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UNITED STATES ENERGY PICTURE: 1981 to 2000

by Wallace E. Tyner, associate professor of agricultural economics

For the last 100 years cheap energy has been an important fuel of economic development in the United States. It was about 100 years ago that coal replaced wood as the dominant energy source in the United States. Coal offered new potential not only for heat but also as a source of coke, tars, fuel gas, and other uses. The increase in use of coal followed a burst of inventions near the middle of the nineteenth century. Coal was used to make synthetic dyes, steel, glass, and other products. Coal remained the dominant energy source in the United States until the early 1940's, when oil and natural gas achieved dominance. Figures 1 and 2 show the changing patterns and amounts of energy used in the U.S. from 1850 through the 1970's. It is important to note that although first wood and then coal declined significantly as a percentage of total consumption (Figure 1), they did not decline significantly in the absolute amounts used (Figure 2). Coal in the first transition and oil in the second became not only a new source of heat but also an integral ingredient in industrial development. Consumption of the new energy source grew very rapidly as it became an important fuel for economic growth.

Today, oil and natural gas constitute three-fourths of U.S. energy consumption, but it is pretty clear that oil production in the United States has peaked and is on the decline. The sources of our oil imports have banded together to sharply increase oil prices and control oil supplies. Today the U.S. is importing about one-half of its oil needs, and imports amount to about 2.7 billion barrels per year or $100 billion per year at $37 per barrel. This outflow of dollars puts a strain on our balance of payments. In addition, our national security is dependent upon availability of liquid fuels. Because of the balance of payments burden and more importantly, because of the perceived threat to national security posed by the high level of imports, the U.S. is seeking means of reducing total oil imports. The next major shift in our energy uses likely will be different in character from the previous shifts from wood and coal. In these cases, the new energy source did not actually displace the old in existing uses so much as it became the source of growth in energy consumption. In our current situation, we face the problem of displacing oil and reducing the rate of growth in total energy consumption.

A number of options to accomplish these goals are being considered including the following:

1. Energy conservation;
2. Increasing the domestic oil supply;
3. Converting solid fuels such as coal and oil shale to liquid fuels;
4. Changing energy consumption from liquid to solid fuels such as coal and nuclear;
5. Increasing use of renewable energy sources such as the sun and growing plants.
Figure 1. U.S. energy consumption patterns.

Figure 2. U.S. energy consumption trends, 1850-1974.


A quad is 1 quadrillion BTUs of energy.
All of these options are aimed at reducing U.S. dependence upon foreign sources of liquid energy either by reducing total energy consumption or by converting from liquid to solid energy sources. It appears that the energy strategy to be followed by the U.S. will include a combination of all these options.

CONSERVATION AND ENERGY CONSUMPTION

Forecasting demand for anything 20 years into the future is always difficult, but forecasting energy demand 20 years hence borders on soothsaying. From the 1920's through the 1960's the real price of energy in the U.S. declined, yet the energy GNP ratio also declined during that period. That is, even with declining energy prices, the use of energy per unit of GNP fell, with GNP growing at 3.1 percent and energy consumption growing at 2.5 percent, or 80 percent as fast. In the 1970's energy prices began rising in real terms, so we would expect the energy/GNP ratio to decline, reflecting the higher energy prices. It would decline because with higher energy prices less energy would be used to produce each unit of goods and services in the economy. The question is how much will it decline over the next 20 years? To accurately answer this question we would need to understand thoroughly the feedback relationships between energy and GNP and to have reliable estimates of the effect of higher prices and incomes on the use of each major energy source. Furthermore, we would need to make assumptions about the rates of development and adoption of new energy conserving technologies.

One major problem in obtaining good long-run projections of energy use is that much of the change in energy consumption requires replacement of the buildings and equipment which we use to consume energy, and that takes place over a long period. We have yet to see all the conservation impacts upon the U.S. economy resulting from the 1973 oil price increase. Turnover of the automobile fleet takes about 8 years. The housing stock is replaced in approximately 50-year cycles. We have hardly begun to see the energy conservation induced by the 1979 oil price increases and the change in policy from regulated prices to market prices. Because these changes take so long to occur, we have no reliable statistical base from which to make demand projections.

