several universities.



THE CELLULOSE PROJECT

Trichoderma viride is not a rare microbe of the tropics but a mold found in the soil everywhere. It performs the vital task of decomposing cellulose in nature, freeing for reuse the carbon locked into cellulose by photosynthesis. As one scientist explained, "If plants continued to grow in the sun, fixing carbon dioxide, and the cellulose were not degraded naturally, within 20 years all of the carbon available in the earth's system would be bound up in cellulose."

Cellulose is a polymer of glucose. That simply means that it is made up of a series of glucose molecules bonded together. Humans cannot digest cellulose and it passes through the body as fiber. Many bacteria, fungi, higher plants, and some invertebrate animals, however, are capable of producing cellulase, the enzyme system that degrades cellulose to glucose. *Trichoderma viride*—affectionately referred to by the GOCHEM researchers as "the bug"—is one of them.

When the Army's Natick Laboratory shifted its research from trying to inhibit the action of the bug to trying to step up its activity as a possible way of solving solid waste disposal problems (by converting waste paper to glucose, fuels, and protein), methods were sought to increase its enzyme production. The laboratory achieved this by irradiating the fungus to form mutant strains. It is one of these strains that is being used by Gulf in its research.

To get its program underway, GOCHEM turned to the academic world, funding a project at Virginia Polytechnic Institute, where Dr. Ross Brown directs an internationally renowned cellulase research program. Other projects were begun at the University of Pittsburgh and Kansas State University. "We went to the schools," Dr. Huff said, "because we had no in-house capability—no one trained in microbiology."

Since the Japanese have long been active in fermentation chemistry, it was agreed that there might be merit in seeking out such expertise in Japan. "Because Gulf had a long-standing association with Nippon Mining Company," Dr. Huff said, "we approached them and outlined our needs. We found they had been thinking along similar lines, largely due to the vision and leadership of the then executive vice president, Mr. Sadakatsu Muraoka of Nippon Mining. We held talks, and by late 1972 a joint research venture was agreed upon by the two companies which resulted in the formation of Bio Research Center Company, Ltd. (BRC), with a laboratory in Japan, whose managing director is Dr. Naoki Yata."

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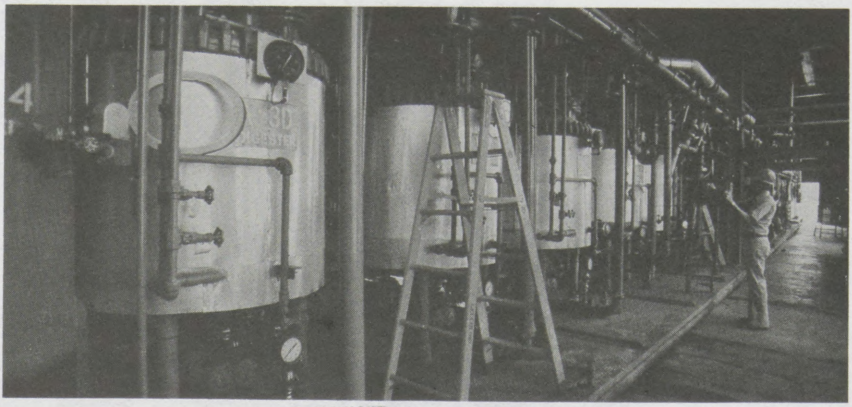


The Pilot Plant has been operating for more than a year and a half. In the foreground are the reactor tanks.

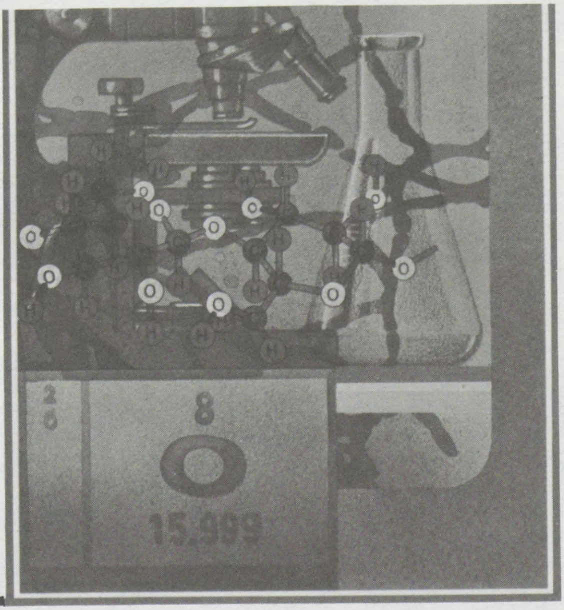
Out of the early work, done largely by BRC and VPI, GOCHEM developed a flow diagram for the process, and Gulf Science & Technology's Engineering Division was assigned the task of designing a pilot plant. As the plans progressed, the fabrication of equipment was begun in Houston. Meanwhile, Dr. George H. Emert, a graduate of VPI who had been teaching at the University of Colorado, was hired to outfit a support laboratory facility at the GOCHEM Research Center at Merriam, Kansas, a suburb of Kansas City. During the summer of 1975, the first equipment was delivered to Jayhawk; by January of 1976, the first processing was started.

An essential step in the process is making the *Trichoderma viride* produce the enzymes needed to break down the cellulose in sufficient quantity to sustain a large-scale operation. "What we have to do is coax the bug to produce surpluses of the enzymes for us," said Dr. Emert, whose title is Director of Biochemical Technology. "Nature is for economy, and normally the microbe would release only enough enzymes to make a sufficient amount of glucose for its own use. We give it a cellulose to feed on that is very difficult to break down. All the chemicals are present to tell the bug to make the enzymes, so it keeps on making them at a rather remarkable rate. In fact, we can get it to produce its own weight of the catalyst in a reasonably short period of time."

Waste pulp from a paper mill is one of the promising feedstocks being tested in the studies now underway.

In the Cellulose Project at the Jayhawk pilot plant, water is added to waste cellulose in a pulper—an oversized blender. This serves both to make a slurry and break up the fibers, creating a greater surface area, allowing the bugs maximum access to the cellulose. A portion of this pulp is sterilized and fed into the enzyme production tanks. There it is mixed with nutrients and air and inoculated with the fungus. Sterilization is necessary in the enzyme production stage to keep out unwanted microorganisms. As Dr. Huff put it, "Since glucose is a universal food, its availability is an invitation to a host of unwanted organisms."

The remaining pulp from the blender moves to the reactor tanks and is mixed with the enzymes along with yeast and nutrients in a controlled environment. Here a simultaneous saccharification and fermentation takes place. The enzymes break down the cellulose to form glucose (saccharification), and immediately as the molecules of glucose form, the enzymes produced by the yeast catalyze their conversion to ethanol (fermentation).



THE CELLULOSE PROJECT

Finally, the mixture from the reactor tanks moves on to a distillation system where the ethanol is recovered. What is left after the distillation—a mixture of yeast cells, enzymes, cellulose, etc.—is high in protein and should make an excellent animal feed. Studies are now underway at the laboratory concerning that possibility.

Part of the attraction of microbial processing is its environmental acceptability. There are no high temperatures or high pressures to cause problems. There are no strong acid or caustic solutions involved. It is a natural process. In addition, in the Gulf operation, feedstocks which are waste materials and may well present disposal problems, are converted into usable products.

While the GOCHEM researchers are highly enthusiastic about the progress that has been made in developing the process to date, they readily admit that there are problems still to be solved. Charles Wosel, Supervisor of the Cellulose Pilot Plant, said, "The first one that comes to mind is sterilization. It might be routine to people who have been working in the fermentation business, but its new to those of us who've been working in the oil industry."

Part of the confidence evidenced by the people involved in GOCHEM's biochemical program stems from their knowledge of the commitment the company has made in this area. Some 60 scientists and technicians are directly involved. In addition, there is the support given by other elements throughout Gulf Oil Corporation, from the Patent Department through the various divisions of Gulf Science & Technology Company.

"Our real achievement so far—the area in which Gulf has a proprietary standing," Dr. Huff said, "is in the conversion of cellulose to glucose. We have an excellent patent position and have developed considerable expertise in this area.

"Conversion of glucose to ethanol has been going on for centuries and, once you have arrived at ethanol, you are on familiar ground. With ethanol, you can make a number of compounds by direct conversion—or you are just one dehydration away from ethylene. With ethylene, you have the basic chemical building block."

Some of the enthusiasm of the employees involved in the biochemical studies undoubtedly comes from the feeling that they are "pioneering"; an awareness that they are perhaps standing on the threshold of a new era in chemistry. While the modern chemical industry relies essentially on refinery offstreams for its feedstocks, the work underway in Biochemical Technology offers the possibility of a whole new industry based on the conversion of cellulose to glucose. As one of the Japanese associates in the BRC said, "Glucose may be the ethylene of the future."

In their approach, the researchers are short-circuiting fossilization. It takes hundreds of millions of years for nature to make petroleum from plant life produced from the energy of the sun. To be able to make those products now derived from petroleum directly from plant life means that we have the capability of tapping an immense renewable resource. It is estimated that worldwide production of cellulose by nature is in the order of hundreds of billions of tons annually.

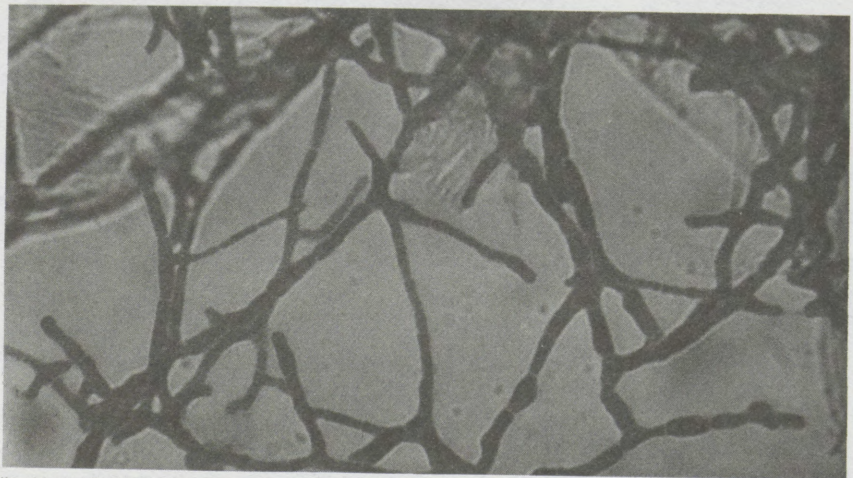
As to the immediate future: "Well, for the next two years we are going to have our hands full with the conceptualization of a commercial-scale plant—one capable, say, of producing 25 million gallons of ethanol a year," Dr. Huff said. "It is the responsibility of GOCHEM's New Business Development Division in Houston to commercialize the research project. The laboratory and pilot plant are working closely with them on a continuous basis.

"We, in the meantime, will also be continuing our work with the process to make improvements wherever possible. We have already made considerable progress in prioritizing waste feedstocks, but will go into that even further. It will be a busy time."

Dr. Huff added quickly, "Of course, the Cellulose Project isn't the only work in which we are interested. We are interested in an algae that can produce chemicals from sunlight, air, and salt water. We are trying to entice other bugs to convert paraffinic hydrocarbons to fatty acids.

"There are also some potential microbiological applications other than to produce chemicals. Microbes might be used to dissipate oil spills or clean pipelines and storage tanks. There are microbes that can live in old oil formations where we've extracted about all the crude oil we can by conventional means. These organisms can break down the complex, heavy molecules of petroleum and produce lighter ones that would flow to the well bore. Then there are the tar sands . . ."

Meanwhile, there's the matter of finding ways of coaxing just a little more of the enzymes from the *Trichoderma viride*.



Hero of the saga is *Trichoderma viride*, "the bug," as seen under the microscope. This common mold secretes enzymes capable of breaking cellulose into glucose.

Senator CHURCH. Can you describe the method which you are using in this pilot plant to produce the ethanol?

Dr. HUFF. Dr. Emert can best answer that.

Dr. EMERT. Basically, sir, we are utilizing a micro-organism to produce an enzyme system which catalyzes the degradation of cellulosic materials into glucose, and simultaneously adding the yeast, which converts the glucose produced to ethanol. And then we recover the ethyl alcohol from that mixture through stripping it from the solid material and water that is there and then taking it through a regular rectification system.

Senator CHURCH. Do I understand then that the method is chemical in its nature. I wonder if you could describe how this differs from the ordinary method of distillation?

Dr. EMERT. Well, first, let me say that industrial-grade ethyl alcohol synthetically derived today is obtained through hydration of ethylene. That is a chemical process, utilizing relatively high temperatures and pressure. The process that we use employs ambient temperatures and pressures, for the most part; and it is different in that it is utilizing a biological system.

Obviously, it is chemical, but it is biochemical rather than strictly chemical.

Senator CHURCH. How much fuel is required to produce the ethanol? You estimate that a commercial plant efficiency would be 59 percent. Could you give us some further explanation of what that figure means?

Dr. HUFF. Dr. Katzen will answer that.

Dr. KATZEN. We would first point out that the waste materials that we utilize are not just cellulose. Municipal solid wastes, mainly newspaper, has about 25 percent of materials that are not convertible to sugars. The sawdust that we use has 20 to 30 percent of these other materials. And even the pulp waste has other materials in it.

As a result, in a typical 1,000-ton-per-day feedstock commercial facility—we will have about 350 tons a day of residue, which we dewater, and that becomes the fuel for our process, by means of cogeneration, which means production of steam and power from the same sources. We become almost completely self-sufficient on energy.

We have taken, you might say, a conservative approach; and the numbers indicate that we purchase in the 1,000-ton-per-day commercial plant about 8,100 kilowatts of power from outside. That is the only outside energy contribution. And, in a less conservative approach, we think we can reduce that further to about 3,000 kilowatts of purchased power.

We have the balance, to give you an idea of the numbers—and these are big numbers, everything is in billions, like the Federal budget, billions of Btu's per day for 1,000 tons of feedstock—and we are talking about contained gross energy value of 15 billion of Btu's per day. The electric power we purchase, which we assume is generated by fossil fuel—is about 2 billion Btu's energy input. That is a total input into the process.

But since we provide our own fuel, we come out with 75,000 gallons a day of alcohol, which has 6 billion of Btu's per day and 150 tons per day of animal feed per day have an energy content of 2 billion Btu's. We have used 8 billion Btu's per day for a gross energy from 17 billion input; a gross energy efficiency of 47 percent.

Now, that is not a fair measure. We get a lot of talk about energy efficiency, and people can dream up all sorts of numbers. But true energy efficiency is what you get out of each component that you use as fuel. That 15 billion Btu's per day of feedstock is a very inefficient fuel.

If we burned that municipal solid waste or pulp waste, it burns only at 67 percent efficiency. That is all we can net out of it by generating steam. The fossil fuel, used to produce electric power, is utilized at only 35 percent of efficiency—that is a national average powerplant. I have seen figures as high as 40 percent but an average is 35 percent. So, we are putting in materials energywise that can be beneficially utilized as fuels.

Now, when we use alcohol for motor fuel, or as a chemical feedstock, industry realizes about 80 to 85 percent efficiency from it, and the animal feed is utilized 75 percent efficiency, either by the animal or as a fuel. So therefore our true net energy efficiency is 59 percent, and that is one of the highest efficiencies in energy projects of this type.

Senator CHURCH. I understand that the Army has experimented with a process in their lab in Massachusetts. How does that process compare with the process that you are using?

Dr. EMERT. Senator, the Natick Research Laboratories have done considerable work over the past 30 years with such a system as we now employ. The greatest difference is their approach has been one of a basic research nature; ours has been one to practicalize the technology.

Additionally, there is a single step, which we call simultaneous saccharification fermentation, which is grossly different from any other procedure. Additional to that, the front end of the process is very different in our case, than in the case of the Natick work.

Senator CHURCH. Senator Bayh, in his testimony, mentioned the work of George Tsao of Purdue University, who uses a very inexpensive cellulosic waste as feedstock, such as cornstalk, pulp, sawmill waste, small limbs and tree branches. Are you familiar with those experiments?

Dr. HUFF. We know of Professor Tsao's work. We have retained Dr. Katzen not only to evaluate our own, but also to evaluate competing processes, because that is one of my nightmares—perhaps we have something, but somebody else may have something better.

Perhaps Dr. Katzen could respond.

Dr. KATZEN. Senator, as consultants, it is our obligation to evaluate this technology objectively and properly, and also the competing technology. And aside from Gulf, we did this 3 years ago for the U.S. Department of Agriculture and the Forest Service, for chemicals from wood.

We have been trying to evaluate Professor Tsao's technology, as the Senator indicated, which has been funded to a major extent by the Department of Energy, and it is somewhat surprising to me—that despite public funding, Tsao's technology is maintained secret.

We offered to sign a secrecy agreement with Professor Tsao, which is common in our profession and industry in order to evaluate his technology. He refused that. Through the grapevine—and every industry and every profession has a grapevine—we have gotten some feel for what he has done.

He has three different techniques. One uses a solvent, Cadoxin, C-a-d-o-x-i-n; this turns out to be a very toxic material, so I think he has abandoned it. I think, I don't know.

He has another technology, using a mixture of an inorganic salt as a solvent. Dr. Emert has done an economic evaluation on this, and it seems very expensive. Tsao may or may not be using this.

A third technology involves what is an ancient, 50-year-old, analytic technique of using concentrated sulfuric acid to dissolve, and then methanol, to precipitate the cellulose. That is a laboratory technique that we have experience with, and I think that is the basis of Dr. Tsao's economics.

Now, we had a brief glance at the economics and I must agree with Senator Bayh, checking to the best of his ability, these are Tsao's figures, 40 to 75 cents per gallon. But I found nowhere any sign of the investment required or any attempt to give an investment number. And, therefore, there is no such thing as fixed charges, amortization, maintenance, interest, taxes, and some of the raw material costs, and energy costs appear to be extremely low.

I do not feel these economics are realistic that Professor Tsao is putting forth. The DOE has recently let two contracts relative to the Tsao technology, to have it evaluated. So, we hope these will yield a realistic evaluation.

Senator CHURCH. What are your plans? You have done your work without Government involvement, I understand.

Dr. HUFF. Yes, sir.

Senator CHURCH. What are your plans now that you have experimented with this pilot plant?

Dr. HUFF. Our immediate plans are to develop the design of the demonstration plant, so that we will know how much it will cost. We have only a rough estimate now. This activity will probably take us through the end of the year; and then we have to find the funding.

Senator CHURCH. What would be the capacity of the demonstration plant?

Dr. HUFF. It would use 50 tons a day of feedstock and make 2,000 gallons. The reason for that size is not to be economic, but so that we can evaluate prototype equipment in order that the commercial plant can then be built with confidence.

Senator CHURCH. When you say you use feedstock, to what are you actually referring? Are you referring to a municipal solid waste?

Dr. HUFF. In our studies to date, it seems the municipal solid waste is the most economically available. Now, we have tried at our pilot plant all kinds of materials, including corn stover, water hyacinths, and so forth. They are all technically feasible feedstocks. The question is, can we economically gather these materials and at some reasonable cost. Municipal solid waste has to be gathered anyway, and the infrastructure for this gathering already exists.

Senator CHURCH. Yes. And you just take it as it comes? How do you have to process it?

Dr. HUFF. It would also have to go through one of the newer waste-recycling plants, where it is separated into various fractions, including a combustible fraction which is largely paper. This fraction is sometimes sold as a fuel; but, as Dr. Katzen indicated, it isn't a very good fuel. But that may give it a value, which can be put into our economics.

Senator CHURCH. What is your company's need for ethanol? Why are you engaged in this experiment?

Dr. HUFF. Our original idea in this was to find an alternate source of chemicals. I am in the chemical arm of Gulf, and this is our business. Ethanol was just an obvious route to take. It used to be in the old days, before the petrochemical industry, one of the key building blocks of the chemical industry. So, maybe petrochemicals is a little blip in history, and we will go back to the old ways. During World War II, we produced ethanol and then made synthetic rubber from that. So there are all sorts of fruits.

Senator CHURCH. Ethanol, in other words, has many possible industrial applications.

Dr. HUFF. It is a basic building block, such as ethylene is now.

Senator CHURCH. What is being done with the municipal solid wastes today in a major metropolitan area?

Dr. HUFF. I think principally—I don't know, there may be others who could answer this better, but I think the most frequently used method is to bury it in sanitary landfills; and I think this is going to be more of a problem, because we are running out of land to put it in.

Senator CHURCH. It is a very serious problem, and landfills have been the traditional way of disposing of municipal waste. Have there been any inroads made into the use of that waste for fuel purposes?

Dr. KATZEN. Yes; the normal way is straight incineration. There are three incinerators in Cincinnati that burn such waste. In Europe, there have been any number of places where the materials are separated and burned to generate steam. And now, energy has become more exepnsive, U.S. economics is causing us to move this way.

But we are saying, by the time you spend the money on a large power plant, which uses municiple waste to produce steam directly at 67-percent efficiency and then convert it to electrical energy with 35-percent efficiency, you are better off to sell the material to Gulf to convert it to alcohol.

Senator CHURCH. It seems to me that the chief defect in the energy balance argument is that it does not take into account the sources.

You have pointed to one resource. In enormous amount of municipal waste that is available and isn't being converted to any fuel is just being buried. It seems to be a terrible waste. I am looking at your chart that shows the availability of municipal solid wastes; New York City alone is generating 8,818,000 tons a year. Los Angeles is generating 6,602,000 tons. You have some estimates showing the tonnage generated by New York City. What is New York City doing? They used to dump it in the ocean.

The EPA, I am told, made them stop that, and now they are shipping it by barge all the way to Georgia.

Senator HANSEN. Why Georgia?

Senator CHURCH. For a landfill. Just think of the waste involved, the cost to the city, barging it all the way to Georgia. Your figures show that if this municipal solid waste were to be used for conversion into alcohol, it would take 27 alcohol plants.

Are those plants the size of the one that you would build for your demonstration project?

Dr. HUFF. We are talking 20 to 25 million gallons each. The reason that we have limited ourselves to that size is because of the 1,000 tons a day feedstock requirement. Perhaps that could be exceeded, but when you get more than that, it is very hard to deliver this solid material to one point. The trucks would be running over each other. Thus, we feel that a reasonable limit would be 25 million gallons per year.

Incidentally, we are referring to the total amount of waste that is probably generated in New York. We have to be a little careful; it may not all be available.

Senator CHURCH. Of course, it is a rough figure. I understand; but, nevertheless, it is very impressive. The waste from Philadelphia could provide the raw material, the feedstock, for 13 alcohol plants, each of which could produce 20 to 25 million gallons of ethanol each year.

Dr. HUFF. Philadelphia used to send their waste to New Jersey, but I think New Jersey stopped that.

Senator CHURCH. It would be interesting if we knew where all this waste material was going, and what future problems may result from it.

Los Angeles could sustain, from its municipal solid waste, 20 such plants; Chicago, 19; Houston, 7; Pittsburgh, 7; Kansas City, 3; and, so on. There is tremendous potential here.

Dr. HUFF. We feel so, Senator.

Senator CHURCH. Now, the ethanol that you will manufacture could be used for various purposes. You are principally interested in it for possible industrial use. But it could also be used for fuel, to be blended with gasoline, and used as gasohol.

Dr. HUFF. Yes, sir. But there are different grades of it. The fuel grade would be different than a chemical grade, and I think we do need anhydrous alcohol. One of the witnesses said they could use 190 proof, but maybe Dr. Katzen could talk to that.

Dr. KATZEN. If I may, Senator, I will try to shed a little light on that. There are any number of anhydrous alcohol production units in this country. Industrial alcohol is a very high purity product. The specifications for it require less than 30 parts per million total impurities, and there is what is called superanhydrous, 99.98 percent alcohol, which is used in pharmaceuticals and aerosol formulations. It is an article of commerce.

There is nothing unusual about making anhydrous alcohol. As far as using 190 proof in motor fuel blends, yes, you can, and it will probably run; but you have to move this out to blenders, distributors, however you do it—I don't believe you want to do it at the local gas station.

This will generate all sorts of conditions, and I can tell you that just an addition of a small additional amount of water to the blend causes the separation of alcohol and gasoline, and then you are in trouble. You are carburating two different materials. They won't carburate the same; and they won't burn the same, and you will have very poor engine performance.

To insure maintenance of the blend, you have to have 199 proof, 99.5-percent alcohol. I was with an engineering company that designed two motor fuel alcohol plants, and as a consultant, on my own, I converted four other plants to motor fuel alcohol.

I took my car to Cuba every summer, running on a motor fuel blend containing 15-percent alcohol; it was a national blend. I didn't have any real trouble after the first year or two; but, first, you loosen up all the gunk in the system, and you clear this out. Next, it attacks the diaphragm of the fuel pump, so you replace that with one that is resistant to alcohol, and after that you are all right.

But keep in mind, this was in the days of 80-octane standard gas. Today, 90 octane is our standard, so you don't get quite the improvement in octane rating as we did with the lower octane gas. So, it is a viable material, and you can drive your car on it with slight modifiations. But a cleanout is needed.

Senator CHURCH. If it were done in quantities and blended into the chain at the sale and distributor method, then you would need something——

Dr. KATZEN. 199 proof, which is 99.5 percent by volume.

Senator CHURCH. What kind of proof of ethanol is in your plant? Would this plant produce——

Dr. KATZEN. It would produce high-grade industrial, high-grade superanhydrous use and motor fuel. If we were designing our plant specifically for motor fuel—I can say this, too. We have advanced the technology for producing straight motor fuel with very low energy consumption. Making anhydrous alcohol takes no more energy than we have utilized in production of spirits—190-degree proof alcohol. So, you are not expending additional energy to make anhydrous.

Senator CHURCH. In other words, it can be made as readily as the other?

Dr. KATZEN. That is right. The impurities can be put back, after removal to let the system work, and then put back in and burned. The impurities are combustible, but they do interfere with the distillation process. But, here again, we are not talking theory. We have designed and operated such a system.

Senator CHURCH. When you use the municipal solid waste, are you mainly using paper?

Dr. KATZEN. Yes; to clarify what this is, the larger cities are putting in separation plants—there are a half a dozen varieties, and we follow these very closely. And these are set up by various mechanical means to separate the light material, which is primarily newspaper and also some plastics—and aluminum foil is one of our problems that is lightweight, also, but not desirable.

It separates the glass and the metals and puts it in various salable forms for recycling. They thought at one time that the waste paper fraction would be good for paper production, but it turns out to be so contaminated that people cannot use it. Next, we use it for generating steam and power, but you have to do some cleanup on it. But we can make better and more efficient use of it through the Gulf technology.

Senator CHURCH. When you say that you think you might be able to achieve as high as 59-percent efficiency, you are speaking of deriving 59 percent of the energy potential in paper in liquid form?

Dr. KATZEN. In the paper, plus the outside energy.

Senator CHURCH. That is a very high efficiency.

Dr. KATZEN. Yes, it is.

Senator CHURCH. How does it compare, let us say, with the amount of efficiency derived from a fossil fuel electric generating plant?

Dr. KATZEN. Our national average is 35 percent; 40 is the highest, with the modern powerplant.

Senator CHURCH. Forty percent is the highest for a modern powerplant?

Dr. KATZEN. Yes, sir; and 35 percent, national average.

Senator CHURCH. So you are almost 20 percentage points above that in your process?

Dr. KATZEN. Another example, Senator, if we are talking about methanol, methanol from agricultural waste which operates at about 40 percent efficiency.

Senator CHURCH. It seems that this is a rather significant thing that you are doing.

Dr. HUFF. We are rather excited about it.

Senator CHURCH. I should think you would be. You said you were looking for some financing for your demonstration plant. Are you planning to come to the Federal Government for that financing?

Dr. HUFF. We want to see how much it will really cost first, and that is a possibility. Perhaps we could get other private organizations interested in joining us through the mechanism of advance royalties on a technology license.

Senator CHURCH. Senator Hansen.

Senator HANSEN. I have no questions, Mr. Chairman.

I thank you very, very much for a most interesting presentation.

Dr. HUFF. Thank you.

Senator CHURCH. Thank you very much for coming, gentlemen. You have been very helpful, and we appreciate the information.

The subcommittee stands in recess.

[Whereupon, at 12:21 p.m., the hearing was recessed, to reconvene Tuesday, August 8, 1978, at 10 a.m.]

THE GASOHOL MOTOR FUEL ACT OF 1978

TUESDAY, AUGUST 8, 1978

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
OF THE COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m., in room 318 Russell Office Building, Hon. Frank Church, presiding.

Present: Senator Church and Bumpers.

Also present: Pete Smith, professional staff member.

Senator CHURCH. The hearing will please come to order. This is a continuation of the hearings of the Subcommittee on Energy Research and Development on S. 2533, the Gasohol Motor Fuel Act of 1978.

Our first witness this morning is Senator Percy of Illinois. I am happy to welcome you to the committee this morning, Senator Percy, and invite you to proceed with your testimony.

STATEMENT OF HON. CHARLES H. PERCY, A U.S. SENATOR FROM THE STATE OF ILLINOIS

Senator PERCY. Mr. Chairman, I thank you and the rest of the Subcommittee on Research and Development for inviting me to participate in your hearings on alcohol fuels. Mr. Chairman, your efforts to encourage this domestic alternative to imported oil are well known and much appreciated throughout the country, including my home State of Illinois. I would like to add my gratitude to my constituents' for your work on gasohol.

Illinois, as you know, has had immense success with its gasohol program. I will say a few words about it now, though I know you have heard an excellent summary of it from Mr. Al Mavis, of the Illinois farm energy program. Mr. Mavis, with an enthusiasm and an energy we all marvel at, has almost singlehandedly turned the attention of the State of Illinois to gasohol.

There are now at least 42 retail gas stations across Illinois pumping gasohol. Prices range from 70 cents to 78 cents per gallon, but they are nowhere more than a few cents higher than premium no-lead, to which gasohol is comparable. Beginning July 1st, gasohol replaced premium no-lead at four pumping stations for Illinois State vehicles. As the use of gasohol increases, the alcohol industry has begun to flourish. Last year there was one supplier of alcohol to Illinois. Now there are four and the price of alcohol has begun to decline.

Illinois' experience points the way the whole country should go. Consider the merits of alcohol: It is domestic, renewable, higher in octane and lower in pollutants than gasoline. It can be distilled from every crop, from crop residues, from forest products, from urban refuse, and from many industrial waste streams. Added to gasoline, it makes a clean, efficient fuel. I have used gasohol in my own car, have been using it, and can testify to its high quality.

Senator CHURCH. Would you mind telling us what it is?

Senator PERCY. Confidentially, it is a Honda. When Hubert Humphrey and I founded the Alliance to Save Energy, Mrs. Percy said my job is to set an example, and she gave up a car that had very poor mileage. I kept mine. It doesn't get very good mileage, but it's 8 years old and I don't intend to turn it in. But she has a car that is an absolute marvel from the standpoint of gasoline consumption. And Detroit now, with its government mandated efficiency standards is going in the right direction.

I think the Members of Congress who used gasohol during our demonstration and a great many of them did, all realized that gasohol is effective, efficient, clean, and our cars work perfectly with it.

At present the major problem seems to be that alcohol is considerably more expensive than gasoline. But let me suggest three reasons why that should not sidetrack us from aggressively developing an alcohol fuels industry.

First, there is no simple comparison between dollars spent at home and dollars spent abroad. Alcohol is a domestic product. Increasing use of alcohol fuels means less imported oil, more American jobs, and greater national stability and security. Such factors must be considered when comparing the price of alcohol to the price of gasoline.

Second, whereas alcohol is too expensive now to burn straight, as a gasoline extender, it is not uneconomic. Gasohol, the combination of gasoline and 10 percent alcohol, is not much more expensive than premium no-lead. A 10 percent reduction in national gasoline consumption through the use of gasohol would be one of the most significant conservation accomplishments this country has made. Such progress is very possible.

As I mentioned, gasohol is being retailed at a number of stations in Illinois and it is doing well. People are buying it, even if it does cost 3 to 5 cents more than premium no-lead. I introduced an amendment to the energy tax bill last fall to exempt alcohol fuels from the 4 cents per gallon Federal gasoline tax.

We need some economic incentives as long as the industry production is relatively small scale.

The amendment, as you may remember, received the Senate's unanimous support. This subsidy would make gasohol competitive with gasoline until such time as the alcohol fuels industry gets going on a large enough scale to bring the price down on its own.

The need for this gasohol tax incentive is as great now, certainly, as when we passed the amendment. I will be very disappointed if we leave in October without incorporating it into law. But I am still optimistic that we can work to get it out of the energy tax conference and into law.

The third and most important reason alcohol's current price should not curtail development is that we must plan for the future. This Nation faces a potentially devastating shortage of liquid fuels sometime in the 1980's. We must begin now to develop alternatives to oil, so they are ready when we need them. Alcohol fuel right now is one of our most attractive alternatives. The more creativity and ingenuity we direct toward it, the more attractive and the more economical it will become.

Mr. Chairman, with your acquaintanceship with the Intelligence Committee you would respect economic research done by the CIA. I took the Board of Directors of the Alliance to Save Energy out to the CIA headquarters in April. Admiral Turner put on a presentation for us. I think every member was startled by the figures. Most startling was the fact that in a relatively few years the Soviet Union, just like the United States, will become an importer of oil. It will be competing heavily with us for oil, and that can only drive the price of oil up faster.

The oil glut we have now is temporary. We would be a short-sighted Nation if we did not look past it. We need the Alliance to Save Energy's programs for conserving energy to take hold nationwide. We need to look forward to a 10 percent cut in gasoline consumption through the use of gasohol.

The added incentive of exemption from the 4 cents per gallon tax we presently impose on gasoline for 10 percent alcohol blends will help gasohol cut out oil imports.

Of course, there are other questions and problems concerning the development of alcohol fuels. I am certain the subcommittee will address them in the course of these hearings. But one of the alcohol fuels' major problems has been a lack of attention, and the subcommittee is already helping to redress that problem by the very fact of these hearings.

Mr. Chairman, I appreciate the opportunity to express my support for gasohol, and I commend the subcommittee for its work on this subject. Thank you very much.

Senator CHURCH. Thank you very much, Senator Percy. I think the committee fully recognizes the lead you have taken in this field for the establishment of a National Conservation Committee with the late Senator Humphrey, and your leadership in promoting the use of gasohol.

It would appear that the State of Illinois has gone farther in actually marketing gasohol than any other State. Also, the fact that there are now 42 stations in Illinois selling the product would indicate that there is a market for gasohol at present-day prices even without the 4 cents per gallon reduction achieved if the Federal tax were removed, which, incidentally, I fully support.

Curiously, the Department of Energy is about to testify, I am told, that studies will have to be undertaken to determine the economic feasiblity of gasohol before the Department is willing to commit itself to any governmental effort to promote gasohol. Is it your opinion that the fact that gasohol is being marketed against the other available products provides pretty convincing evidence that it is economically feasible?

Senator PERCY. These 42 stations are not subsidized. They are in business to make a profit. I can think of no better proof of economic feasibility.

We can use waste crops and city wastes to make alcohol and be very close to commercial feasibility today. What we need to do now is to broaden the market. That should be the purpose of the Department of Energy.

As I said to Dr. Schlesinger the other day, in many countries, the work of the Alliance to Save Energy, is done by Government. Here we had to go in to do a job the Government was not doing.

They were simply not getting the story out. We are going to run television ads this fall. The Advertising Council is contributing $20 million to $30 million to help promote conservation. The Department of Energy is working cooperatively with us, but they should not be following our lead. They should be aggressively promoting conservation on their own. The same holds true for gasohol.

I used to say to my engineers during my 25 years in industry: Don't tell me what you cannot do; I am going to tell you what we have to do and you tell me how we can best do it. That is what DOE has to say. What other alternative is there? If they have better alternatives than gasohol, then they should bring it up and lay it on the table.

Gasohol is feasible. The Congress is behind it. Now let's get the executive branch whole hog behind us.

Senator CHURCH. Thank you very much, Senator. In your testimony you mentioned that the Federal Government mandated the automobile manufacturers to meet a certain standard in fuel efficiency. Once we took that step, industry began in earnest to make the necessary changes that turned Detroit around and started moving it in a more rational direction.

I am of the belief we will have to do the same thing for gasohol. S. 2533 would accomplish that by laying down the requirement, and a reasonable time frame in which to meet it, for mixing alcohol with gasoline. I am just as persuaded that we will not make progress rapidly enough without laying down that kind of requirement.

If we could get the Department of Energy out of the way, I believe we might make some progress.

Senator PERCY. I know you have set a schedule of 1 percent by 1981, 10 percent by 1990. As I look at the CIA projections, I think that schedule would be slow. I would hope DOE would establish a schedule even more aggressive then that. I would hope together we could alert this country and find the financial incentives and a way to move more rapidly. I think the urgency is there.

Senator CHURCH. This bill establishes a kind of target, but also provides language that would give the Government and industry full latitude to move more rapidly if that proves feasible.

Senator Bumpers, do you have questions?

Senator BUMPERS. Senator Percy, are you familiar with the Metrek study? Metrek is a division of the Miter Corp. and I think it was done for DOE. Mr. Chairman, I ask unanimous consent this entire article be submitted for the record.

Senator CHURCH. Very well.

[The article follows:]

Biomass-Based Alcohol Fuels—The Near-Term Potential for Use With Gasoline—July 1978

(By W. Park, G. Price, and D. Salo)

SUMMARY

Biological and thermochemical conversion processes can be used to convert various biomass feedstocks to ethanol (grain alcohol) and methanol (wood alcohol). These two alcohols show the greatest potential for fuel use. Blends of 5 to 15 percent alcohol in gasoline have been used effectively in current generation automobiles.

A liquid transportation fuel system based on alcohol-gasoline blends could be developed in the United States. However, it would be developed at a considerable cost to the American taxpayer. Using available technologies, the cost of methanol produced from wood is about 1.5 times that of gasoline. Ethanol produced from sugar crops and grains would cost at least 3 times as much as gasoline. There would also be an additional cost associated with the delivery of blended fuels to the motorist.

The additional costs associated with alcohol-gasoline blends do not appear large when considered on a unit gallon basis. The costs become substantial, however, when they are considered for the country as a whole. It is estimated that the annual national cost in 1990 of reducing blend prices to those of no-lead gasoline would be 3.2 to 6.9 billion dollars. The additional annual cost in 1990 for each replaced barrel of imported oil ranges from $47 to $79 per barrel. The cost variation depends on the type of alcohol and the amount which would be blended with gasoline.

There are no major technical barriers to the establishment of a biomass-based alcohol fuels system should a decision be made to develop such a system. However, the magnitude of such a commercialization program would probably limit the amount of methanol or ethanol present in fuel blends to a nationwide equivalent of about 5 percent by 1990.

Senator Bumpers. I would like to quote a part of it to Senator Percy and ask him for any comments he has. Let me deliver this caveat at the beginning. I am a strong advocate of gasohol: the manufacturing of ethanol, methanol, and alcohol. But the Metrek study is really troublesome from an economic standpoint. The principal staffer of the Metrek Corp., Wayne R. Park, has said that to compete with gasoline even by 1990, the Government will have to make up the difference in some form of subsidy. Assuming a 5 percent methanol blend replaces all U.S. gasoline demand, Metrek estimates the Government's tab at $6.9 billion. If a 10 percent blend replaced only half of domestic gasoline demand, the subsidy would still come out to $5.9 billion and these are not one-shot figures, they are annual. Gasohol advocates claim an alcohol feed program will reduce imported oil demand. If it does, it will be an expensive way to reduce imports, according to Metrek. The company's study assumes imported oil will cost $18.44 a barrel in 1990. That is in 1976 dollars. But if a gasohol program with a 5 percent ethanol blend were adopted nationwide, Park says it would cost an additional $79 per barrel for each barrel of imported oil that the gasohol replaces.

He goes on to say, and I hate to belabor this, with a 10 percent ethanol blend the additional cost per barrel for replacing imports drops to $67, but that is still expensive oil. Besides, Metrek figures that will

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reduce oil imports in 1990 only 68 to 88 million barrels annually and that is only 2.2 to 2.8 percent of last year's oil import total.

That is a fairly gloomy analysis of gasohol. My staff found this incidentally in Chemical and Engineering News, July 31 edition, put it on my desk a couple of days ago, and I was rather dismayed and depressed after having read it.

As I say, I am a strong champion of gasohol. I think it holds great promise. But those figures from a purely economic standpoint would indicate we have run up against a tough battle if we are trying to do what the Church bill would do by 1990.

Senator Percy. This is a tough battle. However, I understand that other experts dispute the article's figures. I would be very happy to give you that expert opposite opinion, if you will give me a few days. On anything as conjectural as this, you always find a wide range of numbers.

And you will find the pessimists and the optimists. I prefer to look at the doughnut rather than the hole. I am going to do everything I can to push gasohol. As you know, campaign funds are hard to raise these days but I have directed that every car used in my reelection campaign, including my own, use gasohol whenever it can.

Besides, economics is not the only consideration. We heard those same economic arguments 10, 15, 20 years ago from antienvironmentalists. You could not clean up the water, they said. You could not clean up the air. You had to keep polluting and polluting because that was the cheapest, most economical way to do things.

What kind of life are we leading? Is the GNP our god? I am a businessman but I think the quality of life is a lot more important. Our lifestyle in our whole economy is now based on petroleum. Petroleum is running out and we have to realize that. We are talking about how we are going to keep our society running.

We are a mobile population. We are going to be bumper to bumper pretty soon.

Senator Bumpers. Is that intended to be a pun?

Senator Percy. We need rapid transit to control traffic. We need to take a unified look at all energy and energy-related issues. But we must realize that alternatives to gasoline are going to be necessary. If this study claims that gasohol will not be a good alternative, then I want to dispute that study. I will try to provide the best answer to it I can.

Senator Bumpers. I think the Metrek study does make most of its basic assumptions on the use of raw sugar juice as a feedstock. I have a man in Arkansas who wants to build an alcohol plant and he wants to use municipal waste. Right now, the technology to do that, so DOE says, is not advanced enough to make that economical. But he insists it is, and he is one of those creative minds.

Senator Church. We had excellent testimony yesterday in this regard from the Gulf Oil Chemicals Corp. They feel they can produce 2,000 gallons per day of ethylalcohol with a demonstration plant, move on to industrial-sized plants that will manufacture between 20–25 million gallons of alcohol a year using municipal waste. They claim it is 59 percent efficient, which compares to 33 or 40 percent efficiency in our best and most modern fossil fuel electric generating plants.

Senator BUMPERS. This study also indicates that to reach your goal of 10 percent gasohol by 1990, it would require 322 plants operating at 90 percent capacity, producing 20 million gallons annually.

Senator CHURCH. Maybe we have to undertake that kind of national effort. Obviously we are not moving toward a solution of the energy problem now, but in the opposite direction. The testimony yesterday showed that New York City alone, which now has to haul all of its waste in barges to Georgia to dump it into landfill, could support 22 of those plants just with that waste.

Senator BUMPERS. I think these kind of pessimistic statistics always overlook technology, the ability to become more efficient, use ethanol, methanol, at much less cost than today's predictions.

Senator PERCY. The situation is similar with solar energy. Solar was looked on some years back as very impractical. But we are not saying that any more. A real industry is developing now.

