

SYNTHETIC FUELS FROM COAL

ABSTRACT

This report examines the capability of the United States to rapidly achieve large-scale production of clean liquid fuels and synthetic natural gas from domestic coal. In particular, we have focused attention on the possible role of the federal government in accelerating technical development of coal conversion processes and promoting the subsequent growth of a synthetic fuels industry.

The report concludes that government's major role in promoting wide-scale application of coal gasification is removing institutional constraints, whereas rapid application of coal liquefaction would require government support for research and development followed by modification of institutional constraints. If an expanding synthetic fuels industry came into being, government action would also be required to assure concurrent expansion of coal mining production.

The report includes a specific program for government research support and suggestions for new technical activities needed to promote a synthetic fuels industry.

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EXECUTIVE SUMMARY

Synthetic Fuels From Coal

Project Goals and Description

This report examines the capability of the United States to rapidly achieve large-scale production of clean liquid fuels and synthetic natural gas from domestic coal. In particular, we have focused attention on the possible role of the federal government in accelerating technical development of coal conversion processes and promoting the subsequent growth of a synthetic fuels industry.

The basic goal of the suggested synthetic fuel development program is to have at least one coal liquefaction and at least one coal gasification commercial scale plant operational by 1980. Construction of a full-scale, privately financed gasification plant would begin as soon as policies were worked out on price regulation and environmental controls which are acceptable to utilities, financing institutions and the governmental agencies involved. For coal liquefaction a joint industry-government program is recommended aimed at immediate construction of pilot plants followed closely by commercial scale demonstration plants. The pilot plants would be built in existing industrial areas to eliminate the need for acquiring ancillary support facilities. A joint mining development program is also suggested based on one or more technology demonstration mines.

Incremental Add-On of Energy Expected

If successful, the program would make possible the initial development of a coal liquefaction and gasification program in the early 1980's. The potential size of this industry is probably 5-10 million barrels/day oil equivalent by 1990, depending mainly on the future prices of competitive fuels.

Status of Technology

Although no commercial scale coal gasification plants have been built in this country, we find there is an adequate technological base for domestic production of synthetic natural gas from coal at prices competitive with other supplemental sources of natural gas. There have been, in fact, several publicly announced gasification plant projects which propose to use foreign coal gasification processes.

In coal liquefaction we believe that there is no available commercial-scale process for producing economically competitive liquids from coal.

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If an expanding synthetic fuels industry begins in a few years, a concurrent expansion of coal mining and production will be needed. The mining industry feels it has the physical capacity to double coal production before 1980. However, existing institutional constraints may limit rapid mining growth.

Project Costs and Timing of Program

Coal liquefaction technology would be accelerated by starting construction of two or three pilot plants sized in the range of 500-1000 tons/day of coal. The pilot plants would be operational by FY 1978. Construction of a few pioneer commercial scale plant(s) would begin in FY 1977 and they would be operational by 1980. Government support of private coal gasification plants would be aimed at getting the plants operational by 1978/9.

In the area of Eastern and Mid-Western mining, we recommend increasing support of deep mine technology development, including one or more demonstration mines which would be operational by 1977. We estimate the additional federal funding necessary for this program would be \$340 million for liquefaction (assuming 2/3 government funding for pilot plants and 20% for commercial scale plants), \$300 million for mining, \$65 million for gasification and \$120 million for increased supporting technology development, for a total of \$825 million.

The Potential and Time Frame for Development of an Industry

There are probably enough domestic plant sites to support an industry with output equivalent to 10 million barrels/day of oil. The first generation of plants could come onstream in 1983 if the pioneer plants were successful. Providing production costs were sufficiently low, gas and oil production could reach 1-2 million barrels/day equivalent by 1985.

Impact on Energy and Other Energy-Related Industries

The synthetic natural gas (SNG) from high Btu coal gasification would substitute directly for natural gas, and thereby act as a supplemental source in addition to imported LNG and SNG from other hydrocarbons.