In 1980, we consumed about 80 quads of energy. Since the early 1970's, there has been a general decline in the level of all energy demand forecasts, regardless of the bias of the forecasters. The 1972 forecast for year 2000 under low-growth assumptions (125 quads) is about equal to the 1978 forecast with high-growth assumptions (124 quads). Current "low-growth" forecasts range as low as 33 quads for 2000. Even if we disregard the extreme forecasters, there is still a range of about 30 quads or 15 million barrels of oil equivalent per day in 2000. My own belief is that energy demand in the U.S. will increase between 0 to 2.0 percent per year with a most likely range of 1.0 to 1.5 percent per year. This implies a year 2000 energy consumption of 78 to 115 quads with a most likely range of 95 to 105 quads. This assumes: 1) price-induced conservation will occur at increasing rates in the future, 2) auto fuel economy will increase even faster than government standards, and 3) retrofitting will increase conservation in the industrial and residential sectors.

1/To say that real prices of energy declined means that energy prices increased less than the general rate of inflation. In other words, energy prices didn't go up as much as everything else did, on average. GNP means gross national product, a measure of national income.

2/Retrofitting means improving the energy efficiency of existing buildings and equipment by improvements such as insulation.
U. S. ENERGY SUPPLIES AND CONSUMPTION

The U.S. has huge amounts of energy reserves and resources relative to current consumption (Table 1). The term resource refers to the amount of the substance expected to be in place regardless of whether it has been discovered or recovery would be economic. Reserve is that portion of the identified resource which can be extracted economically. U.S. energy reserves could last from 70 to 170 years, and estimated resources could last from 250 to 320 years assuming energy demand increases at 1 percent per year and that the current level of import dependence is maintained.

The extent of energy reserves and resources depends critically upon whether the fast breeder nuclear reactor is developed. Uranium reserves and resources are multiplied by 60 to 100 times with the breeder reactor. In addition, the U.S. has vast reserves of thorium which can be used in a breeder cycle. Comparing Figure 4 with Figure 3, we can see the difference in the relative resource base with the breeder technology. However, large uncertainties remain, and safety, waste disposal, and proliferation problems are not resolved for nuclear power.

These reserve and resource estimates do not include the potential energy available from renewable resources.

Table 1. U.S. energy reserves and resources

<table>
<thead>
<tr>
<th>Resource type</th>
<th>Reserves</th>
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<tbody>
<tr>
<td></td>
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<td>% With LWR</td>
<td>% With FBR</td>
<td>Amount (quads)</td>
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<tr>
<td>Gas</td>
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<td>706</td>
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<tr>
<td>Unconventional gas</td>
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The oil and natural gas liquids resource numbers include enhanced oil recovery.

LWR = Light water reactor.
FBR = Fast breeder reactor.

NOTE: Current U.S. energy consumption is about 78 quads per year plus 2 quads of wood. A quad is one quadrillion BTUs, 1.055 million terajoules, or approximately one-half million barrels per day of oil.

SOURCES: These estimates were derived from studies by Committee on Nuclear and Alternative Energy Systems, Resources for the Future, the Ford Foundation, and other sources. The uncertainty in these estimates is quite large, and other sources may show numbers that differ substantially from these. Generally these numbers are about midway between the CONAES supply panel estimates and the RFF figures.
Figure 3. U.S. energy consumption and resources with the breeder.

Figure 4. U.S. energy consumption and resources without the breeder.
such as solar, hydropower, and biomass. Use of renewables for a portion of energy consumption would extend the stocks beyond the time periods indicated above.

The U.S. energy problem is fundamentally one of a shortage of oil relative to our oil consumption (Table 2). Half of U.S. consumption of energy is oil, but oil resources are only about 1 percent of total resources (Figure 4). The U.S. energy problem is really the national security problem of being dependent upon the rest of the world for half its oil needs. The challenge is to find ways to better match our energy use with domestic energy sources.

