BY THE COMPTROLLER GENERAL

Report To The Congress

OF THE UNITED STATES

Liquefying Coal For Future Energy Needs

On June 30, 1980, the President signed the Energy Security Act establishing a Synthetic Fuels Corporation to provide financial incentives for the development of domestic substitutes for imported oil.

Coal liquefaction, the conversion of coal to a clean-burning, low-sulfur-content fuel, is a technology which the Corporation will consider for funding. It can augment petroleum-derived products such as gasoline and boiler fuels.

There are no commercial plants operating or under construction in the United States for either of the two types of coal liquefaction--direct and indirect. GAO believes that if any portion of the national goals for synthetic fuels is to be met with coal liquefaction, the bulk of the production is likely to come from the indirect processes.

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

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To the President of the Senate and the
Speaker of the House of Representatives

This report provides information on the status of various coal liquefaction processes. It should be of interest in light of the recent passage of the Energy Security Act (Public Law 96-294) which establishes a Federal Corporation to promote the development of synthetic fuels, including coal liquefaction.

We are sending copies of this report to the Director, Office of Management and Budget; the Secretary of Energy; and interested congressional committees.

Comptroller General
of the United States

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

LIQUEFYING COAL FOR FUTURE ENERGY NEEDS

D I G E S T

Coal liquefaction, the conversion of coal to a clean-burning, low-sulfur-content fuel, is a technology that can augment petroleum-derived products such as gasoline and boiler fuels and consequently help meet a requirement for large supplies of liquid fuel.

There are two basic types of coal liquefaction--direct and indirect. Direct liquefaction produces liquids through interaction of coal and hydrogen at high temperature and pressure. Indirect liquefaction involves the gasification of coal to a synthesis gas (hydrogen and carbon monoxide mixture) and the subsequent production of a liquid from that gas through the introduction of a catalyst.

There are no commercial coal liquefaction plants operating or under construction in the United States. The Department of Energy does, however, have an extensive program in liquefaction which includes research, development, demonstration, and commercialization activities.

FOUR DIRECT LIQUEFACTION PROCESSES UNDER DEVELOPMENT

The Department, in conjunction with private industry, is developing four direct liquefaction processes--two variations of Solvent Refined Coal, H-Coal, and Exxon Donor Solvent. Two small Solvent Refined Coal pilot plants are operating and conceptual design of two demonstration plants has been completed. Also, large H-Coal and Exxon Donor Solvent pilot plants have recently begun operating. With the direct processes only

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having operated on a small scale to date, several technical, environmental, and health issues have to be resolved before the processes can be commercialized.

Because the basic technology for all four processes is similar, sharing of information and experience could benefit development of each of the processes. Department officials stated and industry officials agreed that, if the plants operate successfully and information is shared, a commercial plant using any of the four processes could be constructed. Therefore, H-Coal and Exxon Donor Solvent demonstration plants might not be needed if the Solvent Refined Coal demonstration plants successfully demonstrate commercial viability.

Department and industry participants agree that further research and development of direct liquefaction processes is needed. It is unlikely that any commercial direct liquefaction plants will be operating in the 1980s. Therefore, if any portion of the national goals of 500,000 barrels per day by 1987 and 2 million barrels per day by 1992 of crude oil equivalent is to be met with coal liquefaction, the bulk of the production is likely to come from indirect liquefaction processes, which are considered commercially available.

THREE INDIRECT LIQUEFACTION PROCESSES COMMERCIALLY AVAILABLE

Three indirect processes are commercially available and may contribute to U.S. energy supply in the near term--Fischer-Tropsch, methanol from coal, and Mobil Oil Corporation's M-Gas process. However, the Department believes that further research, development, and demonstration can substantially improve these processes and that their efforts to commercialize them can assist in industry adoption of the technologies.

The Department's research, development, and demonstration work on indirect liquefaction focuses on the two major parts of the technology--production of synthesis gas and production of liquids from that gas. Major work on the former is being done as part of the Department's extensive gasification program. This includes the development and demonstration of new gasifiers which, unlike those now in the market, can process eastern coals.

The liquids production work will include such areas as the development of improved catalysts for Fischer-Tropsch and methanol, and a variation of the M-Gas process in which gasoline can be produced directly from coal, thus bypassing the production of methanol.

Since no indirect liquefaction plants currently operate in the United States, there is uncertainty about their health and environmental impacts. The Department's environmental and health research, development, and demonstration efforts involve both technologies because it is believed that the potential problems of direct liquefaction, such as disposal of hazardous wastes and carcinogenic and toxic material, may also apply to indirect processes. However, indirect liquefaction has an environmental advantage over direct liquefaction. During the gasification step of indirect liquefaction, the synthesis gas produced is cleaned, thereby removing sulfur and nitrogen. Since direct liquefaction does not include a gasification step, these elements cannot be removed as effectively.

On June 30, 1980, the President signed the Energy Security Act which establishes a Synthetic Fuels Corporation to provide financial incentives for the development of domestic substitutes for imported oil. The Congress has thus far appropriated $19 billion for use by the Corporation. In the interim before the Corporation is fully operating, the Department of Energy

may use $5.5 billion of the $19 billion to begin offering financial incentives.

It is too early to tell how these incentives will affect coal liquefaction. The goal of the Department's $5.5 billion program is to have the most production in the near term from a balanced range of new domestic alternative fuel supplies. The three indirect liquefaction processes discussed in this report would appear to be likely candidates for the program, since the commercialization of a range of technologies is one of the objectives of the program. They are also logical candidates for funding by the Synthetic Fuels Corporation.

Department officials stated that even though indirect processes are technically proven, the Department had done little to promote their commercialization because (1) they are less efficient than the direct processes under development, (2) they are more costly than the direct processes, and (3) the commercially available gasifiers needed for the indirect processes can only operate on certain coals. Private industry, however, is apparently willing to accept the shortcomings of the indirect processes and, if given financial assistance, is ready to build commercial-size indirect plants. It wants financial incentives because these plants would be first-of-a-kind in the United States and therefore a high risk undertaking.

With the increasing need to develop alternate forms of energy from domestic sources, the United States is faced with a choice between building potentially less efficient, more costly indirect plants now or waiting for the direct processes to be developed. Indirect plants built now could contribute to supply while the direct processes are still under development. Also, information gained from designing, building, and operating commercial-size indirect liquefaction facilities would reduce the uncertainties involved with building future synthetic fuels plants.

OBSERVATIONS

GAO believes that since the direct liquefaction processes have only operated in small test facilities, successful operations in larger-scale plants are needed to reduce technical, health, and environmental uncertainty before commercialization is viable. The successful operation of the recently constructed large pilot plants and the planned demonstration plants should address this uncertainty. However, it is unlikely that any commercial direct liquefaction plants will be operating in the 1980s.

GAO believes that if any portion of the national goals of 500,000 barrels per day by 1987 and 2 million barrels per day by 1992 of crude oil equivalent is to be met with coal liquefaction, the bulk of the production is likely to come from the indirect processes.

AGENCY COMMENTS

Department of Energy officials generally agreed with the accuracy and tone of the report but requested greater emphasis on the Department's low- and medium-British thermal unit gasification program--particularly on the importance of developing and demonstrating new gasifiers which, unlike those now on the market, can process eastern coals. The Department believes there are constraints such as water availability affecting the number of synthetic fuel plants that can be located in the West; therefore, establishing technical capability to process eastern coals is important. GAO included these comments. (See p. 23.)

Contents

ABBREVIATIONS

bbl/d	barrels per day
DOE	Department of Energy
EDS	Exxon Donor Solvent
ERDA	Energy Research and Development Administration
M-Gas	Mobil Gasoline Process
MMSCF	million standard cubic feet
RD&D	research, development, and demonstration
SRC	Solvent Refined Coal
TPD	tons per day

CHAPTER 1

PERSPECTIVE

The Iranian crisis and the earlier oil embargo of 1973-74 highlighted the need for the United States to attain a reliable supply of liquid fuels for its transportation and heating oil markets. Despite these warnings, efforts to reduce U.S. dependence on unstable and ever inflating costs of foreign oil supplies have largely been unsuccessful. Recent measures to encourage domestic production of oil such as the phased programs to decontrol the price of oil and natural gas may lessen U.S. dependence on foreign supplies. The fact remains, however, that domestic sources of crude oil are limited.