Liquids from coal liquefaction plants can be refined into substitutes for petroleum based liquid fuels, e.g., gasoline, residual fuel, jet fuel, heating oil, etc. Thus coal liquefaction products substitute directly for imported crude oil and imported petroleum products.

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Environmental Impacts and Costs

The major additional environmental impact studies would be aimed at surface mine effects, characterization of synthetic fuel plant effluents, and control of identified toxic wastes. A key purpose of the synthetic fuels development program is the successful demonstration of acceptable surface mine reclamation and process plant effluent control so that mine and plant site problems will not eventually constrain the growth rate of a synthetic fuels industry.

Financing Arrangements and Government Policies Required to Induce Maximum Industry Participation

The major government role in rapid establishment of a nationally significant coal gasification industry would be to formulate a stable, definitive pricing and regulatory policy for gasification projects.

Gas producers must have this stability before they will proceed with five-year, \$500,000,000 commercial-scale projects.

To rapidly create the engineering data base for building a coal liquefaction industry, government support will be required to accelerate current industrial schedules for pilot plant construction.

Joint government-industry funding would be used with competitive bidding by industry in private sector funding to assure that only the most commercially promising processes would be chosen for accelerated development.

Further government incentives may be needed later if it is deemed in the national interest to promote very rapid construction of synthetic fuel plants before a comprehensive technical data base has been established at the pilot plant level. The government role would be to provide insurance against disastrous loss due to technical failure so that a large investment of private capital could be attracted to commercial scale synthetic fuels development in the late 1970's.

Legal and Legislative Considerations

One legal and legislative area bearing on a synthetic fuels industry concerns the feasibility of encouraging the industry via tax preferences, guaranteed loans, low cost loans, low cost government energy leases, guaranteed rates of return, guaranteed price, import quotas, variable import tariffs, allocation of scarce resources, cost sharing, performance bids for government energy leases, easing of price controls on energy and energy-producing equipment, streamlining of licensing and environmental legislation and revised patent procedures.

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A second area is the feasibility of accelerating early coal production and site acquisition with temporary waivers of the most stringent environmental protection laws. For instance, a major government role in surface mining appears to be determining the minimal constraints compatible with protection of the public interest against the adverse effects of coal mining. This will require some very carefully drawn up legislation so that the laws will not serve to effectively bar all strip mining.

Government's Role

The report concludes that government's major role in promoting wide-scale application of coal gasification is removing institutional constraints, whereas rapid application of coal liquefaction would require government support for research and development followed by modification of institutional constraints. If an expanding synthetic fuels industry came into being, government action would also be required to assure concurrent expansion of coal mining production.

Description of Phase II

To carry out this program we suggest creation of a focal point in the federal government with the power to recommend whatever regulatory, subsidy, or legislative action is needed to get the job done. We recommend responsibility for design, construction and operation of each project be assigned to a single ad hoc management group and that this group be permitted to operate as independently as possible with maximum flexibility in financing operations.

We have identified a number of other physical and institutional constraints to rapid growth of a synthetic fuels industry. This report includes suggestions for government's part in removing these constraints. Although the report emphasizes immediate actions needed to accelerate development of synthetic fuels technology, suggestions for action aimed at longer range goals are also presented.

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I. SUMMARY

The success of Project Independence requires development of new domestic fuel sources to supplement fuel production from our indigenous petroleum and natural gas reserves. This report examines the capability of the United States to rapidly achieve large-scale production of clean liquid fuels and synthetic natural gas from domestic coal. In particular, we have focused attention on the possible role of the federal government in accelerating technical development of coal conversion processes and promoting the subsequent growth of a synthetic fuels industry.

Although no commercial scale coal gasification plants have been built in this country, we find there is an adequate technological base for domestic production of synthetic natural gas from coal at prices competitive with other supplemental sources of natural gas. There have been, in fact, several publicly announced gasification plant projects which propose to use foreign coal gasification processes. The major government role in rapid establishment of a nationally significant coal gasification industry would be to formulate a stable, definitive pricing and regulatory policy for gasification projects. Gas producers must have this stability before they will proceed with 5-year, \$500,000,000 commercial-scale projects.