POTENTIAL ENERGY SOURCES
Increasing the Oil and Gas Supply

Oil prices in the U.S. have been completely deregulated. Natural gas prices will be deregulated by 1985 or sooner. Price deregulation will be a major stimulus to increasing U.S. reserves of oil and natural gas. However, higher prices alone will not solve the U.S. liquid fuel problem. U.S. oil and gas production in 2000 will very likely be lower than it was in 1979— even with higher prices. The CONAES study projects U.S. oil production to range from 12 to 20 quads in 2000 depending upon the level of national commitment to increased oil production.

Most other studies project domestic oil production in 2000 including enhanced oil recovery to be lower than the 1979 production level of 17 quads.

Domestic gas production in 1979 was about 19 quads. There probably is greater potential for increasing natural gas reserves than oil because natural gas has been under price regulations since 1954, and little incentive has existed for increased exploration. With higher prices, much more exploration will occur, and natural gas production is not likely to decline nearly so much as oil.

Converting Solid Fuels to Liquids

Liquid fuels can be made from coal, oil shale, tar sands, or biomass resources. The U.S. has large resources of both coal and oil shale.

Coal: Synthetic liquid or gas fuels can be produced from coal. Liquid fuels include a crude oil-like product which can be further refined to get petroleum products, gasoline, and methanol. Coal liquids are likely to cost from $40 to $65 per barrel (1980), and coal synthesis gas will cost between $4 and $6 per million BTU's (1000 cubic feet). Coal liquids plants will require a capital investment of about $2 billion. No coal liquid or gaseous fuels are being produced commercially in the U.S. today,

<table>
<thead>
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<th>Table 2. U.S. energy consumption, reserves, and resources</th>
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<tr>
<td>Resource type</td>
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<td>Other</td>
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<td>TOTALS</td>
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</table>

SOURCES: 1979 consumption from Department of Energy, Quarterly Report: Energy Information (April 1980); reserves and resources from Table 2.

3/Biomass is renewable organic materials such as corn, crop residue, and municipal solid waste.
but production in 2000 could range between 2 and 5 quads per year.

Oil Shale: The U.S. has vast resources of oil shale, but only a small fraction of the resource in place is likely to be produced because of environmental and social constraints. A 400,000-barrel-per-day industry (eight plants) could be developed by 1990 without serious difficulties. A one million-barrel-per-day industry, however, would unavoidably violate current environmental air quality standards and cause serious economic and social disruption to the producing areas. Apparently, the environmental, economic, and social systems can accommodate a certain level of development, but once this threshold is reached, the social costs of further development increase rapidly.

A 50,000-barrel-per-day oil shale plant is projected to cost $1.7 billion or $34,000 per daily barrel of capacity. Oil shale costs are projected to range between $35 and $60 per barrel depending upon the crude oil price increase and rate of return used.

Changing from Liquid to Solid Fuels

Half the oil in the U.S. is used for transportation, and the other half for industrial and home uses. To the extent that solid fuels can substitute for this oil, oil imports can be substantially reduced. Fuel oil is used in industrial processes and space heating. It is also used to generate electricity. Coal could be used in industry and perhaps residential sectors for heat, and coal or nuclear power could be used to displace fuel oil in generating electricity.

Nuclear Power: Nuclear energy is a large question mark for the U.S. The energy potential from nuclear sources is very high, yet so are the perceived social and environmental risks. The CONAES estimates for nuclear energy for 2000 are ranged between 12 and 28 quads. Current nuclear power generation is about 3 quads. Even the lowest CONAES estimate entails a quadrupling of nuclear power by 2000. Whether nuclear power will achieve that level or anything higher is an open question.

Coal: Interest in the future potential of coal is quite high. The World Coal Study (WOCOL) estimated that coal could provide one-half to two-thirds of the increase in world energy consumption over the next 20 years. U.S. coal production could grow at an average rate of 4 or 5 percent per year between now and 2000, which means that 2000 coal production would be 2.2 to 2.7 times the current level. Coal could increase from 19 to as much as 35 percent of total energy consumption by 2000. Coal exports may increase also.