One of the great barriers to energy alternatives is the artificial controls we continue to keep on conventional energy sources. Conversion from natural gas to solar energy is not economic today because we artificially control natural gas prices. I have natural gas in my homes in Washington and in Illinois. I think it is an absolute crime how cheap it is. Some of my constituents don't agree with me. They like to have subsidized, low-cost natural gas. But that encourages waste, and discourages conservation and conversion to solar energy.

The same thing is true with gasoline. We undertax gasoline in this country. As you know, I have tried for years to raise the Federal tax on gasoline to a level comparable to that of other countries.

Here we tax it 4 cents, the same thing we did 19 years ago when it was selling for 30 cents a gallon. And we force all the gas tax revenue into a Highway Trust Fund to build roads to make it easier to burn up more energy and fuel.

Those are backward policies in the Government today. I would imagine our gas tax is lower than virtually any other industrailized country's. Gasoline itself is selling cheaper here than in most countries. But let us look at Saudi Arabia for a moment. Sitting on top of the largest oil reserves in the world, they have the biggest investment outside of ourselves in solar energy. They are looking ahead. They are wise. I commend them. We must look ahead too. That is the tremendous responsibility of this subcommitee and the great responsibility of the Department of Energy.

Senator CHURCH. Thank you very much.

[Subsequent to the hearings Senator Percy supplied the following:]

STATEMENT BY SENATOR CHARLES H. PERCY, IN RESPONSE TO MITRE TECHNICAL REPORT 7866: BIOMASS-BASED ALCOHOL FUELS

This study makes one key incorrect assumption. Because of this incorrect assumption, the conclusions of the study are, in effect, meaningless. This assumption is that the "energy content" of alcohol fuels is the determining factor in their market price.

On page nine, Section 2.1 of the report, it is stated that "The energy content of a gallon of gasoline is nearly twice that of methanol and 1.5 times that of ethanol." Gasoline contains approximately 124,000 Btu/Gallon, methanol 64,800 Btu/Gallon, and ethanol 84,000 Btu/Gallon.

I do not dispute these numbers. I dispute their relevance. Btu/Gallon is a measure of heat per gallon. But automotive fuels are used to drive cars, not heat them. The key factor is a fuel's driving performance. Performance is measured in miles per gallon.

The authors of the study do atempt to relate Btu/Gallon to miles per gallon. They state that "The *theoretical* effects of these energy differences on the distances a car would travel on each of the three fuels [gasoline, methanol and ethanol] are presented in Figure 2." Figure 2 shows an automobile getting twice as many miles per gallon with gasoline as with straight ethanol. In short, this chart plots a linear relationship between energy contents and miles per gallon.

Such a relationship, however, does not exist. The theory that a fuel with twice the energy content will deliver twice the number of miles per gallon must simply have been *assumed* by the authors of this study. Had they tested their assumption, they would have found it to be wrong.

The explanation lies in alcohol's properties other than energy content. In a 1977 report on Alternative Energy Technologies in Brazil, Dr. J.M.F. Miccolis states that:

"As a pure fuel, ethanol does have a lower energy content per unit weight than gasoline; however, the energy content per unit weight is not the determining factor for the power generated by an internal combustion engine. Factors like the heat of combustion, thermal efficiency, etc., are important. When these factors are taken into account for gasoline and for pure ethanol, it is clear that ethanol generates about 19% more power."

Alcohol also has a higher octane rating than gasoline. Because of these factors, alcohol has a higher miles per Btu rating than gasoline. The higher miles per Btu rating offsets alcohol's lower Btu per gallon rating in determining the performance of the fuel. Figure 2 is therefore incorrect and misleading.

In reality, alcohol fuels perform quite well. The performance of 100% ethanol or methanol is not really the issue here. What we are concerned with specifically is a blend of 90% gasoline and 10% ethanol. Tests by Volkswagen and Toyota show that this blend of gasohol delivers mileage just 3 or 4% less than straight gasoline. Dr. William Scheller of the University of Nebraska presented research last year that showed this blend of gasohol delivering up to 5% better mileage than gasoline.

In fact, alcohol is such an efficient gasoline additive, it allows distributors to use a cheaper, lower octane gasoline in gasohol, which sells as a high octane, premium fuel.

In basing its calculations of consumer costs on energy content and not on miles per gallon, the study departs from reality. Alcohol's cost per Btu is much higher than its cost per performance. Consumer costs are based on performance. Yet assuming a linear relationship between energy content and performance, the study bases all its further cost analysis, including its conclusions about the amount of government support necessary to maintain a nationwide alcohol fuels system, on energy content.

Consider that, on the basis of its analytical structure, the study posits an 86c price for a gallon of 90% gasoline and 10% ethanol. Yet that blend is selling in Illinois today for about 74c per gallon. If the study is that far off on the status of alcohol fuels today, I think it deserves absolutely no credence as a projection of the status of alcohol fuels in the future.

Senator CHURCH. Mr. Alm.

STATEMENT OF ALVIN L. ALM, ASSISTANT SECRETARY FOR POLICY AND EVALUATION, DEPARTMENT OF ENERGY, ACCOMPANIED BY EUGENE ECKLUND, CHIEF, ALTERNATIVE FUELS BRANCH; AND HENRY MARVIN, DEPUTY PROGRAM DIRECTOR, ENERGY TECHNOLOGY-SOLAR, OFFICE OF CONSERVATION AND SOLAR APPLICATION

Mr. ALM. Mr. Chairman, I am pleased to be here today to discuss S. 2533, the Gasohol Motor Fuel Act of 1978, and the Department of Energy's policies with regard to alcohol fuels. Before talking about this specific legislation, I would like to take a moment to discuss why the Department is moving aggressively ahead to assess the potential of alcohol fuels.

Our Nation is in a period of transition. Estimates of future world oil production capacity underscore the need to reduce dependence on foreign sources of petroleum and to increase domestic production. The slight and transitory excess of production capacity—caused in large part by increased new production on the North Slope of Alaska and the North Sea coupled with lower rates of economic growth—will quickly be overtaken by continued increases in world demand.

Future petroleum shortages will impact most heavily on the transportation sector. In 1977, 9.5 million barrels per day, or more than half the total U.S. petroleum consumption, was used for transportation. Of this amount, about 75 percent, or over 7 million barrels of oil per day, was consumed by automobiles.

This administration is developing a viable long-term national energy policy that will reduce dependence on foreign oil in the short term and develop renewable and essentially inexhaustible sources of energy in the long term. In order to meet these objectives, development of alternative sources of liquid fuels will be necessary.

In this regard, the Department has already made considerable progress in evaluating the potential of alcohol fuels. Last December, in response to congressional concern, a special departmentwide task force was created by Under Secretary Myers to address the potential of alcohol fuels.

This task force represented for the first time an integrated approach to the technical and policy issues surrounding alcohol fuels. In April of this year, that task force concluded its work and released its findings in a position paper and a more detail report entitled, "The Alcohol Fuels Program Plan".

The major findings of the task force are:

The high cost of alcohol fuels relative to conventional sources of petroleum appears to be the major obstacle to widespread commercialization.

Alcohol fuels are suitable fuels for the internal combustion engine, as well as gas turbine peaking units, utility boilers, industrial heating, and fuel cells. The technological problems that do remain can be overcome in a reasonable period of time.

Alcohol fuels technology has progressed to the point where a broader assessment of its commercialization potential is warranted.

On a technical basis, ethanol is considered to have advantages over methanol because of its higher energy content, and better phase stability and volatility in gasoline blends. Ethanol, on the other hand, is a more expensive fuel than methanol.

Since the findings of the task force represented a preliminary assessment rather than a final judgment on the potential of alcohol fuels. the Department is moving ahead to resolve the obstacles to their development and determine what role the Federal Government should play. In this regard, the Department is currently conducting an intensive near-term review of alcohol fuels.

Senator CHURCH. Let's stop here for a moment and I will question as we go along, Mr. Secretary. I know that you have been one of those brave few in the Department of Energy who has spoken up for gasohol.

I know you are endeavoring to step-up the studies that the Congress requested last year on this possibility.

So anything I say or any question I ask is not thrust at you personally. I think we ought to put some questions on the record concerning some of the statements you have made thus far. You say the major findings of the task force are that the higher cost of alcohol fuels relative to conventional sources of petroleum appear to be the major obstacle to widespread commercialization.

We have had testimony as you know yesterday and again today that an active market is developing in Illinois where gas stations are offering gasohol at a price that is sufficiently attractive to obtain a market, and they are making a profit on their sales. This testimony would seem to fly in the face of the task force conclusion that price is a major obstacle to widespread commercialization.

Is there something in the Illinois experiment that is peculiar to or has led the task force to conclude what is going on in Illinois cannot go on elsewhere?

Mr. ALM. Mr. Chairman, I was going to get to that point. I am glad you brought it up at this time. What is happening in Illinois and in other States is that a market is developing. The reason it is developing is that ethanol-based gasohol acts as an octane booster, and hence gasohol can compete with no lead premium gasoline.

In other words, although the price of ethanol is three times the cost of conventional gasoline by boosting octane you derive an additional benefit. It is the unleaded premium gasolines that are the most expensive of all.

Gasohol has competed well in that market, certainly in Illinois. As I understand, about 15 percent of new vehicles that are designed to run on unleaded, regular, are not performing adequately, which means the drivers of these vehicles for one reason or another need premium quality gasoline. That is the market that ethanol can currently compete in.

Senator CHURCH. Do you anticipate that the premium gasoline market will soon disappear?

Mr. ALM. This is one of the issues we are looking into. I simply do not know. It is obviously a question of how cars are manufactured. When the Clean Air Act went into effect, one of the requirements was that new vehicles would run on unleaded gasoline because lead poisons the catalyst. The claim was that these new vehicles by reducing compression ratios, would be able to run on unleaded gasoline. That has simply not happened in the marketplace for a substantial number of vehicles.

I do not know whether this will continue or not. That is one of the aspects of our study.

Senator CHURCH. I think the record should show there are eight gasohol stations operating in Iowa and three in Nebraska in addition to the 42 gasohol stations currently operating in Illinois. As long as I can remember, people in this country have insisted on buying premium gasoline. I do not think that is going to change any time soon. If it is possible for gasohol to compete, pricewise, with premium unleaded gasoline, I should think that in itself is the best evidence of its economic feasibility.

Mr. ALM. I think that is quite true and the Department has taken a few steps to encourage use of alcohol fuels. We have provided treatment to synthetic fuels, including gasohol, that provides a benefit of roughly $2 a barrel. Second, we have put out a ruling which allows any additional alcohol fuel to be rolled into the price of gasoline being sold under our price control requirements.

So, the Department has supported these activities. I think the confusion in the task force report was over widespread commercialism. What does one mean by that? If the 15-percent figure is correct, then it would reduce the market 15 percent where alcohol fuels would compete with the unleaded premium fuels.

Senator CHURCH. I think we would find if we were to lay down some requirement that would force the oil companies to move in the direction of introducing only wide scale gasohol into the market that all kinds of unexpected, unanticipated, unforeseeable, unpredictable things like that would happen, which none of your studies are likely to take into account. We have a tremendously versatile economy out there that can find a way of doing things if it knows, the industry knows, that it must.

Already, we have enough evidence to suggest new methods are being devised. Various sources are being looked at, potential fuel sources are now just being wasted. I have never seen a Government study that took into account, for example, the social costs or the cost of the taxpayers outright of hauling all of the waste of New York City in barges from Manhattan to Georgia, and then burying it instead of converting it to fuel.

Yesterday, Senator Bumpers raised the question of Government studies by asking what the feasibility study would have been for the success of the airplane in 1903 had such a governmental investigation followed in the wake of the successful flight of Kitty Hawk.

There did not seem to be much chance for that to become practical. I think we are right at the edge of a breakthrough here which we ought not to impede with too many formal studies that cannot anticipate the ingenuity of our economy to respond to a requirement once it is imposed.

What do we have to lose if it doesn't work? Suppose, in 3 or 4 years, it is obvious we cannot get that much gasoline? What have we lost? We lower the requirement. But at least we have given ourselves a crack at it, and if the objection is it might force the price of gasoline higher to force that alcohol in, how does that in any way conflict with the objective of the administration which is to force the price of gasoline higher by imposing a tax?

For the life of me, I cannot understand the reason why we have had so much lethargy at the Department, so much resistance at the Department, unless it is the fact the big oil companies dont' want to be bothered with this as long as they have petroleum to sell. It is a nuisance for them to have to mix anything else in with the gasoline.

That is enough lecture for now.

Mr. ALM. Would you like me to respond? I certainly agree with you. We are going to have a position in January, things never move quite as quickly as we like, but we have publicly committed ourselves to have an answer in January in terms of how we come out; in terms of your proposal, I am not in a position to endorse or oppose it.

Some of the points you raise are very good points. Obviously it is a sure way of moving some of these fuels into the mainstream. The question of cost does need to be looked at. Unlike the tax proposal, where the proceeds of the tax then are provided to the economy through rebates and tax reductions or Government programs, any increase in gasohol costs would result in a net reduction in national income.

I think it is clear there is a market for ethanol fuels. The real question is how best to exploit that market. What policy mechanism, what R. & D. and other activities are most appropriate?

It is incumbent upon the administration since Congress has acted in this area, to come up with whatever recommendations it has. Through the debate and the normal processes, action will be taken. We will be looking at a number of potential budgetary increases. We will be looking at regulatory mechanisms similar to yours and we will try to come up with the best package.

Senator CHURCH. Can you assure us this morning the Department will be prepared to make recommendations on gasohol at the first of the year?

Mr. ALM. I can promise you we will make recommendations. I can't promise you what they will be. It is conceivable, although I hope that is not the case, they may be negative. But I think in any event we will come back to the Congress with the administration's programs in that area.

Senator CHURCH. Well, if our hearings accomplish that much——

Mr. ALM. Hearings are very good ways for accomplishing deadlines.

Senator CHURCH. Will you proceed?

Mr. ALM. I will summarize and we will have more time for questioning. The testimony talks about the review we are undertaking. One point I would make. We are going beyond standard numbers and asking the question of what about impact of set-aside programs. What are the economics of that?

We are looking at new processes that will significantly reduce the cost of alcohol fuels. We will be looking at the State experience to get a better feel for their use of alcohol fuels although most of that has been positive up to now.

I comment briefly on S. 2533 and raise a number of questions. Then I briefly discuss the two regulatory activities I mentioned earlier. One is providing entitlement benefits for alcohol fuels. Second, the issue of a price rule which would permit retailers to include in the selling price the higher costs associated with the ethanol portion of the blend.

The testimony briefly discusses R. & D. activities including a new pilot plant competition we got out this June for process development units which would process 3 tons of dry biomass feedstock.

I talk briefly about the State goal and how we hope to work with the States. I did speak to the National Gasohol Association and had an opportunity at that time to talk to some of the State people.

Finally, I end up indicating the Department is vitally interested in this area indicating gasohol has the advantage of being both a domestic source and an environmentally desirable source, and indicate we are very hopeful we can develop a program that can stimulate the use of gasohol.

Senator CHURCH. Yesterday, you may remember, Senator Bayh pointed out Dr. Tsao's process at Purdue University. What does the DOE know about this?

Mr. Alm. We are examining his process. I may turn to some of my colleagues for that.

Senator Church. Senator Bayh's testimony was the Tsao process at Purdue University, Dr. Tsao, was engaged in experimentation for new methods of methanol production, and makes the claim that his methods have produced methanol for very low costs, 40 to 60 cents, which would be in the neighborhood of one-fifth to one-third the cost normally quoted.

I would like to know what the Department knows about this.

Mr. Alm. The Department has helped to fund Dr. Tsao. My information was his cost would be 70 cents per gallon which is a little high, in the upper range.

Senator Church. Even 70 cents would be well below the figure normally quoted.

Mr. Alm. That is correct. That would be roughly $9 per million Btu because of the difference in Btu value. Dr. Marvin may want to comment on this.

Dr. Marvin. What happens in that process is obtained under DOE, then ERDA funding before that. Those patents have been under discussion with Purdue University with regard to ownership of them and we are taking a healthy appoach to that, I think, in making those available to Purdue. The funding has taken place so far and we do have a present proposal which is on the street currently to cover a process of that type.

This is something I assume Professor Tsao would be competing for.

Senator Church. Would this be a pilot plant?

Dr. Marvin. Yes; in that case, what we call a process development unit. A small pilot plant; yes.

Senator Church. I think, Senator Bumpers, this underscores the fact there are new processes being developed even now that have the look of progress for the future.

Senator Bumpers, do you have questions for the Assistant Secretary?

Senator Bumpers. I do not believe so, Mr. Chairman. There was one point here. You say, one of the major findings of the task force, on page 3, is, "Alcohol fuels technology has progressed to the point where a broader assessment of its commercialization potential is warranted."

It occurs to me, or let me ask the question: Why do we have to have a broader assessment? We have alcohol fuel technology from feedstock which is pretty much commercial or is not, and if it is not, we need to redefine the process, try to make it more efficient.

Why would we do a broader assessment?

Mr. Alm. As I indicated before, there is no doubt about the market for premium unleaded fuels: alcohol fuels are in the competitive range now in that market. So the broader assessment would look at a wider use for alcohol fuels. This would include not only use as gasohol but for chemicals and other industrial purposes, since these renewable resources could replace oil imports. This is obviously highly desirable.

The question here is to determine those areas where the markets now exist to allow competitive behavior or to reduce the cost or understand the cost better. With a better understanding, we could move toward a better, broader commercialization of these fuels.

Senator Bumpers. Was this Metrek study of the Miter Corp. done for you? Did you commission that?

Dr. MARVIN. Yes; originally, I think that probably started at NSF and became an ERDA project.

Senator BUMPERS. You are familiar with it? Do you agree with the conclusions reached on that from an economic standpoint?

Dr. MARVIN. The economics continue to be substantiated. Some of the things that go on beyond that as to what size program would be required to produce how much alcohol, we have some subjective things which I would not want to agree with off the top of my head.

Senator BUMPERS. You heard me read the conclusions of the report. I have not read the report itself, and I will do it; I, frankly, do not understand those gigantic figures where it reaches the conclusion that the use of gasohol is going to cost something like $69 a barrel for every barrel of imported oil it replaces.

Follow me through this example and see if this is correct. Let us use a hypothetical figure: if you could make methanol for 40 cents. Methanol has roughly half the Btu equivalent of gasoline, correct? So that means that converts roughly, in today's market, into 80 cents a gallon to make the same Btu equivalent of gasoline.

Now, we can make methanol, for example, from coal. The Church bill, I think, mandates renewable resources, so we are not talking about coal. But let us talk about coal for just a moment, for purposes of whether or not we could, if we did not have that particular provision in the bill, reach the goal of 10 percent by 1990.

We have the technology to make methanol from coal and at today's prices we can make methanol for 46 cents a gallon; is that right or wrong?

Dr. MARVIN. Coal I don't know.

Mr. ALM. That is correct. The range is somewhere between 30 and 50 cents per gallon.

Senator BUMPERS. So we raise the 80-cents-a-gallon figure up to 90 cents a gallon, and it occurs to me that by the time we have enough plants onstream to make anything approaching 10-percent gasohol in this country, 10-percent mix with gasoline at 90 cents a gallon becomes almost feasible right now.

And maybe methanol is a poor way to use or utilize coal, is it?

Mr. ALM. Not necessarily. Let me comment. I believe the Metrek report only dealt with gasohol from ethanol sources, raw sugar juice. Methanol from coal is considerably cheaper. My understanding, but Mr. Ecklund may want to add to this, is that there are technical problems with methanol that you do not run into with ethanol. There is a separation problem in the engine. I think I am getting beyond my technical depth here.

Senator BUMPERS. Let me ask a question. My constituent Stanley Barber in Fort Smith, Ark., has an automobile that will run on either one. You can convert them back and forth with the push of a button. Would you have the same problem with that engine if you had two tanks, one with methanol and one with gasoline?

Mr. ECKLUND. I did not get that.

Senator BUMPERS. Are you familiar with that car in Fort Smith?

Mr. ECKLUND. Yes.

Senator BUMPERS. My question is, he says you have problems with ethanol which you don't have with methanol, as far as the use of the fuel in the engine.

Mr. Ecklund. We are mixing together the use of straight alcohol, with the use of blends, and the problems vary from one to the other. The system Mr. Barber has is a very good system. However, if we considered using straight alcohol—we would probably want to do things to the engine, to make it operate more efficiently. We could perhaps get 20- or 30-percent improvement in efficiency if the engine was adapted specifically for straight alcohol as compared to gasoline.

Senator Bumpers. He has very detailed statistics on both of the cars he has been driving now for about 3 years. He has 80,000 miles on each one of them, and insists he gets as good, if not better, mileage with alcohol as he does with gasoline.

Are you saying you could change the engine and do better on the alcohol side?

Mr. Ecklund. Yes, sir. But there are other problems involved. For example, if you wanted to use a vehicle that operates only on straight alcohol, you have a starting problem. While we are working on that problem, if you are going to use a system that is like the one Mr. Barber has, you have to have dual fuel tanks and some other equipment which makes the vehicle much more expensive.

You get into a variety of tradeoffs.

Senator Church. The Illinois experiment, with State cars mixing 10-percent alcohol with gasoline, showed they got 6 percent more mileage with the alcohol.

Mr. Ecklund. That is not assured. We get results that vary all over the lot. There is good scientific reason for this. In general, if the total population used the 10-percent alcohol with gasoline, we would not expect to get any benefit but we would not exepct to suffer.

Senator Bumpers. It is probably already in the record, but in case it is not, we should not overlook the point that the emission problem is minimal with these fuels. I believe it is the Whirlpool plant in Fort Smith that employs 4,000 or 5,000 people and they are using this system, alcohol fuels, on all of their forklift trucks inside their warehouses. This has eliminated the tremendous problem of emissions.

I have no further questions.

Senator Church. This pilot plant you are thinking about funding, are you going to be duplicating the work that has already been done by the Gulf Co. we heard about yesterday?

Mr. Alm. We are talking about new processes in terms of DOE funding. The Gulf process is an enzymatic processes. We aim to deal with both processes that are advanced like the Gulf process, as well as different from the Gulf process. Obviously we are aware of that process, and as we evaluate the proposals we will make certain the technologies we are funding provide a breakthrough and do not duplicate what is done in the private sector.

Senator Church. We all know that every time we hear a witness before this committee, the chances are 9 out of 10 he will start out by reminding the committee we are going to run out of petroleum. That is rote. They say that at the outset. If that is so, then we are going to have to find some alternative.

Is there, in the short term, given the present state of technology, any better alternative or any other more likely alternative than mixing alcohol with gasoline to reduce our demand for gasoline? Is the coal technology, liquefying coal, is that more advanced? Are there better prospects there for less money?

What are the alternatives here?

Mr. ALM. Let me run you through the alternatives and set forth some of the arguments of proponents and opponents.

For the short term, the only processes available right now to get to the liquid sector are certain forms of taking methanol directly into gasoline, namely, work done in South Africa. Mobil is funding a direct methanol-to-gasoline facility and that is not at the pilot-plant stage yet.

They are planning to go to the pilot-plant stage. The other processes for liquefaction such as the SRC—coal or the Exxon donor solvent are processes that will be developed to the pilot-plant stage in the late eighties and be commercialized in the early nineties.

You are quite right. Ethanol is the closest single technology. Forty-two filling stations in Illinois and other places are presently selling it in the form of gasohol.

Senator CHURCH. We have to get started and find another liquid supplement to our gasoline supply. We have some way to start here. The technology is known. Gasohol is actually on the market through the private enterprise system. It is finding a market.

The next best technology is around the turn of the century, really, for bringing on some form of liquid fuel in adequate quantities and at very great expense. We have to do it. In fact, we are funding it now. But nevertheless, it seems to me we have to move into the gasohol field. We have 20 years between now and the turn of the century when other technology is likely to substitute.

Mr. ALM. That is correct. The methanol to gasoline technologies are much closer in. We could provide you an answer for the record as to how quickly such processes could be developed. I believe in South Africa they are making gasoline from methanol now.

Senator CHURCH. But we could go to gasohol today. We could start the process right now. We don't have to wait for the development of a new technology that South Africa may have developed. We might get that on line sometime down the road.

Mr. ALM. Ethanol right now is making some inroads into that premium market, and I think the policy decision and certainly our studies are aimed at that—markets beyond the premium unleaded market. There is no doubt with the incentives we have already provided through the regulatory program, and the cost differences between ethanol and the unleaded premium gasoline, new things are happening and will continue to happen. The question is, is there a market beyond that in the gasohol fuel area.

Mr. ECKLUND. Senator, if I may, I have been at this for about 4 years now working very closely with the petroleum and automotive companies, independent researchers, and so on. I think if you try to boil the controversy down to a core, the real reason for the problem is the time element. It is a question of how people see our needs from a time point of view. We have the alternatives of shale oil, for example. Fuels from shale oil or coal, in the longer run, and the near-term alternatives of alcohol, whether it be methanol or ethanol.

It really is a situation where a lot of those people who do not see the alcohols as being the answer to the thing are really looking at some of the other alternatives and assuming we have the time to make that transition. If we could ever get the people together to agree we need to do something by a certain time, I think an awful lot of this would go away.

Senator CHURCH. The only reason for having a Department of Energy is so the Government can take the lead. If the Government is not going to establish a policy and take a lead, why have a Department?

We might just as well let industry work it out, muddle through. I doubt that we could afford to do that. I have no doubt that we are going to have to rely more heavily on coal, we are going to some kind of in situ installation of our shale oil, we will have to put our resources to work.

The great advantage of gasohol is we don't turn from one depletable resource to another depletable resource. To the extent we can grow our fuel, we will have a source that will last us as long the soil and the Sun last.

Thank you very much.

[The prepared statement of Mr. Alm follows:]

STATEMENT OF ALVIN L. ALM, ASSISTANT SECRETARY FOR POLICY AND EVALUATION, DEPARTMENT OF ENERGY

Mr. Chairman and members of the Committee, I am pleased to be here today to discuss S. 2533, the Gasohol Motor Fuel Act of 1978, and the Department of Energy's policies with regard to alcohol fuels. Before talking about this specific legislation, I would like to take a moment to discuss why the Department is moving aggressively ahead to assess the potential of alcohol fuels.

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In this regard, the Department has already made considerable progress in evaluating the potential of alcohol fuels. Last December, in response to Congressional concern, a special Department-wide Task Force was created by Under Secretary Myers to address the potential of alcohol fuels.

This Task Force represented for the first time an integrated approach to the technical and policy issues surrounding alcohol fuels. In April of this year, that Task Force concluded its work and released its findings in a position paper and a more detailed report entitled the "Alcohol Fuels Program Plan."

The major findings of the Task Force are:

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Alcohol fuels technology has progressed to the point where a broader assessment of its commercialization potential is warranted.

On a technical basis, ethanol is considered to have advantages over methanol because of its higher energy content, and better phase stability and volatility in gasoline blends. Ethanol, on the other hand, is a more expensive fuel than methanol.

Since the findings of the Task Force represented a preliminary assessment rather than a final judgment on the potential of alcohol fuels, the Department is moving ahead to resolve the obstacles to their development and determine what role the Federal Government should play. In this regard, the Department is currently conducting an intensive near-term review of alcohol fuels.

The Department's review will give special attention to addressing economic, technological, supply and institutional barriers that obstruct commercialization. Our evaluation will include such key developments as State experience and the potential of new technologies to reduce alcohol production costs and increase energy efficiency. We will also assess the impact on the economy of reduced agricultural price supports and set aside programs, reductions in oil imports, and greater domestic energy self-sufficiency.

In short, we will expand the scope of previous analyses and explore some of the broader economic impacts of alcohol fuels.

This near-term review is being undertaken by a Department-wide Alcohol Fuels Policy Review Group. This Review has primary responsibility for directing a series of key policy studies affecting alcohol fuels decisions, and not for preparing policy recommendations and initiatives on alcohol fuels to be integrated with the National Energy Strategy Study. The National Energy Strategy Study is the Department's principal mechanism for evaluating alternative liquid fuel options.

An additional input into the National Energy Strategy Study will be derived from the initiatives developed as part of the Solar Domestic Policy Review. This effort involves 25 Federal Agencies and is intended comprehensively to assess a broad range of solar programs, including alcohol fuels. The Alcohol Fuels Policy Review is soliciting input from various Congressional, State, and local groups affected by decisions on alcohol fuels. We feel that these groups can play a valuable role in assisting the Department of Energy in its effort to formulate a responsible and viable national policy on alcohol fuels.

I would now like to address S 2533, the Gasohol Motor Fuel Act of 1978. This Act establishes a national requirement to produce alcohol fuels from renewable resources at levels ranging from 1% of total gasoline consumption in 1981 and 10% in 1990. The Department of Energy is committed to assessing the potential of alcohol fuels, and based on the results of our assessment, we will make recommendations concerning the commercialization of alcohol fuels. However, because the Department is currently in the midst of conducting this Review, we do not feel at this time that we can adequately comment on the feasibility of a mandatory 10% nationwide alcohol fuel requirement in 1990. We are, however, evaluating a number of issues concerning alcohol fuels that will enable us to make decisions on alcohol fuels by January 1979, and will also enable us at that time to better judge the merits of a nationwide gasohol requirement.

Through our Alcohol Fuels Policy Review, we are currently addressing the supply potential of a number of diverse renewable feedstocks and the costs associated with these feedstocks, the economics of current and advanced production conversion technologies, an assessment of end-use applications of both ethanol and methanol and its anticipated penetration in the marketplace, and an evaluation of which alternative Federal policies would be most effective to increase the use of clean and renewable alternative fuels.

There are a number of uncertainties raised by S. 2533 that should be resolved. They include:

Whether large commitments of crop land would have adverse impact on agricultural prices.

What the administrative and technical requirements would be for administering a nationwide program of this magnitude.

Whether a 10% requirement for alcohol fuel use in motor vehicles would divert alcohol fuels from use in other efficient end-use applications, such as gas turbine peaking units, utility boilers, industrial heating, and fuel cells.

Whether limiting the feedstocks of such alcohol production to renewable resources unnecessarily restricts available and less costly supplies such as methanol from coal.

Whether mandating a uniform percentage of alcohol fuel to be made available on a nationwide basis would disregard the regional characteristics of alcohol fuels that may make it more attractive for use on a regional rather than national scale.

We hope that we will have answers to these and other issues when our studies are completed.

REGULATORY ACTIVITIES

The DOE has taken two regulatory measures to increase the marketability of alcohol fuels. The regulatory actions taken were designed to remove regulatory obstacles to commercialization and provide incentives for marketing of gasohol through state and private programs. These measures include:

Allowance of entitlement benefits—currently about $2 a barrel—for synthetic fuels, including fuels from biomass.

Issuance of a permanent price rule, permitting retailers of gasohol to include in the selling price the higher costs associated with the ethanol portion of the blend.

Both of these regulations took effect on July 1, 1978.

RESEARCH AND DEVELOPMENT ACTIVITIES

Major efforts are already taking place in the Department to improve the technology and economics of producing alcohols and to optimize the utilization of alcohol fuels for use in motor vehicles.

The fuels from Biomass program is conducting research aimed at reducing biomass feedstock production and converstion costs, and accelerating the development of advanced alcohol production technology through the operation of Process Develpment Units and larger scale experimental units. In June, the Department issued a competitive request for proposals for the design, construction, and operation of a Process Develpment Unit which would utilize three tons of dry biomass feedstock a day. This highly important effort will enable the Department to test research results on a large enough scale to allow an assessment of the overall economics of ethanol production from cellulosic material. We are anticipating that this unit will be in operation in FY 1980.

Research is continuing on utilizing abundant, low-cost feedstocks, such as agriculture residues, corn stovers, wheat straw, and forest residues. Cellulosic feedstocks can provide a valuable source of low cost feedstocks which do not compete with food needs. Work is also underway in developing more advanced conversion methods, such as acid and enzymatic hydrolysis of agricultural products, wood factionation, and direct production of alcohol from cellulosic biomass. Also in May, the Department submitted a budget amendment of $10 million for a cooperative program with the Department of Agriculture to produce gasoline directly from biomass.

The Department's Alternative Fuels Utilization Program is examining the potential of alcohol fuels for use in present and modified highway vehicles. The program's activities to date have confirmed that alcohol fuels are suitable fuels for use in the internal combustion engine, and that the use of alcohol/gasoline blends in highway vehicles is technically feasible. Research is continuing in the Department on optimizing the use of alcohol fuels in both conventional and advanced vehicle systems.

STATE ROLE

The role of the States in this effort is crucial. Despite some of the uncertainties regarding alcohol fuels, States have moved ahead to produce and market gasohol. State activities such as road testing programs, research on alcohol production technology, and legislation to encourage gasohol usage and marketing provide a variety of experience that is useful for policy makers in Washington.

The use of gasohol in the State programs appears to support the Department's assessment that the use of 10% ethanol blends in motor vehicle applications is technically feasible. The State programs also indicate that a four point octane boost is brought about by the ethanol component of gasohol.

That octane boost places alcohol fuels in the competitive range with premium, unleaded fuel. The Department plans to conduct analysis on the future prospects for this portion of the market.

CONCLUSION

The Department of Energy is firmly committed to pursuing the potential of alcohol fuels. We will be putting a great deal of effort into understanding economic, supply, and other issues that affect potential commercialization of alcohol fuels. While I cannot predict the outcome of pending analyses, we are hopeful that gasohol and alcohol fuels can play an important role in stretching our energy supplies. We are particularly interested in alcohol fuels because they are environmentally sound and renewable sources of energy. We will make every effort to share our results with your Committee as soon as they become available.

Mr. Chairman, I am pleased to have this opportunity to present to the Committee a status report on where the Department stands on alcohol fuels. I will be pleased to answer any questions you may have.

Senator CHURCH. We have a problem. Under the Senate rules, the Senate came in at 9:30 this morning, and it is now 11:30. The committee is not supposed to continue after 11:30. We would like to hear very briefly from the remaining witnesses and ask them to submit their testimony for the record.

I don't see we have any other alternatives, Senator Bumpers, than to try and squeeze a few minutes out. I am sorry this has happened.

Our next witness is Mr. Weldon Barton, Director of the Office of Energy for the Department of Agriculture. I wonder, Mr. Barton, if we could ask you to submit your testimony in writing this morning.

Mr. BARTON. Yes, Senator, we can do that.

Senator CHURCH. Can you capsulize the position very briefly, so we don't take more than about 5 minutes?

Mr. BARTON. Yes.

STATEMENT OF WELDON BARTON, DIRECTOR, OFFICE OF ENERGY, DEPARTMENT OF AGRICULTURE, ACCOMPANIED BY EARLE JAVITT, AND HARRY BROWN

Mr. BARTON. There are substantial capabilities in the Department of Agriculture which can contribute to the alcohol fuels program in cooperation with the Department of Energy. We have in our statement a brief summary of the research and development activities the Department is currently conducting. These activities are conducted primarily by the Science and Education Administration, the Forest Service, and the Economic, Statistics and Cooperatives Service.

In the 1977 Food and Agriculture Act, Congress authorized and directed the Secretary of Agriculture to carry out a program of pilot projects, and specifically to guarantee loans of up to $15 million for each of four pilot projects convert agricultural commodities and forestry products into industrial alcohols and hydrocarbons.

Senator BUMPERS. Did they give you $50 million or $60 million to do that?

Mr. BARTON. These will be guaranteed loans, based upon the lending authority of the Commodity Credit Corporation of the Department of Agriculture. It would be up to $60 million, or $15 million for each of four projects.

Senator BUMPERS. I thought they gave you $50 million and authorized four projects up to $15 million.

Mr. BARTON. There is no direct authorization. The authorization is to use the vehicle of the Commodity Credit Corporation to guarantee those loans. There is sufficient authority in the CCC fund, assuming appropriate projects to be carried out at that level.

We describe in our statement some of the details of carrying out that program. We published final regulations in the Federal Register of July 11. We are now in the stance of waiting for proposals to come in.

The cutoff period for proposals is October 16. We expect that by the end of the year we will be able to make our recommendations to the Commodity Credit Corporation Board, and that the Secretary will make decisions on which, if any, pilot projects are approved for loan guarantees.

On S. 2533, the Department of Agriculture is in agreement with the goal of S. 2533 to reduce the amount of foreign oil imported into this country, and with setting quantitative goals which can provide impetus and direction to various actions that are required to achieve results. Further, USDA agrees with the principle of anticipating and providing for arrangements to move the alcohol fuels into normal commercial liquid fuel marketing channels. S. 2533 would offer one possible way to accomplish this.

If an alcohol fuels program is to have the best chance of success, there is need for rather firm policy goals toward which individual actions can be directed.

The basic problem that we see with S. 2533 is that it seems to presume that alcohol fuel will be available to refiners in sufficient quantities to meet the quantitative requirements for the respective calendar years, and on that basis would prescribe harsh penalties for refiners who fail to meet the requirements. The development of an alcohol-fuels industry which is economically feasible and energy efficient depends upon many developments beyond the control of refiners. Consequently, penalties against refiners as provided in S. 2533 would not appear to be proper unless such other developments occur.

So in summary, Mr. Chairman, and Senator Bumpers, the Department of Agriculture is carrying out some related programs. We have capabilities that we think can be helpful in this area. We are generally positive toward the need for goals or targets in this area, but we did see the problem wtih the bill that I indicated.

Senator BUMPERS. Would wood waste qualify for one of these pilot projects?

Mr. BARTON. Yes. We have defined agricultural commodities and forestry products rather broadly to make the permissible feedstocks essentially synonymous with biomass materials generally. Wood wastes or crop residues, or the commodities themselves, would potentially qualify if other criteria under the statute are met.

Senator CHURCH. Last year we provided a loan program in an attempt to get four experimental plants——

Mr. BARTON. This is what we were talking about, Mr. Chairman.

Senator CHURCH. Since I was out of the room, can you tell me what success you have had with that.

Mr. BARTON. Yes. We are implementing that pilot project program. We placed proposed regulations in the Federal Register in May. We conducted a series of hearings May 26, June 1, and June 3 across the country.

We published final regulations on July 11. We are now accepting proposals, with a cutoff of October 16.

Senator CHURCH. Have any applications come in?

Mr. BARTON. Harry Brown, can you answer that?

Mr. BROWN. At this early stage we have not received any formal applications. I would point out, however, that during the period we were requesting tentative descriptions to help in preparing the regulations, we received some 50-plus indications of interest in response. We are aware of quite a number of people who are now working on their formal applications, I would expect them to come in before the end of the period.

Mr. BARTON. We just started this July 11. We would expect them to come in before the October 16 deadline.

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Senator CHURCH. On page 6 of your testimony you say, quite properly, that research on biomass conversion processes shows that:

Feedstocks for this large amount of alcohol would have to come from a wide variety of sources in addition to feed and food grains. These would include, for example, agricultural and forest residues below market grade grains, specific energy-farm crops, and nonagricultural materials.

I think that is probably true. We probably have to look to all sources; even newspapers come from a replenishable sources, growing trees. I have spoken to many farmers about gasohol. I think nothing would be more satisfactory to the farmers of this country than the development of new markets for their products.

They would like very much to get away from support prices and programs that pay them not to raise crops. Nothing would be more healthy and nothing might reduce so much the cost of present farm programs than the emergence of a new market in this country for various kinds of farm products. If that can also contribute to a solution of our energy and fuel problem, so much the better.

I would think this is the kind of objective the Department of Agriculture would favor strongly.

Senator BUMPERS. Along that line, you are under a mandate on these projects to see the output of energy is more than the input.

Mr. BARTON. That is correct, Senator.

Senator BUMPERS. Anybody who applies will have to take into consideration the amount of energy it takes to make ethanol or whatever from these wastes, and from that standpoint is it not true that grains, for example, while they might be used in the distillation process, are not very efficient? Let's take cane, for example. As I understand it, that is a good cellulose product where you can use the byproduct in the distillation process, cutting down the amount of energy it takes to produce ethanol.

Mr. BARTON. Our regulations provide that, if a pilot project uses residues rather than grain itself, any energy used in the production of that residue would not be taken into consideration in calculating the net energy balance.

Senator BUMPERS. As long as the residues are being used?

Mr. BARTON. As long as it is residue rather than corn or wheat. This would give an advantage to residues as feedstocks and, in the short term, would perhaps make it easier for projects to meet the qualifications of the regulations.

Perhaps over a bit longer term we can develop, through genetics research and variety selection, plants that will produce energy more efficiently, just as we now produce feed and food efficiently.

Senator CHURCH. I have one in my hand. Are you acquainted with the *Euphorbia lathyrus*?

Senator BUMPERS. I have a whole yard full.

Senator CHURCH. Believe it or not, Senator, that plant is supposed to produce oil and experiments are now underway in California to utilize it.

Senator BUMPERS. Does it have a better name than that, a popular name for it?

Senator CHURCH. There must be.

Mr. BARTON. Earle Gavett says it is a gopher plant.

Senator CHURCH. It flourishes in semiarid parts of the country. It is kind of a desert plant.

Mr. BARTON. Mr. Chairman, we think one should not put all of one's eggs in one basket, but this is one of the real possibilities. If that type of plant can be produced on a large scale over a wide area, it has the ability to use the photosynthesis process to actually produce a petroleum-type product directly. That would cut down on the amount of fuel necessary to run the plants necessary to convert biomass into usable fuels.

Senator CHURCH. I think our time limit has expired. Thank you very much for your testimony.

[The prepared statement of Mr. Barton follows:]

STATEMENT OF WELDON V. BARTON, DIRECTOR, OFFICE OF ENERGY, DEPARTMENT OF AGRICULTURE

Mr. Chairman and Members of the Committee, I am Weldon V. Barton, Director of the Office of Energy of the Department of Agriculture. It is a pleasure to testify before your subcommittee today.

I would like to discuss briefly the energy program of the Department of Agriculture as related to S. 2533, and then indicate our views on the bill itself.

The Department of Agriculture has primary responsibility within the Federal Government for matters related to food, crops, livestock, forest activities, and rural development. USDA programs, authorized under many Acts, include responsibility to assure adequate supply and efficient production, processing, marketing, distribution and use of food, fiber and forest products.

USDA's existing capabilities put the Department in a position to help effectively to develop agricultural and forestry resources as renewable sources of energy, including alcohol fuels. The development and testing of feedstocks for fuel requires the expertise of both DOE and USDA. The implementation of such a program, including decisions on land use and conservation for fuels as opposed to food, feed or wood products, merges directly with the Secretary of Agriculture's present duties.

The Department currently conducts research and development related to alcohol fuels for transportation. In the Science and Education Administration (SEA), Federal Research, we have a number of projects on production and use of energy crops such as grain and sugar cane. We are investigating conversion of these crops and their residues and byproducts, as well as new specialty crops and animal residues into energy fuels, chemicals and petrochemical replacements through fermentation and other processing techniques. The Economics, Statistics, and Cooperative Service is conducting economic analyses of land availability for energy production, the impact of using agricultural commodities in the manufacture of alcohols and hydrocarbons, and anaerobic fermentation of livestock and crop residues into methane. SEA, Cooperative Research, is funding research relating to potential production of alcohol and industrial hydrocarbons from agricultural and forestry products. Raw materials being investigated in these projects include sugar cane, wood residues, animal wastes and other forms of biomass. Products include alcohol, methane, producer gas, pine resins, and chemical feedstocks. The Forest Service has related research and development on silvicultural energy-farms, systems for harvesting forest residues, and development of petrochemical substitutes such as adhesives and oleoresins from wood and bark wastes.