In coal liquefaction we believe that there is no available commercial-scale process for producing economically competitive liquids from coal. To rapidly create the engineering data base for building a coal liquefaction industry, government support will be required to accelerate current industrial schedules for pilot plant construction.

Further government incentives may be needed later if it is deemed in the national interest to promote very rapid construction of synthetic fuel plants before a comprehensive technical data base has been established at the pilot plant level. The government role would be to provide insurance against disastrous loss due to technical failure so that a large investment of private capital could be attracted to commercial scale synthetic fuels development in the late 1970's.

If an expanding synthetic fuels industry begins in a few years, a concurrent expansion of coal mining production will be needed. The mining industry feels it could, if necessary, double coal production before 1980 providing existing institutional constraints limiting rapid mining growth were modified. The government's role in this case appears to be determining the minimal mining constraints compatible with protection of the public interest against the adverse effects of coal mining. If even greater coal production

were required in the 1980's, increased government support of mining research appears necessary.

The basic goal of the suggested synthetic fuel development program is to have at least one coal liquefaction and at least one coal gasification commercial scale plant operational by 1980. Construction of a full scale, privately financed gasification plant would begin as soon as policies were worked out on price regulation and environmental controls which are acceptable to utilities, financing institutions and the governmental agencies involved.

Coal liquefaction technology would be accelerated by starting construction of two or three pilot plants sized in the range of 500-1000 tons/day of coal. Joint government-industry funding would be used with competitive bidding by industry in private sector funding to assure that only the most commercially promising processes would be chosen for accelerated development. The pilot plants would be operational by FY 1978. Construction of commercial scale plants would begin in FY 1977.

In the area of Eastern and Mid-Western mining, we recommend increasing support of deep mine technology development including one or more demonstration mines. A study of surface mine reclamation costs is also recommended.

The major additional environmental impact studies would be aimed at surface mine effects, characterization of synthetic fuel plant effluents, and control of identified toxic wastes. We estimate the additional Federal funding necessary for this program would be \$340 million for liquefaction (assuming 2/3 government funding for pilot

plants and 20% for commercial scale plants), \$300 million for mining, \$65 million for gasification and \$120 million for increased supporting technology development, for a total of \$825 million.

If successful, the program would make possible the initial development of a coal liquefaction and gasification program in the early 1980's. The potential size of this industry is probably 5-10 million barrels/day oil equivalent by 1990, depending mainly on the future prices of competitive fuels.

To carry out this program we suggest creation of a single focal point group in the Federal government with the power to recommend whatever regulatory, subsidy, or legislative action is needed to get the job done. We recommend responsibility for design, construction and operation of each project be assigned to a single ad hoc management group and that this group be permitted to operate as independently as possible with maximum flexibility in financing operations.

We have identified a number of other physical and institutional constraints to rapid growth of a synthetic fuels industry. This report includes suggestions for government's part in removing these constraints. Although the report emphasizes immediate actions needed to accelerate development of synthetic fuels technology, suggestions for action aimed at longer range goals are also presented.

II. INTRODUCTION

A. Program Description

The proposed \$10 billion energy R and D program, recommended to the President on December 1, 1973, was concerned with the structuring of an orderly and well-balanced effort to support near-term objectives while maintaining both mid-term and long-term objectives in perspective. The R and D program recommended several large-scale projects to further develop the production of synthetic fuels from coal, including: (a) an 80 million ft³/day second generation high BTU gas demonstration plant operational by 1980, (b) two advanced technology liquefaction prototype plants operational by 1978, (c) two commercial scale pioneer plants using existing liquefaction technology for operation by 1980.

In response to more recent developments, this report proposes a supplementary synthetic fuels demonstration program which could be the next step of a national program to build productive capacity for significant quantities of liquid and gaseous fuels from coal. In view of the transportation fuels crisis and because commercial-scale production of high and low BTU gas from coal is already being planned by several utilities, we believe accelerated development of coal liquefaction deserves top priority.