The late 1980s and early 1990s will bring new demand for synthetic liquids to fulfill U.S. needs for liquid fuels. Coal liquids are still higher priced than imported oil, but the margin is narrowing. The price of imported oil has more than doubled since 1978. Therefore, the economics along with the continuing threat of supply disruption have prompted the need for the United States to accelerate establishment of a synthetic liquid fuels industry.

On June 30, 1980, the President signed into law the Energy Security Act (Public Law 96-294) which provides for a Synthetic Fuels Corporation. The Corporation is authorized to provide financial incentives for the development of 500,000 barrels per day (bbl/d) by 1987 and 2 million bbl/d by 1992 of substitutes for imported oil from domestic sources.

WHAT IS COAL LIQUEFACTION?

Coal liquefaction converts coal to a clean-burning, low sulfur content fuel by increasing the hydrogen to carbon ratio found in coal. There is generally less than one hydrogen atom for every carbon atom in coal; liquefaction must raise the ratio to at least 1.5 hydrogen atoms to one carbon atom. The amount of liquids obtained and their physical properties will vary according to reaction conditions and the amount of hydrogen used. As the ratio increases, the resultant products range from a low sulfur, ash-free solid material with a melting point of 300 to 400 degrees Fahrenheit to liquids comparable to boiler fuels and gasoline.

There are two basic types of coal liquefaction--direct and indirect. Direct liquefaction produces liquids through interaction of coal and hydrogen at high temperature and pressure. Indirect liquefaction involves the gasification of coal to a synthesis gas (hydrogen and carbon monoxide

mixture) and the subsequent production of a liquid from that gas through the introduction of a catalyst.

These two methods of converting coal to liquids were developed in the early 1900s in Germany. Around 1911, Friedrich Berguis developed the forerunner to direct liquefaction, a process which converted coal to liquid fuel by mixing coal, oil, catalysts, and hydrogen under pressure and high temperature. During World War II, this process provided Germany with approximately 70,000 bbl/d, or about 90 percent of the aviation fuel needed for the German war effort. The indirect method was developed about the same time by Franz Fischer and Hans Tropsch. This method provided only about 10,000 bbl/d to the German effort during World War II.

In the United States, Union Carbide began development of the liquefaction technology to obtain chemical feedstocks during the 1930s. After World War II, the Bureau of Mines of the Department of the Interior funded two small plants to test the processes developed in Germany. However, after the oil fields in the Middle East began providing the United States as well as other nations with a then cheap source of energy, the two Federal plants were dismantled in 1954. Only a few companies continued research in coal liquefaction, primarily to enhance the use of coal by converting it to a clean, low-sulfur fuel. Then in the early 1960s, Federal participation resumed with Interior's Office of Coal Research awarding contracts which laid the groundwork for direct liquefaction processes currently under advanced development by the Department of Energy (DOE).

The only commercial coal liquefaction plant in operation today is the SASOL I 1/ plant in the Republic of South Africa. This plant, subsidized by the Government of South Africa, began operation in 1955, and produces about 10,000 bbl/d of liquid products using the Fischer-Tropsch process. South Africa has recently completed construction of a second Fischer-Tropsch plant--SASOL II--which is expected to be fully operational and produce about 60,000 bbl/d of liquid products in the third quarter of 1980. Also, South Africa is now constructing a 60,000 bbl/d SASOL III, which is expected to begin operation in early 1983.

There are no commercial coal liquefaction plants operating or under construction in the United States. DOE

1/South African acronym for South African Coal, Oil, and Gas Corporation.

does, however, have an extensive research, development, and demonstration (RD&D) liquefaction program. The emphasis of the RD&D program, managed by the Assistant Secretary for Fossil Energy 1/ has been on the development of the direct liquefaction processes which need further demonstration before they are technically, economically, and environmentally ready to compete in the commercial marketplace.

Since DOE believes the indirect processes are technically proven, the responsibility for their commercialization rests with DOE's Assistant Secretary for Resource Applications whose function is to assist in reducing the barriers to a commercial industry. However, until recently, Resource Applications has done little to promote indirect processes as viable candidates for commercialization because DOE believed it best to wait for the more efficient direct processes currently under development.

With the continuing dependence on imported oil and the ever increasing threat of supply interruptions, DOE has also initiated a synthetic fuels commercialization program. This effort, to be conducted within Resource Applications, will offer financial incentives to promote the commercial production of synthetic fuels, which includes coal liquefaction.

SCOPE AND METHODOLOGY OF REVIEW

This study focused on the status of various coal liquefaction processes, and the past and ongoing RD&D and commercialization efforts of DOE. We did not attempt to perform an analysis of the costs and performances related to the various coal liquefaction contracts awarded by DOE, since this is the subject of another ongoing review by our office.

We conducted this review primarily at the DOE offices in Washington, D.C., and at DOE contractors responsible for design, construction, and operation of coal liquefaction projects.

1/In Nov. 1979, the position of Assistant Secretary for Fossil Energy was created when DOE was reorganized by fuels. Prior to this time, the Assistant Secretary for Energy Technology administered the liquefaction RD&D program.

We reviewed legislation, publications, studies, and DOE program documents pertinent to coal liquefaction and observed the operation of various test facilities. We also obtained information and viewpoints regarding coal liquefaction from appropriate officials in

--other Federal agencies including the Department of the Interior's Bureau of the Mines, the Environmental Protection Agency, the Congressional Research Service, the Congressional Budget Office, and the Office of Technology Assessment,

--the Electric Power Research Institute,

--the National Coal Association, and

--eight private corporations (four major oil companies and four architectural engineering firms) who are presently involved in coal liquefaction and have demonstrated substantial interest in commercializing the technology.

CHAPTER 2

FOUR DIRECT LIQUEFACTION PROCESSES UNDER DEVELOPMENT

DOE, in conjunction with private industry, is developing four direct liquefaction processes--two variations of Solvent Refined Coal (SRC) referred to as SRC-I and SRC-II, H-Coal, and Exxon Donor Solvent (EDS). This chapter discusses

--the Federal Government involvement in the development of these four direct processes,

--the status of their development,

--the major issues to be addressed in the Department's RD&D program, and

--industry officials' position on direct liquefaction.

FEDERAL GOVERNMENT INVOLVEMENT

The Assistant Secretary for Fossil Energy has responsibility for the research, development, and demonstration of fossil fuel technologies, including coal liquefaction. The objective of Fossil Energy's liquefaction RD&D program, as stated in DOE's fiscal year 1981 program plan, is to facilitate the establishment of a synthetic liquid fuels industry. Specifically for direct liquefaction, the program goal is to demonstrate the technical capability to commercially produce clean liquid and solid fuels from coal by the late 1980s.

Fossil Energy, in conjunction with private industry, has been supporting the development of four direct liquefaction processes--SRC-I, SRC-II, H-Coal, and EDS. The Government has, in the past, supported development of at least three other direct liquefaction processes, but due to lack of industry interest and unfavorable results from test facilities, the Government has decided against continuing to fund these processes.

The RD&D program was appropriated $218 million in fiscal year 1979 and $250 million in fiscal year 1980 for coal liquefaction. Fossil Energy has requested $524 million for fiscal year 1981 for the technology. This request was

needed in order to begin construction of two demonstration plants 1/ and operation of two pilot plants. 2/

DOE's strategy is to demonstrate the technical feasibility of the SRC-I, SRC-II, H-Coal, and EDS processes through operation of pilot and demonstration plants. The type, location, size, and status of each of these plants are shown on page 7.

As the chart indicates, two small SRC pilot plants have been operating for some time, the large H-Coal and EDS pilot plants recently began operation, and the two SRC demonstration plants are in detailed design. DOE officials stated, and industry officials agreed, that since the technology for all four processes is similar, the information and experience gained from operating these four plants could result in construction of commercial plants for any of the four processes. This assumes, however, that each of the plants will operate successfully and that an exchange of technical and environmental information will take place. Following is a discussion of these four direct liquefaction processes.

1/A demonstration plant is a facility used to demonstrate and validate factors at a sufficient size to minimize uncertainties as to the process economics and technical and environmental performance of a commercial-size plant. This facility may use commercial-scale equipment as a single module production unit. Two liquefaction demonstration plants are currently planned, and both will have a capacity of about 6,000 tons per day (TPD).