An inventory of all USDA energy R & D and technology transfer projects was provided last year to the House Appropriations Committee and is currently being revised. This shows where the work is being done and the source of funding. Some of this research is supported by pass-through funds from the Department of Energy.

Our intention in USDA is to coordinate all work related to energy with the Department of Energy, the lead agency for energy policy in the Executive Branch.

Congress recently provided the USDA with the following additional legislative authorities:

(1) Title XIV of the Food and Agriculture Act of 1977 gave USDA authorization to carry out programs in solar energy on farms, to guarantee loans for pilot projects to convert agricultural commodites and forestry products into industrial hydrocarbons and alcohols (Section 1420), and for research on

production of alcohols and industrial hydrocarbons from agricultural and forest products.

(2) In the Emergency Agricultural Act of 1978, Congress provided the USDA with authority to permit production of energy crops from set-aside acres. In years when there is no set-aside acreage, the Secretary has been authorized to provide incentives to encourage continuity of energy crop production.

We are committed to the implementation of Section 1420 on a timely basis and in a way that gives the pilot projects the best possible chance for success. Our first step in implementing Section 1420 was a request in the October 20, 1977 Federal Register, for tentative descriptions of proposed pilot projects. A total of 51 responses were received by the April 15, 1978, deadline. The information from these tentative descriptions was used by a panel of technical experts in preparing draft regulations. These were published in the May 12, 1978, Federal Register for a 30-day review period. During that time, we held three public hearings in Washington, D.C., St. Louis, Missouri, and Spokane, Washington. During the review period numerous suggestions were made that were considered by the technical panel in preparing the final regulations. These regulations, including a request for proposals, were published in the Federal Register on July 11.

We will receive formal proposals until October 16, 1978. In the meantime, we plan to establish an evaluation committee, including national experts, to review the proposals and make recommendations to the Commodity Credit Corporation and the Secretary regarding selection of pilot projects. We expect to have decisions by the end of the year.

The regulations define eligible feedstocks to include all forms of renewable biomass, including such diverse materials as the grain and stalks of corn, wheat and rice; cottonseed hulls; fruits and vegetables and their processing byproducts and residues; poultry and livestock manures and residues; wood products, including bark, pulp, chips, and residues from logging and paper manufacturing; aquatic plants; and specific energy-farm crops. We have defined industrial hydrocarbon to chemically consist of carbon plus hydrogen as the major constituent.

In calculating energy balance, the regulations require that projects proposing to use residues or below market grade commodites as feedstocks will count only the fossil fuel energy used for collection and conversion to hydrocarbons or alcohols. For projects proposing to use commercially marketable agricultural commodities as feedstocks, the fossil fuel used for growing of the crop through final processing is part of the energy producing system and will be counted in determining the energy balance. This will tend to encourage projects that use residues and below market grade materials and specific energy-farm crops requiring less energy to produce than conventional agricultural commodities. We believe these requirements will, in the long run, enhance the prospects of economic and energy-efficient alcohol fuels for transportation.

There is a great deal of interest in this program, and we are looking forward with much anticipation to the proposals that will be forthcoming.

The Department of Agriculture is in agreement with the intent of S. 2533 to reduce the amount of foreign oil imported into this country, and with setting quantitative goals which can provide impetus and direction to various actions that are required to achieve results. Further, USDA agrees with the principle of anticipating and providing for arrangements to move the alcohol fuels into normal commercial liquid fuel marketing channels. S. 2533 would offer one possible way to accomplish this.

Our experience to date makes us optimistic that commodities and residues from U.S. crop and forestry land could contribute a significant amount to the Nation's liquid fuel supplies by the 1990 date specified in S. 2533. At the present time, the conversion of some agricultural commodities and forestry products into fuels or petrochemical substitutes is neither economically feasible nor energy efficient. Furthermore, we are not confident that we know which practices will result in the largest payoffs in developing a fuels from biomass industry over the next few years or the best sequence of activites to develop the industry. For example, research on biomass conversion processes is not independent from selection, breeding, and testing of plants for feedstocks, since new conversion technologies would influence proper plant development. In any event, the number of promising avenues of development open to us suggests that a sustained effort could be succesful.

If an alcohol fuels program is to have the best chance to success, there is need for rather firm policy goals toward which individual actions can be directed. In the USDA, we have proposed the following quantitative targets for the agricultural and forestry sectors for the year 1990: (1) agricultural production—net energy self-sufficiency, under conditions that sustain productivity; (2) forestry production and processing—net energy self-sufficiency, under conditions that sustain productivity. Conversion of agricultural biomass into energy would have to be the overwhelming means to achieve such goals. Agricultural production and forestry production and processing together consume 6.2 percent of the Nation's energy, or 4.7 quads. Presently, wood residues account for 1.2 quads—almost half of the energy used in forest production and processing. To achieve a net energy self-sufficiency based on biomass alone, we estimate that an additional 4 quads of energy will have to be produced. With the ultimate energy potential of biomass estimated to be well above 10 quads, the 1990 objective of net energy self-sufficiency for agriculture and forestry would appear to be achievable.

The goal of achieving an average of 10 percent alcohol content of all gasoline sold in the United States by 1990, in S. 2533, would be in the general range of the goals which we have proposed in USDA. About 13.8 billion gallons of alcohol fuel, or about 1.14 quads, would be required in 1990 to meet the objectives of S. 2533. Feedstocks for this large amount of alcohol would have to come from a wide variety of sources in addition to feed and food grains. These would include for example agricultural and forest residues, below market grade grains, specific energy-farm crops and nonagricultural materials.

The basic problem that we see with S. 2533 is that it seems to presume that alcohol fuel will be available to refiners in sufficient quantities to meet the quantitative requirements for the respective calendar years, and on that basis would prescribe harsh penalties for refiners who fail to meet the requirements. The development of an alcohol fuels industry which is economically feasible and energy efficient depends upon many developments beyond the control of refiners. Consequently, penalties against refiners as provided in S. 2533 would not appear to be proper unless such other developments occur.

Also, to meet the requirements of Section 7(a) for the calendar year 1981, this Nation would have to be producing over 1.1 billion gallons of alcohol annually to satisfy the 1 percent by volume alcohol motor fuel blend. While there currently is some excess capacity in beverage distilleries there is not enough capacity in total to satisfy the beginning needs of this bill in calendar year 1981. Additionally, to build new distillery capacity will require about 3 years from plant design to full operation for ethanol plants having a capacity of 20 million gallons per year. The production of wood to methanol plants of 50 to 200 million gallons per year capacity will require close to 5 years to bring on stream.

I would be pleased to respond to any questions.

STATEMENT OF PINCAS JAWETZ, CONSULTANT ON ENERGY POLICY, NEW YORK, N.Y.

Mr. Jawetz. Good morning.

Mr. Chairman and members of the committee: As background for my presentation I would like to present for the record an article that was published in Chemical and Engineering News, July 31, 1978. Gasohol: Energy Mountain or Molehill? Everybody Agrees That It Works, but There Is Heated Debate About Whether It Will Be Worth the Effort."

Also, for the record I present two papers:

The first—"Commonsense Suggestions as to How Existing Agricultural Subsidies Could Help Produce Alternative Liquid Fuels Competitive in Price With Petroleum," and a second paper containing the calculations showing the possibility of linking energy policy to farm policy.

In order to avoid misconceptions, I wish to state that I am talking about ethanol as an extender for liquid fuel supplies as in mixtures of ethanol and gasoline containing 10 to 20 percent ethanol, not about engines fueled with pure ethanol, nor am I talking about methanol.

The arguments against the mixtures boil down to two questions: (1) Economics and (2) the energy balance.

The first point I would like to deal with is the technical question—the energy output—energy input ratio; Does the manufacture of ethanol from agricultural products result in a positive energy balance?

At present the battle surrounding this topic is fought with arguments in terms of Btu per gallon. Btu is a measure for the heating value, but not of the effectiveness of fuel in a motor vehicle engine. Ethanol does, indeed, have only about two-thirds the Btu gallon value of gasoline; when used in output/input ratio calculations unfavorable energy balances are brought about.

However, the debaters do not try to quantify such empirical findings as;

(1) That the octane rating of a 10 percent ethanol–90 percent gasoline mixture increases by 4 points as compared with gasoline;

(2) That there is an increase in volume of the mixture as compared with the components; and

(3) That the efficiency as a fuel increases in miles per gallon and in miles per Btu when compared with unleaded gasoline.

Furthermore, road tests in this country and elsewhere show that in effect the mixture is interchangeable with pure gasoline.

Accordingly, we can say that the ethanol as part of a mixture is—at least as effective as gasoline in terms of use as a motor fuel.

Therefore, the argument is that if one use Btu/gallon as a measure in energy balance studies, one should use at least the Btu value of the gasoline that has been saved in the ethanol-gasoline mixture, instead of the Btu value of ethanol which is, in fact, irrelevant to the intended use of the ethanol. Hence an empirical utility factor equal to about 1.5 should be used as a multiplier in the conventional output/input energy ratios.

This approach would prove that the use of motor-fuel-ethanol presents a favorable energy balance.

Furthermore, the utility factor 1.5 implies that a gallon of ethanol in the mixture is perfectly equivalent to the gallon of gasoline that it displaces. Naturally this is a low-side estimate as we have not even taken into consideration the positive change in volume of mixture.

Yesterday, at these hearings, Mr. Al Mavis from the Department of Agriculture, State of Illinois, in an answer to a question mentioned that the State fleet in Illinois using 10 percent alcohol-90 percent gasoline mixtures has obtained a 6.1-percent increase in miles/gallon. This translates into an additional multiplier equal to 1.61 that would then bring up our utility factor to $1.61 \times 1.5 = 2.4$.

When mentioning this perhaps also we should remember Professor Scheller's findings. He evaluated for Nebraska an increase in miles/gallon equal to 5.3 percent. Thus the utility factor in his case should have been 2.3.

Reverting to the question of economics the disregard of reality is even more amazing. Much is being said about the need of the land for food production, with the implication that there is just no resource base for the production of alcohol, and if produced, the ethanol would cost somewhere around $1.20 per gallon, which is much too high compared with the cost of gasoline.

The facts, however, are that in our country this year 24 million acres of farmland are being subsidized not to produce grains and cotton but in order to support prices.

Moreover, similar situations are doubtless going to prevail in the foreseeable future.

The exact subsidies for part of this land are not available at the present time as they are based on guaranteed minimum prices, but for 7 million acres of the so-called "diversion" program we calculated a weighted average of direct subsidy for nonproduction of $126.37 per acre. This money, though already committed to the support of existing farm policy, could become help in the manufacture of alcohol.

One gets 234 gallons of anhydrous ethanol per acre of corn and, if the negative subsidy for nonproduction is converted into a positive subsidy for the production of alcohol, this would mean that 54 cents become available for the subsidization of a gallon of alcohol without involving any new expenditures in terms of new subsidies.

Subtracting 54 cents from $1.17, the cost of a gallon of ethanol as calculated by Dr. Lipinsky in studies sponsored by the Department of Energy at Battelle Columbus Laboratories, leaves us with the cost of a gallon of alcohol of 63 cents assuming that we have paid $2.50 per bushel of corn.

The price of a gallon of ethanol could be reduced further by readjusting the price paid to the farmer per bushel of corn in order to take into consideration that the additional production of corn has been approved after the fact that his capital investment in land and machinery has already been secured by the original minimum target price policy.

When it is agreed that the price of a bushel of corn geared to fuel production could be lower than corn priced for the nonfuel market, one can produce ethanol for between 27 to 45 cents per gallon as I have shown in the attached calculations.

The 7 million acres mentioned here could produce 1.65 billion gallons of fuel ethanol which could provide over 1.5 percent of the yearly need for gasoline and save about $1.3 billion in oil imports. All this without any additional subsidies, or the need for removing any federal taxes or any State taxes from the mixed fuels.

We believe that when considering all agricultural facts a resource base of over 30 million acres and a subsidy of somewhere between 40 to 45 cents per gallon could become available to supply—by this policy alone—about 8 percent of the country's present need for gasoline.

I would be pleased to answer any questions and hope for a chance to present some of the supporting material.

Senator CHURCH. In reaching that conclusion, it is your belief that such a subsidy for producing gasoline from grain supplies would be no greater than the subsidies we now pay for not producing?

Mr. JAWETZ. That is exactly it. I have calculated my numbers on the basis of existing data which I have received from the Department of Agriculture and they were very helpful in providing me this data.

Senator CHURCH. Have you discussed your calculations with the Department of Agriculture? Do you have any response from the Department which indicates agreement or disagreement with your figures or any interest in them?

Mr. JAWETZ. I met with the two people heading the energy task force in the Department of Agriculture. I think I have stirred up some additional thinking in that direction. I would like very much to know this kind of positive effect this thinking would have.

Senator CHURCH. I think the staff should pursue the approach you have suggested and examine it further. I think it has merit, and we ought to explore it. It seems a shame to be spending so much money subsidizing farmers for not raising crops for the same money that could be turned into fuel.

Mr. JAWETZ. May I add one thing. In terms of a national policy which could become unified energy and agriculture policy, I think this way of thinking is imperative. I am amazed at the fact, I sort of bump on these ideas without having seen on any kind of references on such a kind of integrated whollistic approach to national policy anywhere.

Senator CHURCH. I have not heard the proposal made, at least, it has not come from the Department of Energy or the Department of Agriculture to my knowledge, and I do think we should pursue it.

Do you have any questions?

Senator BUMPERS. No questions.

[Material submitted by Mr. Jawetz follows:]

News Feature

Gasohol: energy mountain or molehill?

Everybody agrees that it works, but there's heated debate about whether it will be worth the effort

Earl V. Anderson
C&EN, New York

It wasn't an offer they couldn't refuse. But it was an offer, according to Sen. Carl T. Curtis (R.-Neb.), that they would be foolish to ignore.

So for three days late last month, about 250 Senators, Representatives, and other government officials lined up their cars near the Peace Monument in Washington, D.C. There, they got a free tankful of gasohol—a blend of 90% unleaded gasoline and 10% ethanol.

If every motorist could get gratis fillups, gasohol wouldn't be the controversial issue that it is. They can't, of course, and gasohol has become one of the hottest, most emotional, and highly controversial energy issues in the nation. Some call it a controversial farm issue.

Sen. Curtis, along with several other Congressmen and the American Automobile Association, sponsored the gasohol giveaway. When he made his "offer" on the Senate floor last month, Sen. Curtis had this to say about gasohol:

"This is not just any automobile fuel. It is a highly efficient premium fuel, which, if marketed nationally, could reduce oil imports 20%, while providing a steady market for farm surpluses .... For 50 years, race car drivers have used alcohol in their tanks because it is the most efficient, responsive fuel available.

"By testing gasohol firsthand in their own unmodified engines, Congressmen will be in a better position to answer those skeptics who suggest that gasohol is some crazy scheme concocted by farmers and designed to destroy our cars .... Perhaps if Congressmen themselves get the 'racer's edge' by filling up with gasohol, their endorsement will spur the rise of a domestic industry capable of converting farm, forest, and municipal waste products into energy."

Sen. Curtis' statement contains most of the ingredients that make gasohol the controversial—and political—issue it is. Gasoholics, which is what ardent gasohol supporters call themselves, claim that gasohol will alleviate the oil import problem (and help reduce the huge balance of trade deficit) with one hand while solving the farm problem with the other.

Skeptics disagree. Reflecting on Sen. Curtis' remarks, one observer says that it sounds as if gasohol is a "molehill that's trying to become a mountain." This observer, who is about as neutral a figure as you'll find in the gasohol debate, is obviously skeptical. There are others who are unflinchingly certain that gasohol has neither the economic muscle nor the Btu's to accomplish any of these things. Ethanol, they say, costs about $1.25 per gal, compared to 38 cents for gasoline at the refinery gate. A gallon of gasoline has about 135,000 Btu, whereas a gallon of ethanol has only 85,000 Btu. On a cost-per-Btu basis, then, ethanol runs about five times higher than gasoline. W. Gordon Leith, vice president of Farmland Industries, says blending alcohol with gasoline is "like stretching hamburger with filet mignon."

Gasohol opponents claim that it probably will do more harm than good to the nation's economy, its farmers, its oil imports, and its trade balance. They believe that it is too expensive to use as a fuel as long as less expensive fossil fuels still exist.

Since it takes more energy to produce ethanol than you can get out of it, they say gasohol will increase, not decrease, U.S. demand for foreign oil. This will make the trade balance even worse. So, too, will the drop in farm exports, as farm products are diverted from foreign markets to domestic energy markets. Gasohol opponents even raise a moral question: Is it right to take food from the world's hungry and put it in America's automobiles?

Gasoholics, who fashion themselves wearing white hats, include farmers, farm-state politicians, and energy-conscious environmentalists. Opponents wear the black hats. They are usually oil men, many agricultural economists, and bureaucrats, particularly in the Department of Energy and the Department of Agriculture.

That's about the only thing obvious in the gasohol controversy. It is as confusing as it is heated. For instance, Sen. Curtis' home state of Nebraska, an acknowledged leader in gasohol, coined the name gasohol (a blend of 90% unleaded gasoline and 10% agriculturally derived (meaning grain) ethanol. Yet, in Nebraska's now-famous 2 million mile road test, its ethanol came, not from grain, but from wood. It was supplied by Georgia-Pacific from its plant near Tacoma, Wash.

The ethanol used in last month's gasohol giveaway in Washington came from Archer-Daniels-Midland's corn sweetener plant in Decatur, Ill. And in Illinois, some of the ethanol used in gasohol comes from cheese whey.

Sen. Curtis talks about the "racer's edge." Yet racers usually use 100% alcohol, not a 10% blend. And that alcohol more than likely is methanol.

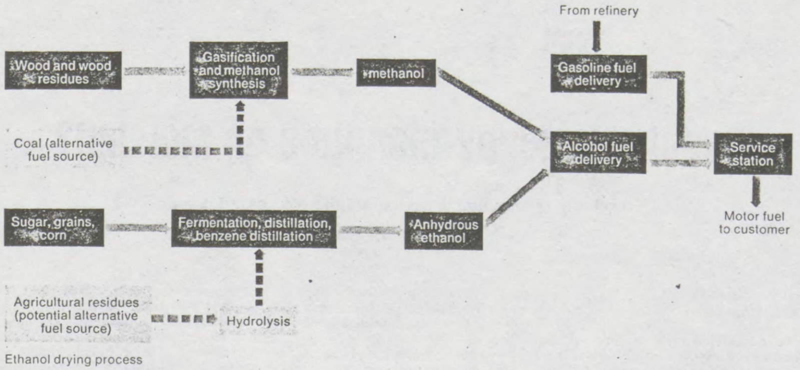
In fact, when Sen. Curtis sees the rise of a U.S. industry "capable of converting farm, forest, and muncipal waste products into energy," he could be talking ethanol, methanol, or both. That's a big part of the problem in the gasohol debate. It's difficult to tell what the rhetoric is all about. Cloud L. Cray Jr., president of Midwest Solvents (Atchison, Kan.), says, "When they want a 50-cent cost, they talk methanol. When they want farmer backing, they talk ethanol."

Pure gasaholics, with an "a" rather than an "o," don't really care which alcohol is used or where it comes from, as long as it is a renewable source. The most likely renewable source of methanol is wood or wood residues, which can be gasified and converted into methanol. Ethanol can be produced from many grains by the well-known fermentation-distillation process used to make beverage alcohols.

But methanol also can come from coal—a nonrenewable source. And ethanol can be produced from a wide range of cellulosic biomass, which first must be hydrolyzed to fermentable sugars.

Different alcohols, different sources, different blend ratios, or even 100% alcohol fuel all contribute to the confusion that exists in the gasohol controversy. But the focal point of the economic, energy,

There are many possible routes to gasohol



Note: Solid lines indicate most likely routes, dotted lines show alternate routes. Source: Mitre Corp., Metrek Division

and political furor is gasohol with an "o," a blend of unleaded gasoline and grain-derived ethanol.

Perhaps it is inevitable. When farm interests are thrown into the same tank with energy interests, such as oil companies, and political interests jump in with them, controversy is certain to follow.

Perhaps, too, there are some skeptics who suggest that gasohol is "some crazy scheme . . . designed to destroy our cars." But there are few, if any, gasohol opponents who say that the material will not work in a car's engine. Gasohol has been used too long in too many places to argue the point. There may be some quibbling over fuel economy, emissions, engine performance, and drivability, but almost everyone agrees that gasohol does work.

That is not the major issue. The two strategic pieces of high ground that both sides are struggling to win are economics and energy balance. And both are far downstream from the fuel tank.

Much has been written and said about gasohol. There's no shortage of data available on the economics and net energy balance of grain-derived ethanol. Most of it, however, is theoretical. Because it is, there is a widely held feeling that the economic and energy jury should remain out until a full-scale plant is actually operating.

But one often-quoted set of data is not theoretical. It comes from Midwest Solvents' Cray. Over the past year, Cray has become persona non grata in the gasohol community. Richard F. Merritt, a confirmed gasoholic, a Washington consultant, and a lobbyist for Nebraska's Agricultural Products Industrial Utilization Committee, says that Cray is "one of the worst adversaries we have."

Last year, Cray chaired a gasohol seminar in Brazil, which has under way a well-known gasohol program of its own. Recalling Cray's remarks there, Merritt says, "Imagine that guy telling the Brazilians that gasohol is no good. It's like going to the Vatican and telling the Pope that religion is no good."

Actually, Cray doesn't say that gasohol is no good. He sees nothing wrong with grain-derived alcohol being used as a motor fuel. In fact, his company's plant started as a gasohol plant—the only one in the U.S.—and produced a commercial product called Agrol.

What Cray does say is that gasohol makes no economic sense in the U.S. as long as there are less expensive fossil fuels available. Nor does producing ethanol from grain contribute anything to the nation's energy supply.

In fact, says Cray, it will do just the opposite. Based on operating experience at Midwest's 15 million gal-per-year plant, which is conceded to be one of the most efficient grain alcohol plants in the world, more energy is consumed producing a gallon of ethanol than you can get out of it.

Cray says that Midwest has reduced its process energy losses from 200,000 Btu to less than 140,000 Btu for every gallon of ethanol it produces. These losses take into account the energy contained in the grain and the by-product animal feed. The gallon of ethanol produced contains only 85,000 Btu, which adds up to a 44% loss on total energy input.

Cray is well aware of the new fermentation and enzyme technology being developed. And he thinks that they eventually may lead to improved energy balances. But the ethanol used in gasohol must be anhydrous. "Unless one of them [new technologies] miraculously converts cellulose or grain products to 200-proof (100%) alcohol, you still have to distill the material and recover the by-products," he says. At Midwest, about 74% of the energy goes into distillation and by-product recovery.

Cray's energy analysis doesn't take into account the energy that went into producing the crop, which he says is an energy-intensive process. If it did, Cray says that it would require 2.7 times more energy to produce the ethanol than the alcohol could deliver to an engine.

Compared to his net energy balance, Cray's economics are even more of a disaster for gasohol. Based on gasoline values at the refinery gate and ethanol's lower Btu content, he estimates that the alcohol is worth about 32 cents per gal when blended in gasohol.

That value will trigger a lot of arguments. But nobody can argue with Cray's production cost figures. He says that the best Midwest has been able to do was 98 cents. That's actual production cost, with no profit. And it happened, says Cray, last July and August, when farmers weren't too happy about the prices they were receiving and when Midwest was using natural gas, its lowest-cost fuel. That amounts to a 66-cent loss, more than double what he considers ethanol's fuel value to be.

Cray's analyses don't set well with gasoholics. He often hears himself being accused of opposing gasohol because he's afraid of the competition. But he doesn't pay much attention to these accusations. "If gasohol works, it means a great deal of profit to my company," says Cray.

Gasoholics have their own figures on economics and net energy balance. For the most part, they can be traced back to Nebraska, where the gasohol craze began.

The Nebraska legislature has gotten behind gasohol in a big way. It provided a 5 cent-per-gal reduction in the state gasoline tax for a 90% gasoline-10% ethanol blend. According to Nebraska officials, that tax subsidy makes gasohol competitive with unleaded gasoline.

Nebraska also established the Agricultural Products Industrial Utilization Committee to administer the state's grain alcohol program. It was this committee that sponsored the 2 million mile gasohol road test, which was completed in 1977. Out of this test came many claims. Fuel economy was 5% better with gasohol than with unleaded gasoline. Gasohol exhaust emissions were about one third lower in carbon monoxide. There was no unusual engine wear or carbon buildup. There were no starting, vapor lock, or drivability problems.

But what the committee is really shooting for is one or more grain alcohol plants in Nebraska. It commissioned Stone & Webster to do a feasibility study. The company concluded that it would be economically feasible to build a 20 million gal-per-year anhydrous ethanol plant in the state. The plant would cost $22.1 million and yield a 22% return on investment.

There are several important points to bear in mind about the Stone & Webster study. One is that it designed a "bare bones" plant and didn't consider marketing costs. Primary plant feed was assumed to be distressed (under grade) grain. This would be "supplemented" by market quality grain. And the study was based, at least in part, on information provided by the Nebraska committee.

One of the most controversial figures in Nebraska, if not the entire gasohol debate, is Dr. William A. Scheller, head of the department of chemical engineering at the University of Nebraska, Lincoln. Scheller has many critics, but gasoholics love him. According to gasoholic Merritt, "Scheller tells it like it is. He speaks the truth."

What Scheller is saying is that from both an economic and energy point of view, gasohol makes a lot of sense. His calculations on the net energy balance involved in producing ethanol from grain have become famous—or infamous—throughout the world of gasohol, depending upon which side you are on.

Scheller claims that producing ethanol from corn yields a positive energy balance of 27,700 Btu per gal of ethanol. That's a lot different from Cray's figures, which show a huge energy loss.

The big difference is that Scheller draws an energy boundary, not around the plant alone, but around the ethanol plant and farm combined. He takes into account the energy required to grow the crop. He also takes a large credit for the energy contained in the stalks, cobs, and husks. He assumes that 75% of these can be transported to the plant and burned as fuel.

The big factor in Scheller's positive energy balance, of course, is the sun. Without the credit he takes as a result of harnessing solar energy through photosynthesis, his balance would be quite different. But as Scheller says, "It's there. Why not use it?"

Scheller also has used another approach to the energy question. But the results are just as attractive for gasohol. He compares the energy used to make 10 gal of gasohol (actually 10.023 gal) with that needed to make 10 gal of straight unleaded gasoline. His conclusion: The country would save 0.69 gal of crude oil for every 10 gal of gasohol (1 gal of ethanol) produced.

This time, Scheller is looking at a different ethanol operation. The unit is more efficient, with additional heat exchange, stack gas recovery, and improved equipment, especially in the distillation columns. He also leaves the heads and fusel oil in the alcohol. Removing these impurities is necessary in producing beverage-grade alcohol. But, says Scheller, it's not necessary to take them out of ethanol that's going to be used in gasohol. Leaving them in saves energy and capital, because two or three distillation columns can be eliminated. The net effect of these improvements is to lower his original energy requirements for the alcohol plant from 108,000 Btu per gal to 94,200 Btu.

Scheller also adds a few other credits to the gasohol side of the ledger. There is, for instance, the distillers dried grains, a byproduct of a fermentation plant. Animals eating these grains, Scheller says, gain 10.3 lb more weight than if they ate straight corn. An energy credit for gasohol. He also gives gasohol energy credits for the volume increase you get when you add 1 gal of ethanol to 9 gal of gasoline. He takes additional credits for improved octane and for improved fuel economy.

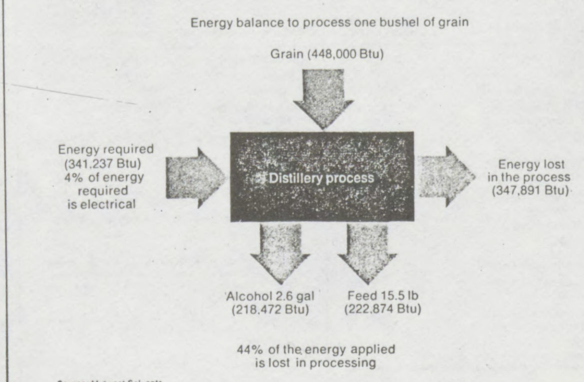
Adding up the score, Scheller says that producing 10 gal of gasohol (1 gal of ethanol) saves the equivalent of 1.81 gal of crude oil, an imported product. In its place, you need to burn the equivalent of 1.12 gal of coal. But, Scheller says, coal is a domestic product and this means an improvement in the U.S. trade balance.

Scheller also has several sets of economic data, based on different raw material assumptions. All of them paint an attractive economic picture for gasohol.

He presented one of his most recent analyses at last fall's International Symposium on Alcohol Fuel Technology in West Germany. Scheller says that, for a 20 million gal-per-year ethanol plant using milo (a variety of sorghum) as feed, total capital investment would be $27 million, including $4 million for working capital. Annual income would be $31.3 million, assuming ethanol sold for $1.10 per gal, distillers dry grain sold for $120 per ton, and carbon dioxide could be marketed for $2.00 per ton.

By purchasing his milo at $3.50 per hundredweight (cwt) and estimating conversion costs at 30 cents per gal of ethanol, Scheller figures that annual expense would run about $21.4 million. After allowing for depreciation and taxes, Scheller's plant would show a net profit of

Fermentation ethanol: do you lose energy . . .



Source: Midwest Solvents

$3.8 million and a net cash flow of $6.1 million, or 22.7% of investment.

Total production costs in this plant are about 74 cents per gal of ethanol. By going to a 50 million or 100 million gal-per-year unit, and depending upon type and price of the raw material, Scheller estimates that production costs could range from 43 cents to 78.5 cents per gal. These costs are considerably lower than the lowest estimate (98 cents) cited by Cray.

For Scheller, who has been involved in gasohol studies for many years, gasohol is the way to go. He believes that a grain alcohol plant can be operated profitably and that it can contribute to the U.S.'s net energy balance. He also believes that gasohol can compete with unleaded gasoline at the pump.

Scheller figures that the value of ethanol in gasohol is $1.20 per gal when you consider all of the advantages that it offers. On this basis, and taking a 3-cent tax credit (now 5 cents) that Nebraska offers, he figures the pump price of gasohol at 63.9 cents. Coincidental or not, this is exactly what he found to be the median price of several unleaded gasolines at the time he made his study.

Scheller's data delight gasoholics. Many others are less than enthusiastic. One in particular is Dr. James Kendrick, an agricultural economist who, like Scheller, is at the University of Nebraska. Some compare the Scheller-Kendrick battle to the old Rocky Graziano-Tony Zale fight. Fierce.

Kendrick disputes just about all of Scheller's data. To gasoholics, he is "a thorn in our side." He believes the net energy loss in a grain alcohol plant is at least 122,000 Btu per gal and could be as high as 145,000 Btu. He thinks Scheller's idea of collecting 75% of the agricultural residue and using it for fuel is impractical. Collection problems alone rule this out, he says. And there is the risk of erosion and moisture-retention problems if that much residue is taken off the land.

Kendrick's production cost estimates are much higher than Scheller's. His latest, adjusted for 1978 conditions, puts the total cost at $1.56 per gal. Even taking a 31-cent credit for the distillers dry grain by-product only lowers it to $1.25. Kendrick's by-product credit is based on an assumed market value for distillers dry grain in Nebraska of only $90 per ton. Scheller used $120.

Using his $1.25 ethanol and assuming a refinery-gate cost of 39 cents for gasoline, Kendrick says the average cost for 10 gal of gasohol would be 47.6 cents per gal—8.6 cents higher than the original gasoline. "Why," he asks "would a refiner pay $1.25 for ethanol as a replacement for 39-cent gasoline?"

By estimating the energy content of gasoline on the low side (115,000 Btu per gal) and that of ethanol on the high side (85,000 Btu), Kendrick figures that ethanol would be "worth" 74% the value of gasoline, or about 29 cents. A gallon of gasohol would contain 112,000 Btu, or 3% less than straight gasoline. To Kendrick, this means that gasohol would provide 3% less mileage than gasoline.

Scheller says that gasohol improves mileage from 5 to 6.7%, although government tests have shown no significant difference in fuel economy between gasohol and gasoline. Scheller's 5% difference in fuel economy may seem trivial. But it isn't, says Kendrick, when you look at the economics.

Kendrick says that, because of the assumed 5% increase, Scheller assigned a 32-cent credit to ethanol, meaning that refiners would be willing to pay 32 cents per gal more for ethanol than the price they charge for unleaded gasoline.

Scheller's campus colleague isn't the only problem he has in his own home state. Scheller, who has been very active in Nebraska's gasohol program, also is president of Nebraska Grain Alcohol & Chemical Co., a fledgling company that is trying to arrange financing for a 20 million gal-per-year ethanol plant it wants to build. As part of that financing, it hopes to obtain a $15 million, federally guaranteed loan—one of four such loans USDA is offering under the Food & Agricultural Act of 1977.

Nebraska's Gov. J. J. Exon has said that he is "bothered" by Scheller's commercial involvement. He also is bothered because, so far, the Nebraska gasohol committee has relied on only one source of economic information—Scheller. Even Stone & Webster's study was based on data supplied by Nebraska's Agricultural Products Industrial Utilization Committee.

Noting that there is "a host of conclusions outside Nebraska" that don't agree with Scheller, Exon asked for an independent study on the economic feasibility of building an ethanol plant in the state. The study, he says, should include marketing data and not depend on figures supplied by the committee.

That study is almost complete. It's being prepared by Development Planning & Research Associates (Manhattan, Kan.). Company officials won't discuss how the study is going. But one says, "We intend to call them as we see them."

One gasohol opponent believes they will. Attesting to the company's reliability, this antigasoholic says, "If they say gasohol makes sense, I won't look to see what they did wrong. I will check to see what I did wrong."

Gov. Exon isn't exaggerating when he says that there's a lot of anti-Scheller opinion outside Nebraska. Since the gasohol craze began, virtually every land grant school in the farm belt has looked at producing ethanol from grains—corn, wheat, sorghum, and milo. Almost without exception, opinions run heavily against gasohol. Here's a sampling:

- Peter J. Reilly, of the department of chemical engineering and nuclear engineering at Iowa State, says that gasohol is a "poor method" of raising corn prices for two reasons. It is highly energy-inefficient and the cost of the product is much greater than the material it is replacing.
- Thomas E. Davés, at South Dakota State's department of economics, agrees that gasohol isn't economically feasible, considering the current technology and relatively cheap alternative fuel supplies. He believes that the large subsidies required for a gasohol program aren't justified by the small benefits that farmers (or any other economic interests) would receive.
- H. J. Klosterman, biochemistry professor at North Dakota State, says that the high energy requirements of mechanized, high-yield farming make it impractical to depend on agriculture to provide the energy needs of a technological society.

. . . or do you gain energy?

Btu per gal of ethanol[a]	Grain alcohol energy balance
Energy production	
Ethanol	75,600
Aldehydes, fusel oil	1,100
75% of stalks, cobs, husks	124,400
TOTAL	201,100
Energy consumption	
Farming operation	46,000
Transportation of stalks, etc.	1,200
Alcohol plant	108,000
TOTAL	155,200
Net energy production	45,900
Net loss in by-product production	18,200
Total net energy production	27,700

a 20 million gal-per-year plant, using 75% of field waste as fuel. Source: Dr. William A. Scheller, University of Nebraska

Gallon-equivalents of oil	Energy required to produce 10 gal of fuel: Gasohol case[a]	Gasoline case[b]
Crude oil refining	28.40	30.0
Corn production for feed	1.31	1.85
Corn production for alcohol	0.33	0.00
Petroleum energy	30.04	31.85
Alcohol plant	0.67	0.00
By-product operation[c]	0.45	0.00
Coal energy	1.12	0.00
Total energy consumption	31.16	31.85

a 1 gal grain alcohol and 9 gal unleaded gasoline. b Unleaded gasoline, enough to move a car as far as in the gasohol case. c Distillers dry grain. Source: Dr. William A. Scheller, University of Nebraska

• Iowa State's R. N. Wisner is concerned about the effects on animal feed prices if large amounts of distillers dry grain become available along with a gasohol program. Assuming a nationwide gasohol program, he says that there would be a "sharp, downward pressure" on prices of both distillers dry grain and soybeans.

What bothers Leonard W. Schruben the most are the subsidies that have been and are being proposed in state legislatures and in Washington, D.C. Schruben, a research economist at Kansas State University (and another outspoken "thorn in our side," according to some gasoholics), believes that subsidizing gasohol programs are the only way they'll work. In Kansas, at least, he doesn't like what this will mean to the highway fund. Bills under consideration there will grant to gasohol a 5-cent exemption from the state gasoline tax. At current consumption rates, this would divert as much as $70 million each year in state tax collections from highways to gasohol, says Schruben.

He figures each 20 million gal-per-year ethanol plant would require a $10 million annual tax subsidy for 20 years (Kendrick estimates $18 million). But what irks Schruben more than anything else is why gasohol proponents are even asking for subsidies when they claim that their grain alcohol plants can stand profitably on their own economic feet. Citing figures published by Nebraska's Agricultural Products Industrial Utilization Committee, Schruben wonders "how much tax-supported incentives are needed on top of already-generous profits described by promoters?"

Another incentive not mentioned in gasohol promotion literature, Schruben says, is the opportunity for an income tax shelter. He thinks that it's possible for a promoter in the 50% income tax bracket to net $15 million with virtually no risk.

To build his $30 million ethanol plant, this promoter could borrow $15 million under the USDA guaranteed loan program and float a revenue bond for another $15 million. At the end of five years, Schruben says, he could pocket—legally—$15 million without making a gallon of alcohol. "All he has to do," Schruben says, "is to admit that he failed. And that's no big deal."

Why does Schruben come on so strong? Probably because he, like many other land grant academics who have spoken out against gasohol, has been feeling the pressure from farmers, state politicians, and other gasoholics. "Pardon me for being cynical," says Schruben, "but I'm tired of being accused of selling out to the oil companies."

There's no avoiding oil companies in any energy-related issue. Gasohol is no exception. Oil companies have been accused in the press and on Capitol Hill of trying to sidetrack the gasohol steamroller. Some companies have been accused of launching a "cunning nationwide campaign" against gasohol and of pouring out "clumsy distortions of the truth."

There's no denying that the oil industry has been cranking out a lot of copy and speeches on gasohol. There's no enthusiastic support for gasohol in any of it. The arguments oil companies use aren't much different from those used by agricultural economists and other skeptics—poor economics, negative energy balance, potential distribution and operational problems, and not of much help to the farmer.

One oil company spokesman says that, contrary to some accusations, he isn't afraid of potential competition from gasohol. We've jumped into coal, he says. And we've jumped into nuclear. "I think we ought to be able to operate a fermentation plant if that's the way to go."

The American Petroleum Institute has been following gasohol for years. Now, it is beefing up its activities. Last November, it reconstituted its alcohol fuels task force. This year, it commissioned Battelle Columbus Laboratories, which has developed an expertise in the entire fuels-from-biomass program, to make an "outside, objective" analysis of alcohol fuels.

In April, API released its policy statement on alcohol fuels. In what gasoholics refer to as a "bland statement," API says that it favors developing all potential domestic energy sources, including alcohol fuels. It thinks that it's possible to reduce alcohol production costs and recommends more research.

What API and its member companies definitely do not want is for government—federal or state—to make the use of alcohol fuels mandatory. They prefer to leave the choice of fuels up to the market place.

Of all the oil companies, Mobil gets the biggest share of brickbats from gasoholics. To gasoholic purists, it makes no difference whether the alcohol is ethanol or methanol.

Generally, methanol is not considered as good a blending component as ethanol. It is toxic. It poses more problems with water contamination, and it has fewer Btu's than ethanol. But if methanol could be produced from coal for the 40 to 50 cents per gal that DOE estimates, it would be much less expensive than ethanol.

Mobil's sin is that it has a process to convert methanol directly into gasoline (C&EN, Jan. 30, page 26). John J. Wise, senior vice president of Mobil Research & Development Corp., calls it the "final link" between coal and gasoline.

Gasohol proponents don't think so. Washington-based gasoholic Richard Merritt notes that the process is only 50% energy-efficient "even if it can be made to work in large-scale plants." And he wonders why Mobil "wants to convert 4 gal of high-octane, low-pollution alcohol into 1.5 gal of polluting gasoline and 2.5 gal of water of dubious quality."

The gasohol debate spills easily over its own boundaries. Ethanol or methanol? Which source? Coal, grain, sugar, wood, or municipal wastes? And there are other possibilities. Shale oil, for instance.

Sorting out these alternatives is the problem facing DOE. To do it, the agency has several different programs under way. There's the alternative fuels utilization program in the transportation division. There also are fossil energy programs and a fuels-from-biomass program.

C&EN staff photo

Sen. Carl T. Curtis (R.-Neb.) speaking at AAA gasohol demonstration

In addition, it has an alcohol fuels program. In response to Congressional pressure, DOE added an "immediate action element" to this program, which calls for more studies and an "early" end-use demonstration.

The key assembly point and evaluation mechanism for a government decision to go commercial with any of the possible fuel options is DOE's supply strategy study. This is supposed to lead, by next January, to a decision on commercializing a nonpetroleum-based fuel. The immediate action element is the primary factor in making that decision as far as alcohol fuels are concerned.

This spring, DOE released a position paper on alcohol fuels. In it, the department says that there are no technological barriers facing alcohol fuels. There are, however, several major uncertainties—among them supply potential, production costs, best way to use the material, and the best way to produce it.

Many Congressional leaders, including some political heavyweights, are convinced that DOE is spinning its wheels on alcohol fuels and isn't taking gasohol seriously. Last October, 27 of them, including Sen. Birch Bayh, Sen. Herman Talmadge, Sen. Russell Long, Sen. Jacob Javits, Sen. Charles Percy, Sen. Curtis, and Sen. Frank Church, wrote a letter to Energy Secretary James R. Schlesinger and Agriculture Secretary Bob Bergland urging both departments to get moving on alcohol fuels.

Since then, DOE has set up an alcohol fuels task force, which produced the immediate action element and the DOE position paper. But this hasn't satisfied Sen. Bayh. He says that DOE has made "no discernible progress on alcohol fuels since the task force was formed."

Referring to the immediate action element at a meeting of the National Gasohol Commission in Washington, D.C., last month, Sen. Percy wondered what "immediate action" it had taken. "None," says Percy. "It will instead do more studies."

One study that Congressional gasoholics won't appreciate was recently completed for DOE. Its major conclusion: It is "premature" to implement an alcohol fuels program in the U.S.

The study was made by the Metrek division of Mitre Corp. Metrek staffer Wayne R. Park unveiled some of the results at last month's fuels-from-biomass symposium at Rensselaer Polytechnic Institute in Troy, N.Y.

The Metrek study assessed the near-term potential (to 1990) for a nationwide alcohol fuel program in the U.S. After 1990, Park says, the situation might change. Petroleum prices likely will continue to rise. And process improvements probably will lower costs of producing alcohols from biomass.