This synthetic fuels demonstration program described in this report has the specific goal of providing the commercial-scale

development that will be required for a massive synthetic fuels production industry in the 1980's. Specific aspects of this program include: (1) removal of institutional and physical obstacles for acceleration of proposed commercial projects for the production of high BTU gas from coal, (2) acceleration of the synthetic fuels pioneer program with higher government funding to compensate for the higher risk, and (3) expansion of the liquefaction prototype plant and synthetic fuels pioneer programs to increase the probability of technological success.

B. Project Description

Two options we considered as possible responses to the needs of Project Independence were, first, a "National Coal Resource Center" at a single site and, second, development of each synthetic fuel process at a separate site.

The objective of the resource center was to provide as quickly as possible a high visibility demonstration at one Eastern or Mid-Western site of commercial scale coal liquefaction, coal gasification, and environmentally acceptable strip mining. Because of the emphasis on near-term results, only those processes at an advanced stage of development with promise of future commercial success would be considered for the demonstration center. Following independent demonstration of each technology, one or more optimized, integrated processes would be developed to produce from a variety of domestic coals the most commercially competitive mix of synthetic clean, solid

gas and liquid fuels. It was hoped that major efficiencies would be gained by gathering at one site technically trained manpower, support facilities, and a stable local work force at one site. For example, coal storage and treatment facilities could be common to all processes. The hydrogen needed for several processes could be generated by a single unit. Also, siting delays would be minimized since preparation and approval of only one environmental impact statement, would be required. This concept assumed that these advantages would more than offset any disadvantages due to loss of industrial participation in a government controlled project and to subsequent "technology transfer delay" in reduction of resource center R and D results to industrial practice.

However, the general consensus of the government and industrial sources contacted by our task force was that the concept of a single coal development center was neither the most efficient nor the fastest way to achieve the potential for building a national synthetic fuels industry. Having several widely separated sites allows a much broader-based industrial participation both in the pilot plant phase and in subsequent construction of commercial plants. A coal company with Eastern bituminous coal reserves would have little interest in a process demonstrated with New Mexico sub-bituminous coal while a firm with substantial lignite coal holdings would have little interest in a process demonstrated with Southern

Illinois bituminous coal, as process performance with different coal feed stocks usually is quite different.

The fastest route to synthetic fuel production appears to be offering government incentives for accelerated development of the most promising industrial coal conversion processes. The incentives would be determined by competitive bidding to assure that only sufficiently advanced processes were promoted by the government, i.e. processes that would be partially supported by industry. The point was made repeatedly to our task force that a major industrial contribution to any conversion project was necessary to get an industrial commitment of "first string" personnel and adequate supporting facilities. Protection against excess profits arising from government aid to development would be maintained by assuring the industrial parties received benefit only in proportion to the financing supplied by the various partners. Also the use of the research data would be made available to all via standard royalty arrangements.

In short the concept of a coal resource center has evolved from the original prospects of one project at a single site to several projects at sites selected jointly by industry and government. Startup time would be minimized by choosing sites already zoned for

industry with an established labor force, resident technical personnel, and existing auxiliary requirements such as bulk transportation, bulk storage, a supply of hydrogen, marketing facilities, refining capability, waste treatment facilities, etc.

C. Background - The program in context

1. The International Setting

Table I gives a ballpark estimate of the magnitude of Project Independence. A typical projection and a range of estimates are given for five private and federal forecasts. These estimates are very approximate because the shortfalls and imports are derived by guessing demand and subtracting the sum of guesses for all the various means of domestic energy production. However, it is clear that under the conditions existing a year ago, when these projections were made, we faced the prospect of overall energy imports in the range 20-20 million B/D and Arab oil imports in the range 5-15 million B/D. These projections were based on extrapolation of long range global trends in energy flow, which seemed practically inevitable a year ago. Under these earlier assumptions, the total synthetic fuels production from domestic coal and shale would rise as high as one or two million B/D by 1990. Most of the production would be from shale. Some estimates were made of what would happen if the international

prices of oil should "soar" to \$5-6/barrel. In this case synthetic fuels production might rise to several million barrels/day by 1990, with considerable production from domestic coal.