However, the increased use of coal, whether it is burned directly or converted to liquid or gaseous fuels, generates several problems. High levels of coal use may strain capital or equipment markets, cause transportation bottlenecks, and cause social disruptions like the boomtown growth in the western United States. Environmental problems include land reclamation, the carbon dioxide (greenhouse) effect, acid rain, air pollution, water pollution, and destruction of scenic beauty. Economically, coal-generated electricity compares favorably with oil-generated power even when all environmental control costs are included. For example, in Japan where environmental control laws are very strict, imported coal costs about $45 a ton and environmental costs add $35 a ton for a total of about $80 a ton—compared to a cost of about $165 a ton for fuel oil power generation. Comparison of coal to nuclear power is not so simple, and the answer depends very much upon the assumptions used in the analysis. Generally, however, coal-generated power is as cheap or cheaper than nuclear power.

Another means of using coal to substitute for liquid fuels is by converting to electric vehicles and trains for motive power. Railroad electrification is one means of substituting electricity generated by domestic coal or nuclear sources for diesel derived from imported oil. Preliminary research results indi-
cate that the oil savings by 2000 could be about 100,000 barrels per day or the equivalent of two syn-fuel plants. The capital investment required to achieve this savings is roughly the same as for an oil shale syn-fuel plant--$35,000 per barrel of daily capacity. However, the operating cost is considerably lower than for a syn-fuel plant.

Use of electric vehicles also would bring about substitution of coal or nuclear power for imported oil. Electricity generated from these sources would charge vehicle batteries, thereby displacing gasoline. By the year 2000, electric vehicles could achieve an oil savings of about 500,000 barrels per day or ten syn-fuel plants (1 quad). The capital cost in new plant and equipment for achieving this savings is estimated to be about $31,000 per new daily barrel of oil saved. Electric vehicles are projected to be competitive at gasoline costs of about $2.00 per gallon ($1980).

We can expect to see increased efficiency in coal power generation over the next 20 years by the successful development of technologies employing cogeneration, fluidized bed combustion, and Magnetohydrodynamic (MHD) coal power generation. Increased power generation efficiency will both lower the cost and reduce the primary energy requirement of coal-based power.

### Renewable Energy Sources

Renewable energy sources include a wide range of sources such as solar, biomass, wind, ocean thermal, and others. Direct solar and biomass are the two most important categories for the near term in the U.S.

Solar: The Harvard study projects solar energy to provide four quads by 1990. Solar energy utilization by 2000 in the CONAES study ranges from 0 to 7.7 quads depending upon the assumptions used. Direct use of solar is often more expensive than conventional sources. Without substantial economic incentives, solar energy in the U.S. will remain small over the next 20 years.

Biomass: The biomass energy category includes a wide variety of sources such as wood, forage crops, crop residues, grains, and municipal solid wastes. Wood currently supplies about two quads of energy, primarily in the forest products industry. The OTA biomass report attributes the highest potential within the biomass category to wood followed by forage crops. The most immediate biomass potential is for ethanol from grains for gasohol. By 1990, ethanol capacity is likely to be 2 billion gallons per year on 145,000 barrels per day oil equivalent (about three syn-fuels plant or 0.3 quads). Current research results indicate that alcohol production significantly higher than 2 to 3 billion gallons could cause corn prices to increase substantially (Meekhof, Tyner, and Holland). Whether grain alcohol production will increase beyond that level will depend upon the impacts alcohol production has on feed/food prices and the policy response that occurs.

By the mid-1980's most authorities believe that cellulose conversion technologies will be commercially available to produce ethanol and methanol from crop residues, forage crops, wood, or municipal solid waste. It is too early to tell whether cellulitic biomass will be gasified, directly combusted, or converted to methanol or ethanol. Biomass energy use in 2000 is likely to range between 2 and 6 quads. After an initial surge in alcohol production in the early 1980's, there probably will be greater use of wood, municipal solid waste, and other cellulosic sources later in the 1980's.