Even now, says Park, technology exists to produce biomass-based alcohols. It's also possible to convert fuel distribution networks and the cars themselves, if necessary, to an alcohol-blended fuel.

But the Metrek report says that it's impossible to build enough alcohol plants to support a national alcohol fuel program that uses a 10% ethanol blend. Even with a 5% blend, the country would have to produce 5.8 billion gal of ethanol per year in 1990 to meet gasohol demand. To do that, Park says, we would need 86 new plants, each with a nameplate capacity of 75.8 million gal per year.

Metrek's estimate is based on plants using raw sugar juice as feedstock. Most gasoholics think in terms of grain alcohol plants with capacities of 20 million gal. On that basis, 322 plants (operating at 90% of capacity) would be needed. Regardless, Metrek thinks that the cost would be the same—a whopping $10.9 billion.

Park says that, because alcohol costs won't enable gasohol to compete with gasoline, even by 1990, the government will have to make up the difference through some form of subsidy. Assuming that a 5% ethanol blend replaces all U.S. gasoline demand, Metrek estimates the government's tab at $6.9 billion. If a 10% blend replaced only half of domestic gasoline demand, the subsidy still would amount to $5.9 billion. These aren't one-shot figures. They are annual.

Gasohol advocates claim that an alcohol fuel program will reduce imported oil demand. If it does, it will be an expensive way to reduce imports, according to Metrek. The company's study assumes that imported oil will cost $18.44 per bbl in 1990 (1976 dollars). But if a gasohol program with a 5% ethanol blend were adopted nationwide, Park says that it would cost an additional $79 per bbl for each barrel of imported oil that the gasohol replaces.

With a 10% ethanol blend, the additional cost per barrel of replacing imports drops to $67. But that's still expensive oil. Besides, Metrek figures that it will reduce oil imports in 1990 only 68 million to 88 million bbl. That's only 2 to 2.8% of last year's oil import total.

With data such as these in its pocket, DOE's go-slow approach to weighing its alternate energy options might be understandable. But not, apparently, on Capitol Hill.

At last month's National Gasohol Commission meeting, Sen. Curtis said that the federal government must stop dragging its feet and begin supporting gasohol. Sen. Curtis, along with many of his colleagues, isn't particularly pleased with USDA, either.

Curtis wants USDA to move faster on the federal loan guarantee program ($60 million) for four pilot projects that it is administering under the Food & Agricultural Act of 1977. And he doesn't like some of the guidelines USDA has drawn up requiring a plant to be economically viable and show a positive net energy balance.

Curtis calls this a catch-22 situation. "Only by allowing such plants to get off the ground will we be in a position to improve alcohol production technology," he says. "If an applicant could provide the type of assurances USDA is requesting, there would be no need for a pilot plant in the first place."

USDA probably lost a few friends on Capitol Hill earlier this year when it published a report called "Gasohol from Grain—The Economic Issues." Among its conclusions: A national gasohol program (10 billion gal of ethanol blended with 90 billion gal of gasoline) would require a subsidy of 10.4 cents per gallon of gasohol. That's $10.4 billion annually.

For each Btu invested in growing and processing corn, USDA says only 0.5 to 0.8 Btu is recovered in the ethanol. Grain production would have to rise substantially, with some acreage diverted from soybeans and wheat. Prices of food and feed grains would rise sharply.

USDA warns that the 35 million tons of by-product distillers dry grain would depress soybean oil meal prices. The soybean crushing industry would just about be knocked out. Soybeans would be left with only food oil and export markets. In addition, USDA believes that livestock production would drop and that consumer food prices would increase. After all of this, concludes USDA, net farm income would go up only slightly.

Despite predictions such as these, politicians are jumping on the gasohol bandwagon. The Senate Republican Conference has endorsed alcohol fuels. Last year, the National Democratic Committee passed a resolution urging President Carter to launch a federal starch conversion program "in the same fashion that President Kennedy launched the space program."

Meanwhile, gasohol-related bills are pouring into the Congressional hopper. Most of them provide subsidies, in the form of exemption from the federal gasoline tax or by allowing rapid (five-year) plant amortization.

Sen. Bayh has introduced a bill (S. 2400) to establish a National Alcohol Fuels Commission to study the problem, advise Congress, and coordinate gasohol efforts. Sen. Church's bill (S. 2533) would make gasohol mandatory, starting with an average 1% ethanol content in 1981 and rising to 10% by 1990. Hearings on this proposal are scheduled for Aug. 8 and 9. Sen. Percy wants to establish a federal gasohol test fleet.

The prospects of federal subsidies don't seem to faze Congressional gasoholics. Sen. Bayh says that the government has been more than generous to the oil companies, with their import quotas, their depletion allowance, and foreign tax credits. Rep. Lee H. Hamilton (D.-Ind.) believes Congress will have to take an aggressive role as a "private sector catalyst."

Through all this smoke on the gasohol battlefield, chemical companies are trying to figure out just what it all means to them. It could mean plenty.

Midwest Solvents' Cray thinks that fermentation ethanol eventually could replace synthetic ethanol from ethylene in industrial markets. So does Scheller, and it's probably the only thing that the two agree on.

Any technological fallout that comes from the gasohol push will help make fermentation ethanol more competitive with its synthetic counterpart. Grain alcohol producers would welcome a better shot at the industrial market, which was about 215 million gal last year. The industry now is operating at only 75% of capacity.

Some grain alcohol already competes with synthetic ethanol in industrial markets. Grain alcohol producers would like more of the market. The big question is: How low will synthetic producers set their price to ward off this competition?

Gasoholics won't be content if their fermentation alcohol goes only to industrial markets. Nor will they be content to watch it go only to gas turbine peaking units or industrial boilers as some suggest.

They want it in gasohol—nationwide. Accomplishing that is no small task. Supporting them is a long, worldwide history proving that it works, an energy problem and a farm problem that must be solved, promising new technology, and a lot of political muscle. Working against them are the pesky problems of economics and energy balance.

At the recent Bonn economic summit, President Carter pledged to reduce U.S. oil imports. Gasoholics are certain to remind him that gasohol may be one way to do it.

Dr. Gary Shults, a research engineer with Continental Oil Co., is a gasohol supporter within the oil industry's own ranks. He says, "Look at it this way. We can buy imported oil or we can use what we have. It may not be as efficient, but it's Btu's that we have vs. Btu's that we don't have." □

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August 2, 1978

COMMON SENSE SUGGESTIONS AS TO HOW EXISTING AGRICULTURAL SUBSIDIES COULD HELP PRODUCE ALTERNATIVE LIQUID FUELS COMPETITIVE IN PRICE WITH PETROLEUM.

The production of ethanol as an extender for liquid fuel supplies has been held up by a series of misconceptions propagated by interested parties. I am talking about a mixture of ethanol and gasoline containing 10-20 percent ethanol, not about engines fueled with pure ethanol, nor am I talking about methanol. Technical people often deliberately confuse these categories for reasons of their own. Many arguments opposing gasohol (the name coined by the State of Nebraska for 10% ethanol - 90% gasoline mixture) confuse the issue.

The arguments boil down to two questions: (1) economics and (2) the energy balance.

Let us deal first with the technical question - the energy output - energy input ratio: Does the manufacture of ethanol from agricultural products result in a positive energy balance?

At present the battle surrounding this topic is fought with arguments in terms of BTU per gallon. This is a measure for heating value, but <u>not</u> of the effectiveness of fuel in a motor-vehicle engine. Ethanol does, indeed, have only about two thirds the

BTU/gallon value of gasoline; when used in output/input ratio calculations unfavorable energy balances are brought about.

However, the debaters do not try to quantify such empirical findings as:

(1) that the octane rating of a 10% ethanol - 90% gasoline mixture increases by 4 points as compared with gasoline;

(2) that there is an increase in volume of the mixture as compared with the components, and

(3) that the efficiency as a fuel increases in miles per gallon and in miles per BTU when compared with unleaded gasoline.

Furthermore, road tests in this country and elsewhere performed with 10% ethanol - 90% gasoline mixtures, as well as the use of ethanol contents of up to 20% (according to Brazilian literature), and ethanol contents of up to 30% (according to Volkswagen literature), show that adjustments of the engine are not required: the mixture is interchangeable with pure gasoline.

Accordingly, we can say that the ethanol as part of a mixture is <u>at least as effective as gasoline in terms of use as a motor-vehicle fuel</u>.

Our argument therefore is that if one uses BTU/gallon as a measure in energy balance studies, one should use at least the BTU value of the gasoline that has been saved in the ethanol-gasoline mixture, instead of the BTU value of ethanol which is, in fact, <u>irrelevant</u> to the intended use of the ethanol. Hence an empirical utility factor equal to about 1.5 should be used as a multiplier in the conventional output/input energy ratios.

This approach would prove that the use of automotive-fuel-ethanol presents a favorable energy balance.

Reverting to the question of economics the disregard of reality is even more amazing. Much is being said about the need of the land for food production, with the implication that there is just no resource base for the production of alcohol, and if produced the ethanol would cost somewhere around $1.20/gallon, which is much too high compared with the cost of gasoline.

The facts, however, are that in our country this year 24 million acres of farm-land are being subsidized not to produce grains and cotton but, in order to support prices.

Moreover, similar situations are doubtless going to prevail in the foreseeable future.

The exact subsidies for part of this land are not available at the present time as they are based on guaranteed minimum prices, but for 7 million acres of the so called "diversion" program we calculated a weighted average of direct subsidy for non production of $126.37 per acre. This money, though already committed to the support of existing farm policy, could become help in the manufacture of alcohol.

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One gets 234 gallons of anhydrous ethanol per acre of corn and can receive a subsidy of 54 cents per gallon of ethanol; the price of a gallon of ethanol could be reduced further by readjusting the price paid to the farmer per bushel of corn in order to take into consideration that the additional production of corn has been approved after the fact that his capital investment in land and machinery has already been secured by the original minimum target price policy.

When it is agreed that the price of a bushel of corn geared to fuel production could be lower than corn priced for the non-fuel market, one can produce ethanol for between 27-45 cents/gallon as shown in the attached calculations.

The 7 million acres mentioned here could produce 1.65 billion gallons of fuel ethanol which could provide over 1.5% of the yearly need for gasoline and save about $1.3 billion in oil imports.

We believe that when considering all agricultural facts a resource base of over 30 million acres and a subsidy of somewhere between 40-45 cents/gallon could become available to supply about 8 percent of the country's present need for gasoline.

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NEWS
U.S. DEPARTMENT OF AGRICULTURE

FINAL WEEKLY 1978 SIGNUP REPORT SHOWS 1,186,143 FARMS ENROLLED:

WASHINGTON, June 21--The ninth and final weekly signup report for the 1978 cotton, feed grain and wheat programs shows 1,186,143 farms enrolled, or 51.0 percent of the 2,325,109 eligible. The signed up farms have 203,946,387 acres (72.3 percent) of the nation's total eligible normal crop acreage (282,135,388 acres), according to Ray Fitzgerald, administrator of the Agricultural Stabilization and Conservation Service (ASCS).

The participating farms intend to plant 50,326,980 acres of wheat and 69,649,667 acres of feed grains for a total of 119,976,647 acres. The feed grain total includes 7,690,695 acres of barley, 49,500,716 acres of corn and 12,458,256 acres of sorghum. Cropland designated as set-aside by the signed farms totals 17,030,363 acres, including 10,065,396 acres under the wheat program and 6,964,967 acres under the feed grain program.

Additional acreage to be diverted by the participating farms includes 545,305 acres under the cotton program and 5,136,741 acres under the feed grain program. The farms plan to graze or cut for hay 1,354,428 acres of wheat.

Participation in the set-aside program is voluntary. However nonparticipants are not eligible for price support loans, disaster payments or deficiency (target price) payments. While farmers needed to signup and comply with set-aside provisions to be eligible for program benefits, they will not be held to the intentions they provided ASCS during the signup period. Final figures will be available after farmers have "certified" their acreage later in the year. Signup began March 1 and ended May 31.

Tables showing state participation in the set-aside programs for the period March 1 through June 15 are on pages 2, 3 and 4.

STATE	NUMBER OF FARMS SIGNED UP	INTENDED PLANTED ACREAGE ON PARTICIPATING FARMS WHEAT	FEED GRAINS
ALABAMA	31,401	29,935.8	337,390.5
ARIZONA	705	16,412.5	41,333.5
ARKANSAS	12,344	81,160.2	87,678.7
CALIFORNIA	2,738	168,106.5	285,989.8
COLORADO	16,454	2,605,953.6	1,172,458.5
CONNECTICUT	477	12.5	10,404.1
DELAWARE	772	3,921.7	52,857.1
FLORIDA	2,980	2,414.1	161,536.7
GEORGIA	20,161	53,353.4	1,029,579.8
IDAHO	11,372	1,130,322.2	841,260.6
ILLINOIS	99,732	609,237.7	7,226,630.9
INDIANA	47,383	311,237.6	3,124,422.4
IOWA	93,451	20,992.0	8,320,558.9
KANSAS	103,461	9,404,767.5	5,402,512.3
KENTUCKY	12,529	35,319.4	513,656.4
LOUISIANA	960	8,388.8	31,786.8
MAINE	1,008	243.5	22,410.7
MARYLAND	3,373	48,976.0	249,542.0
MASSACHUSETTS	66	0.0	5,108.4
MICHIGAN	36,906	231,028.9	1,805,365.0
MINNESOTA	72,495	2,390,109.0	5,666,775.0
MISSISSIPPI	5,583	30,361.8	90,791.5
MISSOURI	54,427	628,304.4	3,043,103.4
MONTANA	17,586	4,512,064.6	1,284,444.8
NEBRASKA	71,855	2,339,170.0	7,370,677.0
NEVADA	260	18,870.8	23,568.4
NEW HAMPSHIRE	422	0.0	9,448.6
NEW JERSEY	760	6,481.3	39,850.3
NEW MEXICO	5,039	500,741.1	391,437.4
NEW YORK	13,926	45,455.0	732,125.1
NO. CAROLINA	20,871	37,174.5	578,728.9
NORTH DAKOTA	59,718	9,415,005.0	3,320,397.0
OHIO	48,670	573,437.2	2,075,827.0
OKLAHOMA	49,618	4,699,171.0	723,060.0
OREGON	5,595	932,096.9	187,756.3
PENNSYLVANIA	13,521	48,838.6	401,087.0
RHODE ISLAND	9	23.3	268.2
SO. CAROLINA	11,193	25,063.4	321,150.6
SOUTH DAKOTA	48,395	3,480,577.0	3,779,948.0
TENNESSEE	18,947	60,016.1	298,082.6
TEXAS	102,697	3,539,037.7	5,500,386.5
UTAH	3,858	226,214.1	123,554.9
VERMONT	369	75.0	14,147.9
VIRGINIA	13,770	48,615.6	416,096.8
WASHINGTON	8,632	1,741,602.1	267,627.2
WEST VIRGINIA	1,029	1,486.2	28,555.2
WISCONSIN	36,171	19,915.0	2,137,417.0
WYOMING	2,454	245,290.2	100,321.1
US TOTAL	1,186,143	50,326,979.9	69,649,666.8

ACREAGE INTENDED TO BE SET-ASIDE

STATE	WHEAT	BARLEY	CORN	SORGHUM	TOTAL FEED GRAINS
ALABAMA	5,987.2	71.3	32,179.9	1,488.9	33,739.1
ARIZONA	3,282.5	698.3	2,370.1	1,119.9	4,188.4
ARKANSAS	16,232.0	25.5	572.1	8,170.3	8,767.9
CALIFORNIA	33,621.3	21,986.5	5,018.4	1,594.1	28,599.0
COLORADO	521,190.7	13,913.3	60,595.3	42,737.3	117,245.9
CONNECTICUT	2.5	0.0	1,040.4	0.0	1,040.4
DELAWARE	784.3	1,054.5	4,231.2	0.0	5,285.7
FLORIDA	482.8	1.5	15,083.7	1,068.5	16,153.7
GEORGIA	10,670.7	787.5	99,453.6	2,716.9	102,958.0
IDAHO	226,064.4	80,547.3	3,571.9	6.9	84,126.1
ILLINOIS	121,847.5	184.8	718,512.4	3,965.9	722,663.1
INDIANA	62,247.5	125.0	311,932.8	384.4	312,442.3
IOWA	4,198.4	67.3	830,590.5	1,398.1	832,055.9
KANSAS	1,880,953.5	3,815.8	157,819.9	378,615.5	540,251.3
KENTUCKY	7,063.9	272.7	50,167.4	925.6	51,365.7
LOUISIANA	1,677.8	0.0	1,604.6	1,574.1	3,178.7
MAINE	48.7	6.8	2,226.6	7.7	2,241.1
MARYLAND	9,795.2	3,631.0	21,211.9	111.3	24,954.2
MASSACHUSETTS	0.0	0.0	508.7	2.1	510.9
MICHIGAN	46,205.6	1,050.5	179,389.2	96.8	180,536.5
MINNESOTA	478,021.8	99,187.3	466,807.3	682.4	566,677.5
MISSISSIPPI	6,072.4	0.0	6,903.1	2,176.0	9,079.2
MISSOURI	125,660.9	347.7	232,001.1	71,961.6	304,310.4
MONTANA	902,412.9	122,026.2	6,408.3	10.0	128,444.5
NEBRASKA	467,834.0	2,266.7	567,071.4	167,729.6	737,067.7
NEVADA	3,774.2	2,108.7	126.3	121.9	2,356.9
NEW HAMPSHIRE	0.0	0.0	944.9	0.0	944.9
NEW JERSEY	1,296.3	410.1	3,544.0	30.9	3,985.1
NEW MEXICO	100,148.2	2,774.4	4,213.2	32,156.2	39,143.8
NEW YORK	9,091.0	349.7	72,856.7	6.1	73,212.5
NO. CAROLINA	7,434.9	1,263.8	53,961.6	2,647.6	57,872.9
NORTH DAKOTA	1,883,001.0	272,075.3	59,831.8	131.6	332,039.7
OHIO	114,687.4	218.8	207,321.6	42.3	207,582.7
OKLAHOMA	939,834.2	4,949.3	6,560.4	60,796.3	72,306.0
OREGON	186,419.4	17,231.1	1,543.9	0.7	18,775.7
PENNSYLVANIA	9,767.7	1,785.6	38,113.2	209.9	40,108.7
RHODE ISLAND	4.7	0.0	26.8	0.0	26.8
SO. CAROLINA	5,012.7	811.1	30,525.3	778.7	32,115.1
SOUTH DAKOTA	696,115.4	60,351.4	287,385.7	30,257.7	377,994.8
TENNESSEE	12,003.2	125.0	27,358.0	2,325.3	29,808.3
TEXAS	707,807.5	6,370.5	116,651.3	427,016.9	550,038.7
UTAH	45,242.8	9,412.8	2,912.7	29.9	12,355.5
VERMONT	15.0	0.0	1,414.8	0.0	1,414.8
VIRGINIA	9,723.1	4,688.5	36,279.0	642.1	41,609.7
WASHINGTON	348,320.4	24,140.7	2,610.1	11.9	26,762.7
WEST VIRGINIA	297.2	120.2	2,732.8	2.6	2,855.5
WISCONSIN	3,983.0	1,451.3	212,255.0	35.4	213,741.7
WYOMING	49,058.0	6,362.3	3,632.0	37.8	10,032.1
US TOTAL	10,065,396.0	769,069.5	4,950,071.6	1,245,825.6	6,964,966.7

. . . . ADDITIONAL DIVERSION. . . . .

STATE	BARLEY	CORN	SORGHUM	TOTAL FEED GRAINS	COTTON	WHEAT ACREAGE GRAZED OR HAYED
ALABAMA	2.0	16,916.3	259.1	17,177.4	21,244.6	2,425.9
ARIZONA	308.6	1,327.5	602.3	2,238.4	13,229.6	240.3
ARKANSAS	1.8	387.7	1,704.3	2,093.8	38,629.7	1,409.3
CALIFORNIA	7,888.0	2,187.2	795.6	10,870.8	24,982.9	5,183.2
COLORADO	3,426.5	46,256.7	14,749.1	64,432.3	0.0	47,473.5
CONNECTICUT	0.0	434.5	0.0	434.5	0.0	0.0
DELAWARE	59.3	4,313.8	0.0	4,373.1	0.0	67.0
FLORIDA	0.0	11,791.2	651.9	12,443.1	176.9	162.8
GEORGIA	64.7	74,255.4	594.7	74,914.8	8,421.8	2,924.7
IDAHO	19,955.6	668.6	0.0	20,624.2	0.0	17,506.0
ILLINOIS	67.2	651,756.2	2,283.5	654,106.9	0.0	4,096.4
INDIANA	42.4	299,096.3	247.9	299,386.6	0.0	1,294.8
IOWA	51.2	803,858.5	980.8	804,890.5	0.0	605.3
KANSAS	143.8	104,307.5	116,491.7	220,943.0	0.0	115,914.3
KENTUCKY	120.1	44,727.0	1,769.9	46,617.0	21.5	7,195.3
LOUISIANA	0.0	700.9	286.7	987.6	25,273.7	804.6
MAINE	7.0	947.6	0.5	955.1	0.0	0.0
MARYLAND	3,002.0	16,747.0	15.0	19,765.0	0.0	410.0
MASSACHUSETTS	0.0	499.2	2.1	501.3	0.0	0.0
MICHIGAN	567.0	160,256.0	38.0	160,861.0	0.0	896.0
MINNESOTA	49,025.0	421,085.0	333.0	470,443.0	0.0	5,039.0
MISSISSIPPI	0.0	4,729.1	536.1	5,265.2	89,747.9	1,497.9
MISSOURI	45.8	203,697.8	40,046.7	243,790.3	7,179.7	20,318.9
MONTANA	26,414.2	902.2	0.0	27,316.4	0.0	26,689.4
NEBRASKA	495.0	504,687.0	93,041.0	598,223.0	0.0	11,616.0
NEVADA	608.8	77.0	44.0	729.8	0.0	2,339.3
NEW HAMPSHIRE	0.0	788.3	0.0	788.3	0.0	0.0
NEW JERSEY	76.5	4,793.4	7.0	4,876.9	0.0	24.0
NEW MEXICO	1,067.4	7,160.3	16,352.3	24,580.0	19,270.5	44,966.1
NEW YORK	124.8	67,920.7	5.2	68,050.7	0.0	292.3
NO. CAROLINA	180.1	41,613.1	267.4	42,060.6	4,102.7	2,741.3
NORTH DAKOTA	119,819.0	44,738.0	56.0	164,613.0	0.0	7,474.0
OHIO	79.4	154,334.0	16.6	154,430.0	0.0	1,189.0
OKLAHOMA	359.0	3,831.0	26,303.0	30,493.0	8,927.0	550,983.0
OREGON	2,995.2	160.7	0.0	3,155.9	0.0	2,687.0
PENNSYLVANIA	1,012.4	31,531.7	94.8	32,638.9	0.0	673.1
RHODE ISLAND	0.0	27.0	0.0	27.0	0.0	23.3
SO. CAROLINA	75.1	18,651.9	215.9	18,942.9	8,562.8	1,392.2
SOUTH DAKOTA	38,619.0	264,737.0	10,880.0	314,236.0	0.0	51,702.0
TENNESSEE	51.7	17,366.4	271.7	17,689.8	17,173.6	6,677.8
TEXAS	1,059.3	82,796.1	171,716.4	255,571.8	258,323.3	395,887.8
UTAH	1,797.3	745.1	72.0	2,614.4	0.0	2,415.4
VERMONT	0.0	963.9	0.0	963.9	0.0	0.0
VIRGINIA	539.4	25,357.3	126.8	26,023.5	36.0	3,450.8
WASHINGTON	1,309.6	323.3	0.0	1,632.9	0.0	2,152.5
WEST VIRGINIA	36.9	2,015.3	1.0	2,053.2	0.0	158.4
WISCONSIN	807.0	203,300.0	30.0	204,137.0	0.0	292.0
WYOMING	1,252.9	1,513.4	10.4	2,776.7	0.0	3,226.0
US TOTAL	283,558.0	4,351,281.1	501,901.4	5,136,740.5	545,305.1	1,354,427.8

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Attachment:

CALCULATIONS LINKING FARM POLICY TO ENERGY POLICY.

Dr. Lipinsky, working for the Department of Energy at Battelle's Columbus Laboratories, has published the following data on the cost in dollars per gallon of ethyl alcohol (ethanol) produced from grain:

the primary ingredient (corn at $2.50/bushel)	-	$ 0.89
conversion cost	-	0.44
annualized capital charge	-	0.20
byproduct credit (mainly for cattle feed)	-	(0.36)
net cost per gallon		$ 1.17

It seems therefore that the major expense is the price of the primary ingredient and when trying to reduce the cost of alcohol it is not enough to try to find technological improvements, but rather it is imperative to understand how one can achieve lower figures for the component of the primary ingredient.

The Carter Administration Agricultural Initiatives, and the Emergency Agricultural Act of 1978 approved by both houses of Congress May 1, 1978, have designed a situation of "set-aside of croplands" and "diversion of croplands" so that governmental subsidies for non production on a percentage of our farm lands will help decrease supply to support the price of farm products. Farmers can join these programs when agreeing voluntarily to let fallow 10% of their usual acreages in feed grains (corn, barley and grain sorghum) and 20% of their usual wheat acreage. The farmers will then benefit from guaranteed minimum target prices for their products, from a subsidized Farmer-Owned Grain-Reserve, and from loans. The farmers that have agreed to this program could then choose to increase the non producing lands beyond the minimum requirement and receive direct payments (subsidies) for the additional acreage. This secondary program is called the "diversion" program . While in the first program the exact amount of the subsidies is dependent on the market price at harvest time, the acreage involved in the diversion program allows for calculations at the present time.

According to the U.S. Department of Agriculture News of June 21, 1978, the acreage pulled out of production this year is over 24 million acres of which 7 million acres are in the "diversion" program. Our calculations will deal hereforth with those 7 million acres as follows:

When a producer decreases his feed-grain acreage by an additional ten percent he will receive a payment of 20 cents per bushel of corn or 12 cents per bushel of sorghum or barley on the normal production from the remaining 80 percent of his planted acres. Considering that the 1977/78 average yield of corn was 90.8 bushel/acre, the yield of grain soghum was 56 bushels/acre, and barley 44 bushels/acre the diversion program translates into the Government directly paying $163.4 per diverted acre that has produced last year corn, or $60.5 per diverted acre that has produced grain-sorghum and $47.5 per diverted acre that has produced barley. Similarly when a Producer decreases his wheat acreage by an additional 20 percent (e.g. by grazing the wheat-land) he receives 50 cents/bushel). At last year's average of 30.6 bushels of wheat per acre this translates to a direct payment of $61.2 per diverted acre. In addition to the feed grain and wheat programs the "diversion program" includes also a cotton acreage program according to which if the farmer "diverts" 10 percent of the acres planted last year he will receive 2 cents per pound on the normal production from planted acres and this translates to a payment of $94.3 per non-producing acre.

The weighted average payment per acre for the 7 million acres of "diverted" land using the data per acre as calculated here, and the appropriate acreage as published in U.S.D.A. News of

June 21, 1978, is a minimum of $126.37 - direct subsidy for non-production per average acre.

Let us assume that this land is used to plant corn. One gets 2.6 gallons of anhydrous ethanol, 200 proof, per bushel of corn or 234 gallons per acre. If the negative subsidy for non-production is now converted into a positive subsidy for the production of alcohol this would mean that 54 cents become available for the subsidization of a gallon of alcoholwithout involving any new expenditures in term of new subsidies.

Substracting 54 cents from $1.17, the cost of a gallon of ethanol as calculated by Dr. Lipinsky, leaves us with the cost of a gallon of alcohol of 63 cents assuming that we have paid $2.50/bushel of corn.

Furthermore, the Administration's policies in support of the farmers income have already guaranteed the farmers expenses for land and machinery, and the $2.50/bushel of corn is thus exagerated when considering a crop grown on our "diverted" land. The price of corn for the production of alcohol could be as low as $1/bushel corn, a value that does not seem unreasonable under our conditions since the cost of seeds and fertilizers amounted in 1977 to 22.7 cents/bushel, and keeping land fallow has its expenses too, as land preservation requires that it be covered with some plantation anyway.

A $1/bushel corn could produce a 10 cents/gallon ethanol. A $1.50/bushel corn will result in 27 cent/gallon ethanol, and a $2.00/bushel corn will result in a 45 cents/gallon ethanol. Any of these values produces ethanol that is highly competitive with gasoline from imported crude oil and it seems that alcohol distilleries should be planned as part of a joint - Agricultural and Energy - National Policy.

We believe that when the agricultural facts will be available in the fall, a somewhat similar analysis will apply to all the 24 million acres involved. Furthermore, the original Senator Talmadge proposal for an Agricultural Emergency Bill involved 31 million acres and a flat subsidy of $75/acre and was considered not to include subsidies high enough in order to achieve the farm price support. This program would have translated to a production program making available 32 cents/gallon of ethanol. Our belief is that when a resource base of over 30 million acres is considered a subsidy of somewhere about 40-45 cents/gallon could become available, 8 billion gallons of fuel ethanol could be produced for less than 40 cents/gallon, enough to supply about 8 percent of the need for gasoline with a saving of about $6.3 billion from the present import of oil.

Department of Energy
Washington, D.C. 20545

AUG 18 1978

Mr. Pincas Jawetz
425 East 72 Street
New York, New York 10021

Dear Pincas:

I have reviewed the information which you presented at the recent Senate hearings on Senator Church's alcohol fuels bill.

Certainly the information which you presented is pertinent. However, I believe that considerations of your information must be applied in context, and I'm not sure that what you suggest is any better or any worse than other approaches. Further, I must caution that some of the material is quite general and therefore must be used with caution.

First, I'll address the energy aspect. It is difficult to quantify the benefit of octane. Octane of itself provides no fuel economy since it is by definition a measure of anti-knock quality. In order to quantify this one needs to assess the impact on refinery operations with regard to at least economics and energy. This first requires enough technical data on chemical/petroleum characteristics to be able to adjust fuel compositions. Our work is at a point where we expect to assess the refinery impacts of alcohol fuels in FY 1979, but are probably about 18 months from having meaningful answers.

The increase in volume in the mixture is small and in essence is accounted for in the fuel economy figures.

The miles per Btu do increase, but the miles per gallon do not if applied to gasoline on a one-to-one basis. Our report on Comparative Automotive Engine Operation When Fueled with Ethanol and Methanol explains this. Field performance will give a wide variety of results, and there is a tendency for alcohol proponents to accept the best and ignore the others. Alcohols are good fuels, but we have to accept the facts.

Your statement, "that adjustments of the engine are not required" is true, but only if we are willing to accept the results. Anytime one retunes an engine, the results change--performance, fuel economy and emissions. This may or may not be noticable, but certainly is measurable. With the exception that alcohol/gasoline blends may (not necessarily will) run leaner than gasoline, any results obtained with alcohol blends can be achieved with gasoline by retuning the engine. The consequences of such are generally predictable. EPA is sufficiently concerned with emissions that they are moving to prevent adjusting gasoline engine tuning.

Whether or not it is valid to ignore Btus is dependent on framing and defining the assessment to be made. Our feasibility studies on alternative fuels, for example, assessed 9-10 various categories which can not be inter-related on a purely quantitative basis. With regard to your remarks, I will buy 1.3-1.35 as a utility factor as you describe it, but not the 1.5 you suggest. My number is judgemental based on fuel economy results in work done by the experts. There is some synergism that overcomes much of the Btu deficiency in a blend. Now, this leads into the system being assessed. Net energy is typically assessed on a Btu-in/Btu-out basis for good reasons, including the fact that one fuel can be compared to another. Btus are pertinent to combustion and work, regardless of fuel. If you want to look at the system from resource through propulsion, you can conceivably use some other input/output parameters. The benefits from the alcohol are derived because of the cooling of the air/fuel charge into the cylinder and to the change in air/fuel ratio. The former is in a loose sense similar to supercharging an engine and relates to what is called volumetric efficiency. The latter relates to the fact that at leaner mixtures (achievable through tuning regardless of fuel) there is less thermal loss in the system and the thermal efficiency increases.

Now the question is whether one takes credit for this in the vehicle system or applies it to processing. It is a total system improvement, but it really is a vehicle factor. The system aspect is very important, and the attached graph from our Alternative Fuels Program Plan shows how this can materially influence results. It is the driving force behind much of our work. Even so, it must be taken in context because it is simplistic and can quickly lead to extensive debate once one gets beyond the generalities.

To put net energy of ethanol in perspective one needs to apply it to selected scenarios. One would be using surpluses to produce fuel, accepting the fact that the energy for crop production was written off. Another is to determine the true savings in fuel if land is put into production that is not used now. Even if only 0.8 unit of fuel is used to produce one unit, it means that for every unit of petroleum replaced 5 units of replacement must be provided. It is important that we ascertain all the process savings that can be made to provide as much benefit as is possible, but it has to take much more land than people calculate in order to do the job.

I will not comment on the subsidy matters as others have more expertise in that than I do. However, when I ran through the calculations on the set-aside benefits my results were at variance with and lower than yours. Also, from a practical marketing viewpoint I can not buy the idea of two widely divergent prices for crops for food and for fuel. My sensitized reactions based on substantial marketing/sales experience rejects the possibilities of that occuring. I might add that much of my activities were of a dynamic, pioneering type which must be classed as highly positive and successful. I must also add that in achieving many difficult goals, I was only able to do so by recognizing the facts and limitations imposed while capitalizing on the true benefits.

Sincerely,

E E Ecklund

E. Eugene Ecklund, Chief
Alternative Fuels Branch
Office of Highway Systems
Division of Transportation
Energy Conservation
Office of Assistant Secretary
Conservation and Solar Applications

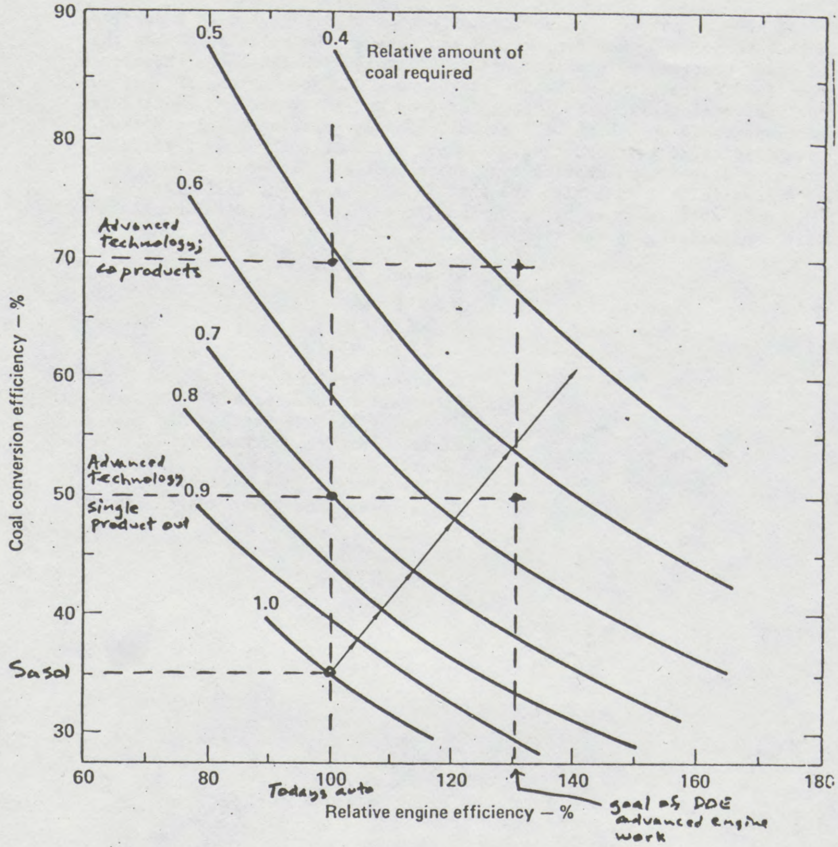

Figure 4.2. Relative resource requirements for fuel/engine systems based on coal liquids (27).

Pincas Jawetz
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Mr. Eugene Ecklund
Chief, Alternative Fuels Branch
Division of Transportation Energy Conservation
Office of Assistant Secretary Conservation
and Solar Applications
Department of Energy
Washington D.C. 20545

September 4, 1978

Dear Mr. Ecklund,

I have appreciated very much receiving your comments on my testimony before Senator Church and the Subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources.

For the record I would like to mention that your letter to me was the first reaction I have ever received from the Department of Energy on my several logical proposals on the subject of National Policy. To give you an illustration of my bitterness, I will just mention that the Assistant Secretary for Policy and Evaluation, when refusing to meet with me, has even given me the wrong information about who handles in the Department the subject of discussion.

Now getting to the point of our correspondence.

As I have proposed before the Committee, the problems with ethanol-gasoline mixtures revolve around two topics (a) the energy balance (b) economics. My argument is that on both these questions answers that will lead to an ethanol-for-fuel industry can be found if a novel constructive look is taken.

Your concern is basically with the question of the energy balance, while you make only short comments on the question of economics. As such, I will deal here first with the question of economics and then, more at length, with the question of the energy balance.

In what regards farm policy, the size of the Administration's subsidy for non-production in the basic "set-aside" program and in the land "diversion" program, all my numbers are taken from official documents of the U.S. Department of Agriculture.

U.S.D.A. News of June 21, 1978 - the final signup report of 1978 - that I have submitted to be included in the record of the hearings,-shows exactly that 17,030,363 acres were included in the basic set-aside program and 7,035,474 acres in the land diversion program. The acreage "diverted" includes 5,136,741 acres under the feed grain program (corn, barley, sorghum), 1,354,428 acres under the wheat grazing program (the use of cut hay is allowed on part of this land), and 545,305 acres under the cotton program. To be specific my calculations were based on seven million acres of the diversion program.

The weighted average of direct subsidy for non production, as submitted by me before the Committee was $126.37 per acre. This number is based on the average yields per acre according to the 1977 crops. As you know, this year's bumper crops are going to dwarf last year's yields, and I expect now that the subsidy per acre will be larger and probably about $133 per acre.

All this just to tell you that my economical calculations were not too high but indeed may turn out to be too low.

Now to the more important question of the energy balance.

With due respect I would like to refer you to my opening statement: "I am talking about a mixture of ethanol and gasoline containing 10 to 20 percent ethanol, not about engines fueled with pure ethanol, nor am I talking about methanol." The attachment to your letter - "Relative resource requirements for fuel/engine systems based on coal liquids", based on Sasol technologies and on Advanced technologies, is not germane to my presentation.

I do reject off hand any reference to methanol: (1) because of the inherent differences in properties between methanol and ethanol - and as you know ethanol is the better fuel between the two, and (2) because of the fact that my presentation tries to take advantage of a very definite and unbelievable lapse in our farm policy, the correction of which could make possible the production of ethanol via fermentation.

When talking about the substitution of 10% ethanol for 10% gasoline in a 10% ethanol-90% gasoline mixture, I assume that all the differences between the properties of the mixed fuel and the 100% gasoline fuel are credited to the ethanol fraction of the mixture. As such, the total difference in properties between a gallon of ethanol and a gallon of gasoline is equal ten times the difference between a gallon of mixture and a gallon of gasoline. All this obviously only if we define the production of a 10% ethanol-90%gasoline mixture as the sole objective for the production of ethanol at first place.

Having said this, I regard the motor-vehicle engine as the only arbiter for the use of ethanol. I am talking empirical science and when doing so I reject at this stage any theoretical explinations as interference with the facts. I would go even so far as to say that my own arguments (1) the increase in octane rating, (2) the positive change of volume of mixing, and (3) the increase of miles per BTU, are an impediment to the main argument.

My only intention when bringing up those points was to hint, as an applied physical-chemist is supposed to do, at possible physico-chemical explanations to the improved performance. A 0.5% increase in the volume per gallon could be translated to a 5% gain per gallon of ethanol, and an improved octane rating indirectly also causes fuel economy to the driver.

The only true argument is the measurement of miles per gallon under identical conditions optimized for better all around performance (i.e. power, emission, noise etc.).

Having said this, I am not interested in the attempts of the refiner in improving the octane rating of unleaded gasoline. The Division of Petroleum Chemistry of the American Chemical Society is going to have three sessions on "Octane in the eighties" at the 176th National Meeting, Miami Beach, September 13-14, 1978. My suggestion would be simply - if you can decrease the need to use lead compounds by introducing ethanol, why should then one worry about changes in refinery operations? My approach would require 2-3 months of experimentation with engines running under controlled conditions, while you mention studies of refinery operations requiring 18 months for "having meaningful answers".

Going back to my proposal. I do not suggest to take the evaluations that have been mentioned e.g. Al Mavis' statements that one achieves a 6.1% improvements in miles/gallon over the use of unleaded gasoline when using a 10% ethanol-90% gasoline mixture, or Prof. Scheller's statements that one achieves a 5.3% improvement in miles/gallon for a similar fuel. All what these numbers say to me is that there is probably an improvement in miles/gallon when using the mixture compared to a control experiment using unleaded gasoline. All what I say is: - let us find out the exact amount of this improvement and the result of such an investigation is the only relevant information when talking about energy balances.

To repeat: I am not interested in the energy output in the production of ethanol but only in the energy value of the gasoline that has been replaced by using ethanol in the mixture. The question now is how to measure energy contents in an acceptable way.

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Here we get to the BTU issue. Off-hand, BTU is the wrong unit as it measures a different property of the fuel. But, as we have no better unit at our disposal, I suggest to establish the engine as final judge, and to use the ratios of performance in term of miles/gallon in order to define the utility factor.

These utility factors start from 1.5 which is the utility factor for perfect substitution: that is for the case that you can achieve exactly the same performance when using the mixture as you achieve from using pure gasoline. As I have explained before the Committee the factor 1.5 is derived from the fact that we have substituted ethanol for gasoline, and ethanol does have only a 2/3 BTU/gallon value as gasoline. Any actual case where the performance of the mixture is an improvement over the performance of pure gasoline will result in a factor larger than 1.5. I calculated for the Al Mavis case this is 2.4 and for the Prof. Scheller case this is 2.3.

To add here - in a letter to the editor of Chemical and Engineering News, John Hind writes that in the Philippines "we found that 1000 BTU of alcohol (ethanol from sugarcane molasses) could replace up to 1600 BTU of gasoline, and possibly more" (C&EN, August 28, 1978). This would translate a utility factor of 1.6.

I am gratified by your accepting the soundness of the idea of using utility factors, though I believe that your suggested 1.3-1.35 factor is too low as it does not even allow for perfect substitution. I expect the factor to be not 1.5 but probably closer to 2. This factor is than used as a multiplier of the conventional BTU output/BTU input analysis and the study of the objectivity of that analysis is a separate subject matter.

This logic is true for all cases when an alternate fuel is used to substitute as a means of conservation in our present petroleum based fuel economy. Similar factors should be introduced for any other new alternate fuel.

Hoping that this letter has clarified the arguments

Sincerely yours

Pincas Jawetz

STATEMENT OF RAY H. DALEY, SPECIAL PROJECTS MANAGER, PUBLIC AND GOVERNMENT POLICY, AMERICAN AUTOMOBILE ASSOCIATION, FALLS CHURCH, VA.