Today the price of low sulfur oil imports exceeds \$12/bbl. Most estimates for prices of coal-based synthetic fuels fall below \$10/barrel making synthetic fuels production potentially profitable today.

Table I
Projected Energy Flows (Million B/D Oil Equivalent)^a

	1980	1985	1990
Domestic Shortfall Range	13 (6-16)	16 (3-19)	25 (22-27)
Arab Imports Range	8 (4-10)	11 (2-15)	13 (11-15)
Canada & Venezuela Imports	3	3	2
Synthetic Fuel ^b Production Current Plans	0-.2	0.5-1.1	1.-4.0
Synthetic Fuel Production Estimated Maximum Possible ^b	.1-.5	1.-2.5	2.5-4.5

^aTypical Number

^bCoal liquefaction and gasification, shale.

2. The National Setting

The current use of fossil fuels in this country is broadly characterized as:

- a) Transportation - 1/4 of total consumption (over 1/2 of all oil consumption): supplied by non-substitutable petroleum liquids
- b) Building space heating and chemical feed stocks - 1/4 of total consumption - supplied by natural gas and oil (1/3 to 1/2 of all gas, 1/4 of all oil): relatively difficult to substitute alternate fuels
- c) Industrial and utility - 1/2 of total consumption - by cheapest available fuel (1/2 - 2/3 of all gas, 1/4 of all oil): relatively easy to substitute alternate fuels.

The overall national demand pattern is now about 40-40-20 for gas, oil and coal. In 1985 the end use pattern has been projected to be approximately the same except that nuclear energy will contribute about 10% of domestic supply.

The national pattern of recoverable fossil fuel reserves is reversed with coal comprising over 80% of reserves, oil shale less than 20% of reserves and oil and gas totaling less than 10% of reserves. Unfortunately, we are beginning to run out of cheap readily recoverable domestic oil and gas. At present natural gas consumption is limited by North American production capability which industry predicts will be as much as 20% lower in 1985. Domestic oil consumption already exceeds domestic

production by half and today's best estimates show oil demand will be more than double production capability by 1985. At the heart of the national self-sufficiency problem are the facts that by the mid-1980's: 1) domestic oil production will just about be able to match non-substitutable domestic transportation fuel demand, and 2) domestic natural gas production will be about equal to the relatively non-substitutable space heating demand. On a regional basis the situation is even worse, since the Eastern U.S. already consumes far more energy than it produces.

However, we have abundant supplies of cheap coal and uranium. Even with soaring prices there may be trouble maintaining today's level of domestic oil and gas production for more than a few decades whereas there is enough coal to supply the country for centuries if fuel prices remain high enough to warrant recovery of coal reserves that are now economically marginal.

The "Energy Crisis" is due not to lack of resources, but to the problems involved in rapidly shifting our energy base from oil and gas to coal and uranium. The sudden urgent need for implementing a massive shift in energy base is countered by the inevitable delays in developing and constructing new energy production systems.

There are serious problems incurred by increasing the utilization of domestic coal. Coal combustion produces toxic

sulfur oxides; coal conversion to gas and liquids is now extensive; coal mining can have severe environmental impact; and the bulk of our coal is located far from population centers. Also, institutional problems such as restricted leasing of Federal lands for coal mining and social problems such as doubling or tripling the population of coal rich states also mitigate against accelerated utilization of domestic coal.

For these reasons coal (and shale) now supply around 20% of our national needs, although potentially by gasification and liquefaction they could supply 90% of our needs.

3. The Regional Setting

The characteristics of a coal based synthetic fuel industry will be largely set by the regional nature of our energy problems. The bulk of oil imports now come to energy demand centers in the East. These centers also consume coal from Eastern and Mid-Western mines which produce over 90% of our national coal output. Most of this coal is high sulfur and direct combustion of it is environmentally unacceptable under current regulations. Thus direct substitution of Eastern coal for oil imports is ruled out by environmental considerations. In addition, more than half of the Eastern and Mid-Western coal is deep mined at costs considerably higher than surface mined coal. Rapid expansion of Eastern and Mid-Western coal production is constrained by both the long

time lags required to open deep mines on land that is now agriculturally productive.