2/A pilot plant is a facility which combines commercial type (not commercial size) components into a model plant to test and evaluate the critical parameters of scale-up; to acquire engineering data needed to assess economic feasibility, process variables, and potential environmental constraints; and to permit design of a larger near commercial-size plant. Under DOE's liquefaction program, pilot plants range in size from 6 to 600 TPD.

Major Direct Liquefaction Projects

Type	Location	Size	Status
Pilot plants:			
SRC-I	Wilsonville, Ala.	6 TPD	In operation
SRC (note a)	Ft. Lewis, Wash.	50 TPD	In operation
H-Coal	Catlettsburg, Ky.	600 TPD	Began operation June 1980
EDS	Baytown, Tex.	250 TPD	Began operation June 1980
Demonstration plants:			
SRC-I	Newman, Ky.	6,000 TPD	Conceptual design completed July 1979; operation targeted for 1984
SRC-II	Morgantown, W. Va.	6,000 TPD	Conceptual design completed July 1979; operation targeted for 1984

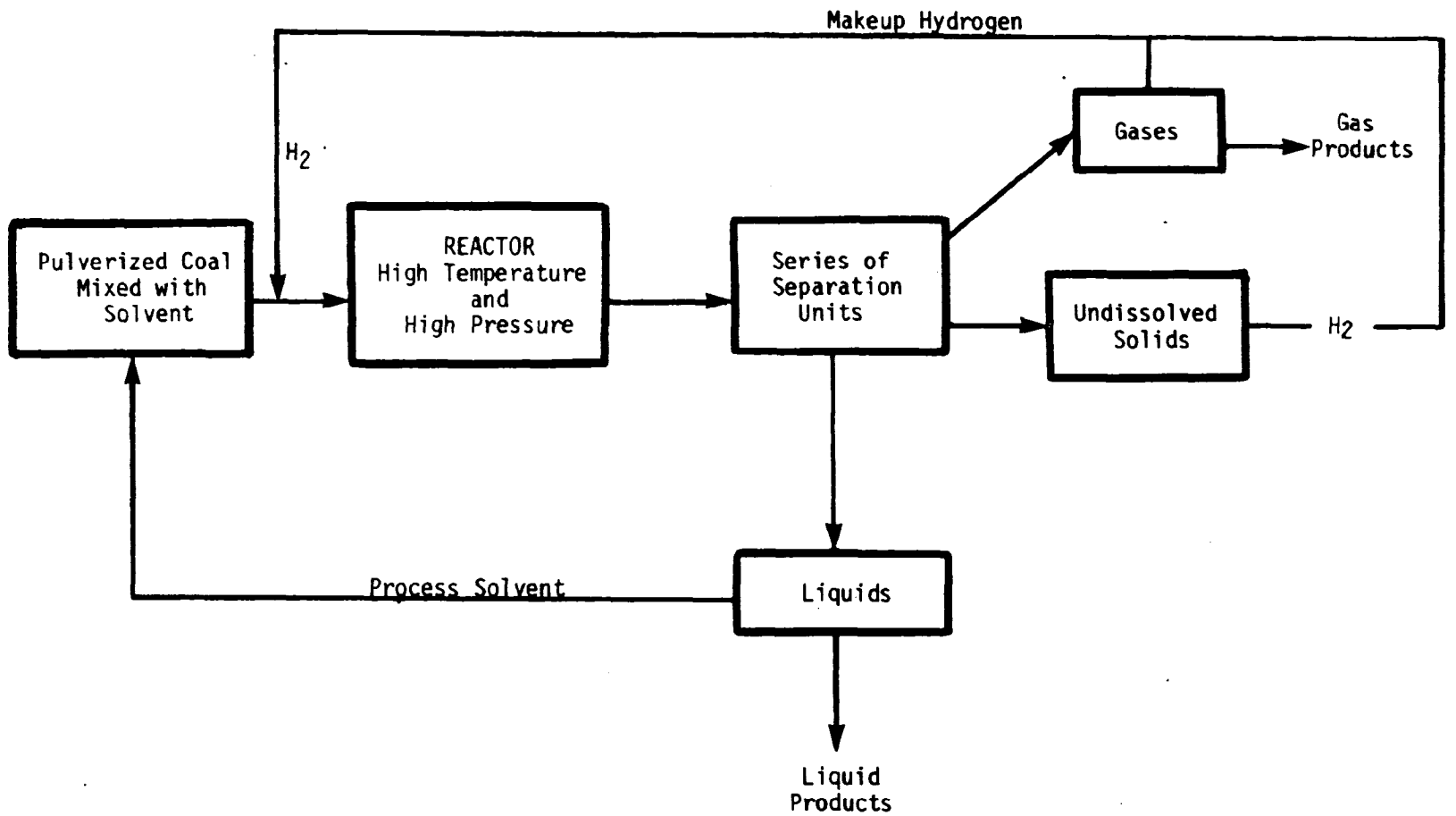
a/Can operate in both the SRC-I and SRC-II modes.

Solvent Refined Coal

There are two variations of this process; one, referred to as SRC-I, produces primarily a solid product, and the other, referred to as SRC-II, produces primarily a liquid boiler fuel.

In the SRC-I process (see diagram on page 8), pulverized coal is mixed with a process-derived solvent to form a slurry. Hydrogen is then added to the slurry and submitted

SIMPLIFIED PROCESS DIAGRAM FOR DIRECT LIQUEFACTION



to high temperature (815 degrees Fahrenheit) and pressure (between 1,000 to 2,000 pounds per square inch). Undissolved solids and the coal solution in the slurry are then separated in a solid-liquid separation unit. The solids are sent to a gasifier to produce hydrogen for use in the process. Process solvent is recovered by distillation and recycled to slurry the coal feed. What remains is the final product, which becomes a solid at room temperature.

The projected product output of a 25,000 TPD SRC-I plant is estimated to be 10,880 TPD of solid fuel, and 7,500 bbl/d of fuel oil. Since the SRC-I process is designed to remove most of the ash and sulfur in coal, the solid material produced is a clean-burning fuel which can be burned without scrubbers under current environmental regulations and can replace coal in coal-fired boilers. For example, the SRC-I product obtained from a western Kentucky bituminous coal having 7.1-percent ash and 3.4-percent sulfur typically contains 0.1-percent ash and 0.8-percent sulfur.

In SRC-II, a variation of the SRC-I process, the process solvent is recycled earlier in the process causing the slurry to be richer in hydrogen. The additional hydrogen increases the severity of the reaction, producing a lighter liquid boiler fuel.

The daily product yield for a 25,000 TPD SRC-II plant is estimated to be 5,500 barrels of liquefied petroleum gas, 10,700 barrels of naphtha, 1/ 45,300 barrels of fuel oil, and 23.1 million standard cubic feet (MMSCF) of gas. SRC-II's main product is fuel oil which can replace petroleum-based fuel oil used in industrial and utility boilers.

The SRC process has been under development since 1962. Two small pilot plants have been in operation since 1974--a 6-TPD SRC-I unit in Wilsonville, Alabama, and a 50-TPD unit in Ft. Lewis, Washington, which can operate in both the SRC-I and the SRC-II modes.

The Pittsburg and Midway Coal Mining Company, a subsidiary of Gulf Oil, was awarded a contract in 1966 by

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1/Naphtha is a light hydrocarbon in the same boiling range as gasoline which is used as a feedstock to make gasoline and other products.

the Department of the Interior's Office of Coal Research 1/ to design, construct, and operate the Ft. Lewis pilot plant. Construction of the plant did not begin until 1972 because of Federal budget limitations, and operations began in 1974. The project has been entirely funded by the Government.

Construction of the Wilsonville plant began in 1972 as a joint effort between Southern Company Services and Electric Power Research Institute. The plant became operational in January 1974 and the Government became a co-sponsor in 1976, contributing about 65 percent to the operating cost of the project.

Combustion tests have been performed on the products from the SRC-I and SRC-II pilot plants. A combustion test of the SRC-I solid product, performed by Southern Company Services in a utility boiler at Georgia Power in 1977, demonstrated its capability to meet current emission standards for sulfur and nitrogen oxides. Similarly, a combustion test of the SRC-II fuel oil, in a utility boiler owned by Consolidation Edison Company in New York City, successfully demonstrated that emissions will also comply with sulfur and nitrogen oxide regulations.

These pilot plants are still in operation and will continue to be used for testing and environmental and health studies in conjunction with the demonstration plants now being designed.