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4/ Magnetohydrodynamic power generation probably is more than 20 years away from commercialization, but has a good potential for the next century.

5/ Municipal solid waste was not included in this Office of Technology Assessment report.
HOW WILL THE FUTURE DEVELOP?

Over the next 5 years, the most important changes in the U.S. energy picture will be increased conservation and increased ethanol production from grain. The 1979 oil price increase plus the phased deregulation of domestic oil and gas will induce much greater conservation than has occurred in the past. A grain alcohol plant can be completed in 2 years. The equivalent of at least two syn-fuel plants of ethanol will be in production before the first coal or oil shale plant comes on stream. Within the next 5 years, there will be no commercial syn-fuels production from coal or oil shale, little use of electric vehicles, a small increase in nuclear power, and a very low growth in solar energy. It takes 6 years to build a syn-fuel plant and 10 to 12 years to bring a nuclear power plant to completion.

Over the next decade, syn-fuel plants will come into production as will electric vehicles and rail electrification. By 1990, savings due to rail electrification likely will be less than one syn-fuel plant equivalent, but electric vehicle savings could be about three syn-fuel plants equivalent, roughly the same as biomass alcohol production. Oil shale syn-fuels could be as much as eight plants with roughly the same amount from coal gases and liquids. By 1990, methanol from coal will be in production with the major use probably for turbine electric power generation (displacing fuel oil) for peaking power. Methanol from coal will grow fairly rapidly for stationary plant energy needs and perhaps for motive power as well.

From 1990 to 2000, syn-fuels from coal will grow fairly rapidly along with solar, biomass, electric vehicles, and nuclear power. During the next two decades, the absolute level of U.S. dependence on foreign oil will decline very little, but the percentage dependence could decline from about 21 percent of total energy today to 13 or 14 percent in 2000.

Table 3 and Figures 5 and 6 summarize where the U.S. is likely to be in the year 2000 for two demand levels. Oil and natural gas both decline relatively, and coal and nuclear power both increase. Coal will grow faster than most experts have forecasted, and nuclear power will grow slower. Biomass and solar both grow rapidly in percentage terms but still constitute less than 7 percent of total energy consumption in 2000, about the same as nuclear energy. The U.S. will not be on either a "hard" or "soft" path exclusively; "hard" and "soft" paths are not mutually exclusive options. The U.S. will have some of each with the "hard" path being dominant over the next two decades.

From the vantage point of the year 2000, we will probably be able to look back and see that the U.S. has developed to some extent many of the energy sources discussed here including oil shale and coal liquids, electric motive power, nuclear power, solar, and biomass. If that is the case the U.S. will be in a much better position in the year 2000 to project to 2020 than it is in today. My own feeling (from the 1980 vantage point) is that nuclear and solar energy (perhaps strange bedfellows) will provide much of the growth in energy from 2000 to 2020 and beyond. The U.S. may not be able or willing to greatly expand the syn-fuels industry or biomass because of the serious environmental degradation that could occur. Synthetic liquid fuels may be only transition fuels. To the extent that the U.S. is not able or willing to expand nuclear power, coal based power is the most likely alternative. If that becomes the case, growth in coal based syn-fuel development almost certainly will be limited and conservation and solar alternatives become much more important.

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6/ The term "hard path" refers to increased reliance on centralized energy forms such as nuclear power, oil, and gas. "Soft path" refers to a more decentralized energy supply system relying more on solar, biomass, wind, geothermal, etc. Coal plays an important role in both hard and soft path futures.
<table>
<thead>
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<th>2000 Demand = 105</th>
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<tr>
<td></td>
<td>Quads</td>
<td>%</td>
<td>Quads</td>
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<td><strong>100.0</strong></td>
<td><strong>95</strong></td>
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</table>

\(^a\) In 1979 coal production actually was 17.4 quads with 1.7 quads exported and 0.6 quads change in stocks. Year 2000 coal numbers include synthetics.