In the West, where the bulk of the United States coal is located, sulfur contents are typically low enough for direct coal use, but the cost of shipping coal to user sites is often prohibitively high. Much of the Western coal is surface mineable and in principle Western coal production could be rapidly increased if it were not for problems of land reclamation in arid regions.

Coal gasification and liquefaction play a role in each of these regions. In the East and Mid-West coal conversion can produce clean, environmentally acceptable fluid fuels from indigenous high sulfur reserves. In the West, coal can produce fluid fuels which can be cheaply transported to demand centers far from the coal mines. On a national scale, of course, the synthetic fuel industry opens the market for coal based fuels from less than 20% of national demand to over 90% of national demand by effectively transforming coal into a clean transportation and space heating fuel.

4. Economic Factors

There are many market factors influencing the economic viability of synthetic fuel processes which convert

relatively cheap coal (now largely an electric utility fuel) to relatively expensive clean gas and oil (which are largely transportation and space heating fuels). Coal derived liquids and gases must compete with domestic crude oil and natural gas, shale oil, nuclear electricity. Coal feed stocks must compete with other demands for coal such as low BTU gasification and direct combustion (influenced heavily by several ongoing R/D projects). All of these compete with cheap oil and gas imports.

The effect of price, environmental constraints, national policy, the world economy, etc., on supply of all these energy sources relative to their effect on the price of coal and coal products will determine the eventual economic viability of coal conversion processes. In order to draw up a specific program for synthetic fuel development we have assumed economic conditions will remain relatively constant. However, we realize these initial assumptions can change with time. The synthetic fuel development program described here must be implemented with sufficient flexibility to allow the projects to adjust to changing economic factors. In particular, allowance must be made for changes in the level of industrial participation (either higher or lower) as external factors change over the 5-10 year life of some of these projects.

D. Project Definition

The most important parameter in defining a program for developing coal liquefaction and gasification is projected production schedule. Possible alternatives lie between 1) a maximum rate program featuring an immediate start on heavily government subsidized construction of many commercial scale plants using various processes, and 2) a laissez faire situation, with no government participation, in which the normal market place factors determine the buildup rate of a synthetic fuel industry. The result of the maximum rate program would be several million barrels a day of synthetic fuels in about 1980 whereas private sector investment alone would probably not spur development to this level until around 1990. The accelerated development program recommended by Chairman Ray in "The Nation's Energy Future" could probably bring coal based fuels significantly on line in the late 1980's.

We are essentially proposing in this report an intermediate course between an all-out crash program and the accelerated development program. In the liquefaction area we believe that immediate full-scale construction using today's technology would be counter-productive in the long term. The massive investment required could be much better spent on developing new technologies. The capital investment for the existing Fischer-Tropsch Liquefaction processes

is exceedingly high compared to the investment for processes now only a few years away from commercial scale testing. By the mid-1980's a given national investment spent on developing and building new processes would result in much more productive capacity than the same investment spent on existing technology today. Also Fischer-Tropsch liquids cost twice as much as liquids from the new processes.

Thus, in coal liquefaction we are recommending a program in which large pilot plants are immediately constructed for the most advanced processes. Follow-on prototype commercial plants would be brought to operational status by 1980. This would give the United States a synthetic liquid fuel from coal option in the 1980's. We would have the potential for rapid buildup of a competitive synthetic fuel industry before 1985.

In the area of coal gasification, where there is available technology to immediately start construction of commercial scale plants, the strategy is different. The role of government is to decide what the proper development schedule should be in light of future national needs and offer any necessary subsidies or cooperation required to meet that schedule.

In both developments neither a *laissez faire* nor a approach is being suggested. Joint government/industry cooperation is indicated and the success of the program will depend strongly on the degree to which this cooperation can be effected.