This design work was initially funded by contracts awarded by DOE in July 1978 to develop preliminary designs for demonstration plants of both the solid and liquid variations of the SRC process. Both the SRC-I and SRC-II demonstration plants would be full-scale modules of commercial plants and would convert about 6,000 TPD of coal into an equivalent of about 20,000 bbl/d of crude oil.

In October 1979 DOE announced that a demonstration plant for each process would be constructed. The International Coal Refining Company will be the prime contractor for the SRC-I demonstration plant at Newman, Kentucky. Pittsburg and Midway Coal Mining Company will be the prime contractor for the SRC-II demonstration plant at Morgantown, West Virginia. Construction of both plants

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1/The Federal Government's fossil energy research, development, and demonstration program was transferred to the Energy Research and Development Administration (ERDA) on Jan. 19, 1975, and from there to DOE on Oct. 1, 1977.

is scheduled to begin in March 1981 with operations to begin in October 1984.

Both plants, currently estimated by DOE to cost $1.4 billion, 1/ will be cost-shared by DOE and the private sector. The cost-sharing agreements have not been signed, but for the SRC-II plant, it appears that agreements have been reached with the Federal Republic of Germany and Japan for each to contribute 25 percent (about $350 million each) of the $1.4 billion estimate, Pittsburg and Midway Coal Mining Company to contribute $100 million, and DOE the remainder of the total cost. For the SRC-I plant, the State of Kentucky will contribute $30 million, the International Coal Refining Company $90 million, and DOE the remainder of the total cost.

These contracts were under negotiation for some time. Cost-sharing was subject to much debate as were other provisions such as patent rights, royalties, and final disposition of facilities.

H-Coal

The basic SRC process of feeding a coal slurry under high temperature and pressure through a reactor, and then through separation units to produce a liquid product is basically the same for H-Coal. However, the H-Coal process uses a catalyst 2/ in the reactor to intensify process reactions.

The H-Coal pilot plant, which began operations in June 1980, is capable of producing in two modes. The daily product output of a 25,000-TPD H-Coal plant in one mode is estimated to be 18,200 barrels of naphtha, 42,200 barrels of fuel oil, and 19.7 MMSCF of gas. For the other mode for that size plant, the daily yield is 31,900 barrels of naphtha, 24,300 barrels of fuel oil, and 56.3 MMSCF of gas.

The conditions of the H-Coal process--specifically the amount of hydrogen used and the period of time the slurry

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1/The $1.4 billion estimates are based on conceptual design completed in July 1979. Current contractor-prepared estimates are higher.

2/Catalyst--a substance that accelerates the rate of a chemical reaction without itself undergoing a permanent chemical change.

remains in the reactor--affect the type of fuel produced. For example, to produce a high proportion of naphtha, more hydrogen is required and the slurry has to remain in the reactor longer than needed to produce mainly boiler fuel.

The mode selected for commercial use would depend on the desired end product. For example, Ashland Oil is interested in building a commercial H-Coal plant capable of producing a high percentage of naphtha. Its decision may be based in part on the fact that there are currently no substitutes for gasoline, which represents 38 percent of U.S. demand for petroleum. However, there are substitutes already in the marketplace--natural gas and coal--which can be used as boiler fuel.

Hydrocarbon Research, Inc., began work on the H-Coal process in the late 1950s without Government assistance. In 1965 Interior's Office of Coal Research awarded a contract to Hydrocarbon Research, Inc., to accelerate the development of the process. This contract terminated in 1967 because of Federal budget limitations.

Government sponsorship again resumed in May 1974 when the Office of Coal Research authorized the design and later entered into a cost-sharing contract for the design, construction, and operation of a 600-TPD pilot plant in Catlettsburg, Kentucky, using Hydrocarbon Research, Inc., as the technical consultant. The cost-sharing participants are Electric Power Research Institute; the Commonwealth of Kentucky; Ashland Oil, Inc.; Conoco Coal Development Company; Mobil Oil Company; and Standard Oil Company of Indiana. The Government is providing 87 percent of the financing, with the other participants financing the remaining 13 percent. The plant, now estimated to cost $296 million, began operations in June 1980.

Exxon Donor Solvent

The EDS process is similar to SRC in that it (1) liquefies crushed coal in a noncatalytic reactor under high temperature and pressure in the presence of hydrogen and a hydrogen-rich solvent and (2) the slurry leaving the liquefaction reactor is separated into products by distillation. The unique aspect of this process is that the solvent receives special treatment by being sent through a catalytic reactor where additional hydrogen is added before being recycled.

The EDS process, like the other direct processes, produces a high percentage of boiler fuel. The daily yield from a 25,000-TPD EDS plant is estimated to be 3,270 barrels

of propane, 3,500 barrels of butane, 19,900 barrels of naphtha, 28,700 barrels of fuel oil, and 41.9 MMSCF of gas.

Exxon began development of the EDS process in 1956. Through 1975, Exxon spent $32 million to develop and demonstrate the process in laboratory-scale reactors of up to 1 TPD. In August 1975 Exxon submitted an unsolicited proposal to ERDA to cost share on a 50/50 basis an estimated $268 million to design and construct a 250-TPD pilot plant. ERDA, in July 1977, agreed to fund 50 percent of the project, with Exxon funding 23 percent and making agreements with the following companies--Electric Power Research Institute, Japan Coal Liquefaction Development Company, Phillips Coal Company, ARCO Coal Company, and Ruhrkohle AG--to cost-share the remainder.

The plant, located in Baytown, Texas, began operation in June 1980. The estimated cost of the project has increased to $360 million due largely to the decision to include a program to test alternatives for processing the waste material to obtain additional marketable products.

MAJOR ISSUES TO BE ADDRESSED BY THE RD&D PROGRAM

The direct processes have only been operated on a small scale, and several major technical, environmental, and health issues have to be resolved before the processes can be commercialized. Therefore, DOE plans to address these issues during operation of the pilot and demonstration plants.

DOE and industry officials involved in developing these processes acknowledge that there are many major problems to be resolved but foresee no insurmountable technical or environmental constraints to a commercial industry assuming successful operation of the plants. Following are some of the major issues which must be addressed during operation of the plants. In resolving these issues, specific aspects of the process that affect its operation and the ability to scale-up such as thermal balance and corrosion of vessels, although not discussed in this report, must also be addressed in operating the pilot and demonstration plants.

Technical issues

Scale-up

The current test facilities are too small to adequately address the operability and reliability of a commercial-scale plant. Scale-up in size is required to proceed from existing and planned direct liquefaction pilot and demonstration

facilities to commercial-size plants. The existing test facilities for the processes under development by DOE range in size from 1 TPD, which produces approximately 3 bbl/d to 50 TPD, which produces approximately 150 bbl/d, while a typical commercial plant would produce about 50,000 bbl/d from 18,000 TPD of coal.

Larger test facilities are needed to address the operability and reliability of large-scale plants. As an example, according to Air Products and Chemicals, a co-owner of the International Coal Refining Company, reactor vessels for SRC-I must be scaled up from 2 feet in diameter in the current test facilities to 17 feet in the demonstration plant. An official of the Electric Power Research Institute stated that because chemical changes could occur when a process is scaled up, larger-scale facilities must be operated to demonstrate a sustained rate of operation at the larger scale. Also, since these plants will be first-of-a-kind and involve large capital costs, the financial community is concerned about scale-up and may not invest capital in commercial plants unless the processes are operated at a size large enough to demonstrate commercial operability and reliability.

Fossil Energy's program includes two demonstration plants for the SRC processes, each consisting of one commercial-scale module which could be combined with other modules of the same size to form a commercial plant. Fossil Energy and the private sector believe that operation of these commercial-scale SRC demonstration plants, in combination with the experience gained from operation of the pilot plants, might enable construction of commercial EDS and H-Coal plants without demonstration plants for these two processes. This assumes, however, that each of the plants will operate successfully and that an exchange of technical and environmental information will take place.

Liquid/solid separation

The reliability on a commercial scale of liquid/solid separation units which remove undissolved coal from the products is still a major concern to be addressed in the pilot and demonstration plants. The EDS and SRC-II processes use distillation for liquid/solid separation, which is a proven technology. But SRC-I and H-Coal have had little success with a filtration process. Also, DOE believes filtration's capital, operating, and maintenance costs will be expensive. As a consequence, testing and large-scale operation in the pilot and demonstration plants of a new

solvent de-ashing 1/ process developed by Kerr-McGee and a new filter developed by U.S. Filter Company are planned.