Mr. Daley. We will submit our statement for the record. I want to say some things that talks about what we believe should be done and what we believe the efforts are that are coming forward.

Triple A, as you know, is a consumer motorist organization with some 20 million members. Basically, in submitting our testimony we cover an awful lot of ground. To summarize it, it comes up to a point where we believe instead of waiting for a single solution for our national energy problem it is time the country start applying some of the numerous partial solutions already at hand. We are in a position now with our stance on energy whereby we seem to be concentrating on defense in this war on energy President Carter is talking about.

AAA believes it is time we move on to the offensive and in a small way not too long ago, as you may know, Senator Church, AAA, with yourself as a sponsor, and Senator Jackson, who is Chairman of the Energy and Natural Resources Committee, along with Senators Bayh, Javits, Curtis, and Percy, along with four Members of the House, sponsored a program which put a 6,000-gallon tank truck down in front of the Capitol with gasohol and invitations were sent to your colleagues, to every Member of the House and Senate, inviting them to come in for a free fillup. We also invited important members of the administration. I am happy to say Members of Congress from some 35 States did come down and take our invitation.

We have received over half of the possible responses. We have received almost 95 percent of those from the House and Senate. Today the figures are running 88 percent of the total, found the performance to be as good or better than that they received with their regular gasoline.

Of that whopping majority, almost one-half said the performance was superior. Obviously, this is not a test which can be put down as scientific. However, it indicated a couple of things. It indicated, number one, people were willing to try it and were satisfied with the performance.

I think it is very important. Most people did not notice the difference. But those who did, said, when the remarks came in, they noticed better pickup, starting. In any event, the sum and substance of this was we were willing to take a positive stance on moving toward a solution of our energy problem.

I think without dwelling on that particularly, what I would like to say is we feel it is probably safe to say most Americans today believe that energy including motor fuel will become more expensive. One of the distressing things about the present energy bill which Congress is struggling with, is the public perception of it seems to be, we will be paying more and getting less. Prices will rise only to make us conserve. Americans might understand having to pay if we thought we were financing a safe domestic energy supply for ourselves and for our children.

As consumers we might object to the idea of higher prices but at least we would understand.

Along with our written testimony is a digest of the current alcohol fuels laws which I hope you will find useful. We appreciate the opportunity to testify. We hope the Senate will be a leader and members of this committee particularly in providing our Nation with an alternative fuels bill.

Senator CHURCH. Thank you very much, Mr. Daley. I must tell you, I have appreciated the work the AAA has done to promote this concept. I think the demonstration to which you have referred to has brought the message home to the Members of Congress better than all of the talk about this subject.

I think it is a very constructive and useful step. I want to thank the association for its support and you for your testimony.

[The prepared statement of Mr. Daley follows:]

TESTIMONY OF RAY H. DALEY
SPECIAL PROJECTS MANAGER
PUBLIC AND GOVERNMENT POLICY
AMERICAN AUTOMOBILE ASSOCIATION

before the

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
U.S. SENATE
AUGUST 8, 1978

Mr. Chairman, I am Ray Daley, Manager of Special Projects, Public and Government Policy for the American Automobile Association. AAA is an organization of consumer motorists. We have some 210 clubs and more than 950 offices in the U.S. and Canada, and our membership numbers 19.9 million. We would like to thank the Subcommittee on Energy Research and Development of the U.S. Senate Committee on Energy and Natural Resources for inviting AAA to comment on alcohol-blended fuels.

While AAA does not sell or produce automobiles or motor fuel, AAA members and all motorists have a deeply vested interest in the benefits of auto use. Our nation's great growth, wealth, and patterns of living have been based in large part on the freedom of mobility that ownership and use of private transportation have afforded. The significance of this American transportation fact is obvious in the 106 million cars owned by Americans and the current annual consumption of over 100 billion gallons of gasoline.

Like many major organizations, AAA has been monitoring the nation's energy situation for some time. The summer before the Arab Oil Embargo, we were already advising our members on how to conserve gasoline. During the Embargo, we made weekly surveys of some 5,000 service stations around the country to help learn when and where fuel was available.

Since 1975, we have operated a structured national voluntary gasoline conservation program call GAS WATCHERS. Its purpose is to inform drivers of the need for conservation, how much conservation is necessary and how to go about it in painless ways. But conservation itself - no matter how necessary - isn't enough.

While there is no doubt that we must practice sensible conservation, AAA believes that it is even more imperative that we speed up the search for, and utilization of, new energy resources.

We will attempt to present an argument for beginning the immediate development of domestic alternative energy sources. Our case is built upon alcohol fuels, but we do not intend to exclude other domestic alternatives. We believe it is time to move away from a very few major energy sources and toward a greater range of energy supplies from a variety of sources.

Oil - Today's Energy Supply

The major energy source for the U.S. today is oil. It is currently in surplus, but we know that no matter how much oil is left, it is disappearing at a relatively rapid rate. Also we know that the U.S. presently imports 44% of its petroleum, and in the recent past we have seen how vulnerable this nation is to foreign embargo. Opinions as to how much oil is left within the country and abroad are diverse, and even expert opinions are only educated guesses. Corporations using the most modern and expensive technology, drill and do not find oil where they think it is. These uncertainties make clear the need to get alternate fuels into production. It will take years before production of any alternative will be able to make a significant contribution.

Criteria for a Motor Fuel Alternative

To evaluate various alternative fuel alternatives, certain criteria should be set. Keeping in mind that AAA's constituency is the motorist, we suggest the following criteria for a liquid fuel for transportation:

1) An alternative should have a proven history of powering the Otto cycle engine, which is the power system of most of the 106 million cars presently on the road. Changes and modifications of the fleet may be required, but this will take time.

2) An alternative should have sufficient domestic source or sources.

3) An alternative should be compatible with the established fuel supply, by its utility as a supplement to gasoline. Cars now in service should be able to use the gasoline/alternative blend on an occasional basis in order to accommodate that period of time when an alternative will be available some places but not others.

4) An alternative should have minimum effect on the environment, both through its production processes and end use.

5) The effect on the nation's economy should be salutory.

6) The implementation of production and distribution of the alternative should be able to be left to the private sector. Here it must be recognized that no demand for an alternative exists, since gasoline currently is in surplus supply and it is the most economical transportation fuel available with present technology.

Additionally, one point should be made relative to all these criteria. Recent historical events have shown that energy supplies are tied to a) geographically distinct deposits and b) the problems affecting centralized corporate management and labor and c) the relative ability of government to deal with a problem so complicated by foreign affairs and gross economic interests.

This leads us to believe that it would be beneficial to look to an alternative that would lend itself to decentralized domestic energy supply as a buffer to stimulate competition with centralized energy supply systems.

Measuring the available alternatives against this list of criteria, we at AAA find ourselves in agreement with Henry Ford and Alexander Graham Bell, both of whom believed that America would turn eventually to alcohol fuels.

Discussion of Alcohol Fuels and AAA's List of Criteria

1) The history of alcohol as a motor fuel parallels the creation of the Otto cycle engine. Repeatedly in the past, alcohol has been used in times of shortage. Its disappearance from the market was not due to a failure of alcohol, it was due to the re-emergence of plentiful and cheap supplies of petroleum. If we could be certain of gasoline price and supply stability over the long term we would not need to be here discussing alternatives.

2) Regarding supply potential of alcohol, the most obvious conclusion for the observer seems to be that there is much debate and little real knowledge. At this time, we haven't sufficient empirical evidence to determine whether domestic alcohol production could ever allow replacement of the entire gasoline supplies for our nation.

   Indeed, there are those who say the U.S. could not replace even a significant portion of petroleum with alcohol:

   Martin Clines, speaking for Phillips Petroleum, said: "We would have to give up eating all wheat, corn and potatoes just to satisfy 14% of our annual gasoline requirement." And according to Harold R. Taliaferro, Amoco Oil, "...it would take about 67% of the 1977 U.S. corn crop to produce 10% of the nation's gasoline requirements..."

   There is quite a bit of disparity between those two statements.

Now consider these quotes from Fred Lindsey, President of AGFERM, a company which will reportedly develop a new industry for Gulf Oil Chemical Company: "In 1972, 70% of our corn went to feeding livestock... Take that same amount of corn, make alcohol out of it, that would make 11 billion gallons of ethanol and not affect the food supply for people." And "the waste from fermentation is almost equal in nutrition to the original corn grain as cattle food."

There is a multitude of other statements which could be cited, but they only add to the collection of contradictory information.

It is important to note, however, that most of the statements have to do with alcohol made from grain. Alcohol can also be made from garbage, wood, cheese whey, sugar beets, sugar cane, a wealth of other agricultural products and coal.

Also, the new industry which Gulf Oil Chemical Company is entering is making ethanol from cellulose. And there is more cellulose produced annually in the world than anything else.

Moreover, a process reportedly being developed by an agronomist named Donald Brewer may add another gross alcohol supply source. If Brewer's process -- using rapid growing single-cell algae -- proves out, estimates for volume production of alcohol could take a quantum leap.

Again, AAA is not qualified to make definitive judgements in the area of potential alcohol fuel supply. However, the evidence seems to indicate that supply could be available.

In considering the compatibility of alcohol with gasoline, it is important to differentiate among types of alcohols. Methanol has been experimented with extensively by the major auto manufacturers in this country. Their feeling seems to be that it functions better as a straight fuel in a modified auto engine. Modification may be suitable in fleet operations, such as certain government or industrial vehicles, but most American drivers need a fuel that does not require modification of their cars.

And American motorists want to be able to stop at any convenient filling station and use the fuel available there.

Looking at ethanol, we believe it may have the compatibility with gasoline that we think is required. Serge Gratch, Director, Chemical Sciences Laboratory of the Ford Motor Company has said, that driveability is acceptable in present cars running on a blend of 10% ethanol and 90% gasoline. And Dr. Winfried Bernhardt of Volkswagen has stated that a 10% blend of ethanol would require no change in floats, gaskets or other engine components of present cars.

Gary Shults of Continental Oil's Ponca City, Oklahoma laboratories has said that experience in Nebraska's two-million mile road test has shown that cars can alternate fill-ups from their ordinary gasoline to a blend of 10% ethanol and 90% gasoline without harm to the car or substantial deterioration in performance.

Of considerable interest is the opinion of several experts that disadvantages of certain of the alcohols might be overcome by mixing them.* If a mix would bind the alcohols to gasoline, even with the presence of some water and still operate efficiently without modification or deleterious effects to present auto engines, that would be a very positive development.

4) Regarding the emissions of alcohol/gasoline blends, there is, to date, no evidence accepted generally as conclusive. There are conflicting claims that emissions are greatly improved and greatly worsened.

AAA is urging the Environmental Protection Administration to conduct tests. We know that they have recently purchased some 200 proof ethanol. We are hopeful that they may have some sort of demonstration testing here in Washington with a Mobile Emissions Testing Facility in the near future.

Also, certain of our clubs have indicated a desire to run their own gasohol vehicles and have certified tests done on them. The Automobile Club of New York will be among the first to do this.

5) Our nation's economy would benefit from a reduction in payments for foreign petroleum, if an alternative fuel could be produced at a price we could afford. The energy input should not require petroleum and the technology should show promise for improvement. AAA believes alcohol fuels qualify. Moreover, new industry means new jobs, and the diversity of small-scale alcohol fuels production would mean that the potential benefit could be spread widely across the country.

*Dr. Thomas B. Reed, formerly with the Massachusetts Institute of Technology and presently head of the Solar Energy Research Institute, Golden, Colorado, has suggested that a mix of ethanol and methanol can combine the virtues of price of methanol with the higher BTU content of ethanol and overcome methanol's phase separation problems. Work on creating an alcohol blend, called "Methanol X", is currently being conducted under the direction of Mr. Charles Stone, Director of the Synthetic Fuels Program of the California Legislature. The mix would include ethanol, methanol and tertiary butanol, blended with gasoline.

Some critics maintain that using alcohol would actually increase petroleum imports because it takes more energy to produce alcohol than the alcohol contains.

Further investigation, however, indicates that in any conversion of energy from one form into another a loss of energy, as measured in BTU's, takes place. Such a conversion is made only to process the energy into a more useable form.

The reason for making alcohol from agricultural products, garbage, cellulose, etc., would be to convert the energy value of those source materials into a useful form. It makes no sense to think of burning oil to distill alcohol. Both are liquid fuels.

Critics of alcohol do not suggest we stop using electricity, even though the energy balance is much worse. It takes at least three units of energy for every one unit arriving to users. (Because of further "in use" losses, some experts even say it takes five units to get the effect of one.) In fact, according to DOE, almost 20% of our entire U.S. energy consumption never reaches users. That loss is attributed to making electricity and transporting it across power lines. This is the penalty we pay for energy in a useful form.

Using manure or wood chips or even coal for heat to convert biomass, coal or garbage to alcohol may involve a loss in BTU, but it is making power in a form that we can use in our cars.

Another point will affect the energy balance of alcohols. Ethanol made in this country today is high quality industrial grade or "white goods" (potable). There is not one gallon of fuel grade ethanol produced commercially in the United States. Fuel grade alcohol would require less energy to produce.

According to Dr. Raphael Katzen, a chemist with over 30 years experience in alcohol fuels, industrial and drinking alcohols require 50% more energy in the distilling process than fuel grade alcohol does. Distilling is the most energy intensive part of the process of converting source materials to ethanol.

AAA believes that technology for the making of fuel grade alcohols will be vastly improved once a demand is created. Dr. Dwight Miller of the U.S. Department of Agriculture has said: "I am convinced that better fermentation techniques or better, more efficient factories could be installed... The fermentation factories have not changed drastically for several decades... I am also convinced...we can get better conversions so we can get higher yields of alcohol from the original materials."

6) Regarding the question of whether private industry, if left alone, can create an alternative fuels industry, we feel confident that the answer would be "yes", except for the demand that such a new industry be started immediately.

Our belief that some government involvement is required and can be beneficial is based on present market conditions and an established precedent for such government involvement.

Almost all alternative transportation fuels presently known are more costly than gasoline. Consequently, until the price of gasoline rises beyond that of an alternative in a free market, gasoline presumably would continue to be the fuel of choice.

Beyond normal inflation any drastic rise in the price of gasoline would result from shortages created by actions of foreign suppliers, from taxation, or actual depletion of petroleum sources. Allowing normal market forces to compensate for a gradual depletion of world oil supply with a corresponding growth of an alternative fuel will continue our present heavy dependence on foreign energy sources for decades.

Any demand for an alternative fuel will have to be artificially stimulated. Since the development of sufficient supply potential of alternatives will take years, this stimulation would seem the wisest course.

A March 1978 study done by Battelle Laboratories for the Department of Energy said, "a precedent exists for utilizing federal incentives to increase energy production." The study details that our government has expended approximately $125 billion (1976 Dollar equivalent) to stimulate energy production from Nuclear, Hydro, Coal, Oil and Gas sources.*

President Carter has said that America's approach to solving energy problems should be morally equivalent to that of a nation at war. Unfortunately, the Administration's programs seem to encourage defense in that war, as opposed to offense.

AAA believes it is essential that the U.S. take the offensive in the energy war by creating a demand for an alternative domestic fuel supply.

*Also, the study reveals that fully 60% of the total figure, which amounts to $77.2 billion, has gone to the oil industry. Not included in that amount was the monetary benefit of legislation restricting the importation of lower-priced foreign oil. Though unquantifiable, the March 1959 actions of President Eisenhower, limiting imports, meant many millions of dollars to strengthen the U.S. Domestic oil industry.

Rhetoric is Not Enough

In a small way, we at AAA launched an offensive in the energy struggle. AAA took the unusual initiative of sponsoring a Congressional Alcohol Fuels Demonstration with ten distinquished members of Congress.

Senator Frank Church of Idaho, chairman of this subcommittee, and Senator Henry Jackson of Washington, Chairman of the Senate Energy and Natural Resources Committee, were both sponsors of the AAA event. Others were Senators Birch Bayh of Indiana, Carl Curtis of Nebraska, Jacob Javits of New York and Charles Percy of Illinois. Sponsors from the House were David Emery of Maine, Walter Fauntroy of the District of Columbia, Paul Findley of Illinois and Dan Glickman of Kansas.

On June 28, 29 and 30, 1978, a 6,000 gallon tank truck containing a mixture of 90% unleaded gasoline and 10% ethyl alcohol from U.S. grown agricultural products sat at the base of Capitol Hill. Invitations had been sent to every member of Congress, the President, the Vice-President, members of the Cabinet and high ranking officials in agencies having to do with energy, transportation, agriculture and the environment. All they had to do to try the mixture, commonly called gasohol, was to show up or send someone with their cars. The fill-up was free!

Senate and House members from 35 states came down personally to receive a tankful, and many more members sent their aides down to have their cars filled. A few Administration officials who are working on energy, auto emissions and farm problems showed up, but not in the numbers one might have expected since this was an opportunity for first-hand experience with a fuel they are often asked to testify about.

We requested that those trying the fuel send in pre-paid cards describing how gasohol functioned in their autos. We have received over half the total possible responses and nearly three-quarters of the Congressional responses. More than 95% of the members of Congress who have sent in cards found that the gasohol performed as well as or better than their standard gasoline. Over 88% of the total respondents found the same thing to be so, and just about half of that whopping majority actually found gasohol to be superior to gasoline alone.

AAA stood to gain nothing from this gasohol giveaway, and we underwrote the major portion of the expense to insure that it was not an expression of a vested interest. We did not intend to promote any single alternative fuel to the exclusion of others by this action. What we did intend was to show that instead of waiting for a single solution to a big national problem, it is time the country started applying some of the numerous partial solutions already at hand.

It is our opinion that Congress should begin clearing away the regulatory barriers that stand in the way of getting started.

The Environmental Protection Agency's regulation concerning fuel additives to gasoline was meant to protect the automobile's catalytic converter from substances (such as lead) that would foul it. We have seen no expert evidence or opinion that suggests that a 10% alcohol blend would do so, but because of the wording of the regulation alcohol is officially an illegal additive. This should be changed.

Certain stipulations in regulations covered by the Bureau of Alcohol, Tobacco and Firearms require high bonding from all ethanol producers, and the control regulations for on-site Bureau supervision involve costly equipment, security facilities, manpower and paper work. Small scale production of ethanol for fuel can be blocked by such regulation.

We believe it is important to protect the public from the illegal manufacture and sale of spirits for drink, but regulations should be tailored to allow legitimate small scale businesses, such as farmers and farm cooperatives, to produce fuel grade alcohol. Also simpler methods of insuring that the proper denaturants are added to the ethanol to prevent it being used for human consumption must be provided.

Furthermore, Congress should provide stimulus to this new industry. AAA believes that incentives, perhaps regional combined with federal, in the form of investment tax credits and rapid amortization schedules, can stimulate action on varied energy alternatives. The most practical alternatives will become reality. We think alcohol might be among them.

AAA hopes that members of this subcommittee and the Committee on Energy and Natural Resources will join with your colleagues in the Senate and House to create an alternative fuels program for our nation.

I will be glad to answer any questions.

Attached to this statement is a digest of the Congressional initiatives concerning alcohol fuels. It was compiled by AAA's Legislative Affairs Department.

GENERAL ENDORSEMENT OF CONCEPT & RESEARCH LOANS & GRANTS	AMORTIZATION	CLEAN AIR ACT EXEMPTION	TAX EXEMPTION	SET-ASIDE ACREAGE
H.R. 3248 (Glickman) H.R. 3368 (Sebelius) H.R. 4720 (Glickman, et.al.) H.R. 6702 (Marlenee) H.R. 9547 (Fithian) H.R. 10895 (Roe) H.R. 11293 (Weaver) H.R. 12163 (Teague) H.R. 12791 (Hagedorn) H. Res. 1023 (Brinkley)	H.R. 8029 (Emery, et.al.) H.R. 8042 (Robinson) H.R. 9765 (Glickman, et.al.) (Identical: H.R. 9895, H.R. 10167, H.R. 10630, H.R. 10951, H.R. 12794) H.R. 11730 (Hamilton) H.R. 13241 (Emery, et.al.) (Identical: H.R. 13242)	H.R. 9765 (Glickman, et.al.) (Identical: H.R. 9895, H.R. 10167, H.R. 10630, H.R. 10951, H.R. 12794) H.R. 11730 (Hamilton) H.R. 12791 (Hagedorn)	H.R. 2522 (Sebelius) H.R. 5263 (Energy bill) H.R. 8029 (Emery, et.al.) H.R. 8042 (Robinson) H.R. 13241 (Emery, et.al.) (Identical: H.R. 13242) H.R. 12791 (Hagedorn)	H.R. 5263 (Energy bill) S. 2201 (Bayh)
S. 1461 (Curtis, et.al.) S. 2240 (McClure) S. 2312 (McClure) S. 2400 (Bayh) S. 2533 (Church) S. 2692 (DOE Authorization)		S. 2633 (McClure & Church) S. 2679 (Curtis)	S. 2201 (Bayh)	P.L. 95-279
P.L. 95-113 P.L. 95-238				

HOUSE BILLS

H.R. 2522 (Sebelius) - Ways and Means Committee

To amend the Internal Revenue Code to provide a two cents per gallon refund of the gasoline tax on gasoline using cereal grain alcohol as a substitute for lead.

STATUS: pending; no action scheduled.

H.R. 3248 (Glickman) - Science & Technology Committee

- Identical Bills: H.R. 4720 (Glickman, et.al.)
  H.R. 6702 (Marlenee)

To require research into the comprehensive and various uses of grain or grain products in the development and use of fuels.

STATUS: all bills pending; no action scheduled.

H.R. 3368 (Sebelius) - Science & Technology Committee

To amend the Energy Reorganization Act of 1974 to direct the Administrator of ERDA to include studies of gasoline and grain alcohol as part of the alternate fuels research and development program.

STATUS: pending; no action scheduled.

H.R. 8029 (Emery, et.al.) - Ways and Means Committee

- Similar Bill: H.R. 8042 (Robinson)

To amend the Internal Revenue Code of 1954 to encourage the use of alcohol as an alternative fuel for motor vehicles by allowing the rapid amortization of facilities producing alcohol for use as such a fuel, and by providing that fuels which are at least 10-percent alcohol will not be subject to the Federal excise taxes.

STATUS: both bills are pending; no action scheduled.
- similar tax language included in a Senate amendment to the energy bill (H.R. 5263).

H.R. 9547 (Fithian) - Agriculture Committee

To encourage the use of agricultural commodities in the production of certain blended fuels.

STATUS: pending; no action scheduled.

H.R. 9621 (Glickman, et.al.) - Ways and Means Committee; Interstate and Foreign Commerce Committee

- Identical Bills: H.R. 9765, H.R. 9895, H.Rl 10167, H.R. 10630, H.R. 10951, H.R. 12794, H.R. 13352 (Glickman, et.al.) H.R. 11730 (Hamilton)

To encourage the use of alcohol in motor vehicles by requiring certain retailers to make alcohol-blended fuels available for sale, by allowing the rapid amortization of facilities producing alcohol for use in motor vehicle fuels, and by exempting alcohol-blended fuels from certain requirements of the Clean Air Act.

STATUS: all bills pending; no action scheduled.

H.R. 10895 (Roe) - Science & Technology Committee

To establish a National Alcohol Fuels Commission and for other purposes.

STATUS: similar language incorporated into Department of Energy authorization. The bill is identical to S. 2400 (Bayh).

H.R. 11293 (Weaver) - Agriculture and Interstate and Foreign Commerce Committees

To provide for the use of alcohol produced from renewable resources including silvicultural materials from the national forests as home heating and motor vehicle fuels.

STATUS: pending; no action scheduled.

H.R. 12163 (Teague) - Science & Technology Committee Department of Energy authorization

Recommends FY 1979 authorization for DOE Fuels from Biomass program of $52.6 million, an increase of $25.7 million over original administration request of $26.9 million.

STATUS: up soon for consideration on House floor.

H.R. 12791 (Hagedorn) - Agriculture; Interstate and Foreign Commerce; Science & Technology; and Ways and Means Committees

To provide for research programs under the Secretary of Agriculture and the Secretary of Energy, to amend the Internal Revenue Code of 1954 to encourage the use of grain-produced ethanol as an alternative fuel for motor vehicles, to provide guaranteed loans for ethanol-producing facilities, and to amend the Clean Air Act to exempt gasoline mixed with ethanol from certain prohibitions, and for other purposes.

STATUS: pending in all committees; no action scheduled.

H.R. 13241 (Emery, et.al. - including Findley) - Ways and Means Committee

- Identical Bill: H.R. 13242 (Emery, et.al.)

To amend the Internal Revenue Code of 1954 to encourage the use of alcohol as an alternative fuel for motor vehicles by allowing the rapid amortization of facilities producing alcohol for use as such a fuel and by providing that fuels which are at least 10-percent alcohol will not be subject to the Federal excise taxes.

STATUS: pending; no action scheduled.
- similar tax language included in Senate amendment to energy bill (H.R. 5263).

H. Res. 1023 (Brinkley) - Science and Technology, and Interstate and Foreign Commerce Committees

Resolution to express the sense of Congress that the Department of Energy and the Department of Agriculture establish a liaison office between the two agencies for the purpose of advancing and developing a means of promptly and efficiently bringing alcohol fuels into commercial use.

STATUS: pending; no action scheduled.

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SENATE BILLS

S. 1461 (Curtis, et.al.) - Agriculture Committee

To expand the research in agricultural commodities and forest products.

(The bill is an amendment to Title V of the Rural Development Act of 1972. It provides for research grants to state colleges and universities for research into alcohol fuels. Also, the bill provides for the construction, through a system of guaranteed loans, of four pilot plants for the manufacture of alcohol.)

STATUS: pending; no action - similar language was added to the Food and Agriculture Act of 1977 (P.L. 95-113).

S. 2201 (Bayh) - Agriculture Committee

Provides for the use of set-aside acreage for production of any agricultural or forestry product which is to be used or sold by such person for primary use in the manufacture of a gasoline blend exempted from taxation under Section 4081(c) of the Internal Revenue Code of 1954. (Alcohol Fuel Incentives Act.)

STATUS: pending; no action.
- similar language was included in a Senate amendment to the Energy bill (H.R. 5263).

S. 2240 (McClure) - Agriculture Committee

To provide for and encourage the production of agricultural commodities suitable for use in the manufacture of hydrocarbons which can be used to blend with gasoline or other fossil fuels.

STATUS: pending; no action scheduled.

S. 2312 (McClure) - Agriculture Committee

To amend the Food and Agriculture Act of 1977 to further encourage and strengthen the National commitment for the production and marketing of industrial hydrocarbons and alcohols from agricultural commodities and forest products.

STATUS: pending; no action scheduled.

S. 2400 (Bayh) - Energy Committee

To establish a National Alcohol Fuels Commission and for other purposes.

STATUS: incorporated into Department of Energy authorization, with slight revisions.

S. 2533 (Church) - Energy Committee

To provide for the use of alcohol produced from renewable resources as a motor vehicle fuel.

(This bill is named the "Gasohol Motor Fuel Act of 1978." It establishes a timetable for bringing gasohol into the market and requires that blending gasoline and alcohol begin by 1981, and by 1990, a 90-10 blend must be available nationwide. The bill puts the burden for production and distribution of renewable resources alcohol on the oil refineries.)

STATUS: hearings scheduled August 7, 8, 9, 1978.

S. 2633 (McClure and Church) - Environment Committee

To amend the Clean Air Act to further encourage and strengthen the Nation's commitment for the production and marketing of industrial hydrocarbons and alcohols from agricultural commodities and forest products.

STATUS: pending; no action scheduled.

S. 2679 (Curtis) - Environment Committee

To amend the Clean Air Act in order to remove a prohibition against the use of alcohol as a fuel additive.

STATUS: pending; no action scheduled.

S. 2692 Department of Energy Authorization

Incorporates S. 2400/H.R. 10895 (in slightly revised form) providing for the establishment of a National Alcohol Fuels Commission.

STATUS: reported out of Senate Energy Committee.

H.R. 5263 Energy Bill (Senate version)

Four Senate-added amendments to the energy bill dealt with alcohol fuels:

1. Authorized the Secretary of Agriculture to allow the use of farm set-aside acreage to grow fuel crops.

2. Created a federal test fleet of vehicles operated on alcohol fuel blends.

3. Exempted alcohol fuels derived from agricultural and forest products or municipal wastes from the four cents per gallon federal excise tax on gasoline.

4. Authorized a tax credit for equipment that converts municipal and agricultural wastes or other organic matter into fuel or energy.

STATUS: Energy conferees have not taken up these amendments.

P.L. 95-113 Food and Agriculture Act of 1977

Authorized a 5-year, $24 million research program to be carried out by the Department of Agriculture through grants to colleges and universities. It also authorized the department to extend up to $15 million in loan guarantees for each of four pilot plants to produce alcohol and industrial hydrocarbons, such as asphalts, adhesives and solvents.

Loans are expected to be awarded at the end of 1978. Experts estimate it will take 36 months to bring the plants into production.

P.L. 95-238 ERDA-Authorization Act

Authorized ERDA Administrator to make loan guarantees for alternative fuel demonstration facilities. Established special research and development program for development of advanced automotive systems with attention to those which are flexible to type of fuel used. Established Financial Support Program for waste reprocessing into fuels.

P.L. 95-279 Emergency Farm Act

Contains a provision authorizing the Secretary of Agriculture to permit farmers to grow crops for gasohol production on set-aside acreage and to make incentive payments to producers of gasohol crops when no set-aside or diversion programs are in effect.

Senator CHURCH. That will conclude the hearing.

[Whereupon, at 12 noon, the hearing was adjourned.]

APPENDIX

Additional Material Submitted for the Record

STATEMENT BY SENATOR CARL T. CURTIS
BEFORE THE COMMITTEE ON ENERGY AND NATURAL RESOURCES
CHAIRMAN, SENATOR CHURCH
AUGUST 1978

Mr. Chairman, as an advocate for the past 25 years of converting renewable farm surplus and waste products into alcohol fuels for our cars, I am pleased that you are holding this important hearing before the Energy and Natural Resources Committee. I do not intend to comment on specific provisions in your bill, other than to endorse its spirit, which is to further the marketing of Gasohol for the benefit of this nation.

Introduction: The Problem

As most Americans are aware, petroleum is becoming an increasingly scarce and expensive commodity. The U.S. dependency on foreign sources of oil is over 50 percent already, and rising. The adverse impact of such a dependency is, of course, pervasive - spurring inflation and trade deficits, jeopardizing defense, and threatening individual freedom of mobility. Some action to mitigate dependency on oil must be undertaken as quickly as possible. Gasohol, a mixture of 10 percent ethyl alcohol with gasoline, holds the promise of slowing or halting overdependence on foreign oil by tapping renewable resources grown or located in the United States. An extensive energy forecast released by the Department of Commerce on January 20, 1977, projects that alcohol fuels derived from biomass ultimately can supply but a fraction of our total energy demanded by the year 2000, but stresses the essential role such fuels must play until more sophisticated alternate sources of energy are developed.

The Potential

The U.S. has enough surplus grains and distressed crops on hand right now to produce 10 billion gallons of alcohol - enough to achieve the President's goal of conserving 10 percent of the gasoline we currently consume annually. Widespread marketing of Gasohol could allow the United States to mount an economic counteroffensive against foreign oil suppliers who charge exhorbitant prices and against foreign crop customers who oftentimes bluff us into accepting discounts for the food we export.

If every gallon of gasoline sold in this country contained 10 percent alcohol, current oil imports could be reduced by 20 percent. At the same time, a new domestic industry would be providing jobs, while the farmer receives a new market for his goods which reduces the need for farm support payments.

The Practical Experience

Gasohol is sold today at 30 stations throughout Illinois (at 73.9 cents per gallon), three stations in Nebraska (at 69.3 cents per gallon), and at five stations in Iowa. The retailers report very favorable motorist response, with a buyer return rate estimated at over 50 percent.

A point that should not be overlooked is that few, if any, Gasohol opponents deny that the fuel works in a car engine. Even the American Petroleum Institute admits, "If cars were operated on alcohol blends, the chief advantage would be a reduction in knock and after-running..."

In separate tests performed by Volkswagen and by the State of Nebraska, periodic checks of spark plug condition, cylinder compression pressure, and other engine parts, revealed no unusual wear or deterioration. As well there occurred no starting, vapor lock, or drivability problems.

The simple truth, then, is that Gasohol will work in all cars today without modifying car engines. This lends it a tremendous advantage over electric and solar powered cars whose sophisticated mass production capability is years away.

The Administration's Posture

President Carter's Energy Messages have conspicuously ignored the alternative of alcohol fuels. Considering the national publicity Gasohol is receiving in both Jack Anderson's and Paul Harvey's columns and on NBC's nightly news, I am puzzled as to an explanation for this oversight. Perhaps the Administration is determined to shock Americans into strict conservation by forcing us to make do with present and anticipated supplies of domestic crude oil. If so, this policy will serve only to engender a circle-the-wagons philosophy in the economy, while stifling private ventures into new energy frontiers. It is imperative that this nation develop alternative domestic energy sources immediately, and Gasohol is one such source with proven technology.

Secretary of Energy, Dr. Schlesinger, admitted during Congressional testimony that Gasohol is a solution to the farm problem. Despite repeated pleas by Congress, however, his department refuses to promote its development. Currently, a DOE task force is embarking on a six-month feasibility study. This would be encouraging were it not for the fact that sufficient study is already available in this area. We need less study and more action.

The Department of Agriculture, supposedly the farmer's friend, has shown even greater reluctance to give Gasohol a chance. The Department is busily engaged in drawing-up guidelines which require an applicant for one of four pilot alcohol plants (mandated by the Food and Agriculture Act of 1977) to virtually guarantee economic and technical success. This is a "Catch 22" situation. Only by allowing these plants to get off the ground will we be in a position to improve alcohol production technology, test marketing and distribution methods, and try out ways toward greater energy efficiency. If an applicant could provide the type of assurances USDA is requesting, there wouldn't be a need for a pilot plant program in the first place.

USDA had also issued an erroneous study indicating that Gasohol would require a $10.4 billion subsidy to compete with conventional OPEC gasoline. There is no evidence supporting this arbitrary figure.

The fact is this whole new field of converting renewable resources into energy holds great benefits if the Administration will open its mind and help private initiative further its development.

A Synopsis of the Criticism of Gasohol

A recent news feature on Gasohol entitled "Gasohol - Energy Mountain or Molehill" in the July 31, 1978 issue of Chemical & Engineering News sums up the major reasons advanced by those who oppose Gasohol:

> "Gasohol opponents claim that it probably will do more harm than good to the nation's economy, its farmers, its oil imports, and its trade balance. They believe that it is too expensive to use as a fuel as long as less expensive fossil fuels still exist.
>
> "Since it takes more energy to produce ethanol than you can get out of it, they say gasohol will increase, not decrease, U.S. demand for foreign oil. This will make the trade balance even worse. So, too, will the drop in farm exports, as farm products are diverted from foreign markets to domestic energy markets. Gasohol opponents even raise a moral question: Is it right to take food from the world's hungry and put it in America's automobiles?"

Mobil Oil has sent a lengthy position paper to my office which attempts to support these arguments. Before I refute each major objection the oil companies raise, I would like to suggest that these handsomely paid trustees of our national energy resources spend a little more of their time and money finding more petroleum, and a little less trying to thwart attempts to develop new and varied sources of fuel.

Economics of Gasohol

Skeptics maintain that Gasohol is too expensive based on the current price of $1.25 per gallon of ethanol. Comparing cost strictly by unit is misleading where chemical interaction is involved.

Due to alcohol's octane-boosting qualities in gasoline, less expensive lower octane gasoline will operate splendidly in an alcohol blend. Also, a recently concluded two-million mile road test conducted by the State of Nebraska resulted in a 5 percent saving in fuel over comparably driven cars using straight gasoline.

Fuel savings with alcohol are acknowledged by the major oil companies themselves. Mobil Oil admits that adding alcohol to gasoline would result in a leaner mixture being fed to the engine, and an increase in fuel economy. Exxon, published a research paper in 1975 stating that a Btu of alcohol is 26- to 45 percent better than a Btu of gasoline in optimized conventional car engines.

Combined with a waiver of the four-cent Federal excise tax on gasoline as provided in the present Energy Tax Bill, now in Conference, these characteristics translate into a Gasohol price at the pump of only 64 cents per gallon. For this reason, I cannot overemphasize the importance of passing the excise tax waiver (even if it means breaking it out of the present bill and sending it to a vote on the floor) as a means of permitting Gasohol to get a foothold in the market.

The Energy Efficiency of Producing Gasohol

Chevron Oil, one of the most adamant detractors of Gasohol, claims it is "not opposed in any way to the use of alcohol as a motor fuel so long as it is economic and results in a net saving in energy." Having addressed the economic question, I would like to demonstrate that the fact alcohol requires more energy to distill than is derived does not mean we will be burning up more oil in the process than it can replace in our cars. If that were the case, Gasohol proponents would be suggesting a fool's solution.

Fuel resources other than petroleum such as plentiful coal, garbage, and agricultural waste products can be burned to distill alcohol. Alcohol distillation, unlike petroleum refining, is a relatively simple, low heat process.

Innovative techniques such as constructing alcohol plants beside utility power plants to tap exhaust heat can also mitigate the effect of an adverse energy balance.

It is important to realize that alcohol from corn is actually 94 percent energy efficient if one-half of the cobs, stalks, and musks available are used to heat the process, and the marketable high protein cattle feed resulting from the distilling process is considered. In comparison, making gasoline or diesel fuel from crude oil is only 90 percent Btu efficient if all factors from OPEC well to consumer are counted. And, of course, this can be done only once now that dinosaurs are extinct. In contrast, alcohol can be made annually from farm surplusses and even daily from resources such as garbage.

Humanitarian Benefits of Gasohol

Extensive fermentation of U.S. grain and other foodstuffs has drawn criticism such as this statement from Mobil Oil: "To do so would raise the possibility that the U.S. might well be unable to play the role as an emergency breadbasket for a world whose population is still rising and in which major crop failures do occur."

But remember that the world is protein short, not starch deficient. We must encourage improvement of processes to extract protein fit for human consumption from the original grain before it is converted to alcohol. The extracted commercial protein would weigh but a fraction of the original grain and could be shipped less expensively and with less likelihood of spoilage to those who need it.

One of the biggest fallacies of "humanitarian" objections to Gasohol is the failure to acknowledge that land currently unused under the farm price support system could be planted for alcohol production. By doing so we will not be jeopardizing our ability to export grains if needed.

I should add that a serious disease, aflatoxin, has rendered millions of bushels of grain in Southeastern U.S. unfit for consumption. While afflicted grains cannot be used as feed or exported, they can be converted to alcohol.

Conclusion

I urge the Administration and the major oil companies to heed the advice offered by nationally-syndicated columnist John Chamberlain in his article of February 8, 1978:

> "It is now some five years since the Arab boycott, which subsequently modulated into the OPEC price-fixing conspiracy in restraint of trade. There is no danger of Arab oil running out in a generation, but the United States can't afford an adverse balance of trade year after year that runs into billions.
>
> "If only one big oil company -- just one -- would announce that, henceforward, it plans to offer a gasohol mixture using 10 or 15 percent alcohol, it would be the public relations coup of the decade. The first oil company to take action on gasohol would exempt itself automatically from charges that 'big oil' is only concerned with 'obscene' profits. Jimmy Carter would be forced to pat it on the head, and other companies would soon be following the pioneering company's example.
>
> "A 10 percent reduction in our overseas oil bill would be of benefit to the entire

fuel-using world. It would not only help save the dollar, it would serve notice on the OPEC price-fixers that further competition from alcohol could be expected any time the price is right."

NEW YORK

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August 7, 1978

TESTIMONY BEFORE THE SENATE ENERGY AND NATURAL RESOURCES SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT

by Senator Jacob K. Javits

I have become increasingly concerned about the need to develop a secure and reliable domestic alternative to imported petroleum which accounts for one half of our oil imports. One of the most promising additives, and ultimately perhaps a replacement for petroleum, is alcohol fuels. As you know, alcohol can be produced easily with current technology from a wide variety of domestic resources that are renewable and plentiful, including urban waste, surplus and contaminated grains, timber and milling wastes, coal and even algae.

Importantly, the alcohol created from these sources can already replace petroleum in a number of end-uses. For example, alcohol can be used as a blend of up to ten percent with gasoline without the need to modify existing automobile engines. It can also be used to drive industrial and utility peak-turbines, or as a new industrial chemical base.

The subcommittee's initiative to explore the future possibilities for the utilization of alcohol as a fuel is most gratifying. Tests in Germany, Brazil and the United States have concluded that there are no insurmountable problems regarding the production or blending of alcohol with gasoline.

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Popular support for the alcohol fuel program in Brazil is high and both Sweden and Germany are considering similar prorams. Even the Soviets are making overtures to the major European industrial and automotive manufacturers regarding alcohol production for automotive fuels.

Although alcohol fuel will not in itself solve the energy crisis, it can make a significant contribution by decreasing the size of petroleum imports, and by putting to use domestic resources that would otherwise be wasted.

As the senior Senator from New York, I must make special mention of the potential use of urban waste as a base resource for fuel. As you can imagine, New York City has more waste per capita than any other city or region in the country. What once was a major problem may now be an urban salvation and even considered a national salvation. At this point in time, the safe disposal of these wastes is becoming an ever increasing problem because of the high costs of disposal and the difficulty in finding environmentally safe places for dumping and treatment. Several major eastern cities have had their permits extended by EPA for the ocean dumping of wastes; the problem is coming to a climax and now we may have a vehicle for positive action.

The population of the United States generates 2.5 quads worth of refuse annually which equals $5 billion dollars of OPEC oil. Producing alcohol or methane from this waste seems to be the most viable option because of its environmental advantages as well as its multiple end-use possibilities. We should not overlook the resources of our cities in their previously wasted refuse and the employment possibilities such technologies offer.

Senator Church, I believe your legislation which I have cosponsored, is a measure which attempts to integrate synthetic fuels into our transportation system in a realistic manner and I hope we can bring it to the Senate.

I would like to offer some suggestions as to how the Department of Energy can assist alternative fuel production from renewable resources. This five point plan represents an effective, not very costly and innovative approach to actively spur alternative energy production in the United States. The Department of Energy should:

a. Organize cooperative programs with the private sector to use available private sector automobile fleets for tests with alternative fuels. Automotive and truck rental companies, delivery and messenger services, phone and utilities all have a potential to be used for test and conservation efforts.

b. Survey and assist those companies that have turbines to blend synthetic fuels in these turbines so new markets and data can be developed in the United States.

c. Investigate the use of alternatives to petroleum and natural gas as a base for industrial chemicals. In many cases, ethanol, methanol and ethylene can be made from renewable resources very close to the costs to produce these chemicals today from natural gas or petroleum. These new technologies should be encouraged.

d. In conjunction with the Environmental Protection Agency and State Public Service Commissions, identify and test utility peak-turbines on synthetic fuels and develop cooperative federal/state programs in this regard.

e. Use its Energy Extension Service, which now assists ten states, to develop programs, sponsor classes and provide other general technical assistance projects for those regions, towns and people and small businesses that are interested in energy production. This kind of field assistance could do as much for energy as the Agricultural Extension Service has accomplished in the production of food.