\(^b\) Biomass production and consumption, primarily wood in the forest products industry, currently is not included in official Department of Energy statistics. The 2 quads of biomass explains the difference between the DOE 78 quads and the 80 quads shown here.

\(^c\) Natural gas imports in 1979 actually were 1.2 quads. The figure is adjusted here to make production plus imports balance with consumption.


IMPORTANT ISSUES AND QUESTIONS

Because of the long lead times involved in the development of the energy alternatives, the U.S. faces several critical choices in the next few years that will influence its ability to make the transition away from oil to other energy sources. Deregulation of oil and natural gas prices has begun--steps which are absolutely essential if the U.S. is to achieve the conservation and alternative fuels development levels outlined in this paper. One policy alternative is to go further and place a tax on crude oil to make ourselves pay the full social cost of dependence on imported oil. A crude oil tax would reduce demand growth as well as stimulate development of energy alternatives. Proceeds of a crude oil tax could be used to reduce the burden of individual and corporate income taxes.
Another major choice the U.S. must make over the next decade is between the economic potential, environmental disruption, and societal risks associated with coal power and nuclear power. Some of each will be needed, but the choice concerns emphasis. The U.S. will spend the next 5 to 10 years developing both coal and nuclear power, but during that time she will have to decide how best to handle the uncertainties, risks, and by-products associated with each of these major power sources.

In the energy business, we are surrounded by prophets of doom. About 150 years ago, Macoulay wrote the following passage regarding the prevailing mood of his time:

We cannot absolutely prove that those are in error who tell us that society has reached a turning-point, that we have seen our best days... On what principle is it that, when we see nothing but improvement behind us, we are expected to see nothing but deterioration before us?

It is true that doomsday prophesies have been with us for hundreds of years. Has the time come for us to believe the prophets of doom, or can we see hope for improvement in the future? In forecasting our nation's energy future there is ample cause for both despair and hope. The hope is premised on our ability to accurately perceive the nature of our energy problems and to take prompt effective actions to solve them. One basis for optimism is that market forces will both induce conservation and increase energy supplies. Detroit is on a

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Figure 5. Energy supply and demand for 2000: demand = 95.

<table>
<thead>
<tr>
<th>Source</th>
<th>OIL $ NGL</th>
<th>NATURAL GAS</th>
<th>COAL</th>
<th>NUCLEAR</th>
<th>SHALE OIL</th>
<th>GEO-THERMAL</th>
<th>SOLAR</th>
<th>BIOMASS</th>
<th>HYDRO &amp; OTHERS</th>
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<th>GAS IMPORTS</th>
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Figure 6. Energy supply and demand for 2000: demand = 105.

<table>
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<tr>
<th>Source</th>
<th>OIL $ NGL</th>
<th>NATURAL GAS</th>
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<th>BIOMASS</th>
<th>HYDRO &amp; OTHERS</th>
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<td>2000 demand</td>
<td>25.5%</td>
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<td>1.9</td>
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crash program to produce fuel efficient autos not because Washington requires it to, but because you and I--the consumers--have required it to. Oil drilling rates have set new records in the U.S. in 1981 in part because of oil price deregulation. Entrepreneurial activity all over the country is developing or marketing conservation products and new energy alternatives.

This does not mean that government policy is unimportant. Development of syn-fuels will not occur without government assistance--at least initially because the private risks are too great. Also, weighing social risks against private costs must be accomplished in the political arena. In the United States we have ample energy resources, if we can just master the will and the ability to use them wisely.
REFERENCES


Cooperative Extension Work in Agriculture and Home Economics, State of Indiana, Purdue University and U.S. Department of Agriculture cooperating. H. G. Diesslin, Director, West Lafayette, Ind. Issued in furtherance of the Acts of May 8 and June 30, 1914. It is the policy of the Cooperative Extension Service of Purdue University that all persons shall have equal opportunity and access to its programs and facilities without regard to race, color, sex, or national origin.