Product upgrading

The products of direct liquefaction processes are still considered deficient in hydrogen and must be upgraded before they can replace the petroleum-derived products ranging from boiler fuel to gasoline. The operation of the H-Coal and EDS pilot and SRC demonstration plants will provide a considerable increase in the amount of coal liquid product available for testing. Even with the addition of hydrogen during the coal liquefaction process, the liquid products resulting still tend to be hydrogen-deficient when compared to naturally occuring petroleum. Thus, it is more difficult to process finished fuels from coal liquids than from naturally occurring petroleum.

Studies have been performed to determine the degree of the processing required to obtain marketable boiler fuels and transportation fuels from coal liquids. 2/ A December 1979 study by Mobil Research and Development Corporation stated that both SRC-I and SRC-II can be upgraded to higher-grade boiler fuels by means of standard refining techniques. A June 1978 study by Chevron Research Company stated that although SRC-I does not appear to be an attractive feed for conversion to transportation fuels, preliminary results on standard processing of SRC-II to transportation fuels is encouraging.

DOE plans to continue gathering data on upgrading by testing liquid products from the SRC-I and SRC-II demonstration plants and the EDS and H-Coal pilot plants.

Health and environment

DOE's direct liquefaction program will also address potential environmental and health hazards. DOE's Office of Environment prepared process-specific environmental plans in the spring of 1979 for SRC-I, SRC-II, EDS, and H-Coal which outline the environmental RD&D activities to be performed for each of the processes.

1/De-ashing is removing the solid residue--the ash--from the liquid products.

2/The testing dealt almost exclusively with SRC products since sufficient amounts of products from the H-Coal and EDS processes were unavailable.

In August 1979 this Office also prepared an Environmental Development Plan which identifies the environmental concerns and research and development necessary for assessing the potential environmental impacts and mitigating measures associated with coal liquefaction technology as a whole. The key health and environmental issues to be addressed in the Department's RD&D program are discussed as follows.

Worker protection and potential public health risks

The products and emissions of a coal liquids plant contain compounds that are known or suspected to be carcinogenic (cancerous) and mutagenic, 1/ and/or contain toxic (poisonous) elements.

As a result, DOE stated in its coal liquefaction Environmental Development Plan that coal liquefaction may pose some potential hazards to worker health and the environment. The plan added that although the potential hazards are still being researched and catalogued, it appears that the risks will be similar to those in the production, transportation, and end-use of other commercial material such as tars, which are a by-product of coking ovens and are used in the production of pitch--a roofing material.

According to the plan for coal liquefaction, biological research to pinpoint these hazardous elements is in its infancy. The characterization of the products and emissions of direct liquefaction plants and the development of (1) technologies to control potential adverse effects and (2) monitoring systems are underway and will be tested in the pilot and demonstration plants.

The composition of coal liquefaction products and emissions depends on process parameters such as temperature, hydrogen concentration, and coal type; it will change as these parameters are varied. Although some testing has been performed at the operating SRC pilot plants, a clearer picture of the risk to the worker or the general public will be formulated after testing is done in the larger pilot and demonstration plants.

In the area of worker protection, DOE's process-specific environmental plans for the pilot and demonstration plants call for the developing and monitoring of industrial hygiene

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1/Changing of an individual's genes or chromosomes causing a departure from the heritable (parent-like) characteristics.

and safety programs, as well as the continuing collection and assessment of data on the carcinogenicity, mutagenicity, and toxicity of coal liquids. Present pilot plant facilities for SRC also consider the potential carcinogenic and mutagenic hazards to the workforce and include an industrial hygiene and worker education program which, according to DOE, complies with the Occupational Safety and Health Administration guidelines.

Concerning plant releases to surrounding areas, DOE believes that state-of-the-art control technology can keep these releases to the air and water at levels consistent with current legal requirements. In addition, DOE plans to monitor the emissions from the pilot and demonstration plants, determine any new requirements for their control, and continuously assess the effectiveness of the control technology.

Siting

DOE has assessed the major environmental and regulatory constraints to siting a synfuels industry in a January 7, 1980, draft report. 1/ Factors considered in this analysis included air quality, water availability, water quality, community development, fish and wildlife, vegetation disruption, optimization of use of Federal lands, global carbon dioxide concentrations, waste disposal requirements, and product safety impacts.

A general finding of DOE's report is that, assuming application of the most effective environmental control technologies and management practices, development of synthetic liquids facilities on an accelerated basis appears feasible. This would require the reduction of some environmental impediments that require careful planning, but no major exclusionary constraint is expected.

DOE emphasized that its report did not determine specific sites for locating technologies. When a specific site is chosen for a plant, a more detailed and site-specific analysis will be performed including a comprehensive environmental analysis and a nonenvironmental analysis on such factors as economics, land ownership, and transportation costs.

1/"Synthetic Fuels and the Environment: An Environmental and Regulatory Impacts Analysis," Jan. 7, 1980. The final report is expected to be released soon.

The Council on Environmental Quality has stated that DOE's draft report is biased and views environmental laws and regulations as costly barriers to be overcome rather than mechanisms to maintain environmental quality. The Council suggested that the overall tone of the report needs to be changed to make it more sensitive to environmental concerns.

Management of solid wastes

There is limited data concerning the nature of the solid waste from coal liquefaction facilities. As a result, considerable research must be conducted in order to identify gaps in the data and potential problem areas in solid and hazardous waste disposal.

DOE and the Environmental Protection Agency are continuing to identify those waste materials that can be classified as carcinogenic, mutagenic, and/or toxic. Also, the pilot and demonstration plants will develop waste management procedures and monitor their operation.

A primary concern to industry is that regulations for handling process wastes are not in place and may not be promulgated for 2 or more years. In fact, tests to be conducted by the Environmental Protection Agency to determine if the wastes are hazardous are now undergoing revision. If a solid waste is declared hazardous, the cost associated with meeting the regulations could have a substantial impact on the economics of the technology.

INDUSTRY OFFICIALS' POSITION ON DIRECT LIQUEFACTION

Industry officials we talked to support the Department's RD&D program and agree with DOE's position that the direct processes must be demonstrated before they are ready for commercialization. For example, Gulf officials stated that a demonstration phase is essential to establishing the technical, environmental, and economic feasibility of a process. Two concerns they specifically mentioned which will be addressed in the SRC-II demonstration plant are waste disposal and socioeconomic impact. Officials of Hydrocarbon Research and Air Products and Chemicals stated that problems such as waste disposal and hardware reliability will be addressed during the pilot and demonstration phases. Officials of the Electric Power Research Institute, who are involved in the EDS and H-Coal pilot plants, also felt that a large-scale demonstration program is needed to prove hardware reliability, to sustain operation of the processes, and to gather data to be able to scale-up to commercial size.

In summary, DOE and industry participants agree that further demonstration of direct liquefaction processes is needed. It is unlikely that any commercial direct liquefaction plants will be operating in the 1980s. Therefore, if any portion of the national goals of 500,000 bbl/d by 1987 and 2 million bbl/d by 1992 of crude oil equivalent is to be met with coal liquefaction, the bulk of the production is likely to come from indirect liquefaction processes which are considered commercially available. These processes are discussed in the next chapter.

CHAPTER 3

THREE INDIRECT LIQUEFACTION PROCESSES AVAILABLE

There are currently no commercial-scale plants operating in the United States using indirect liquefaction. However, three indirect processes--Fischer-Tropsch, methanol from coal, and Mobil Oil Corporation's M-Gas process--are commercially available and may contribute to U.S. energy supply in the near term. This chapter discusses

--how these processes work,

--the Federal Government's involvement,

--why DOE has not promoted indirect liquefaction,

--industry officials' position on indirect liquefaction, and

--the rationale for building commercial indirect liquefaction plants now.