I would like to submit for the hearing record, one of the first reports on alcohol fuels entitled "Alcohol

Fuels: An Overview." This report was published last year by The New York State Alliance to Save Energy, Inc. which I cofounded with Senator Moynihan.

We must act now in order to ensure a varied and reliable energy base in the future. This country cannot sustain the enormous financial drain caused by its oil imports. And even if we could, the world's supply of petroleum may well be so depleted in the not too distant future as to make our present policy untenable and a disaster imminent.

New York State Alliance to Save Energy, Inc.

FOR RELEASE
2 P.M., Friday, Oct. 21, 1977

CONTACT: Sophia Liang
(212) 840-8383

ALCOHOL POWER! - SIDEWALK PRESS CONFERENCE
36 West 44th Street, New York City
2 P.M., Oct. 21, 1977

"We welcome this caravan to New York City," said Richard Berman, Executive Director of the New York State Alliance to Save Energy.

"The trip from the nation's capitol to New York City - on 'gasohol' - proves that alcohol fuels are technologically feasible. It should also serve to bring America a significant step closer to adopting a sensible alcohol fuel policy.

"There are some very positive implications of 'alcohol power' ranging from the environmental integrity sustained by using renewable energy sources to the national security enhanced through reliance upon domestic - as opposed, for example, to OPEC - production.

"It's clearly time that we conducted full, open and conclusive experimentation with this very promising alternative energy source. The New York State Alliance recommends an alcohol fuel action program consisting of:

1. A comprehensive public education campaign to discuss the pros and cons of alcohol fuels.

2. Congressional hearings to evolve a strategy for the gradual introduction of alcohol blends into the marketplace.

3. A Department of Energy study of (i) the costs associated with retrofitting cars to accommodate alcohol blends and (ii) safety standards for alcohol fuels.

4. Alcohol fuel tests with government owned fleet vehicles.

"Alcohol fuel's time has come."

* * * *

The New York State Alliance is a non-profit organization of persons from all walks of life - labor, industry, education, environmental and consumer movements - whose objective is to "popularize" the discussion of energy issues. It is a completely private organization, but has the support of New York's local, State and Federal officials.

1. Abstract

There are any number of reasons that alternative fuels are now being widely discussed. Decades ago, scientists anticipated the dwindling of available oil resources and the market mechanism that would eventually drive up the price of petroleum. Few anticipated the formation of an Arab oil cartel that has almost quadrupled the price of oil in the space of four years, but it is this factor that has been instrumental in spreading awareness of the need for a comprehensive national energy plan.

President Carter's National Energy Plan proposes the elimination of gasoline price controls by the end of the year. Although the plan stipulates that price ceilings might be imposed if gas prices rise above a predetermined level, there is no question that gasoline prices will be rising significantly. As gasoline becomes more expensive, the attractiveness of such alternative fuels as methyl alcohol (methanol) and ethyl alcohol (ethanol) becomes more apparent.

The promise of alcohol fuels lies not only in their potential role as replacements for waning gasoline supplies, but also as improvements on petroleum fuels. There is considerable evidence that mileage, performance, and emissions characteristics of certain alcohol fuels would make them even more suitable fuels for some internal combustion engines than gasoline.

But the most encouraging facet of the alcohol fuel picture is the diversity of the multiple renewable sources from which alcohol fuels may be derived.

However, there is no escaping the fact that large-scale conversion to 100% alcohol-fueled cars would entail numerous problems. Even with anticipated gasoline price rises, it will be some time before pure alcohol fuels will be economically competitive with gasoline. Large capital investments for the construction of alcohol production plants will be necessary, for instance. Some technical problems, too, are encountered in the use of alcohol fuels in unmodified gasoline engines. Also oil companies have a vested interest in the maintenance of petrol-fueled transportation. It has already been demonstrated that their lobbying efforts can thwart legislation that encourages alcohol fuel production.

Another promising possibility is the use of blended fuels - admixtures of gasoline and alcohol fuels - which offer some

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of the benefits of pure alcohol fuels and which do not present most of its technical disadvantages.

II. The Basics of Alcohol Fuels

1. Methanol

a) The Nature of Methanol

Methyl alcohol or methanol (popularly known as wood alcohol) is the lightest of the alcohol family. At normal temperatures and pressure conditions, methanol is a liquid which makes it immediately attractive as a fuel. Methanol is widely used in industry, and current annual U.S. production of methanol is about one billion gallons per year. At present, most methanol is produced from natural gas, with some production from heavy industrial residues and naptha. But methanol can be produced from a wide variety of energy resources. Any resource from which hydrogen and carbon monoxide can be produced can also be used to produce methanol, with conversion efficiency varying from material to material. Methanol can also be produced from coal, wood, and of particular interest, municipal wastes.

b) Methanol Resources

Coal. Of the nonpetroleum sources of methanol, coal seems the most promising resource for practical development. The nation's coal resources are sufficient to support the manufacture of ample amounts of methanol, although environmental and land use considerations should be carefully examined before coal production is expanded for this purpose. The United States consumes about one hundred billion gallons of gasoline annually in private cars. If a ten per cent methanol fuel were to be added to gas, and fuel consumption remains constant, ten billion gallons or thirty million tons of methanol would be required. The efficiency of converting coal to methanol is probably about fifty per cent. Therefore, about sixty million tons of coal per year, or just over ten per cent of our present coal output, would have to be diverted to methanol production.[1]

Several factors make it difficult to determine a reasonable manufacturing cost of methanol from coal. The cost of the coal, location of mining operations, size and location of conversion plants, and method of financing conversion would all affect the price of methanol made from coal. Sidney Kattell, chief of process evaluation at the U.S. Bureau of Mines at Morgantown, West Virginia, computed some costs of methanol produced from various grades of coal for a New Mexico conversion plant. The cost of a gallon of methanol produced there would range from forty-one cents (in 1975 dollars) using coal costing five dollars a ton at a twelve per cent discounted cash flow to sixty-three cents using coal priced at nine dollars a ton at a twenty per cent discounted cash flow.[2]

Wood. The development of a process for obtaining methanol from wood is being investigated by the Office of Energy Resources of the State of Maine. Researchers for that office have determined that there is enough forest land in America to make methanol production from wood economically feasible. Project calculations indicate that 2,250 gallons of methanol can be produced per acre of forest land. If the alcohol for a ten per cent methanol mixture were to be obtained from wood resources, this would require that 4.5 million acres of forestland be converted into methanol. This constitutes under one per cent of total forest acreage of the United States.[3] Again, though, environmental considerations could not be discounted before embarking on such an endeavor.

Urban Wastes. A number of proposals have been advanced pertaining to the production of methanol from carbon wastes. Several nation-wide projects are conducting preliminary experiments for the establishment of garbage separation and methanol refining facilities.

2. Ethanol
   a) The Nature of Ethanol

Ethyl alcohol or ethanol (commonly known as grain alcohol) can be manufactured from most plant material that has stored chemical energy through the process of photosynthesis. Biomass, or plant material in any form from algae to wood, has an energy content which is approximately half that of better-grade coals. Numerous land and water crops that are easily grown are being investigated as possible sources of energy by bioconversion. The National Science Teachers Association, under contract with the U.S. Energy Research and Development Administration, estimates that a farm the size of Texas (about 6.5 per cent of the total U.S. land area) could fuel all the energy needs of the

United States in 1985 even if only three per cent of the solar energy falling on it could be converted.[4] Research on ethanol potential over the last three decades reveal that a pound of dry plant tissues, when harvested and burned, can produce as much as 7,500 BTU's (British Thermal Units) of heat, a bit more than half of the heat obtained from the combustion of an equal weight of coal. The Teachers Association notes that "with some engineering improvements, a ton of biomass can be processed to yield 1.25 barrels of oil, twelve hundred cubic feet of medium BTU gas, and 750 pounds of solid residue that is roughly equivalent to coal in heat value."[5] Stanford University research has found "that the energy consumption for biomass production amounts to no more than about 5.5 per cent of the energy value of the biomass produced when adequate local supply of water is guaranteed."[6]

b) Conversion Efficiencies

There are numerous problems in the bioconversion process that may prohibit the economical manufacture of ethanol for auto fuel. Firstly, photosynthesis is a relatively inefficient process, in only a few cases exceeding three per cent efficiency during the growing season. A year-round average of one per cent efficiency is typical for most high-yield crops, so that huge tracts of land are required to yield appreciable amounts of energy.[7] Land required for a relatively small one hundred megawatt organic-fired plant would be a minimum of sixteen thousand acres. If the nation were to adopt a ten per cent mixture of ethanol and gasoline, four billion bushels of grain, or forty per cent of the nation's grain harvest, (if only grain were to be used) would have to be diverted to ethanol production, if grain were to be used exclusively. The total United States grain harvest, if burned for fuel, would satisfy only twenty-five per cent of our automotive needs.[8]

c) Pricing of Ethanol

Because of this supply situation, the cost of grain alcohol greatly exceeds both that of gasoline and synthetic alcohols produced from petrochemicals.

The Congressional Research Service estimates that the base cost of alcohol produced from grain would be at least one dollar per gallon (this excludes the added expenses of distribution, sales taxes, and producers' profits). Moreover, it is difficult to estimate the added surcharges on the pump price of ethanol attributable to unanticipated costs of distillery construction for large-scale grain alcohol production. The current market price of ethanol is as much as four times that of methanol in some areas of the world. Newly discovered means of ethanol production, though, may reduce the costs of ethanol considerably.[9] This will be discussed more fully under "Current Research on the Use of Ethanol as Fuel". Improved biomass and silviculture (forest resource management) technologies, too, may make ethanol cost competitive in the future, according to Volkwagen and Congressional Research Service reports.

III. The History of Alcohol Fuels

Both ethanol and methanol have been used previously as motor fuels. Alcohol has been for years used as a fuel for racing cars because of its high energy output and cool burning properties.

It has also had much more widespread application. A 1939 report by the National Resources Committee to Congress includes a compendium of early foreign experiences with alcohols as fuels. In the 1930's, Germany mandated the use of a ten per cent admixture of ethyl alcohol with gasoline.[10] By 1937, the blend proportions were altered to include methanol.

In 1935, eleven European countries used 180 million gallons of wood alcohol in four million vehicles.[11] South American nations, Japan, Australia, and the Phillipines also used alcohol fuels for various periods of time and in varying degrees in the 1930's and '40's.

The possibility of introducing alcohol fuels to the American market was periodically discussed in the 1950's and '60's. The DuPont Chemical Company operated a methanol-from-coal plant at Belle, West Virginia in 1955-1956, producing synthesis gas to make methanol, ammonia, and other products. The plant was plagued by erosion of slag pool linings, but was closed in 1957 as inexpensive natural gas became available in the plant locality, making the continued use of coal uneconomical.

IV. Current Research on the Use of Methanol as Fuel

The increasing price of gasoline and forecasts of dwindling supplies have spawned any number of serious research experiments into the feasibility of introducing methanol as a fuel. Although past foreign experience has mostly concentrated on the use of ethanol fuels, current market prices of ethanol make it a far less attractive pure fuel alternative than methanol in most estimations.

Tests that have been conducted and publicized concerning pure methanol and methanol admixture fuels emphasize several inadequacies in performance.

1. Performance

General Motors Research Laboratories' report on methanol gasoline blends was probably the most pessimistic of similar research findings. GM ran tests with a fleet of fourteen employee-owned cars ranging from 1966 to 1974 models. According to GM, a solution consisting of ten per cent methanol as "less doesn't save enough gasoline, more involves driveability problems."[12] Still, the driveability "demerits" by which GM rated the methanol blend performance and compared it to straight gasoline averaged 104 per cent more than with gas. Poor driveability is here atrributed to "leaning effect" - the result of the high oxygen content of methanol molecules which essentially reduces the amount of fuel that is fed to the engine.

But other research efforts indicate that, while driveability is to some degree adversely affected by the introduction of methanol admixtures, acceptable driveability is a realizeable goal even with blends containing higher percentages of methanol than GM used. A thesis submitted to the Graduate Department of the University of Minnesota, and printed (though not endorsed) by the U.S. Energy Research and Development Administration concludes that most vehicles could be adjusted for "optimum efficiency within pollution limits" even when running on blends of up to fiteen to twenty per cent methanol in gasoline.[13]

A test conducted with six 1971 cars by the Richmond Chevron Research Laboratory also concluded that driveability demerits with a ten per cent methanol blend exceeded those of gasoline.[14] The gasoline base was, as in the GM tests, unleaded. Two of the six cars maintained acceptable driveability levels even with these added demerits while those whose demerit levels were unacceptable had only reasonable or poor driveability levels operating on pure gasoline. The tests demonstrate that, with high methanol concentrations, the leaner mixtures can be used without lowering driveability standards unacceptably.

Methanol blend tests conducted cooperatively by Volkswagen and the Federal Republic of Germany also indicate that adverse effects caused by the leaner mixtures are not unacceptable in light of the favorable fuel conservation, anti-knock, and exhaust emissions results.

Two of the deficiencies of methanol blends most often cited by researchers are the vapor lock and phase separation problems. One of the chemical peculiarities of methanol is that it has a lower vapor pressure and higher heat of vaporization (boiling point) comparable to molecules of gasoline and other molecules of comparable weight. The result is that, at colder temperatures - below 10^{o} C (50^{o}F) - there are considerable ignition problems.[15] It takes almost four times as much heat to vaporize methanol as to vaporize gasoline.[16] Moreover, dilation in large quantities of gasoline disperses methanol molecules and enables them to vaporize too readily. Under some circumstances, this causes vapor lock, when gasoline or gasoline blends boil in the fuel pump inlet, reducing the fuel flow to the carburetor. Testing reveals that straight methanol fuels do not cause vapor lock, "but low concentrations of methanol have drastic effects," according to <u>Automotive Engineering</u>.[17] One possible solution to this problem is to use base gasoline blends with higher molecular weights and hence lower vapor pressures. Alternately, a small amount of methanol could be ignited by an electric current and provide the vaporization heat for the blended fuels necessary for ignition.

Methanol's low vapor pressure, it should be noted, is attractive in terms of safety. The temperature required to ignite methanol by flame is more than thirty degrees higher than the -20^{o} C (40^{o}F) required to ignite gasoline by flame.[18]

The introduction of methanol technolgy would also entail a problem with respect to phase separation. Accidental introduction of small quantities of water (approximately 0.1 per cent) at low temperatures will cause phase separation.[18] A methanol-rich phase coalesces and sinks while the gasoline-rich phase remains on top. As the methanol-rich phase has an air-fuel requirement which is about one-half that of the blend as a whole, efficient fuel delivery is inhibited. Several fuel economy tests during a period of relative humidity ranging from thirty to ninety per cent at moderate temperatures resulted in engine stall caused by methanol separation in the carburetor.[19]

The water-solubilizing additives that have been tested and found to be most effective in preventing phase separation are alcohols such as isopropanol and tertiary butyl alcohols, but the cost of using these additives at the high concentrations required for effectiveness makes them uneconomical. Of the more than 150 additives that have been tested, the Atlantic Richfield Company's "Aranol" additive seems to be the most effective and problem-free.[20]

Venting of vehicle fuel tanks and carburetor bowls would have to be via a drier to reduce the intrusion of moist air. The development of special fuel handling techniques such as those used in the handling of jet fuels has been proposed. But Volkswagen tests indicate that such techniques are not necessary. The VW test results summary states that:

> It has often been claimed that there is no way of preventing water from entering (as a result of rain or air humidity) during the production, distribution, storage, tanking and use of methanol-petrol fuel mixtures. The VW Programme has shown that these problems can be solved if appropriate precautionary measures are taken when handling these fuels. It is not, however, necessary during transport and storage to take special measures to prevent air humidity from entering. The water content of the stored methanol fuel varies in summer between 500 and 700 ppm (parts per million), and is even less than 400 ppm in winter; it is thus in a range in which demixing would only occur at below -20^{o}. In addition, solubilizers such as isopropanol or isobutanol can to a large extent solve any problem of demixing.[21]

Corrosion and swelling of certain fuel transport engine components have also proved problematical. Methanol's hydroxyl group is more corrosive of metals than petroleum hydrocarbon. The corrosive properties of methanol are compounded when water and salts are dissolved in the fuel. The metals most severely affected are zinc, lead and magnesium (used increasingly in fuel pumps and engine blocks).

Aluminum and copper are also attacked more by methanol than by petroleum hydrocarbons. These metals need to be coated or lined with resistant coatings.

Also, methanol swells or softens several of the plastics and rubbers used as gaskets and floats in today's auto fuel systems. Certain polyethylene and polyacetal seals appear to be satisfactory replacements for these susceptible components.

Corrosion problems are compounded in cars which utilize in-line electric fuel pumps. The addition of forty per cent methanol admixture to gasoline reduces gasoline's insulative properties and creates a small current between the fuel pump commutator and gas tank.[22] Continued exposure to such a blend will electrolytically strip a new fuel tank of its terne-plate coating and then corrode the exposed sheet metal. Although redesign of new cars would entail minimal engineering changes and little additional cost to the consumer, retro-fitting the existing car population would entail more extensive problems and greater costs to the motorist. By contrast, lesser admixtures do not require extensive or entail unacceptable costs.

All of the above problems are exacerbated when pure methanol is used in auto engines. Corrosion is much more severe than that caused by methanol blends. Cold starts problems which are far worse. Very little vaporization occurs in the engine and most of the methanol fuel remains in liquid form. Nine times more heat is required to vaporize methanol than gasoline.[23] The redesign of the engine to heat the intake manifold and intake air might effect satisfactory vaporization, but this requires more investigation and design study. Also, as methanol has a heat of combustion only half that of gasoline, and its latent heat of evaporation is almost four times as great, if pure methanol were to be used as an auto fuel, double-sized gas tanks would be required to maintain current driving ranges.[24] There is some evidence, though, that raising fuel compression ratios may preclude the necessity of double-sized tanks.

The benefits of methanol use, though, are manifold. Despite the need for double-size gas tanks with pure methanol blends, GM concedes that methanol's fuel economy and energy efficiency are roughly equal with those of gasoline. But these estimates are conservative. Volkswagen tests indicate that energy efficiency and power output are greatly increased using pure methanol. Blended fuel tests indicate that more power is obtained with methanol because its higher latent heat of vaporization cools the air entering the engine more than does gasoline, increasing air density. The gain in power output, according to Automotive Engineering, is as much as ten per cent if rich methanol mixtures are used.[25] In any case, the fifteen per cent usage of methanol in slightly modified American cars would reduce by fifteen per cent American dependency on OPEC oil.

The desirability of methanol as a fuel is further enhanced by its anti-knock property. Methanol's most attractive aspect is its high octane quality: Reported Road Octane Numbers (O.N.) of methanol fuels range from 105 to 115.[26] Depending upon what research method is used, methanol is either equal to or surpasses the best gasolines in octanes. Moreover, methanol has a demonstrated ability to boost gasoline's octane quality. When methanol is blended with gasoline in small quantities, it increases the gas octane rating by more than the proportion added. By adding only ten per cent methanol, the octane blending value is raised to 135 O.N..

2. Emissions

At least as important as performance, criteria for methanol fuels is their level of exhaust emissions. Lower combustion temperatures of pure methanol, owing to its cooling ability, results in substantially lower nitric oxide (NO_x) emissions relative to gasoline. Exxon tests show that emissions for methanol decreased from a peak of three thousand ppm to below one hundred ppm with increased in-fuel ratios. This compares with 230 ppm for gasoline at similar air-fuel ratios.[27] General Motors, too, found that NO_x emissions were reduced with pure methanol. GM tests also demonstrated that aldehyde emissions were reduced, but unburned fuel and other organic emissions were increased over those of gasoline. Further reductions in these emission levels were obtained by Volkswagen by more effectively vaporizing the methanol and mixing it with the air. This was accomplished by heating intake manifolds with exhaust gases and improving fuel-air spray atomizations. Carbon monoxide emissions were generally higher with methanol than with gasoline, but can be significantly reduced by improving the fuel mixture preparation system.[28]

In GM tests, methanol blends had about the same average hydrocarbon emissions as gasoline, although in some cases the emissions were drastically lower and in others higher than those of gasoline. The addition of methanol to gasoline decreased carbon monoxide emissions by a good deal. NO_x emissions varied, but averaged an eight per cent decrease relative to gasoline.[29]

Methanol also produces neither sulphur oxides nor sulphuric acid mists due to the de-sulphurization process required in its manufacture. Nor does it produce soot when burned. Addition of methanol to leaded gasoline also eliminates some of the lead emissions after combustion.

3. Methanol's Biological Hazards

Methanol is toxic and has numerous biological hazards. Initially it has a mild passing narcotic effect. A latent period, varying in length from less than an hour to three days after exposure, is also characteristic of methanol poisoning.[30] Symptoms of poisoning include weakness, dizziness, headache, sensation of heat, nausea, abdominal pain and vomiting, visual disturbances, convulsions, coma and death. Degree of exposure and variable individual tolerance determine the severity of the poisoning. Methanol is eliminated from the body only very slowly, and the latent physiological damages it can cause are results of the metabolic products of methanol, such as formaldehyde and formic acid. Methanol damages the central nervous system, having its most apparent effect on the optic nerve. Muscle rigidity and eventual loss of coordination, and progressive damage to the kidney, liver, heart, and other organs are final stages of latent poisoning.

Those exposed to high concentrations of methanol vapors can develop acute poisoning after only brief exposures. A vapor concentration of one thousand ppm will cause irritation to the eyes and mucous membranes. Five thousand ppm will cause sleepiness or stupor. One or two hours' exposure to fifty thousand ppm can cause narcosis and even death. Mere dermal contact with methanol can result in methanol poisoning by absorption through the skin. Immediate exposure to methanol, whether by inhalation or ingestion, will affect the eyes to some extent, from minor blurring of vision to destruction of the optic nerve. In some cases, visual symptoms may disappear, but return and cause blindness later.

V. Current Research on the Use of Ethanol as Fuel

Most of the considerations that apply to methanol with respect to performance also apply to ethanol. Like methanol, grain alcohol boosts gasoline octane numbers, reduces exhaust emissions and in some ways improves driveability.[31]

Ethanol may even be considered preferable to methanol as an alternative fuel in some respects. Most importantly, ethanol affords about twenty-five per cent better mileage than methanol, probably due to its high BTU content - 89,000 BTU's per gallon as compared to about 57,000 BTU's per gallon for methanol.[32] Also, the solubility of methanol is only about thirteen per cent in regular grade gasoline, while ethanol's is much higher. An ethanol content of ten per cent in premium gasoline at 10°C (50°F) may dry up a tank with under 0.3 per cent water content; two-and-a-half times that amount of methanol would be required to absorb the same amount of water. Consequently, ethanol is much less plagued by water sensitivity than is methanol.[33] Ethanol also suffers less from vapor lock, and may be more compatible with plastic engine components than is methyl alcohol.

Also, ethanol is producable from any sugar or starch, much more bountiful and obtainable resources than even the diverse sources of methanol. Recent technological breakthroughs in the production of glucose (from which ethanol is easily and quickly fermented) may make ethanol economically competitive with methanol sometime in the not-too-distant future, even though the current price of ethanol is as much as four times that of methanol in certain parts of the world.[34] An accidental discovery by U.S. Army researchers attempting to combat fungus growths resulted in the creation of fungus mutation that can convert cellulose (plant fiber) into glucose. The Army Natick Laboratories in Massachusetts estimate that one ton of waste paper can produce a half ton of glucose, which can be converted into sixty-eight gallons of ethanol. Natick's calculations indicate that the present domestic fuel shortage of 2.5 to 5 million barrels of oil per day could be eliminated by the daily hydrolysis of the nation's 1.5 to 3 million tons of cellulose in municipal and agricultural wastes. The annual world production of cellulose is about one hundred billion tons per year.[35]

The fact that ethanol fuel is more than just a bright idea that is unmarketable is demonstrated by Nebraska's ethanol auto fuel, or "gasohol" program. In an effort to supply a new domestic source of energy and rejuvenate the Nebraskan agricultural economy, the state legislature in 1972 enacted a program to aid the development of a grain alcohol industry by introducing an automotive fuel blend of ten per cent agriculturally derived ethanol and ninety per cent unleaded gasoline. The legislation provides for a three-cent per gallon reduction in the state gasoline tax on all gasohol purchased. Publicity for the program asserts that "with this tax reduction the price of GASOHOL is competitive with that of unleaded gasoline."[36]

Test vehicles for the Nebraska Department of Roads indicate that consumption of gasohol is five per cent less than of unleaded gasoline. No excessive engine wear or carbon deposit build-up has been reported, nor have drivers complained of poor

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driveability, ignition or vapor lock problems. More than ninety thousand gallons of GASOHOL were sold to the public during eleven weeks at a state-supported service station in Holredge, indicating enthusiastic consumer acceptance of this alternative fuel.[37]

Brazil, too, in an effort to reduce its dependency on foreign oil, has embarked on an ambitious program to produce alcohol from sugar cane and manioc (cassava) to be mixed with gasoline.

By the early 1980's, Brazilian ethanol production is slated to reach four billion liters of alcohol per year, which should satisfy about twenty per cent of Brazil's estimated auto fuel needs.[38]

Almost 2.25 billion of Brazil's total cropland of more than 110 billion acres will be used to produce the alcohol. The production of a metric ton of sugar cane will yield ninety-two kilograms of sugar and 10.7 liters of alcohol from the sugar crop's residual molasses.[39]

Brazilian automotive engineers do not expect that the twenty per cent alcohol admixture will require engine modifications, and it will permit that nation to reduce its petroleum imports by about ten per cent, saving Brazil four hundred million dollars annually in foreign exchange.[40]

VI. Ancillary Uses of Alcohols

Brazil is not restricting its intended use of alcohol to automobiles. It is also considering using its alcohol yield to power electric generating plants. A number of applications have been suggested for alcohols.

Vulcan Cincinatti, Inc. successfully tested methanol in a commercial utility boiler in Louisiana in 1971. Although the commercial boiler required only minimal modification, it is believed that methanol use in home or industrial furnaces would necessitate redesign of the fuel system to accomodate methanol's toxic and explosive hazards. General Electric Co. has run tests in a combustion chamber which demonstrated methanol's suitability as a turbine fuel. Anticipated power output gains can be increased with the addition of twenty per cent water in methanol.[41] Some pollutants from the turbine would be drastically reduced, but others, such as carbon monoxide, would be increased approximately threefold. Public utility electric power turbines are now principal elements in satisfying unprecedented peakload demands. These combustion chambers are oil-fired, but a number of fuels, including methanol, are compatible with turbine equipment. As the total domestic consumption of oil may almost quadruple by 1980, the attractiveness of methanol as a substitute for turbine oil may increase.[42] Accessible quantities of least polluting fuels for electric power generation - natural gas, low sulphur coal, and low sulphur oil - are waning. Moreover, the equipment that fulfills the intermediate load (twelve to fourteen hours per day for a five-day week) may not be adequate for the purpose in the future.[43] Utility companies have, since before 1960, intermittently used older base load equipment to satisfy intermediate load requirements, but newer generating technologies are not suited to cyclical intermediate load operation. One of the more hopeful alternatives to satisfy these needs is the combustion-turbine-steam-turbine combination, whose numbers are expected to increase at the annual rate of thirty per cent through 1985.[44] This trend, it is expected, will mandate the introduction of methanol fuels and ensure their economic competitiveness as conventional low-pollution fuels become scarce and expensive.

Methanol may also have a more basic use than powering machines - it may indirectly power people. While direct methanol ingestion is lethal to most forms of life, a species of single cell algae bacteria and yeast thrives on a feedstock of methanol and inorganic nutrients. These algae have a high protein content and are currently being used to replace milk and soybeans in calf feed. Some European nations are now involved in the construction of plants which will grow single-cell protein bacteria on methanol. The possibilities of such production in less developed countries in arid regions of the world are limitless. It is considered technologically feasible to utilize large-scale solar energy collectors in the great deserts of the Sahara area, Australia, Northern India, and the Southwestern United States to produce methanol from atmospheric carbon dioxide and water. The methanol produce could be used as the feedstock for the high-protein algae in areas where limited water supplies inhibit conventional agriculture practices. The yield may even be higher than that of conventional agriculture.[45]

RECOMMENDATIONS

1. Development of a comprehensive public education campaign to discuss the pros and cons of alcohol fuels.

2. Congressional hearings to evolve a strategy for the gradual introduction of alcohol blends into the marketplace.

3. Department of Energy sponsored study of (i) the cost burdens associated with retrofitting cars to accommodate alcohol blends; (ii) the effect upon State revenues for highway maintenance, etc.; (iii) safety standards for alcohol fuels; (iv) the alcohol industry, including tariff structures; and (v) areas where additional research is needed.

4. Increased federal funding of garbage separation and municipal waste conversion plants, particularly in urban centers.

5. Alcohol fuel tests with government owned fleet vehicles.

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cooperation Scott Sklar.

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ALCOHOL FUELS FOR TRANSPORTATION

Statement by The American Petroleum Institute

Submitted to

Energy and Natural Resources Committee
Subcommittee on Research and Development

U. S. Senate

The American Petroleum Institute has addressed the subject of alcohols as fuels through an Alcohol Fuels Task Force, comprising a small group of petroleum technologists and engineers. This group has worked together since 1973 on the technical aspects of the utilization of alcohols as fuels, and as a potential means for broadening our present petroleum base for transportation fuels. Because this statement reflects views of the task force, a roster of present membership is attached.

Before responding to the stated purpose of these hearings, we would first like to clarify the API position on the development of alcohols as fuels and chemical feedstocks. We recognize this to be an issue where many groups of our fellow citizens now perceive a common interest. In addition, we are sensitive to the criticism that we are not interested in the development of such fuels because they compete with our traditional petroleum fuels business.

On the contrary, we thrive on new technology, and are interested in any new fuel or chemical supply. Alcohols represent one of many possibilities. Alcohols are versatile chemicals that have a wide variety of potential uses as fuels and chemical feedstocks. As fuels, alcohols have desirable properties such as high thermal efficiency and high octane, which could be fully exploited in certain uses. As chemicals, alcohols made from coal and agricultural and forestry products could replace alcohols made from petroleum, thus releasing the petroleum to fuel markets.

It makes no sense for a petroleum company to ignore alcohols or any other product that could successfully compete with its petroleum reserves. If, by adding either ethanol or methanol to its gasoline pool, a company could offer the public a superior product at or below existing product costs, it would pay to do so. To ignore alcohols would be to impose a cost on the company in one of two ways: The company would forego a chance to increase its market share and profits if competitors were unaware of the advantage of alcohols. The company would suffer an actual loss of market share and profits if competitors were aware of the advantage of alcohols and acted on it. Note that this argument is independent of the source of ethanol and methanol, e.g., petroleum, natural gas, grains, municipal wastes, etc.

In fact, the petroleum companies have not ignored alcohol fuels. Evidence of petroleum company interest in ethanol and methanol as motor fuels is in the research files of virtually every petroleum company, dating as early as the 1920's.

Petroleum companies have been and continue to be interested in ethanol and methanol, but do not market them as motor fuels, because they have been and continue to be more costly than the available alternatives relative to their advantages as motor fuels. Various technical problems have also been a factor, but these problems are solvable. Each time companies have become seriously interested in the advantages of ethanol and methanol as gasoline blending components, less expensive octane improvers or improved processing techniques, such as catalytic reforming, have been developed.

As an industry and as individual companies that have studied the uses of alcohols for many years, we have on various occasions offered our research findings as an aid in public deliberations on policies to encourage the development and use of alcohols as fuels. We have also attempted to identify higher-valued uses for alcohols than as motor fuels.

In our comments, we have discussed various technical problems that would arise in distributing and using straight alcohol fuels and alcohol/gasoline blends. None of the problems we have identified are technically insurmountable, although the cost of their solution would be reflected in the price of motor fuel.

The API does not oppose the development and use of alcohols as motor fuels, but believes that the most efficient uses of alcohol fuels may be other than as blends with gasoline. We believe that the entire hierarchy of potential domestic energy resources should be developed in the most efficient sequence consistent with all of our national objectives. If and when ethanol and methanol become cost competitive as motor fuels, petroleum companies will market them.

Toward this end, the API supports the encouragement of further research on the production of alcohols and the use of alcohols as fuels and chemical feedstocks. If, in the national interest, such a policy is adopted, alcohol fuels should be considered along with other options. This policy should recognize the social and economic benefits of the various options as well as their contribution to improving the overall U.S. energy supply situation.

The API does oppose governmental mandating of the sale and/or use of alcohols as fuels or feedstocks. Under current conditions, mandating would force a higher-priced product on consumers without taking into consideration the best and most economical uses of alcohols and other fuel options. Existing competitive fuel and chemical markets will direct alcohols to their highest-valued uses as they become cost competitive.

From this perspective we would first like to review the results of our studies on the applications of alcohols as fuels. We reference our Report No. 4261, "Alcohols -- A Technical Assessment of Their Application as Fuels," dated July 1976 (copy attached). Then we will give you a preview of results from our contract study on the net energy impacts of alcohol fuels from biomass sources, which is still in progress. The potential for stretching our fuel supplies is often given as justification for subsidizing gasohol, so the energy balance has become an important issue.

APPLICATION OF STRAIGHT ALCOHOLS

If you look only at combustion properties, the low molecular weight alcohols (methanol and ethanol) because of their wide flammability limits, high flame speeds, and low flame luminosity, unquestionably make superior fuels compared with petroleum derived hydrocarbons. At the same time, all of the nation's automobiles have been developed to burn petroleum fuels, and only new engines specifically designed for alcohol fuels could exploit these advantages. Generally, except for octane value, they are lost in blends with gasoline.

The combustion superiority of alcohol fuels potentially could be realized more completely in gas turbines, where the low luminosity of alcohol flame permits safe operation at much higher energy inputs. This has the effect not only of increasing the power output of an existing unit, but the energy conversion efficiency, as well. Such turbines are widely used in industrial applications, particularly in the electric power industry for "peak-shaving" operations. Generally, minimum modifications to turbine engine fuel pumps and storage systems would be required.

Alcohols also can be clean burning, with essentially no emissions of particulates and carbon monoxide (CO), and reduced emissions of nitrogen oxides (NO_x). However, emissions of unburned fuel (mostly the alcohol, itself) tend to be about the same, or even higher, than they are with hydrocarbon fuels. In addition, emissions of aldehydes tend to be substantially increased.

These latter emissions are not now regulated, and their effects of air quality are not fully understood. Aldehydes are well known to aggravate existing respiratory problems, and to cause eye irritation. While methanol vapors have very low atmospheric reactivity (oxidant, or "smog" forming potential), they are acutely toxic. This is not generally true for hydrocarbons, although some may prove to be chronically toxic. Both of these emissions would tend to be controlled in catalyst equipped cars.

Although the emission of regulated air pollutants from vehicles equipped with engines specifically designed to use alcohol fuels would be reduced, such emissions would not be low enough to meet present and future standards without the same type of emission controls presently used and under development for cars fueled with gasoline. Such cars would not be fueled with gasoline unless they were developed with costly dual-fuel systems. Preferably, they would not become part of the general vehicle population, but would be used only in segregated fleets where their special fueling needs could be catered for at lower cost and with adequate public safeguards.

These generalities all apply to methanol, and in lesser measure to ethanol. The real problem with alcohols as fuels is their poor prospects for availability in large quantity at low prices. If alcohols can be manufactured at sufficiently low costs -- lower than today's fuels, or lower in the future than other synthetic fuels -- they surely will be manufactured and used for fuels purposes.

APPLICATION OF ALCOHOLS IN GASOLINE BLENDS

Except for octane value, combustion advantages of straight alcohols just discussed are lost almost entirely when alcohols are considered as possible components of the gasoline pool. At the same time, serious disadvantages can arise, including:

- the forced removal of light hydrocarbons from the pool,
- increased marketing and distribution costs,

- new product liability and public safety hazards,
- decreased customer satisfaction,
- increased exhaust emissions with certain cars,
- need for vehicle retrofits.

The extent of these disadvantages depends on the type and concentrations of alcohols employed.

The low molecular weight alcohols, because of the strong hydrogen-oxygen bond, behave more nearly as a gas than a liquid when in dilute solution with hydrocarbons. Thus, a few percent methanol, when added to gasoline, raises the vapor pressure about 3 pounds per square inch (psi). In the case of ethanol, it's about 1 psi.

But vapor pressure of motor fuels must be controlled to meet specifications designed to prevent vapor locking in the vehicle fuel system. In the case of methanol-gasoline blends an amount of light hydrocarbons (butanes and pentanes) about equal in fuel value to the methanol added would have to be <u>removed</u> from the fuel pool to meet product specfications. Apparently, from this effect alone the underlying objective of increasing motor fuel supplies would be mostly defeated by methanol blending and partly defeated by ethanol blending.

Because of alcohols' strong affinity for water, corrosive activity and incompatibility with many of the materials used in contemporary gasoline storage and distribution systems, substantial additional marketing and distribution costs would attend a switch to alcohol blends. In the case of methanol, it probably would be necessary to store and distribute the methanol and the gasoline separately, blending them only at the point of sale. For ethanol blends (gasohol) we know from experience that special measures must be taken to keep water out of a normally wet distribution system, but we do not know the extent to which materials changes would have to be made, since corrosion and degradation of rubber parts is a gradual process.

Similarly in the case of motor vehicles, very little retrofitting might be required if used car owners would be willing to overlook the gradual corrosive attack and degradation of non-metallic fuel system components attendant to the use of blends. This situation would be less troublesome with ethanol (gasohol) blends, but a question at least arises of who (if anyone) would be liable for damage.

There has been much debate about the potential environmental hazards of alcohol fuels relative to hydrocarbons. Perhaps the only present point of agreement is that they at least are different. The blending of alcohols into gasoline will surely challenge the ingenuity of those who would wish to separate the two, thus giving rise to serious and presently unresolved alcohol tax and drug abuse questions. Motor fuel spills can and do occur. When they do, the results are sometimes serious but almost never catastrophic. With its extreme affinity for water, high acute toxicity, yet rapid biodegradability, the consequences of a serious spill with a fuel containing methanol can only be speculated upon. This is an area where we need more information.

Since the blending of alcohols into hydrocarbon fuels has the effect of diluting the fuel value of the hydrocarbon, the results for today's vehicles, both with respect to driver satisfaction and exhaust pipe emissions, are similar to what otherwise could be obtained simply by mechanically leaning out the carburetor. Depending on pre-existing conditions, these results can be (1) favorable, (2) inconsequential, or (3) unfavorable (similar to the results when insufficient fuel is fed to the engine.)

When alcohol-gasoline blends are used in older cars (especially those with dirty carburetors and/or those built before emissions controls), driver satisfaction (so-called driveability) may not be much affected, and emissions of CO, in particular, and hydrocarbons (HC) to a lesser extent, will decrease. At the same time, NO_x emissions will increase.

Cars of more recent manufacture generally will suffer from the effects of fuel starvation. Hesitation, stalling, and impaired acceleration performance can occur, depending upon which alcohol has been blended, and how much. In addition, there can be surging -- an annoying condition characterized by uneven performance at road speeds. HC emissions, and to a lesser extent NO_x emissions, may rise.

There is reason to speculate that car models with advanced, so-called closed-loop fuel metering systems, now being introduced into the California market and planned for subsequent introduction nationwide to meet stringent emissions controls, will prove to be insensitive to the leaning effect of alcohols. But this has not yet been demonstrated.

We would now like to conclude our discussion of alcohol/gasoline blends (including gasohol) by stating that we find this application, though possible, to be technically the least meritorious of the major, potential fuel uses. To underscore this conclusion, we wish to call to your attention that proprietary work has been done voluntarily within the petroleum industry to convert alcohols to more useful blending agents, including (1) ethers, and (2) gasoline.

NET ENERGY IMPACTS OF ALCOHOLS FROM BIOMASS SOURCES

Our interest in the net energy consequences of competing processes for synthesizing alcohols from biomass sources relates to their potential impact on the energy requirements from petroleum, including foreign imports. More specifically, we are concerned that (1) these processes as they now exist are highly energy intensive, and (2) the energy supplied (at least in most cases as they are practiced in the United States) comes from petroleum and natural gas, those very resources the nation is now trying to conserve.

We have contracted with a research firm well grounded in both the agronomic and processing aspects to provide us with an independent energy assessment of the principal methods under consideration today. These include three routes to ethanol (from corn, sugar cane and sugar beets) and two routes to methanol (both from silviculture, or "tree farms"). We hope to have these studies completed by the end of the summer, at which time we will be pleased to make them available to this subcommittee.

While it would be premature to speculate on final results now, it already seems clear that almost two energy units must

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be invested to yield one in the form of ethanol from grain sources, while ethanol from sugar cane looks like a break-even energy balance. At least one of the routes to methanol from wood also appears to afford a break-even energy balance.

From the inventory of required energy inputs, that for process heat predominates. Thus, it would be very important to the national interest for process heat in any commercial venture to be supplied from non-petroleum sources. In the case of ethanol from grains, the heat requirement for mash cooking and still evaporation alone is so high that, were it supplied from coal, the whole process begins to look like an energy alternative to straight coal gasification followed by alcohol synthesis.

SUMMARY

Based upon the findings discussed above, we conclude the following:

1. Despite current obstacles to their use as fuels, alcohols have excellent combustion properties. Accordingly, further study of the problems facing production and widespread use of alcohol as fuels should be encouraged, commensurate with national policy to develop alternatives to petroleum.
2. Alcohols have many potential fuel uses that are higher-valued than blending with gasoline. For example, use of straight alcohols in stationary gas turbines or specially designed vehicle fleets would make optimum use of alcohols' inherent combustion

advantages. Also, direct use of biomass as fuels should be investigated. Possibilities include burning agricultural wastes as boiler fuels.

3. The API recognizes that alcohols represent several in an hierarchy of alternative fuel candidates. If it becomes a matter of national policy to encourage the production of alternative fuels, then alcohols should be considered along with the others and phased into production in the most efficient sequence.

4. Existing, competitive fuel and chemical markets are capable of directing alcohols to their highest-valued uses as they become cost competitive. The market should be allowed to perform this function.

5. Government mandating of markets for alcohols as fuels or feedstocks accordingly should be avoided. Such mandating would force consumers to subsidize alcohol producers with no assurance that the higher priced product represented commensurate value, or that it had been directed to the most efficient end use.

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Alcohols

A Technical Assessment of Their Application as Fuels

American
Petroleum
Institute

FOREWORD

This report was prepared by Task Force EF-18 of the Committee on Mobile Source Emissions, Environmental Affairs Department, American Petroleum Institute. It is based on published information as well as on private reports from a number of API member companies. The assistance of these companies is gratefully acknowledged and special thanks are due to William Biller, who assembled much of the information originally, and to Gordon Bixler and API staff members, who helped prepare the final version for publication.

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CONTENTS

1. PREFACE

This report summarizes the state of the art of applying alcohols as fuels. It develops conclusions specific both to the technical advantages as well as to the disadvantages of alcohols with respect to hydrocarbon fuels. In addition, it points out that there are substantial costs associated with the conversion of existing vehicles, other fuel burning equipment, and fuel distribution systems for the use of alcohols.