PROCESS DESCRIPTIONS

Fischer-Tropsch

The Fischer-Tropsch process, as it operates in SASOL I (see diagram on page 21), uses a Lurgi gasifier 1/ to combine coal with steam and oxygen at high temperatures and moderate pressure to produce synthesis gas. This gas then goes through several stages where (1) it is cooled; (2) the hydrogen/carbon monoxide ratio is adjusted; and (3) tars, sulfur, and carbon dioxide are removed. Some of the gases are then routed to a fixed-bed catalytic reactor and some to a fluidized-bed catalytic reactor, 2/ both using an iron-based catalyst. The resulting gases from the reactors go through

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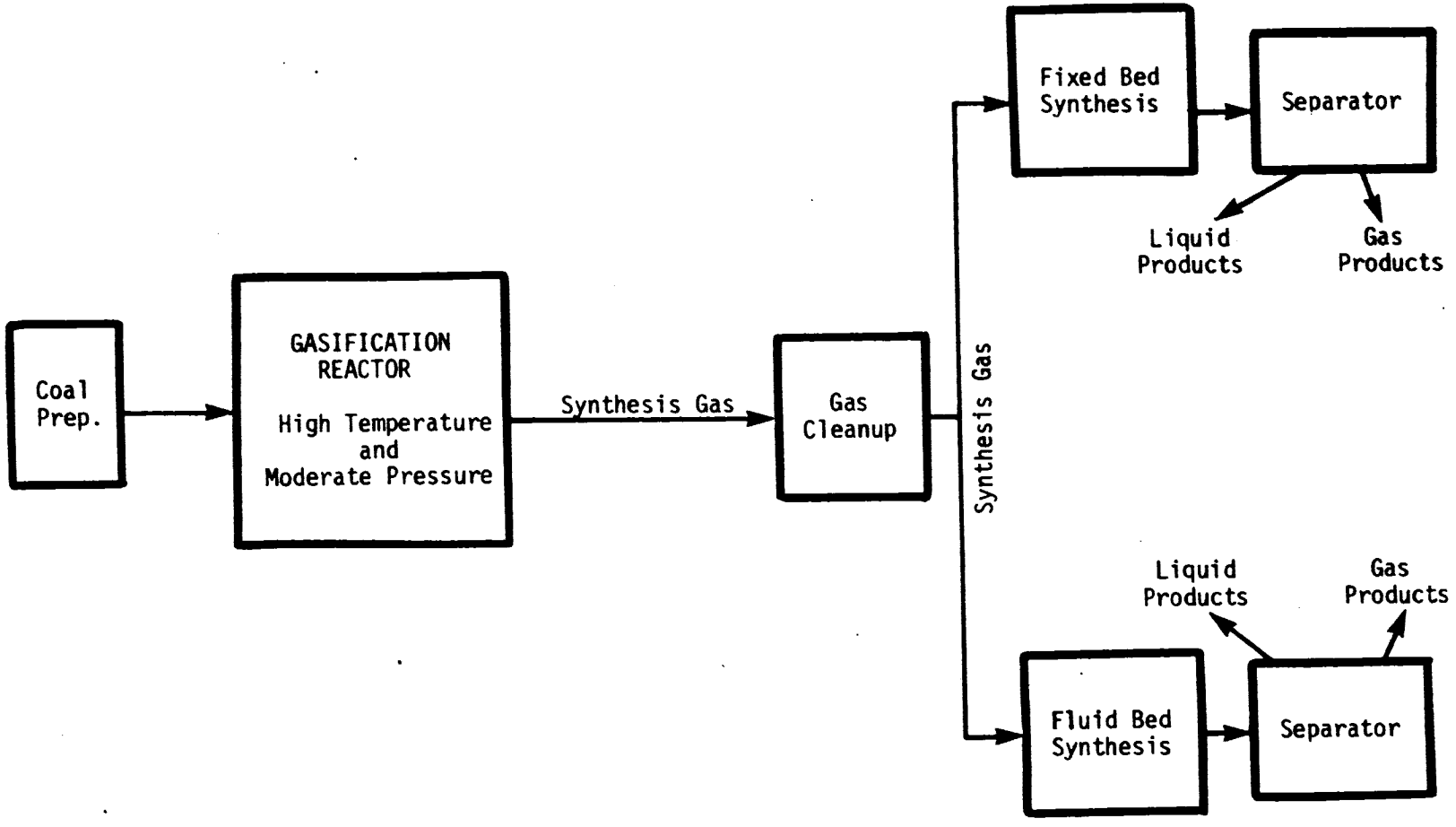
1/The Lurgi gasifier was developed in Germany and has operated on a commercial scale since 1936. It uses a fixed-bed catalytic reactor where stationary solid particles are in contact with fluid passing through them.

2/As opposed to a fixed-bed reactor where the solid particles remain stationary, in the fluidized-bed reactor solid particles are maintained in suspension by upward motion of air.

SIMPLIFIED PROCESS DIAGRAM FOR SASOL I--FISCHER TROPSCH PROCESS



a series of separation units to produce a range of liquid and gaseous products. A Fischer-Tropsch plant processing 25,000 TPD is estimated to produce daily 18,200 barrels of gasoline, 18,800 barrels of liquefied natural gas, 1,200 barrels of middle distillate, 2,000 barrels of fuel oil, and 127.9 MMSCF of gas. The Fischer-Tropsch process produces more light fuels such as gasoline and less heavy fuels such as fuel oils than the direct processes.

Methanol from coal

Methanol is an alcohol which is currently being made from natural gas in the United States. Using a variation of the Fischer-Tropsch process, methanol can be made from coal. As in the Fischer-Tropsch process, synthesis gas is produced and then the hydrogen/carbon monoxide ratio is adjusted and the impurities are removed. The basic difference between the Fischer-Tropsch and methanol processes and the resulting end products is the catalyst used to produce liquids from the synthesis gas. While an iron-based catalyst is used for Fischer-Tropsch, in the methanol process, the synthesis gas is catalytically converted into crude methanol using chrome/zinc-based catalysts which operate under high pressure or copper-based catalysts which work under low pressure.

The crude methanol is then purified in a distillation unit. Using the commercially available gasifiers in a 25,000 TPD plant to produce the synthesis gas, the resulting daily product yield after distillation is estimated to be equivalent to 121,800 barrels--50 percent methanol and 50 percent methane gas.

Methanol can be used as a peaking fuel for turbines in generating electricity or as a supplement to gasoline in automobiles. With the current designs of automobile engines, a more than 10 percent methanol mixture is not feasible, however, since it causes corrosion and deterioration to the plastic and rubber engine parts. Automobile engines could be redesigned to run on straight methanol, but this would mean constructing a special distribution system for methanol which would be costly. It appears that the use of methanol-powered automobiles would be practical only for a specific controlled group of vehicles such as an urban fleet or vehicles used by a military installation or a Government agency.

M-Gas

The Mobil Gasoline process (M-Gas) takes the methanol from coal process one step further. After the crude methanol

is produced, the M-Gas process reacts this methanol with a zeolite catalyst (developed by Mobil) which separates water from the hydrocarbons in the methanol and rearranges the hydrocarbons to form high-octane gasoline.

According to a DOE official, a high grade methanol is not needed for the M-Gas process. Therefore, the distillation step common to the production of methanol can be eliminated. The daily product yield for a 25,000 TPD M-Gas plant is estimated to be 52,700 barrels of premium gasoline and 7,300 barrels of liquefied petroleum gas. The synthetic gasoline is comparable with petroleum-derived gasoline and can be mixed in distribution/marketing systems and used in the automobile gas tank without adjustments.

FEDERAL GOVERNMENT INVOLVEMENT

The Federal Government's role in indirect liquefaction includes RD&D and commercialization activities. Although the three indirect processes are commercially available, DOE believes that further RD&D can substantially improve them, and that their commercialization efforts can assist in industry adoption of the technologies.

RD&D

Fossil Energy's RD&D work on indirect liquefaction focuses on the two major parts of the technology--production of synthesis gas and production of liquids from that gas. Major work on the former is being done as a part of DOE's extensive gasification program. Currently DOE is funding detailed design for two demonstration plants in the low- and medium-British thermal unit area. These projects include the development and demonstration of new gasifiers which, unlike those now on the market, can process eastern coals. Establishing technical capability to process these eastern coals is important because there are constraints to the number of synthetic fuels plants that can be located in the West. According to a DOE official, water availability, transportation systems, and lack of miners would limit the number of plants located in the western portion of the country.

Prior to DOE's fiscal year 1981 Fossil Energy program plan, the production of liquids from synthesis gas was not a part of DOE's indirect liquefaction program. The liquids production work outlined in its new program plan will include such areas as the development of improved catalysts for Fischer-Tropsch and methanol, and a variation of the M-Gas process in which gasoline can be produced directly from coal, thus bypassing the production of methanol.