If alcohols can be manufactured at sufficiently low costs—lower than today's fuels, or lower in the future than other synthetic fuels—they surely will be manufactured and used. Many different studies of manufacturing costs have been made, and these continue. Unfortunately, a considerable disparity exists among various estimates, depending upon different available processes, raw materials and different financial premises.

The definitive treatment of the economics of alcohols as fuels is a complex subject in itself, and is entirely beyond the scope of this report. Nevertheless, the following facts and generalized conclusions are widely accepted, and will facilitate interpretation of the report:

Ethanol today is made either by fermentation starting with agricultural carbohydrates, or from ethylene derived from petroleum. About 65% of the total U.S. production is from petroleum. Even if the volume of fermentation alcohol were tripled, there would only be enough for existing non-fuel uses, and none would be available as a petroleum fuel substitute.

Fuel markets would not attract fermentation ethanol because it is prohibitively expensive. To be competitive on an equal-energy basis with gasoline at the refinery gate, ethanol would have to sell for about 21¢/gallon (1975 prices). Made from corn at $2/bushel, the most optimistic estimate (70) is about $1/gallon. Made from wood chips (enzymatic conversion of cellulose to glucose followed by fermentation) the cost is somewhat lower, but still over twice as high as other possible synthetic fuels (70).

Methanol from coal (the cheapest large-scale raw material) is considerably cheaper than ethanol, but still not competitive with gasoline at the time of this writing (1975). Several calculations for methanol have been made, with widely varying results (59-76). However, even the cheapest (76) gives a cost of about 32¢/gallon, roughly twice the refinery price of gasoline on an equal-energy basis. Other estimates are nearly twice this high.

Although the cost of gasoline can be expected to increase over the years, the cost of making synthetic fuels also will increase, and it is very unlikely that methanol ever will become competitive based on economics alone. Short range, there is no question that methanol cannot compete on a cost basis.

Longer range, where planning for synthetic fuels is required in order to assure a continuing supply, alcohols should be compared with synthetic gasoline from coal and shale. Hopefully, the future of alcohols as fuels will be determined by the facts of economics and technology, *i.e.*, how well they can compete with other synthetic fuel alternatives in terms of 1) cost, 2) raw materials utilization, and 3) product application (the subject of this report). The methanol fuel question is but a sub-issue of the much larger question of coal utilization to help meet national energy needs, and it cannot properly be addressed as a separate issue outside the overall context of coal conversion to liquid and gaseous fuels. A definitive answer is at least a decade away.

As this report shows, alcohols have a few advantages (such as octane number) that could make them more valuable than petroleum derived gasoline, and significant disadvantages (such as low energy content) that increase their transportation and distribution costs, and thus make them less valuable. Furthermore, there are substantial costs associated with the adaptation of existing vehicles and fuel distribution systems to use alcohols. These factors are significant; the ultimate choice among competing alternative fuels will be based largely on their overall cost to the consumer per unit of energy. For the immediate future, these costs for alcohols are much too high. Over the long term, efforts to promote alcohols as synthetic fuels will prove to be misguided unless overall costs to the consumer compare favorably to those of gasoline derived from coal and shale.

2. SUMMARY AND CONCLUSIONS

In the search for an independent energy base for transportation in the United States, alcohols are being proposed as fuels to supplement domestic oil and natural gas supplies.

In today's economy, synthetic fuels, including alcohols, would be considerably more expensive than petroleum fuels. This differential is expected to remain as long as petroleum is generally available. Longer term, if synthetic fuels were to become cheaper than petroleum, alcohols should have to compete against hydrocarbon liquids from coal and shale, both in cost and in raw material utilization. Should alcohols become competitive, their best use at the start would appear to be as gas turbine fuels for land-based peak power generation, and in other premium fuel applications, where their clean-burning and low nitrogen oxide formation characteristics can be used advantageously. Following this, their use in automobiles could be considered. Here the use of straight alcohols in appropriately modified engines would be preferable to the use of alcohol-gasoline blends.

The chemical and physical properties of alcohols, particularly those of methanol and ethanol, differ considerably from those of conventional hydrocarbon fuels. Energy contents of alcohols per unit volume are substantially lower than those of hydrocarbons. Solubilities in most petroleum fuels are limited, the exception being in aromatic gasolines. Even here, only very small amounts of water cause the alcohol blend to separate into two phases. Alcohol-gasoline blends also exhibit disproportionately high vapor pressures which, if not corrected, would greatly increase the risk of vapor lock in automobiles.

Alcohols also differ from petroleum fuels in corrosivity towards metals, compatibility with plastics and rubbers, toxicological properties and fire hazards. Their application as fuels would therefore require the use of different materials in fuel handling systems, and at least a comprehensive review, if not an extensive revision, of current safety codes.

If the levels of performance and reliability currently expected of petroleum fuels are to be ensured, alcohols—either straight or in blends—cannot be interchanged with gasoline in conventional vehicles without costly modifications to both vehicles and fuel distribution systems. Moreover, with prices of methanol and ethanol substantially higher than those of gasoline, there exists no economic incentive to make these modifications.

Straight Alcohols as Automotive Fuels

If used to fuel vehicles *specifically designed for optimum use of their properties,* straight alcohols offer potential advantages that could outweigh disadvantages in certain situations. An example might be a large fleet, where both vehicles and fuel distribution facilities could be designed as a coordinated system, and where fuel production could be justified by the local supply pattern of raw materials and energy. In this case, performance relative to gasoline compares as follows:

- *Thermal efficiency/Fuel economy.* Thermal efficiency is potentially better with alcohols because they have more favorable thermochemical properties, can be burned leaner, and can operate at higher useful compression ratios. However, to the general public, the most evident difference would be significantly fewer miles per gallon, which is a direct result of the lower energy contents of the alcohols. Methanol has about half the energy content per unit volume of gasoline, and ethanol about two-thirds.
- *Exhaust emissions* of hydrocarbons (or unburned fuel) and of carbon monoxide are practically the same when methanol and gasoline are compared at the same relative mixture strength (equivalence ratio). Aldehyde emissions are higher with methanol. Emissions of nitrogen oxides are generally lower with methanol, especially at very lean mixtures where operation without misfire would not be practical with gasoline. However, with these lean mixtures, the other emissions would not be low enough to meet projected emission standards without emission controls like those required with gasoline.
- *Driveability,* except for starting quality, has not received sufficient attention to date. Starting methanol-fueled, carbureted engines below 50-60°F requires a special starting aid, such as a volatile additive in the fuel or an auxiliary volatile fuel. Even with aids, starting below 10-20°F is extremely difficult.
- *Durability* of some components of engines and fuel systems may be impaired with alcohols, especially with methanol. Terneplate (a common fuel tank material), copper and brass show evidence of increased corrosion, and some plastics and rubbers show increased softening or swelling.

Supplying straight alcohols as automotive fuel would also require new and separate distribution systems designed to deal with the different materials compatibility and corrosion characteristics, the different fire, explosion, and health hazards encountered in handling and storing alcohols, and the necessity of preventing deliberate or accidental adulteration with water.

Alcohol-Gasoline Blends as Vehicle Fuels

Alcohol-gasoline blends have been seriously proposed for use only in conventional automobiles. Their characteristics in unmodified cars are predictable from the relatively leaner fuel-air mixtures they produce:

- *Thermal efficiency/Fuel economy.* Thermal efficiency increases somewhat, particularly in those cars with rich mixture calibrations (mainly pre-1968 models); however, fuel economy measured in miles per gallon generally decreases, approximately in proportion to the alcohol content of the blends. The offsetting improvements in thermal efficiency are of lesser magnitude than the reduced energy content of the blends.
- *Exhaust emissions* change to the same extent they would have changed using gasoline, were the carburetor adjusted to an equivalently leaner mixture strength. Hydrocarbon and carbon

monoxide emissions are reduced somewhat (particularly in older cars originally set rich) but the improvement is not enough to obviate the need for emission controls. With emission controls, alcohol offers no advantage in this regard. NO_x emissions are not much different with alcohol blends, being somewhat higher for cars set rich and somewhat lower for cars set lean. Aldehyde emissions increase somewhat.

- *Driveability* suffers significantly, just as it would if gasoline alone were used with equivalently lean carburetion.
- *Durability* of fuel system components is impaired with alcohol-gasoline blends, although not as severely as with straight alcohols.

If cars were operated on alcohol-gasoline blends, the chief advantage would be a reduction in knock and after-running in those afflicted with these symptoms. The chief disadvantage would be (1) the risk of phase separation at winter temperatures, or if water contamination were present; (2) the corrosion or deterioration of sensitive fuel system parts; and (3) a directional deterioration in vehicle driveability, not only because of leaner operation, but also because of the higher vapor locking tendency of the blends.

Avoiding these problems would require (1) modifying fuel distribution systems to exclude water, (2) replacing sensitive fuel system materials, (3) re-calibration of engine fuel metering systems as needed to offset the leaning effect and/or modifying engine fuel systems or reformulating base gasolines to avoid vapor locking and maintain driveability. In the case of methanol, reformulating the base gasoline would exclude from the gasoline pool a quantity of butane and pentanes about equal to the methanol added. Although these components could find a fuel use elsewhere, it would make more sense to find an alternative use for the methanol.

Fire, Explosion and Health Hazards

Handling requirements for alcohols are generally the same as those for gasoline except for two crucial differences:

- The alcohols have much wider flammability limits. As a result, their vapors in storage tanks, including vehicle tanks, are explosive at ambient temperatures while those of gasoline are too rich to ignite.
- Methanol, in addition to its generally known toxicity when ingested, presents an insidious health hazard in its ability to induce blindness when inhaled, or absorbed through the skin. For methanol-gasoline blends, the health hazards are such that under current law they would require the skull-and-crossbones label.

Conclusions

Short range, as indicated in the *Preface,* alcohols are too expensive to be considered for large-scale fuel use. Longer range, when synthetic fuels from coal, shale, wastes, or agricultural products become economically competitive with petroleum, the use of alcohols as fuels should be reexamined. The most attractive of such uses would be in land-based gas turbines, or as a straight fuel in automobile engines specially designed to take advantage of methanol's special properties. Use of alcohol-gasoline blends is the least attractive alternative because of the handling problems associated with them and because the potential advantages of straight alcohols are lost and not realized in blends.

3. INTRODUCTION

Projecting energy needs and calculating total energy resources are patently difficult tasks. Nonetheless, it is becoming increasingly clear that domestic oil and natural gas supplies are not sufficient to meet this country's future energy needs. In the past several years, numerous proposals have been advanced for providing additional liquid and gaseous fuels from coal as well as from primary agricultural products, agricultural by-products, and even municipal waste.

Many of these proposals involve making methanol from coal in large plants and making ethanol in quantity by fermenting grains, other agricultural products, and possibly glucose derived from municipal wastes rich in cellulose. In most of these proposals, the resulting alcohols are assumed to be suitable either for use directly or in blends with gasoline to fuel automobiles and trucks and for use in stationary applications such as gas turbine generators for electricity production.

Proposals for using alcohols as fuels are far from new. When the Industrial Denatured Alcohol Act was passed in 1906, removing the tax from ethanol used industrially, some industrial and government personnel believed that ethanol would become a major motor fuel. In spite of much research, however, ethanol never overcame the two major obstacles in the United States of high cost compared with gasoline and lack of sufficient technical advantages to justify the higher cost (1, 2, 3).

Prior to World War II, ethanol was sometimes blended with gasoline for a number of markets outside the United States. Major incentives included providing outlets for farm produce, avoiding dependence on imports of scarce raw materials, and establishing large capacities for ethanol to make explosives. When the war ended and gasoline again became readily available, Europeans virtually stopped blending ethanol in gasoline. Today, only countries with large supplies of sugarcane, such as Brazil, Cuba, and the Philippines, continue to use it in motor fuel.

The practice of injecting methanol-water solutions into the induction systems of supercharged aircraft engines during World War II to increase power caused a flurry of interest in alcohols as fuels for automobiles and trucks in the United States. This interest, however, related to its use as a minor additive and did not extend to its use as a significant fuel blending component. Furthermore, supercharged engines were not improved enough to justify the complexity of a dual fuel system (2). Today, methanol is used as a vehicle fuel in the United States only in high-performance racing cars, where additional power is obtained at a considerable sacrifice in fuel efficiency.

In the United States in the mid-1960's, interest in ethanol as a fuel rose again, this time as a way to reduce automobile exhaust pollutants. Studies of blends of ethanol with gasoline, however, failed to show practical advantages. Interest thus waned again until recently, when sharply rising prices for oil and natural gas, increasingly scarce domestic reserves, and a national goal of becoming more energy-independent re-stimulated interest in alcohols as fuels.

Scope and Conclusions

In 1971, the American Petroleum Institute (API) studied the feasibility of blending ethanol with gasoline to improve automotive fuel supplies (1). Now, because of expanded interest in using alcohols as fuels, API offers an updated technical assessment. In contrast with the earlier study, the scope is broadened to embrace other applications in addition to transportation and emphasis is shifted to methanol in accordance with its emergence as the supplemental fuel of most current interest.*

*This study, and the earlier one, are based largely on the published literature, but a substantial portion is supported by unpublished research results made available to API by a number of companies.

4. CHEMICAL AND PHYSICAL PROPERTIES OF ALCOHOLS

The chemical difference between hydrocarbon fuels and alcohols, such as methanol, ethanol, isopropanol, and tertiary butanol, is the presence of oxygen in the alcohol molecule (Table 1). As a result, alcohols differ substantially from hydrocarbons in such important fuel parameters as the amount of oxygen required to burn them and in the volumes of products made (Table 2). In addition, alcohols, when burned, generate less heat per gallon than hydrocarbons do. They also require more heat for vaporization than hydrocarbon fuels (Table 3).

These differences have important practical implications for proposals to substitute any of the alcohols, or blends of them with hydrocarbon fuels, to ease shortages of oil and natural gas. These implications will be dealt with more fully in the sections that follow. The volatilities and solubilities of the alcohols, however, are also strongly influenced by their chemical structure, and these properties will be dealt with here.

Volatility and solubility are particularly important when considering alcohols as blending components for gasoline. The polar effects

TABLE 1

Some Properties of Alcohols and Gasoline

Property	Methanol	Ethanol	Isopropanol	Tertiary Butanol	Gasoline
Formula	CH_3OH	CH_3CH_2OH	$(CH_3)_2CHOH$	$(CH_3)_3COH$	Mixture of C_4 to C_{12} Hydrocarbons
Molecular weight	32.04	46.07	60.09	74.12	100-105 avg.
Composition, weight percent					
Carbon	37.5	52.2	59.9	64.8	85-88
Hydrogen	12.6	13.1	13.4	13.6	12-15
Oxygen	49.9	34.7	26.6	21.6	0
Specific gravity, 60° F./60°F.	0.796	0.794	0.789	0.791	0.72-0.78
Density, lb./gal.	6.63	6.61	6.57	6.59	5.8-6.5
Boiling temperature, ° F.	149	172	180	181	~80-437
Flash point, ° F.	52	55	53	52	−45
Autoignition temperature, ° F.	867	793	750	892	495
Flammability limits, volume percent					
Lower	6.7	4.3	2.0	2.4	1.4
Higher	36	19.0	12.0	8.0	7.6

TABLE 2

Combustion of Alcohols and Hydrocarbons in Air

Fuel	Reaction Equation	Stoichiometric Air-Fuel Ratio (Lb./Lb.)	Volume % Fuel In Vaporized Stoichiometric Mixture	Ratio Moles Product / Moles Charge	Ratio Moles Product / Moles $O_2 + N_2$
Methanol	$CH_3OH + 1.5O_2 + 5.66N_2 = CO_2 + 2H_2O + 5.66N_2$	6.45	12.3	1.061	1.209
Ethanol	$C_2H_5OH + 3O_2 + 11.3N_2 = 2CO_2 + 3H_2O + 11.3N_2$	9.00	6.5	1.065	1.140
Benzene	$C_6H_6 + 7.5O_2 + 28.3N_2 = 6CO_2 + 3H_2O + 28.3N_2$	13.2	2.7	1.014	1.042
Isooctane	$C_8H_{18} + 12.5O_2 + 47.2N_2 = 8CO_2 + 9H_2O + 47.2N_2$	15.1	1.6	1.058	1.075
Gasoline	$C_nH_{2n} + 1.5nO_2 + 5.66nN_2 = nCO_2 + nH_2O + 5.66nN_2$	14.7	2.0	1.047	1.070

TABLE 3

Thermal Properties of Alcohol and Hydrocarbon Fuels

Property	Methanol	Ethanol	Isooctane	Typical Gasoline
Heating value				
Higher, B.t.u./lb. (Liq. fuel/liq. water)	9,750	12,800	20,560	20,300
Lower, B.t.u./lb. (Liq. fuel/water vapor)	8,570	11,500	19,070	18,900
B.t.u./gal. at 68° F. (Liq. fuel/water vapor)	56,560	75,670	110,000	115,400
B.t.u./lb. at 68° F. (Gas. fuel/water vapor)	9,080	11,900	19,200	19,050
Stoichiometric mixture "heating value"				
B.t.u./cu. ft. at 68° F. (Mixture in vapor state)	92.5	92.9	94.0	95.2
B.t.u./lb. of air (Fuel in liquid state)	1,330	1,280	1,270	1,290
Latent heat of vaporization				
B.t.u./lb. at 68° F.	506	396	135	~150
B.t.u./gal. at 68° F.	3,340	2,378	779	~900
B.t.u./lb. air for a stoichiometric mixture at 68° F.	78.4	44.0	8.94	~10

caused by the presence of oxygen in the molecule significantly influence the volatility of blends and the solubility of alcohols in hydrocarbons. These effects are most pronounced for methanol and to a lesser degree for ethanol and the higher alcohols (since properties of the alcohols approach those of nonpolar hydrocarbons as the number of carbon atoms in the alcohol increases). The discussion will focus on methanol, since it represents the limiting or most extreme case.

Volatility

Methanol is a single compound that boils at 149°F, while gasoline is a mixture of compounds that boil over a range of temperatures (which can start as low as 80°F, but which generally do not exceed 437°F). Thus, methanol's volatility is a constant, while gasoline's volatility can be tailored over a range by adjusting the relative amounts of different hydrocarbons in the mixture. The difference in volatility between methanol and gasoline is especially important in the way methanol performs in automobile engines with respect to starting, warm-up, vapor lock, and other driveability characteristics. These effects will be discussed in detail in the next section on automobile performance.

Adding methanol to a hydrocarbon such as *n*-hexane or gasoline causes a large increase in vapor pressure (Figures 1 and 2), and depresses the boiling temperature over a range that increases as more methanol is added (Figure 3). From a typical equilibrium vapor composition curve for methanol in a hydrocarbon (Figure 4), it is apparent that, in the flat region, alcohol vapors exist at concentrations disproportionate to the alcohol concentration in the blend. Studies with gasoline have shown that both the vapor pressure and the fraction distilled below about 160°F govern the tendency to vapor lock. Addition of methanol to gasoline, therefore, should increase the fuel's tendency to vapor lock.

Removing all butanes and reducing the pentanes would be one way to adjust a methanol-gasoline blend to have the same vapor-locking tendency as a base gasoline. Doing so to adjust volatility, however, would negate the increase in gasoline volume sought by adding methanol.

The high concentration of methanol in vapors above dilute blends of methanol in hydrocarbons and the flat induced in a blend's distillation curve also indicate that the blend would fractionate in the intake manifolds of automobile engines. The methanol concentration in the fuel-air mixture would be expected to vary markedly among the individual cylinders, leading to operational problems. Even a blend of matched vapor-locking tendency gives a distillation curve with a prominent flat, and would still be expected to cause impaired distribution among cylinders.

Solubility

Methanol and non-aromatic hydrocarbons are not very soluble in each other, and solubilities decrease as temperature is lowered (Figure 5). In addition, the solubility of methanol in gasoline is affected by the chemical nature of the hydrocarbons making up the gasoline (Figure 5, Table 4). Methanol, for example, is fully soluble in *n*-hexane above about 110°F, but only about 3 percent will dissolve in *n*-hexane at about 40°F. Methanol and *n*-octane are only sparingly soluble in each other over the same temperature range. In benzene, however, methanol's solubility is very high even at low temperatures.

Methanol thus dissolves less readily in paraffinic hydrocarbons than it does in aromatic hydrocarbons (Table 4). The variability among gasolines in the ratios of paraffinic to aromatic hydrocarbons, therefore, would be a complicating factor for any proposal calling for methanol to be blended with gasoline.

Ethanol and higher alcohols dissolve more readily in hydrocarbons than methanol does, and they can be added to a methanol-gasoline blend to increase methanol's solubility (6, 10-15). For example, in a gasoline that dissolved only 3 percent methanol at 32°F, 5 percent of ethanol increased the methanol solubility to 10 percent, and 5 percent of isobutanol increased it to 20 percent.

Water Sensitivity

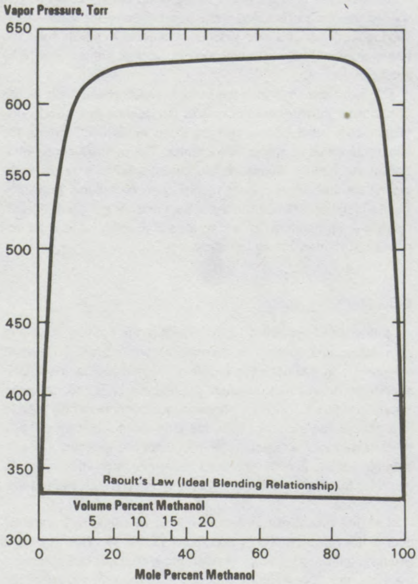
The solubility of methanol in gasoline in the presence of water is very limited at room temperature (Figure 6), and ethanol behaves similarly (Figure 7). Thus, when small amounts of water are added to a methanol-gasoline blend, hydrogen bonds form between the water and methanol molecules, and the blend separates into two phases. Paraffinic hydrocarbons predominate in the upper phase, while the lower phase consists primarily of methanol, water, and small amounts of aromatic hydrocarbons.

Data on the water sensitivity of methanol-gasoline blends (Table 5 and Figure 8) show that blends containing 10 percent methanol must be protected against water in concentration greater than about 0.05 percent, or the blend will separate. Gasoline as conventionally transported, however, is exposed to water in volumes often greater than 1 percent. This point will be discussed more fully in Section 7.

A number of alcohols and higher-molecular-weight emulsifiers have been tried as coupling agents in attempts to overcome the problem. They improve water tolerance somewhat (Table 6 and Figure 9), but the improvement is not enough to protect blends from separating when they encounter levels of water typically found in gasoline distribution systems. The use of methanol-gasoline blends as automotive fuels, therefore, would require anhydrous systems to prevent water contamination.

Figure 1

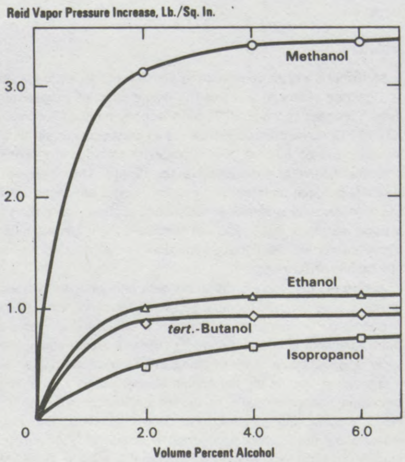
Vapor Pressures of Methanol-*n*-Hexane Blends Are Higher Than Predicted by the Ideal Blending Relationship



Conditions: 113°F.
Source: Timmermans, J. (4).

Figure 2

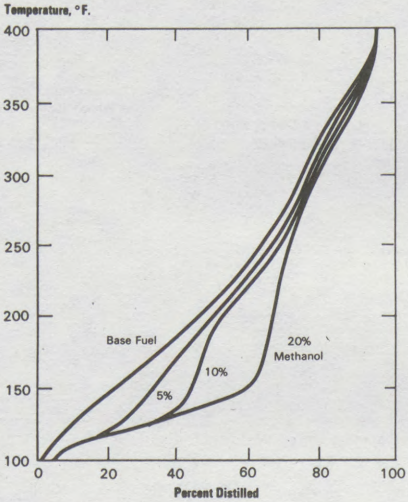
Alcohols Increase Gasoline's Reid Vapor Pressure



Source: Exxon Research and Engineering Co. (5).

Figure 3

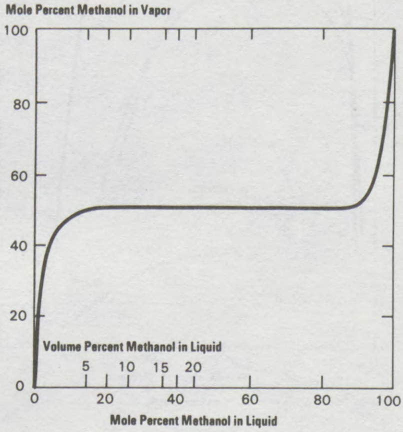
Methanol Depresses Gasoline's Distillation Temperature



Conditions: ASTM Method D-86.
Source: Crowley, A. W., *et al*, as presented before the Society of Automotive Engineers (6).

Figure 4

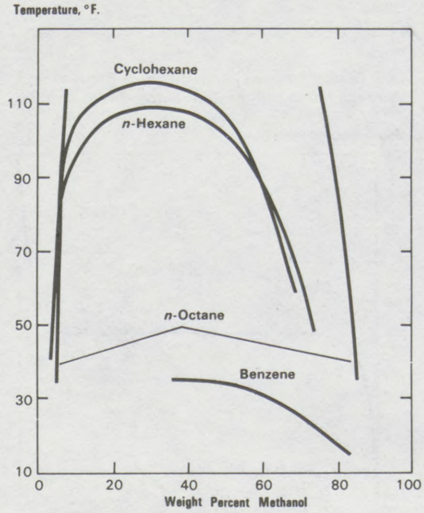
Low Concentrations of Methanol in Blends Produce Much Higher Concentrations in Vapors



Conditions: Vapor-liquid equilibrium of methanol in *n*-hexane at 113°F.
Source: Timmermans, J. (4).

Figure 5

Temperature and Chemical Nature Affect Methanol's Solubility in Hydrocarbons



Sources: Seidell, A. (7); Stephen, H., and Stephen, T. (8).

TABLE 4

Solubility of Methanol in Gasoline

Aromatics in Gasoline, Volume Percent	Methanol Solubility, Volume Percent	
	−10° to 0° F.	32° to 37° F.
16	2-3	5-10
28	5-10	15-20
31	5-10	>50
42	>50	>50

Gasoline Composition			Minimum Temperature At Which 10% Methanol Will Dissolve, ° F.
Saturates	Aromatics	Olefins	
100	—	—	80
65	21	14	44
43	2	55	20
20	78	2	4

Source: Upper—Gulf Oil Corp. (9).
Lower—Crowley, A. W., *et al* (6).

Methanol and Ethanol Dissolve Only Slightly in Gasoline When Water Is Present

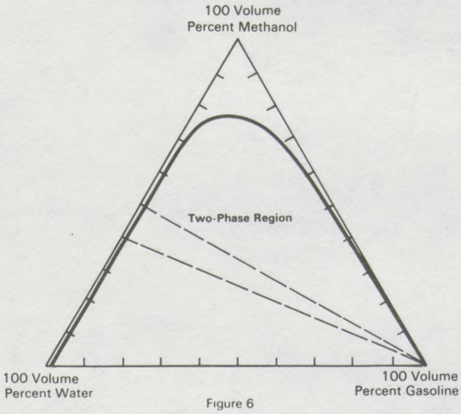


Figure 6

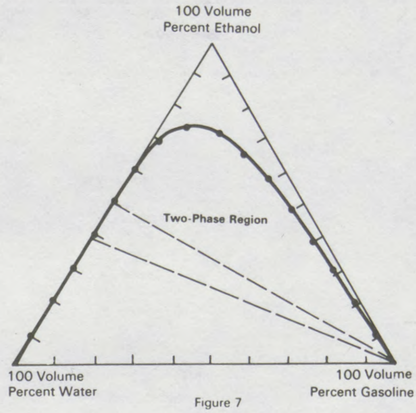


Figure 7

Conditions: Methanol at 77° F., ethanol at 76° F.
Sources: Methanol—Rogers, J. D., Jr. (16). Ethanol—American Petroleum Institute (1).

TABLE 5

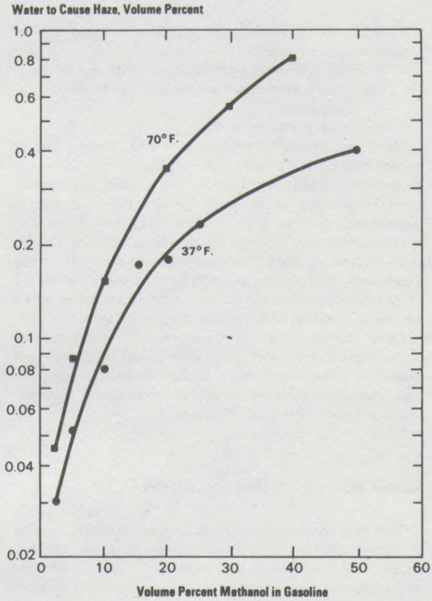
Water Sensitivity of Methanol-Gasoline Blends

Blend in Gasoline	Percent Aromatics	Water Added To Haze Point, Volume Percent	Temperature, ° F.
10% Methanol			
Chevron U	19	0.025	37
Chevron U	19	0.10	70
Chevron S	37	0.08	37
Chevron S	37	0.15	70
Texaco G	26	0.13	Room
Texaco M	32	0.16	Room
20% Methanol			
Chevron S	37	0.1	37
Chevron S	37	0.3	70
Texaco G	26	0.23	Room
Texaco M	32	0.26	Room
30% Methanol			
Chevron S	37	0.23	37
Chevron S	37	0.50	70
Texaco G	26	0.35	Room
Texaco M	32	0.38	Room

Sources: Ingamells, J. C., *et al* (13).
Texaco Research Center (14).

Figure 8

Methanol-Gasoline Blends Tolerate Little Water



Source: Ingamells, J. C., *et al*, as presented before the Society of Automotive Engineers (13).

TABLE 6

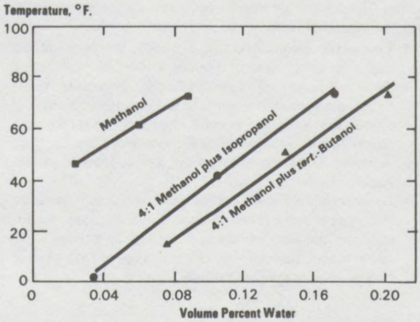
Stabilizers for Methanol-Gasoline Blends at 70° F.

Blend Composition	Percent Stabilizer In the Blend	Water Added To Haze Point, Volume Percent
10% Methanol in 37% aromatic gasoline	None	0.17
	1% *sec.*-Butanol	0.22
	3% *sec.*-Butanol	0.35
	10% Ethanol	0.8
	10% Methyl benzoate	0.29
	10% Dimethylphthalate	0.35
20% Methanol in 28% aromatic gasoline	None	0.24
	5% Isopropanol	0.62
	5% *n*-Butanol	0.79
	5% Isobutanol	0.91
17% Methanol in 37% aromatic gasoline	None	0.3
	3% *tert.*-Butanol	0.5
	3% Methyl acetate	0.5
	3% Dimethoxyethane	0.6
	3% Tetramethylurea	0.6

Sources: 10 and 17% methanol—Ingamells, J. C., *et al* (13).
20% methanol—Texaco Research Center (14).

Figure 9

Water Increases the Minimum Temperature at Which 10% of Alcohol Is Soluble in Gasoline



Source: Crowley, A. W., *et al*, as presented before the Society of Automotive Engineers (6).

5. ALCOHOLS AS AUTOMOTIVE FUELS

Alcohols offer the possibility of increasing the volume of the gasoline pool in two ways:

- Indirectly, by displacing petroleum fuels used in other equipment, such as gas turbines, and freeing these fuels for conversion into gasoline.
- Directly, as an automotive fuel.

When used directly as an automotive fuel, alcohols may be blended with gasoline or used alone. Alcohol blends are in some respects more or less interchangeable with gasoline, and therefore have the apparent advantage of being suitable for current automobiles. As shown later in this section, however, alcohol-gasoline blends have some serious drawbacks nullifying that apparent advantage. With methanol-gasoline blends, many automobiles would perform unacceptably by present standards and would require modifications to replace materials in the fuel system that are incompatible with methanol blends. On the other hand, straight alcohols—particularly methanol—would require automobiles with redesigned intake systems, and are therefore not suitable for current automobiles. Engines specifically designed to utilize the unique properties of methanol combustion, however, would have some interesting advantages.

Alcohol Blends for Fueling Automobiles

When an alcohol blend is used in an unmodified engine, the most pronounced effect is a leaner fuel-air mixture. An engine operating on an alcohol blend behaves as if the carburetor is adjusted to give less fuel. For the heavier alcohols (those having three and more carbon atoms), this leaning effect is relatively small, and these blends behave much as does straight gasoline. For methanol and ethanol, however, the engine will operate quite lean (unless the carburetor is adjusted to compensate for the added alcohol).

Lean operation, since it accounts for most of the differences between alcohol-gasoline blends and gasoline, is worth brief examination as regards expected effects when engines are operated leaner than the theoretical fuel-air ratio:

- *Less power:* Because less fuel is burned, the output of the engine for any given throttle setting is correspondingly less.
- *Better fuel economy:* First, peak efficiency occurs at any throttle opening when the fuel-air ratio is slightly lean. Second, the throttle must be opened more for a lean engine to get the same power. A wider throttle opening also improves efficiency, since the lower pressure drop across the throttle leads to smaller pumping losses.
- *Lower carbon monoxide and hydrocarbon emissions:* As there is more air available to burn the fuel, combustion is more complete and emissions are lower. If the fuel-air mixture is excessively lean, however, hydrocarbon emissions will increase because of poor combustion characteristics.
- *Generally higher emissions of nitrogen oxides:* Emissions of nitrogen oxides peak on the lean side of the theoretical fuel-air ratio. Tuning engines increasingly leaner from this peak, however, will again reduce nitrogen oxide emissions.
- *Poorer driveability:* Engines perform best when tuned slightly rich. Lean operation can cause hard starting, poor acceleration, hesitation, stalling, and other malfunctions.

Alcohol blends in unmodified engines produce almost exactly the same effects. With only minor exceptions, the effect of adding alcohol to gasoline can be duplicated with gasoline alone by operating engines set leaner, as shown in the following paragraphs.

Fuel Economy. Although some reports note exceptionally good fuel economy with alcohol-gasoline blends, particularly at constant speeds (17-19), more meaningful tests based on the Federal Test Procedure or over-the-road driving show much more modest changes (5, 6, 9, 13, 14, 20-24). Virtually all of the data indicate that miles per gallon go down, but miles per B.t.u. go up. Motorists would therefore note a slight drop in fuel economy, although actual engine efficiency in terms of B.t.u. utilization might be slightly higher. The change in economy is due to the lower energy content of alcohol-gasoline blends (see Table 3), while the change in efficiency is due to the leaning effect.

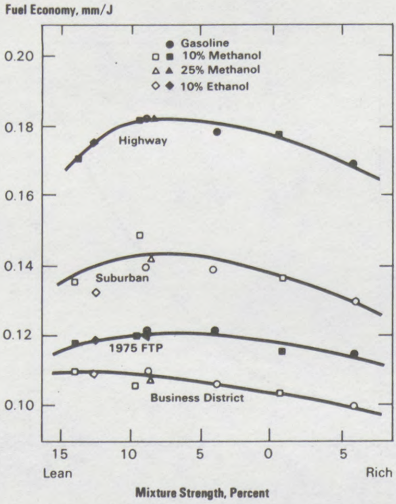
Tests performed in 1957 showed that cars run on 15 percent methanol in gasoline lost only 3 percent in miles per gallon compared to the expected loss of 7.5 percent, based on energy content (5). In more recent tests (9), results were similar. Blends of 10 percent methanol in gasoline, according to cyclic tests, gave between 2 percent and 10 percent fewer miles per gallon, and 20 percent methanol blends gave between 8 percent and 20 percent fewer miles per gallon. Under cruise conditions, the corresponding losses were 4 percent to 11 percent and 12 percent to 25 percent. In some of these tests, methanol-gasoline blends actually gave poorer efficiency than gasoline on a miles-per-B.t.u. basis.

In a 50,000-mile road test, four 1974 cars run on a 10 percent methanol blend gave 4.4 percent poorer fuel economy than straight gasoline, or almost as low as predicted from the lower energy content (6). Six cars using 10 percent methanol in gasoline showed only a 3 percent loss in mileage and a 2 percent gain in efficiency (13). In a fleet of 14 cars using a 10 percent methanol blend, 12 showed a loss in fuel economy, the average being 3 percent (23).

It has been pointed out (20) that older cars were normally set slightly rich, so that a leaning-out effect would tend to improve efficiency, whereas cars with emission control systems are already set lean, and further leaning out would not result in the same efficiency improvement. Test data confirmed this reasoning. Others, meantime, have shown that the improvement in efficiency using methanol blends in a 1973 car was due entirely to the leaning-out effect (23). When compared at the same equivalent fuel-air ratio, gasoline gave the same efficiency as blends of gasoline with 10 percent ethanol and 10 and 25 percent methanol under all driving conditions (Figure 10).

Figure 10

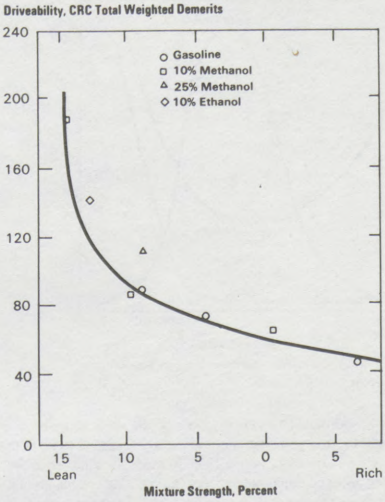
Alcohol-Gasoline Blends Give the Same Fuel Economy as Gasoline at the Same Mixture Strength



Source: Brinkman, N. D., *et al.* as presented before the Society of Automotive Engineers (23).

Figure 11

Alcohol-Gasoline Blends Show the Same Driveability Demerits as Gasoline at the Same Mixture Strength



Source: Brinkman, N. D., *et al.* as presented before the Society of Automotive Engineers (23).

Driveability. Items that contribute to a good driveability rating include quick starting (especially at low temperatures), stall-free engine warm-up, smooth idle, hesitation-free response to throttle opening, surge-free operation under cruise conditions, and freedom from vapor lock at high temperatures. Driveability commonly is rated at idle, during acceleration, and under cruise conditions as the car is driven through a prescribed cycle. The cycle is repeated several times until the car's performance stabilizes, and demerits are assigned for substandard performance in any phase of the cycle. The final driveability rating is a composite of all the assigned demerits.

Engines were formerly set to run slightly rich, because such tuning gave the best performance and minimized operating problems, particularly during warm-up. When set lean, an engine is more prone to suffer from driveability problems. Such problems have been apparent in the 1973 and 1974 models, which were set lean to reduce emissions. Owners, as a result, have complained increasingly of stalling, hesitation, and surging, and one would expect a similar increase in complaints if alcohol-gasoline were substituted for gasoline.

Several studies have indeed shown driveability to be impaired with methanol-gasoline blends (6,9,13,14,23,25). In a 14-car fleet of 1966-74 models, for example, 12 showed driveability losses, with demerits increasing an average of 104 percent when tested with a 10 percent methanol blend.Only two showed driveability improvements, the largest of which amounted to only a 12 percent reduction in demerits (23). Another study with two 1974 cars showed that driveability became progressively poorer as methanol concentration was increased in three base gasolines of different volatilities (6). Data obtained in these controlled tests using the procedure described were corroborated by the more subjective observations of drivers who used six 1971 cars in commuter service. With 10 percent methanol blends, driveability demerits increased about 90 percent compared to those associated with the base gasoline (13).

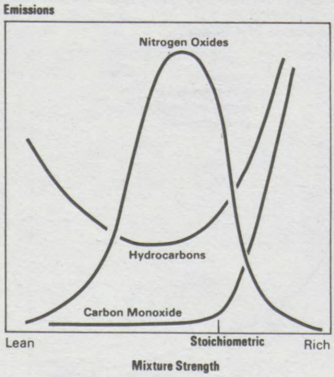
All of these driveability losses can be attributed to the mixture-leaning effect of methanol (14, 23). Similar deteriorations in driveability occurred when the mixture was made equivalently lean either by methanol addition or by mechanical adjustment of the carburetor (Figure 11).

Driveability, however, does not always deteriorate with alcohol blends (17, 18, 25). In fact, evidence of improved starting relative to gasoline alone has been reported (9). Even so, a loss of performance often appears after starting, during warm-up, and under the high ambient temperatures that cause vapor lock.

Driveability results also have been reported for blends of higher-molecular-weight alcohols with gasoline. Ethanol, for example, when tested at 25 percent, degraded driveability (23, 26); it affected driveability the same as does methanol when blends of the two were compared at the same equivalent fuel-air ratio (23). Higher alcohols

Figure 12

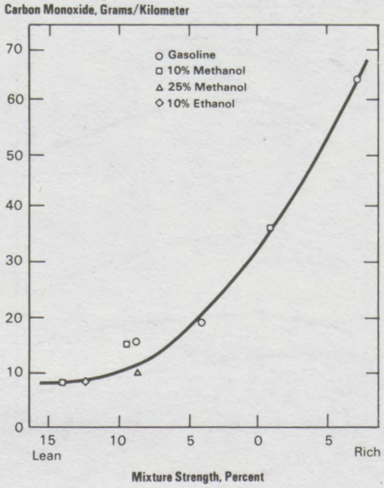
Emission Levels Depend on Mixture Strength



Source: Brinkman, N. D., *et al.* as presented before the Society of Automotive Engineers (23)

Figure 13

Alcohol-Gasoline Blends and Gasoline Emit Equal Amounts of Carbon Monoxide at the Same Mixture Strengths



Source: Brinkman, N. D., *et al.* as presented before the Society of Automotive Engineers (23)

such as *tert.*-butanol, however, should not affect driveability as such, since their properties are more nearly similar to those of hydrocarbons. Drivers of twelve 1968-70 model cars in normal daily driving noted no difference between base gasoline and blends of up to 5 percent *tert.*-butanol, and the frequency of complaints rose only 7 percent as *tert.*-butanol content was raised to 15 percent (27).

At the higher ambient temperatures under which vapor lock can occur, alcohol-gasoline blends are more susceptible to vapor lock than is the base gasoline (6, 24). This result is related to the disproportionately high vapor pressure increase observed when methanol is added to gasoline, as discussed in Section 3. In a fleet of six 1974 cars tested at 90°F, for example, three showed more severe vapor lock with 10 percent methanol blends than with gasolines of approximately equivalent volatility (6). Adding 15 percent methanol to gasoline caused a three-fold increase in vapor-lock frequency in tests at 70°F and 100°F in a fleet of 13 cars spanning the model years 1967-74. Adjusting the hydrocarbon composition of the base fuel to reduce the volatility of the methanol blend, however, reduced the frequency of vapor lock (24).