The Assistant Secretary for Fossil Energy has requested an additional $27 million for fiscal year 1981 for work in producing liquids from synthesis gas.

Since no indirect liquefaction plants currently operate in the United States, there is uncertainty about their health and environmental impacts. DOE and industry officials promoting indirect liquefaction believe that the potential problems of direct liquefaction, such as disposal of hazardous wastes and carcinogenic and toxic material, may also apply to indirect processes. Therefore, DOE's environmental and health RD&D efforts include both technologies.

A DOE official stated that the Department is just beginning to define the environmental parameters of the indirect processes as well as the cost of environmental control technology. DOE's Office of Technology Impacts, under the Assistant Secretary for the Environment, has two studies underway on the Fischer-Tropsch indirect liquefaction process to

--determine the cost of a plant with and without pollution control requirements and

--investigate the environmental consequences of the plant.

Indirect liquefaction has an environmental advantage over direct liquefaction. During the gasification step of indirect liquefaction, the synthesis gas produced is cleaned, thereby removing sulfur and nitrogen. Since direct liquefaction does not include a gasification step, these elements cannot be removed as effectively.

A report on the Fischer-Tropsch process prepared for DOE by Booz-Allen & Hamilton Inc., 1/ stated that current environmental standards affecting indirect coal liquefaction technologies pose no insurmountable barriers to the commercial application of these processes but may require additional capital and operating costs.

1/"Economics and Siting of Fischer-Tropsch Coal Liquefaction," July 1979.

Commercialization

Developing a strategy for reducing the barriers to commercialization of indirect coal liquefaction is the responsibility of the Assistant Secretary for Resource Applications. Until recently Resource Applications had not been active in commercializing indirect liquefaction. Currently, however, it has a program underway to offer $5.5 billion to spur commercial production of synfuels, including indirect coal liquefaction.

In the past, Resource Applications had done little to promote the commercialization of the indirect processes since DOE believes the direct processes, which are still under development, have the potential to be more efficient, less costly, and adaptable to a wider range of coals than the indirect. For example, in fiscal year 1978, Resource Applications had only $200,000 for two liquefaction projects--a methanol marketing study (completed March 1980) and an economic analysis of the Fischer-Tropsch process (completed July 1979). Resource Applications received no funds for fiscal year 1979 for these types of liquefaction efforts.

With the President's July 1979 announcement of an Oil Import Reduction Program, which includes a contribution from coal liquefaction towards the goals of 500,000 bbl/d by 1987 and 2 million bbl/d by 1992 of crude oil equivalent, the climate for commercializing indirect liquefaction changed.

On June 30, 1980, the President signed the Energy Security Act which establishes a Synthetic Fuels Corporation to provide financial incentives for the development of domestic substitutes for imported oil. The Congress has thus far appropriated $19 billion for use by the Corporation. In the interim before the Corporation is fully operating, the Department of Energy may use $5.5 billion of the $19 billion to begin offering financial incentives. Originally, DOE was appropriated $2.2 billion; later in the year a supplemental $3.3 billion was added. Under the original $2.2 billion program managed by Resource Applications, selections have been made to fund proposals for

--cooperative agreements leading to the construction of commercial facilities producing alternate fuels (individual agreements not exceeding $25 million and total funding for cooperative agreements at $100 million) and

--feasibility studies leading to construction of commercial alternative fuel facilities (individual

awards not exceeding $4 million, and total funding for feasibility studies at $100 million).

Later this year, DOE will issue solicitations for proposals requesting financial assistance in the form of loan guarantees, purchase commitments, and price guarantees. One and a half billion dollars is available for the purchase or production of alternative fuels by means of purchase commitments or price guarantees. Five hundred million dollars is available as a reserve to cover any defaults from loan guarantees of not more than $1.5 billion. The additional $3.3 billion will also be used for feasibility studies, cooperative agreements, loan guarantees, purchase commitments, and price guarantees.

Once the Corporation is operating, any portion of the $5.5 billion not spent by DOE would revert to the Corporation. Also, the Corporation's Board of Directors may determine by vote those DOE projects under the $5.5-billion program to be transferred to it.

It is too early to tell how these financial incentives will affect coal liquefaction. The goal of the $5.5-billion program is to have the most production in the near term from a balanced range of new domestic alternative fuel supplies. The three indirect liquefaction processes discussed in this report would appear to be likely candidates for the program, since the commercialization of a range of technologies is one of the objectives of the program. They are also logical candidates for funding by the Synthetic Fuels Corporation. Direct liquefaction projects, however, may be less likely to receive funds because of the risk inherent in attempting to commercialize a process only operated to date on a small scale. We are currently reviewing DOE's present and planned commercialization efforts for the synthetic fuels technologies of coal liquefaction, coal gasification, oil shale, and tar sands, including the $5.5-billion program.

WHY DOE HAS NOT PROMOTED INDIRECT LIQUEFACTION

According to DOE officials, even though indirect processes are technically proven, until recently DOE had done little to promote their commercialization because (1) they are less efficient than the direct processes under development, (2) they are more costly than the direct processes, and (3) the commercially available gasifiers needed for the indirect processes can only operate on noncaking coals.

The estimated thermal efficiency of indirect liquefaction is 45 to 60 percent while that of the direct processes is 65 to 70 percent. This is largely due to the fact that estimates of the amount of coal required per unit of product are almost always greater for the indirect processes than for the direct processes. For example, per ton of coal, liquid yields are in the range of 1.6 to 1.7 barrels of fuel oil equivalent for the Fischer-Tropsch process, 2.2 to 2.5 barrels of methanol equivalent for methanol from coal, and 2 barrels of gasoline equivalent for M-Gas. The direct processes, on the other hand, are currently estimated to yield in the range of 2.5 to 3.0 barrels of fuel oil equivalent per ton of coal.

DOE's estimate that the indirect processes will be more costly is based partly on the lower efficiency argument discussed above, and also on the fact that a more complex plant is required for indirect liquefaction since it must include the hardware to first gasify the coal before liquefaction occurs, whereas direct liquefaction omits the gasification step and liquefies the coal directly.

The degree of cost differential between direct and indirect processes varies with each new report or study. For example, a June 1979 report 1/ by Fluor Corporation estimated the cost of direct liquefaction products at $20 to $30 per barrel and indirect liquefaction products at $30 to $40 per barrel (1978 dollars). A September 1979 report by Cameron Engineers 2/ estimated the cost of direct liquefaction products at $34 to $38 per barrel and indirect products at $35 to $39 per barrel (1979 dollars), while the Electric Power Research Institute, in October 1979 testimony before the Advisory Panel on Synthetic Fuels of the House Science and Technology Committee, estimated $51 per barrel for coal liquids from direct processes and $56 per barrel for methanol from coal (1978 dollars).

These variations reflect the cost uncertainties that will exist until commercial-size plants are operating. Current estimates are based on small pilot plant operations and engineering designs for larger facilities. These estimates were formulated using assumptions regarding capital cost, coal price, interest rates, cost of satisfying

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1/"Coal Liquefaction Technology," June 1979.

2/"Overview of Synthetic Fuels Potential to 1990," prepared for the Synthetic Fuels Task Force of the Senate Budget Committee, Sept. 1979.

Government regulations, and other items as they were perceived at that moment. However, all these factors are not only constantly changing but also the basic process design of the plant changes as more is learned about the processes. Efforts have been made to develop a standardized basis for cost comparisons. This has been useful for closely matched and well developed technologies but has little effect in improving the reliability of estimates for new technologies. Thus it appears that the true magnitude of the cost differential between direct and indirect processes can not be determined until the operation of larger-scale plants.

Another factor inhibiting indirect liquefaction is its inability to use caking coals from the eastern United States. Unlike direct liquefaction which potentially can process all U.S. coals, the indirect processes can currently operate only on western noncaking coals. Unless modifications can be made to demonstrate technical success with eastern caking coals, indirect plants will probably be located in the West where they would have easy access to noncaking coals. Otherwise, western coals would have to be transported long distances at substantial cost to eastern plants. In any event, eastern coals may not be used until improvements in technology occur. DOE's RD&D gasification program emphasizes the development and demonstration of gasifiers that can process eastern coals. It is currently funding the design of two demonstration plants in the area.