Adjusting the volatility of a methanol-gasoline blend requires that some of the butanes and pentanes be removed from the gasoline. For comparable vapor-lock protection, the volume removed could equal that of the alcohol added (24). Since the hydrocarbons removed have twice the energy content of methanol, adding methanol would not increase the available supply of gasoline. Of course, the hydrocarbons so removed could find good fuel uses elsewhere, but so could the methanol; and it would make more sense to find alternative uses for the latter.

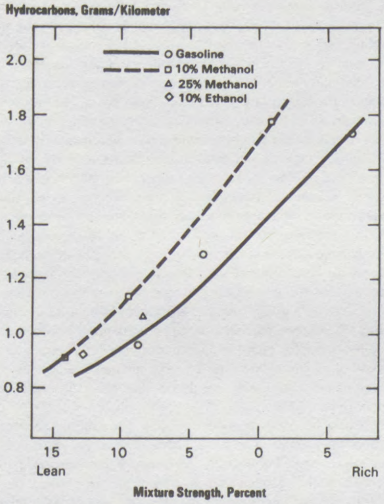
Emissions. Alcohols mainly affect exhaust emissions by making the fuel-air mixture leaner. The effect of variations in fuel-air ratios on the three primary pollutants (carbon monoxide, hydrocarbons, and nitrogen oxides) is well known. Leaner operation will either reduce or not significantly change carbon monoxide, will usually reduce hydrocarbons (unless the mixture is very lean), and may either increase or decrease nitrogen oxides, depending on the original carburetor setting (Figure 12).

Substantial decreases of carbon monoxide emissions have been reported by all investigators when methanol or ethanol is added to gasoline (2, 6, 9, 14, 17-24, 26, 28-35). Moreover, there seems to be general agreement (2, 6, 14, 23, 24, 29, 31, 32) that these reductions are due entirely to the leaning-out effect caused by the addition of the alcohol (Figure 13). Although the percentage decreases for typical carbon monoxide emissions are impressive in several cases and range up to 75 percent, they rarely are enough to meet current Environmental Protection Agency standards for carbon monoxide of 15 grams/mile (9.3 grams/km.). To meet statutory standards of 3.4 grams/mile (2.1 grams/km.), cars would require an emission control system of the same type required for gasoline. The use of alcohol-gasoline blends, therefore, would not provide an alternative to the additional hardware.

Some experiments have shown either no change or an increase in hydrocarbon emissions when alcohol is blended with gasoline (32, 33, 36), but the bulk of the data show a decrease (2, 6, 14, 22-24, 26, 28, 30). The decrease is not so great as in the case of carbon monoxide and is not enough to meet Federal standards in most cases.

Figure 14

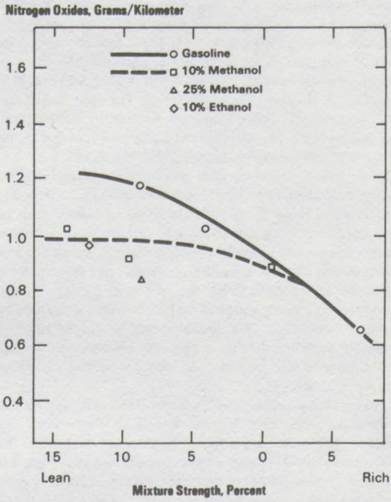
Alcohol-Gasoline Blends Emit Slightly More Hydrocarbons Than Gasoline at the Same Mixture Strength



Source: Brinkman, N. D., *et al.* as presented before the Society of Automotive Engineers (23).

Figure 15

Alcohol-Gasoline Blends Emit Somewhat Less Nitrogen Oxides Than Gasoline at Lean Mixtures



Source: Brinkman, N. D., *et al.* as presented before the Society of Automotive Engineers (23).

The changes in hydrocarbon emissions are due primarily to the change in carburetion (6, 23, 31, 32). But there is also a secondary effect due to volatility (23, 24)—namely, that the increase in vapor pressure caused by adding alcohol increases unburned fuel emissions slightly (dotted line, Figure 14).

Generally, blending alcohol with gasoline reduces emissions of nitrogen oxides somewhat (6, 14, 22, 23, 26, 31, 32, 36), although such emissions sometimes increase from older cars, which normally are set rich (24). As before, the result stems largely from the leaning-out effect (23, 24, 31, 32). There is some evidence (14, 23), however, that emissions of nitrogen oxides from methanol blends operating lean are about 20 percent lower than predicted from the fuel-air ratio (Figure 15). Overall, the effect of blends on nitrogen oxides may be considered minimal.

Octane Number. A well-known advantage for alcohols is that they can increase the laboratory octane rating of gasoline substantially (5, 9, 13-16, 23, 25, 27, 35-41). The increase depends on the octane level of the base gasoline, the gasoline's hydrocarbon composition, the amount of alcohol added, and the octane rating method (Research or Motor). Therefore, no single value for blending octane number can be assigned. The consensus appears to be that 10 percent methanol or 10 percent ethanol in current unleaded gasoline will raise the Research octane rating by four or five units and the Motor octane rating by one or two units.

The large increase in Research octane rating has prompted the suggestion that alcohols could be a possible substitute for tetraethyllead (36). Laboratory octane ratings, however, do not tell the whole story of knock resistance of a fuel in an automobile engine. Road octane ratings made during road driving under the conditions that most commonly reveal knocking show only small increments for alcohols. These increments are more nearly similar to the small Motor octane increments associated with the alcohols than they are to the larger Research octane improvements.

Road octane performance of alcohol blends has been investigated most extensively for methanol (13, 23, 25). In a number of 1967-71 cars, the road octane increments obtained with 10 percent methanol in gasoline ranged from a decline of one to an increase of three octane numbers (13, 25). In cars of that vintage, road octane ratings are related to both Research and Motor octane ratings. In newer cars, Motor octane rating alone is the better predictor of road octane rating. In one example, however, the road octane value of methanol blends in a 1973 car was even poorer than expected from the Motor octane rating and became lower than that of the base fuel when the methanol concentration exceeded 5 percent (23).

In summary, the strikingly high Research octane rating of alcohols translates into little or no advantage in road driving for blends in late-model automobiles. Any advantage from the alcohol is much smaller than that traditionally obtained from lead in typical gasolines.

Straight Alcohol for Fueling Automobiles

Alcohols appear somewhat more viable as motor fuels when used straight instead of in blends. The two major problems of blends—water sensitivity and higher vapor pressure—are absent. (In blends, water sensitivity can cause phase separation during transportation and storage, as discussed in Sections 4 and 7, while higher vapor pressure affects driveability adversely, as discussed in Section 4 and elsewhere in this section). As a result, the unusual properties of the alcohols can be used to some advantage. The most important of these is the ability to burn leaner than gasoline. By burning leaner, alcohols provide better efficiency and produce lower emissions, particularly the hard-to-reduce nitrogen oxide emissions.

Using straight alcohols as fuels, however, introduces certain new problems. Intake systems of engines would have to be redesigned to handle the alcohol's much higher latent heat of vaporization and different fuel metering requirements. In addition, some fuel system metals, plastics, and elastomers would have to be changed to avoid corrosion and compatibility problems. Finally, cars designed to run on alcohol would not be able to run on gasoline.

In recent years, only methanol has been considered seriously as a straight alcohol fuel. This discussion will be limited largely to methanol, therefore, although to a lesser extent both the advantages and disadvantages of methanol will apply generally to ethanol and the higher alcohols.

Power, Fuel Economy, and Emissions. Methanol has long been favored for racing cars, because it develops more power than gasoline (42). It does so, however, by operating much richer than gasoline (about 40 percent rich). There is a correspondingly high fuel consumption (roughly three times that of gasoline on a miles-per-gallon basis), and such rich operation is of no interest for on-the-road operation (except for emergency acceleration at full throttle). Besides the high fuel consumption, rich operation leads to high emissions of unburned fuel and carbon monoxide. For passenger car use, the advantages of methanol would stem largely from its ability to burn lean without misfire.

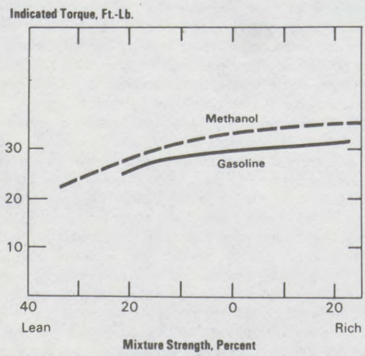
A great deal of apparently conflicting information has been reported concerning the performance of engines when operating on methanol versus gasoline (43-46). Most of the confusion comes from deciding which conditions are truly equivalent for the two fuels. They differ widely in such properties as burning speed, degree of evaporative cooling, and lean misfire limit. All of these properties, in turn, affect the choice of the proper spark advance and the fuel-air mixture strength to be selected in running comparative tests.

The most extensive and fundamental engine tests comparing methanol and gasoline used a single-cylinder laboratory engine and measured ignition delay, combustion time, power, and exhaust emissions over a wide range of speeds, loads, and fuel-air mixtures (47). In these tests, methanol produced about 10 percent more power than did gasoline at the same mixture strengths and with the spark set for best torque (Figure 16). In addition, methanol extended the lean misfire limit, but fuel consumption was twice as high for methanol on a gallon basis and slightly lower on a B.t.u. basis (Figure 17). Carbon monoxide and hydrocarbon emissions were nearly the same for each fuel, but emissions of nitrogen oxides showed a distinctly different pattern. For methanol, emissions of nitrogen oxides were lower, and they peaked at a richer mixture strength (Figure 18).

These data are complete enough to allow a comparison between methanol and gasoline to be made, taking advantage of methanol's leaner misfire limit. For example, methanol, if it is carbureted 10 percent leaner than gasoline, will give about the same power, provide a 10 percent improvement in efficiency, and produce considerably lower nitrogen oxide emissions.

Figure 16

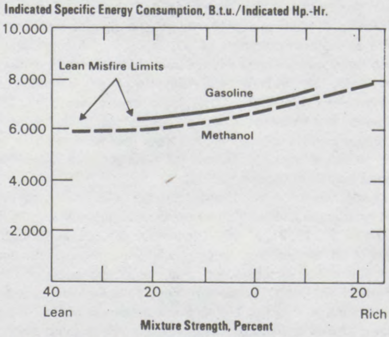
Methanol Produces About 10% More Power Than Gasoline



Conditions: 1,000 r.p.m.; spark advance MBT
Source: Harrington, J. A., *et al*, as presented before the Society of Automotive Engineers (47)

Figure 17

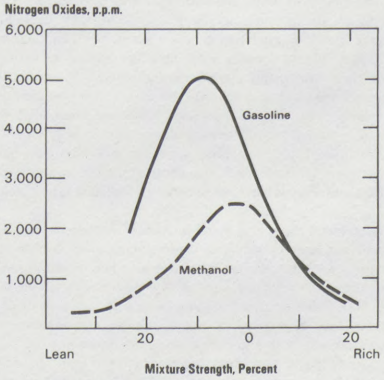
Methanol Extends the Lean Misfire Limit and Gives Slightly Better Thermal Efficiency Than Gasoline



Conditions: 1,000 r.p.m.; spark advance MBT
Source: Harrington, J. A., *et al*, as presented before the Society of Automotive Engineers (47)

Figure 18

Methanol Emits Less Nitrogen Oxides Than Gasoline



Conditions: 1,000 r.p.m., spark advance MBT.
Source: Harrington, J. A., *et al*, as presented before the Society of Automotive Engineers (47).

The foregoing tests were made with an engine having a constant compression ratio and therefore did not take advantage of methanol's higher knock resistance. Other investigators, however, not only conducted similar tests, but also went further (48). Their tests showed that methanol may operate superlean at compression ratios as high as 12:1 in single-cylinder laboratory engines if 20 percent water is added to the methanol. Such very lean operation showed an improvement of 25 to 40 percent in fuel economy over straight methanol in an engine having a compression ratio of 8:1. Emissions of carbon monoxide and nitrogen oxides also were very low. The investigators pointed out, however, that many design problems need to be solved before these advantages can be applied to multicylinder commercial engines.

Several cases are reported in which automobiles or full-scale engines have been modified to run on methanol (13, 49-53). The most notable effect in these tests is that fuel consumption is roughly double that of gasoline because of methanol's lower energy content. Automobiles fueled with methanol, therefore, would have to have fuel tanks twice as large for comparable range. However, methanol can show an economy advantage on an equal energy basis. For example, a Volkswagen operated "near stoichiometric" and equipped with a heated intake manifold to evaporate the fuel and thus take advantage of the added heat of vaporization showed a 10 percent increase in power and a simultaneous improvement of 15 percent in efficiency (49). In another test comparing operations at 14 percent lean on methanol with 5 percent lean on gasoline, a 1971 fuel-injected Volvo showed improved economy and reduced emissions (13):

		Emissions, Grams/Mile		
Cold Start Tests	Miles/ Million B.t.u.	Hydro-carbons	Carbon Monoxide	Nitrogen Oxides
Gasoline 5% lean	137	3.0	20	8.3
Methanol 14% lean	157	4.2	14	3.1

Similarly, a 1973 Ford V-8 engine operated lean with methanol compared to the standard setting with gasoline showed a slight reduction in power but improved efficiency (52). Again, emissions of nitrogen oxides were reduced dramatically to a level not attainable with gasoline unless the engine were severely derated. The low level of emissions of nitrogen oxides is thus one of the major advantages of methanol.

Operation under lean conditions will also affect the other pollutants, carbon monoxide and unburned fuel. Carbon monoxide emissions will be very low, but unburned methanol emissions may be high. Some of the data in the literature were obtained using the standard sampling method for exhaust hydrocarbons. This method includes a water trap which will also trap methanol, thus giving fictitiously low results for unburned fuel. Experiments performed more recently, using heated sampling lines and flame ionization detectors, provide more reliable comparisons of unburned fuel emissions between methanol and gasoline. Compared to emissions from gasoline, however, emissions of unburned methanol do not contribute to smog. Methanol is considered a relatively unreactive species in the smog-forming process, and experiments have shown that the unburned material in the exhaust of cars fueled with methanol is largely methanol itself (49, 50).

While methanol thus appears to offer some advantages relative to emissions, many investigators have reported substantial quantities of formaldehyde in the exhaust of methanol-fueled cars (13, 24, 49, 50). Formaldehyde is the first product in the oxidation of methanol and is quite stable under exhaust conditions. It is an acknowledged pollutant, irritating the eyes, having an offensive odor, and being about equal to olefins in reactivity to form smog (55). (Increased formaldehyde has also been found in cars operating on methanol-gasoline blends (9, 24).) Catalytic converters offer some protection, however. A 1972 Gremlin modified to run 20 percent lean on methanol, for example, produced high formaldehyde emissions of 130 to 155 p.p.m. (50). Installing a catalytic converter reduced the emissions to 30 to 35 p.p.m. (and also reduced unburned methanol 90 percent).

Driveability. Little quantitative information exists comparing driveability using straight alcohols with driveability using gasoline in equivalent cars, and the available information is limited largely to methanol. Methanol has a much higher heat of vaporization than gasoline. For acceptable operation, therefore, intake manifolds of normally-carbureted engines must be heated, for instance, with exhaust gases or cooling water (13, 49, 50, 52). Once such heat is supplied, difficult cold starting at temperatures below 50° to 60°F usually is the only operational problem reported. Since it is a single-component fuel with an intermediate boiling temperature, methanol cannot vaporize sufficiently, even under choked carburetor conditions (as gasoline does), to enable a cold engine to start below about 50°F ambient temperature (13, 52). Cold starting problems have been alleviated by supplementing methanol with a volatile fuel that is either added to the methanol or injected into the manifold as needed for starting. Volatile materials such as propane, butane, isopentane, and others have been used (13, 19, 50, 52), and starting is reported at temperatures as low as 10°F with the more effective systems (52).

In one car equipped with fuel injection, driveability after start-up was found to be equivalent for both gasoline and methanol at their theoretical fuel-air ratios, but driveability degraded more rapidly with gasoline as the fuel-air ratios were made lean (13). This is another indication of methanol's ability to burn leaner than gasoline.

Octane Number. Alcohols have much higher octane ratings than many current (*i.e.,* nominally 91 Research octane number) unleaded gasolines. Some difficulty has been reported in measuring octane ratings of alcohols, however, because the ASTM rating methods were developed for use with hydrocarbons and are not wholly suitable for alcohols. Thus, the reported Research octane rating for methanol ranges from 106 to 115, depending upon the data source, and that for the Motor octane rating from 87 to 92 (1, 37, 48). The most recently reported ratings of 109.6 Research octane number and 87.4 Motor octane number may be the most reliable (48).

One of these sources (37) compared values of several alcohols as follows:

	Octane Number	
Alcohol	Research	Motor
Methanol	112	91
Ethanol	111	92
Isopropanol	106	99
tert.-Butanol	113	110

The exact value of the octane rating, however, is rather academic for alcohols. Almost all investigators point out that straight alcohols can be and should be metered much leaner than gasoline if the usual properties of these fuels are to be exploited to the greatest extent. Under such conditions, the ASTM octane ratings, which are determined at the fuel-air ratio for maximum knock intensity, lose much of their significance.

Corrosion and Compatibility

As a polar material, methanol is more active chemically than is gasoline. Potential problems are corrosion of metals and the swelling or deterioration of plastics and elastomers. Both methanol alone and methanol-gasoline blends have been reported to attack the lead-tin coated steel (Terneplate) from which automobile fuel tanks are fabricated (13). In one case involving a fuel-injected car having a submerged electric fuel pump, methanol effectively stripped the coating from the tank in less than two days, and severe corrosion developed in the exposed sheet steel. In addition, the whitish lead corrosion product partially plugged the fuel filter. A wide variety of corrosion inhibitors has been screened, including polyamide, polyamine, dithiocarbamate, thiophosphate ester, organic acid, sulfide, and selenide types, but none have been found to be effective (13).

Other investigators have found evidence of increased corrosion of copper and brass by methanol blends compared to gasoline (6). Similar reports indicate that metal corrosion is common in racing cars fueled with methanol, particularly if dissimilar metals are present (42). Carburetor and fuel gauge floats, both frequently made of plastics, have been noted to stick in cars operated on methanol-gasoline blends. In another case, a fuel pump failed after 4,000 miles because the plastic pump head shrank and cracked (39). Methacrylate and Viton parts have been attacked, and fiber gaskets have been softened (13). Racing cars use more expensive plastic parts to avoid swelling or hardening of seals and diaphragms (42).

Other investigators, however, have reported no serious problems with plastics when using a 10 percent methanol-gasoline blend (5), and no corrosion or compatability problems have been noted when small amounts (about 0.15 percent) of methanol are added as an anti-icing additive (27).

These problems are likely to be most severe with straight methanol. Other problems that could possibly be aggravated by alcohols are deposit formation, rusting, and wear in engines. For example, engine failure caused by excessive cylinder wear occurred in duplicate runs in the standard ASTM Sequence Test V-C procedure when straight methanol was used as a fuel (56). Excessive cylinder wear is also reported with straight methanol in racing engines (42), but no adverse effects have been found with methanol-gasoline blends in laboratory engine tests (6).

6. ALCOHOLS IN NON-AUTOMOTIVE FUEL USES

The only alcohol presently being considered seriously for non-automotive fuel use is methanol. Potential applications include providing space and industrial process heat, generating electricity with steam, powering gas turbines and fuel cells, and fueling a miscellaneous group of engines such as diesels, portable generators, and lawn mower engines.

The toxicity and low flash point of methanol (which are discussed more fully in Section 8) make it less attractive than fuel oil for heating homes and small commercial buildings. Potential users, therefore, preferably would be those with both the experience and the facilities for handling a fuel with somewhat different safety requirements, such as utilities and other large commercial and industrial consumers. Even so, burning the coal or other raw material in these large installations would be far more desirable from an energy efficiency standpoint, since making methanol would waste a substantial part of the heat energy available in such starting materials.

Alcohols have not been given much attention as diesel fuels because of their low cetane number and low viscosity and because they are immiscible in diesel fuel. However, if methanol is carbureted into a diesel engine (while a pilot charge of ordinary diesel fuel is also injected in the usual manner), it reduces smoke and cools the charge, both of which allow higher power to be developed (57). The extra cost and the complexity of the dual fuel system could be justified only if methanol were cheap and widely available.

Methanol could also be used in small engines that power lawn mowers, portable generators, chain saws, and the like. Its corrosive attack on aluminum and magnesium would be a definite drawback, however, since these metals are used extensively in the fuel systems of small engines. Moreover, the toxicity of methanol would expose the general public to new risks that would require the prior establishment of adequate safeguards.

Beyond the automotive applications discussed in Section 5, fuel cells and stationary gas turbines appear to offer the only practical possibilities for methanol as a fuel. Fuel cells, however, are still mostly experimental, although they could, if developed, provide a significant market for methanol. Stationary gas turbines, then, remain as probably the most attractive potential use for methanol as a fuel. Utilities in particular employ gas turbines to produce power for peak load periods, and it is projected that they could consume 800,000 barrels of petroleum a day by 1990 (58), which is about 5 percent of the present consumption of petroleum in the United States.

Depending on their design, gas turbines can use almost any fuel, provided that the ash content is low and certain trace metals are virtually absent. Methanol has been examined for this application to a considerable extent. It ignites well, flows at low temperatures, and resists high-flow blowout. Its transient flame stability is good, and it results in satisfactory temperature distribution at the first-stage nozzle. In addition, methanol alone, methanol containing 20 percent water, and 25 percent methanol and 75 percent No. 2 fuel oil (metered as separate fuels) all provide more power in gas turbines than does No. 2 fuel oil, according to reported tests (58). These methanol fuels also produce substantially less nitrogen oxide pollutants, and they do so without requiring that turbines be operated less efficiently. Carbon monoxide emissions, although higher with methanol and methanol-water than with No. 2 fuel oil, remain low and within Environmental Protection Agency requirements.

Methanol has some disadvantages when used in gas turbines. Both its heating value and its lubricity are low, and users would have to make fuel systems explosion proof because of methanol's low flash point and wide flammability range. For the same reason, users would also have to start turbines with No. 2 fuel oil and purge them when shutting down. In addition, turbine blade metals are very sensitive to contamination by traces of sodium in fuels. Methanol manufacturers, distributors, and users therefore would have to avoid contaminating methanol fuels with salt water. Doing so would be very costly in the case of barge and tanker transportation.

7. DISTRIBUTION AND STORAGE OF ALCOHOLS

Certain properties of alcohols and of alcohol-gasoline blends would introduce differences in the details of design and operation of distribution and storage systems as compared to these systems for gasoline. Chief among them are the significantly lower heating values of the alcohols, their potential incompatibility with some present materials of construction, and the very low tolerance that alcohol-gasoline blends have for water contamination.

Volume Requirements

Methanol has about half and ethanol about two-thirds of the heating value of hydrocarbon fuels (see Section 4). If supplied with straight alcohols, therefore, users would need twice as much methanol and half again as much ethanol to receive the same amount of energy that they now receive with gasoline. If supplied with, say, a 10 percent blend in gasoline, they would need about 5 percent more of a methanol blend and 3 percent more of an ethanol blend to receive a fuel supply having the same total energy.

These greater quantities of blends needed to provide essentially the same vehicle range might be distributed and stored without enlarging present facilities. Part of the increase required for distributing straight alcohols might likewise be provided by increasing the throughput for existing facilities—that is, by pumping at higher rates in pipelines and delivering loads more frequently by truck. It is more likely, however, that the distribution of straight alcohols would require that facilities be enlarged to handle both increased throughput and increased quantities in storage. Moreover, if both hydrocarbons and alcohols were to be distributed simultaneously, then a second system would have to be provided for the alcohols.

Materials of Construction

As noted earlier, alcohols corrode some metals and attack some plastics, elastomers, and sealants more readily than do hydrocarbons. Such materials would have to be replaced with more resistant ones, or more frequent maintenance and repair would have to be provided to ensure reliable operations. These requirements would be more stringent with straight alcohols than with blends of alcohols and gasoline.

Contamination with Water

Small quantities of water are present routinely in systems for distributing hydrocarbon fuels. Residual ballast water in tankers and barges is one important source of such contamination, as are rain leaks into tanks with floating roofs and through filler ports, such as those for underground tanks at service stations. Less serious, but also of concern, is contamination that occurs as humid air is drawn into tanks during diurnal breathing cycles and when fuel is withdrawn from them. Similar breathing contamination likewise can occur in automobile fuel tanks and carburetors.

Water contamination rarely causes problems with hydrocarbon fuels. Water is virtually insoluble in such fuels, and it settles innocuously to the bottom of storage tanks. Fuel is withdrawn through lines positioned above the level of water expected, and provision is made for periodic withdrawals of accumulated water as necessary.

If tanks with similar contents of water were to be exposed to straight alcohols, the water would dissolve in the alcohols. If the tanks were supplied with alcohol-gasoline blends, the water would extract the alcohol from the blend and cause the components to separate into two phases.

The consequences of limited water contamination of straight alcohols would be minimal, since most engines and burners would run on the fuel with no appreciable loss in performance. Contractual obligations to supply according to product specification, however, would have to be allowed for. The consequences for blends, meantime, would be much more serious, especially if the blends were for automotive use. Depending on the gasoline's composition and the temperature, as little as 0.05 percent to 0.2 percent water will cause a blend of 10 percent methanol in gasoline to separate, while about 0.5 percent water will affect a 10 percent ethanol blend similarly (see Section 4). These quantities are within the ranges found in current distribution systems. In one series of tests, for example, it was found that 95 percent of the gasoline shipped during one year in a major pipeline averaged 0.02 percent water and that 5 percent ranged from 0.05 percent to 0.34 percent water (77). For tanks served by pipeline, these same tests showed that water content in samples from eight ranged from 0.01 percent to 0.44 percent, with four exceeding 0.10 percent. In addition, five tanks served by marine transport had water contents ranging from 0.13 percent to 1.07 percent. Similar findings would be expected in other distribution networks.

Reports of actual marketing experience with blends of 10 percent and 25 percent ethanol in Cuba and Finland in the 1940's and 1950's show little evidence of customer complaints because of phase separations, and a 10 percent blend of ethanol is now being marketed in Brazil with similar results (5). Special measures, however, have had to be taken to prevent water contamination following blending. In Brazil, for example, ethanol is blended with gasoline only at the point where tank trucks are filled for service station deliveries. Whenever contamination occurs, trucks and service station tanks are pumped out, dried, and then refilled. In the earlier experience in Cuba and Finland, special procedures were instituted to prevent the entry of water, and tank bottoms were drained more frequently.

Ethanol blends with gasoline tolerate water better than do methanol blends, and the experience might well have been different had methanol been used. Actually, field experience with methanol blends is very limited. Refiners have added methanol to gasoline as an anti-icing agent in the winter, but the quantities involved generally are less than 1 percent. These amounts have been too small to cause water phases in tanks to rise to levels that interfere with fuel withdrawals.

In Germany in the early 1950's, a 50:50 mixture of methanol and isopropanol was blended with gasoline, first at 7.5 percent and later in gradually reduced amounts down to 1.5 percent, as problems were encountered with water. At the higher levels, phase separation was difficult to control in tanks with floating roofs, and close control was required at service stations. In addition, customers complained of stalling, power losses, and generally poor performance because of phase separations. Changing the ratio to 60:40 methanol-isopropanol only worsened the problem, and the practice finally was discontinued in 1970 when a tax was placed on the alcohol (78).

As noted in Section 4, additives such as surface active agents have been considered as ways to stabilize alcohol-gasoline blends in the presence of water (13, 79). These chemicals increase tolerance somewhat, but not enough to prevent phase separation under conditions that normally exist in the petroleum industry.

Some of the difficulties of transporting and distributing alcohol-gasoline blends might be avoided by blending the components at service station pumps. Doing so, however, would require a separate storage and distribution system for the alcohols. In addition, water contamination would still have to be avoided, since phase separation would occur in vehicle fuel tanks if contamination exceeded the very low limits permissible. Moreover, dual fuel systems would also complicate problems associated with vapor emission control during refueling.

If the alcohols were destined for use in gas turbines, special care would have to be exercised to prevent contamination with brackish or sea water. Otherwise, the sodium entering the system would corrode turbine blades severely. Tankers and barges moving by sea would therefore have to be equipped with segregated ballast systems.

Distribution of alcohol fuels would thus present a new situation in terms of volumes handled, corrosion of materials of construction in transportation and storage equipment, and contamination by water. The problems presented are largely economic rather than technical, but the costs would be substantial. If blending were required, anhydrous systems would have to be provided from the point of blending through the point of retail sale. Greater throughputs would have to be provided to move the same amount of energy now moved with present fuels, and materials of construction would have to be changed or repairs made more frequently. Making such changes in the nationwide fuel supply network would impose major logistical costs and would require extensive new investments in blending, storage, and transportation facilities. The question then would become one of balancing the costs against any net societal benefits the new fuels might provide.

8. SAFETY AND TOXICITY ASPECTS OF USING ALCOHOLS

Fire Safety

The relative fire hazards associated with alcohols and gasoline can be compared by means of the following properties:

Property	Methanol	Ethanol	Gasoline
Flash point, °F.	52	55	−45
Autoignition temperature, °F.	867	793	495
Flammability limits, volume percent	6.7-36	4.3-19	1.4-7.6
Vapor pressure at about 70° F., p.s.i.	1.9	0.8	4-8
Concentration in saturated air at 68°F., volume percent	13	5.4	25-50

In terms of flash point and autoignition temperature, methanol and ethanol appear somewhat less hazardous than does gasoline, but shipping regulations do not distinguish between them. All are classified by the Interstate Commerce Commission and the Coast Guard as flammable liquids requiring "red label" identification and handling (80). The higher alcohols isopropanol and butanol also require similar labeling and handling.

When flammability limits and vapor pressures are considered, it appears that methanol and ethanol present explosion hazards that may be more serious than those of gasoline. The saturated vapor concentration over both alcohols in storage tanks, for example, is within the flammable or explosive range at ambient temperature, while vapors over gasoline under similar conditions are much too rich to ignite. For bulk handling and storage of both alcohols, therefore, flame arrestors are recommended for all vents, as are dry nitrogen blankets in storage tanks (16). In addition, explosion-proof electric motors and pumps should be used that meet requirements of the National Electrical Code (81), and handling practices should follow API recommendations (82).

Water is not recommended for extinguishing alcohol fires, since the diluted alcohols have dangerous flash points. The recommended extinguishing agents are carbon dioxide or dry chemical, the same as for gasoline (80, 83). Special foams are also recommended for methanol and ethanol (84).

Toxicity

Methanol requires special labeling under the Federal Hazardous Substances Act (85). Because death and blindness can result from ingestion of methanol, containers for it and for mixtures containing 4 percent or more methanol by weight must include the signal word "Danger," the additional word "Poison," and the skull-and-crossbones symbol. The statement of hazard must include "Vapor harmful" and "May be fatal or cause blindness if swallowed." The label must also bear the statement "Cannot be made non-poisonous."

What are known as threshold limit values (TLV's) are set for protection against health hazards in occupational exposures for up to eight hours daily. The TLV for methanol in air is 200 p.p.m. (80, 86), and the TLV for ethanol is 1,000 p.p.m. (79). TLV's are not reported for gasoline, because they differ greatly depending on the concentration and type of aromatic hydrocarbons present. It should be noted that while the TLV for methanol is 200 p.p.m., methanol is barely detectable by odor at a concentration of 2,000 p.p.m. (86).

Toxic hazard ratings for methanol, ethanol, and gasoline indicate a moderate-to-high hazard for methanol compared to slight-to-moderate hazards for ethanol and gasoline (Table 7). When subjected to different conditions of severity and duration of exposure to methanol vapor, persons exhibit signs of intoxication that include itching of the skin, eczema, dermatitis, irritation of all mucous membranes, headache, roaring in the ears, tiredness, insomnia, rapid and involuntary oscillations of the eyeballs, dilated pupils, clouded or double vision, colic, constipation, labored breathing, trembling, vertigo, unsteady gait, nausea, vomiting, and blindness (86).

TABLE 7

Toxic Hazard Ratings*

Exposure	Methanol	Ethanol	Gasoline
Acute local			
Irritant	1	1	1
Ingestion	—	—	1
Inhalation	1	—	1
Acute systemic			
Ingestion	3	2	—
Inhalation	2	2	2
Skin absorption	2	1	—
Chronic local			
Irritant	1	1	1
Inhalation	1	—	—
Chronic systemic			
Ingestion	2	1	—
Inhalation	2	1	1
Skin absorption	2	1	—

*0 = no harm or harmful in overwhelming doses.
1 = slight, causes readily reversible changes which disappear after exposure.
2 = moderate, may involve both reversible and irreversible changes, but not severe enough to cause death or permanent injury.
3 = high, may cause death or permanent injury after short exposure to small quantities.
Source: Sax, N. I. (80).

The toxicology and the physiological effects of methanol are described in detail in common reference books on industrial hygiene (86, 87). The lethal dose of methanol for different animals is reported to range from 6 to 18 grams/kilogram of body weight (87). In these tests, methanol was administered either orally or intravenously. In man, numerous cases of blindness and death have been reported when a few ounces of methanol has been ingested. Injuries and fatalities also have been reported from inhalation and skin absorption.

The systemic effect of ethanol differs from that of methanol. Ethanol is oxidized rapidly in the body to carbon dioxide and water, and no cumulative effect occurs, in contrast to methanol (80).

No literature is available on the biological interaction of gasoline and methanol, so the risk to handlers of methanol-gasoline blends cannot be quantified. The hazards, however, probably are greater for the misuse of blends than they are for the misuse of gasoline, since inhalation, ingestion, and possibly absorption can cause blindness.

Despite the rather extensive information available in recognized sources (*e.g.*, 80, 86, 87), a recent manuscript from the National Institute of Environmental Health Sciences (88) reviews several areas of insufficient information on the biohazards of methanol in proposed new uses such as fueling automobiles. Among these areas are:

- Hazards of exposure of children.
- Hazards of interactions of combined exposure to methanol and other chemicals or conditions.
- Abuse hazard.
- Delayed and irreversible toxicity.
- Inhalation and dermal exposure hazards; hazards of siphoning.
- Potential for toxic products from incomplete combustion.

For further information on these and the higher alcohols, authoritative sources should be consulted, such as those given in the bibliography (80,86,87).

TABLES

FIGURES

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americans for
energy independence

STATEMENT OF AMERICANS FOR ENERGY INDEPENDENCE

FOR THE

SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT

SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

HEARINGS ON S.2533,
"GASOHOL MOTOR FUEL ACT OF 1978"

August 7-8, 1978

Americans for Energy Independence (AFEI), a non-profit public interest coalition uniting members of the business, labor, academic, scientific, consumer, conservation, religious and ethnic communities throughout the nation in pursuit of effective national energy policies, strongly favors early implementation of a gasohol program.

In view of the dangerously increasing U.S. dependence on foreign oil, we applaud the initiatives undertaken in the Congress to press for rapid development of this nation's capability to convert readily obtainable domestic resources--agriculture and forest products, coal, and wastes--into alcohol fuels.

Our continuing dependence on foreign oil costs this country tens of billions of dollars each year. It has contributed heavily to record U.S. balance of payments deficits. In 1977, we spent $45 billion for imported oil, a major factor in the whopping $31 billion trade deficit for that year. The loss of confidence in the ability of the United States to reduce oil imports has been an important factor in the weakening of the dollar. We have even had to resort to the sale of assets to support our costly OPEC habit.

The consequences of huge oil imports for U.S. foreign policy are also becoming painfully clear. We are tolerating compromises and distortions of the principles that have made this country great in order to curry favor with certain OPEC nations. The U.S. decision to sell sophisticated fighter jets to Saudi Arabia is the most obvious recent example. Indeed, the Chairman of the Senate Committee on Armed Services said the rationale for the sale could be summed up in one word: "Oil."

We have encountered additional difficulties on the international side as a result of the energy crisis. We are witnessing disturbing and growing divisiveness among oil-importing nations. Many of these countries believe that the United States is ignoring their oil needs and the threats to the continuity of their economic progress. They are demonstrating a considerable degree of frustration and anger toward the United States. They point to what they consider America's disproportionately large share of international oil consumption when we have so much in the way of alternative domestic energy resources while many of them have no choice but to rely on foreign oil.

Transportation accounts for about half of the total U.S. oil demand; two-thirds of transportation's share is used for gasoline production. Clearly, gasoline consumption must be a major target in the national effort to reduce U.S. dependence on foreign oil. Along with conservation measures such as mandating minimum automobile efficiency standards and discouraging excessive automobile use, a gasohol program can make an important contribution to this effort in the transportation sector in the very near term.

Gasohol also holds the promise of expanding American employment opportunities. It has been estimated that if the money spent to purchase one million barrels of imported oil per day were used instead to produce an equivalent amount of domestic energy, it would generate one-third of a million new U.S. jobs. Thus, with U.S. gasoline consumption now at 110 billion gallons per year, a 10% alcohol blend would means 11 billion barrels of domestically produced alcohol and over 700,000 new jobs.

The use of alcohol for fuel has been questioned on the basis of economics. For example, the present refinery price for ethanol is $1.40 per gallon, as compared to $0.40 per gallon for gasoline. However, it should be noted that gasoline now includes both lower-priced domestic oil and higher-priced imported oil. It is misleading to calculate the comparative cost of a gallon of ethanol on the basis of the cost of a gallon of gasoline, which represents the <u>average</u> cost of the oil used to produce it.

The extra cost involved in producing a 10% alcohol blend is hardly overwhelming, particularly because the alcohol would be used to substitute for the expensive imported oil component in conventional gasoline. The trade-offs in price stability, security of supply, economic development, job opportunities and environmental benefits of the cleaner-burning alcohol blend far outweigh the added cost. Furthermore, gasohol's initial cost disadvantage may well disappear if OPEC continues to exercise monopolistic control over the pricing and flow of international oil supplies.

An array of alternative energy production concepts offer promise as sources of energy for the future. Long-term options include solar electric power, fusion, ocean thermal gradient power, and other technologies whose technical and economic feasibility have not yet been demonstrated. For the most part, these concepts are further from commercial use than the general public realizes.

For the near term, the nation must make full use of available domestic oil, gas, coal and uranium resources while maximizing the benefits of solar water and space heating and other proven renewable resource technology. We must proceed in a practical and efficient manner to provide an ample and reliable supply of energy using the resources and technologies at hand. Compounding the Administration's failure to assure these major sources of U.S. energy supply is its refusal to recognize the need and opportunities to act on a number of other measures which could add up to considerable savings in imported oil. An alcohol fuels program is one very practical measure which the Department of Energy continues to downplay, despite the tremendously successful Brazilian experience, for no apparent reason other than inertia.

With the backing of an unusually diverse and powerful Congressional coalition, gasohol has the virtue of being both politically and technologically viable. The importance of this uncommon advantage cannot be overstated at a time when controversy over so many other key energy issues is severely impeding the nation's progress with respect to both energy supply and conservation. As a broad-based public interest organization, AFEI feels uniquely qualified to call on the Federal Government to press this advantage to its fullest.

The multi-billion dollar Department of Energy, which was created to confront the harsh and pressing realities of the energy crisis, is turning into the world's most expensive wishful thinking machine. While the energy problem is being talked to death, little has actually been achieved to provide for the nation's energy security. This lack of action has not been lost on the American people. If they are to believe that this nation is in fact facing a serious energy problem, they need to see that something is being done about it, and a gasohol program is clearly within our grasp.

We support legislation to give gasohol the tax breaks necessary, at least for the near term, to enable alcohol fuels to become competitive with conventional gasoline. We note that this approach is proving successful on the state level in the Midwest, which has pioneered in the sale of gasohol.

We are convinced that gasohol has progressed beyond the whether-and-why stages and that further study should be directed specifically at determining which alcohol sources would be most beneficial, taking into account both regional and national considerations, and how the national alcohol fuel program should be implemented. We are therefore supportive of the proposals in S.2533 requiring goal-oriented DOE studies, with firm and realistic deadlines.

We are also supportive of the concept of setting production goals, although question whether these goal can or should be legislated with the degree of precis contained in S.2533. It seems to be something of a contradiction in terms to orc the Secretary of Energy to determine production goals in one section of the legis tion, and then, in effect, to tell him in another section of the legislation wha those goals will be. On the other hand, given the unfortunately unenthusiastic attitude of the Department of Energy toward gasohol, we understand that this kin mandatory language may be the only way to get a national alcohol fuels program g and, therefore, we believe it may be justifiable in this case.

STATEMENT OF ROBERT HODAM
FUELS OFFICE MANAGER
CALIFORNIA ENERGY COMMISSION

Before the

ENERGY R. & D. SUBCOMMITTEE
UNITED STATES SENATE

AUGUST 7, 1978

Mr. Chairman, I am Robert Hodam, Manager of the California Energy Commission's Fuels Office. I appreciate the opportunity to share with the Subcommittee my thoughts on the matter of commercializing alcohol fuels.

It is generally recognized that alcohol fuels can be produced from a variey of feedstocks which include natural gas, coal and biomass. Alcohol fuels are desirable because they have clean combustion characteristics and they can be produced from certain wastes and other renewable resources. It is important, I believe, that any program to encourage/mandate the production and use of alcohols capitalize on these points.

To meet the goal of establishing alcohols in the marketplace, its use as blending stock for gasoline should be encouraged. However, mandates or incentives should apply to alcohols produced from any source except from domestic natural gas. I suggest that a graduated scale be devised based on the resource used to produce the alcohol (i.e.; foreign, domestic, and domestic renewable) and the relative merits of the alcohol produced. The following is a suggested breakdown for such an incentive scale (for feedstock materials):

1.) 10 cents per gallon (of gasoline) for the use of wastes or domestic renewable resources;

2.) 5 cents per gallon for the use of domestic coal;

3.) 2 cents per gallon for the use of non-domestic natural gas.

To encourage production based on the energy value of the alcohols, I suggest that a 3 cent-per-gallon credit be given for the production of ethanol and, because a gallon of methanol has approximately 75% of the energy content of a gallon of ethanol, a 2.25 cent-per-gallon credit be given for the production of methanol. Additional credits for the relative emission characteristics of various alcohols could be set when those characteristics are established.

Total tax credits for feedstock source and energy content would therefore be as follows:

1.) 13 cents per gallon for ethanol produced from wastes or renewable resources; 12.25 cents per gallon for methanol from the same source;

2.) 7.25 cents per gallon for methanol produced from domestic coal reserves; and

3.) 5 cents per gallon for ethanol produced from non-domestic natural gas; 4.25 cents per gallon for methanol from the same source.

These credits would help to accomplish the first goal of establishing alcohols in the marketplace and would also encourage the use of wastes and domestic renewable resources. Further encouragement of the use of renewable resources could be achieved through the establishment of an expiration schedule for the credits. That is, the credits for alcohols produced from natural gas might be set to expire in 1995; the credits for alcohols from coal could expire in 2015; those for alcohols from domestic renewable resources could expire in 2025.

In summary, if a program of tax credits such as the one I've outlined could be properly implemented, the Congress would accomplish the goal of establishing alcohol fuels in the marketplace while encouraging the use of domestic renewable resources. The development of laws and regulations to mandate the use of alcohol fuels would be unnecessary, I believe, under this program.

I greatly appreciate the opportunity to review and comment on this important legislative matter.

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