INDUSTRY OFFICIALS' POSITION

The industry officials we talked with appear willing to accept the technical limitations of the indirect processes and, if given financial assistance, are ready to build commercial indirect plants. Industry wants financial incentives because these plants would be first-of-a-kind in the United States and therefore a high financial risk. Also, the cost of the products as currently estimated would not be competitive with petroleum-derived products.

Officials of the Fluor Corporation believe that the Fischer-Tropsch process can be commercialized in the United States. Fluor maintains that the Fischer-Tropsch process can be modified to (1) adapt to all U.S. coals using a commercially available Lurgi gasifier and (2) maximize the production of transport fuels such as gasoline, diesel, and jet fuel. For example, Fluor estimates that the process can be modified to reduce the yield of other products and raise the production of transport fuels from 68 to 94 percent.

South Africa has already achieved this increase in gasoline production using the Fischer-Tropsch process. The SASOL I plant contains two types of reactors, one producing a high percentage of gasoline and the other producing the bulk of the other products. In building SASOL II and III, South Africa is using only the reactor which produces a high percentage of gasoline and has developed its own catalysts which are more efficient than catalysts used in SASOL I. These same modifications to the process can be made for use in the United States.

Several companies have expressed interest in building commercial plants using an indirect process. For example, Texas Eastern was selected for a cooperative agreement with DOE under the $5.5 billion program to build a commercial plant using the Fischer-Tropsch indirect process in western Kentucky.

Both Conoco and Badger Construction Company are interested in building coal to methanol plants. Both companies submitted unsolicited proposals to DOE in January 1979 to request financial assistance to begin designing commercial plants, but the proposals were not funded because DOE then lacked enthusiasm for indirect liquefaction. Conoco officials told us they are still planning to go forward with the project without assistance.

Mobil officials stated they were ready to build a commercial M-Gas plant to produce gasoline, but due to the projected uncompetitiveness of M-Gas with petroleum-derived gasoline, they would require financial assistance to begin the project.

RATIONALE FOR BUILDING INDIRECT LIQUEFACTION PLANTS NOW

We have already discussed on pages 26 to 28 why DOE has not promoted indirect liquefaction on a commercial scale in the United States. But with the increasing need to develop alternate forms of energy from domestic sources, the United States is faced with a choice between building potentially less efficient, more costly indirect plants now or waiting for the direct processes to be developed. As stated earlier, Fluor, Texas Eastern, Badger, and Mobil have stated that they are willing to build commercial plants if offered financial assistance. Indirect plants built now could contribute to supplies while the direct processes are still under development. Also, information gained from designing, building, and operating commercial-size indirect liquefaction facilities would reduce the uncertainties involved with

building future synthetic fuels plants. These points are discussed in the following sections.

Contribution to supply

Even though indirect plants will not solve the energy crisis, they could have a place in the economy and could contribute to supply. For example, in 1978, about 24 million barrels of methanol was produced from natural gas for use in the production of glue, plastics, and synthetic fibers. Producing this methanol from coal would free natural gas for other uses. Also, since over 50 percent of petroleum demand is in the transportation sector, gasoline produced from the M-Gas and Fischer-Tropsch processes could be used to supplement our dwindling supplies.

Information base generated

An information base on which to design a comprehensive strategy for future plant construction of both direct and indirect processes can also be formulated. Commercial-size facilities would provide facts, not projections based on smaller facilities, about construction and operating costs, environmental impact, and technical reliability.

A June 1979 Congressional Research Service report 1/ on synthetic fuels from coal listed the following areas where commercial indirect liquefaction plants could contribute to information needs.

--Providing experience in dealing with the institutional requirements for commercialization. For example, the requirements for engineers, construction equipment, and coal production and transportation are just some of the areas where commercial-size plants will provide experience. This information will not only assist the next plants being built but also establish an information base to help determine the needs for an entire synthetic fuels industry.

--Obtaining from commercial operation hard technical data that could form the basis for subsequent incremental improvements to future commercial plants. There are lessons to be learned from commercial plant

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1/"Synthetic Fuels From Coal: Status and Outlook of Coal Gasification and Liquefaction," Congressional Research Service, June 7, 1979 (Revised Sept. 21, 1979).

operations that could not be experienced in test facilities. For example, since a commercial plant will consist of more than one module, experience can be gained on how to maintain a constant production flow, even if a segment within one module malfunctions.

--Defining regulatory requirements and initial standards for commercial projects. The Environmental Protection Agency cannot issue regulations for a first-of-a-kind industry such as coal liquefaction until a plant operating on a commercial scale can be monitored. Also, a myriad of permits must be obtained at the Federal, State, and local levels before a plant can be constructed. Experience will be gained not only for the companies applying for permits but also for the agencies that will be ruling on these first-of-a-kind plants.

--Gaining information and experience on the environmental impacts of a commercial synfuels plant and appropriate control technologies. As stated earlier, the composition of coal liquefaction products and emissions vary depending on process conditions. Therefore, once a plant is operating on a commercial scale, reliable data can be obtained and control technology can be adjusted or added as necessary.

In summary, industry believes the indirect processes are technically proven and is willing, if offered financial incentives, to construct commercial plants. Even though direct processes still under development are potentially more efficient, it may be appropriate to build commercial indirect liquefaction plants because (1) a nearer term contribution to energy supply could be made and (2) valuable information on the operation of commercial plants could be gained.

CHAPTER 4

OBSERVATIONS AND AGENCY COMMENTS

The United States will continue to require larger supplies of liquid fuels. With domestic oil production unable to meet this requirement and a continuing threat of a foreign oil supply interruption, the United States has been prompted to develop alternative liquid fuels technologies. Coal liquefaction is one such technology that can supplement the Nation's supply of petroleum-derived products such as gasoline and boiler fuels.

There are no commercial coal liquefaction plants operating or under construction in the United States. DOE does, however, have an extensive program in liquefaction which includes RD&D and commercialization activities. The emphasis of the RD&D program, managed by the Assistant Secretary for Fossil Energy, has been on the development of the direct liquefaction processes which DOE believes need further demonstration before they are technically, economically, and environmentally ready to compete in the commercial marketplace.

Since DOE believes the indirect processes are technically proven, responsibility for their commercialization rests with DOE's Assistant Secretary for Resource Applications, whose function is to assist in reducing the barriers to a commercial industry. However, until recently, when a $5.5-billion program was established, Resource Applications had done little to promote indirect processes as candidates for commercialization.

On June 30, 1980, the President signed the Energy Security Act which establishes a Synthetic Fuels Corporation to provide financial incentives for the development of domestic substitutes for imported oil. The Congress has thus far appropriated $19 billion for use by the Corporation. In the interim before the Corporation is fully operating, DOE may use $5.5 billion of the $19 billion to begin offering financial incentives to spur alternate fuels development.

Industry officials we talked to agreed with DOE that the direct processes must be further demonstrated before they are ready for commercialization. Although industry officials agreed that indirect liquefaction processes are commercially available, they said that commercial plants have not been built in the United States because of the financial risk involved in building first-of-a-kind plants. Some companies are ready to commit resources to build commercial indirect

liquefaction plants, but would like their risk reduced by financial incentives from the Government.

We believe that since the direct liquefaction processes have only operated in small test facilities, successful operations in larger-scale plants are needed to reduce technical and environmental uncertainty before commercialization is viable. Successful operation of the recently constructed large pilot plants and the planned demonstration plants should address this uncertainty. However it is unlikely that any commercial direct liquefaction plants will be operating in the 1980s.

We believe the indirect processes could contribute to U.S. energy supply in the near term. DOE's goal is to have the most production in the near term from a balanced range of new domestic alternative fuel supplies. Therefore, the indirect processes are certainly among the logical candidates for funding as a part of DOE's $5.5 billion program. They are also logical candidates for funding by the Synthetic Fuels Corporation. If any portion of the national goals of 500,000 barrels per day by 1987 and 2 million barrels per day by 1992 of crude oil equivalent is to be met with coal liquefaction, the bulk of the production is likely to come from the indirect processes.

AGENCY COMMENTS

We met with DOE officials to receive oral comments on a draft of this report. The officials generally agreed with the accuracy and tone of the report but requested greater emphasis on the Department's low- and medium-British thermal unit gasification program--particularly on the importance of developing and demonstrating new gasifiers which, unlike those now on the market, can process eastern coals. DOE believes there are constraints such as water availability affecting the number of synthetic fuel plants that can be located in the West, therefore establishing technical capability to process eastern coals is important. GAO included these comments where appropriate. (See p. 23.)

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