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COAL CONVERSION: GASIFICATION AND  
LIQUEFACTION (REVISED)

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## INTRODUCTION

The conversion of the vast U.S. coal resources to gas and liquid fuel offers a significant potential for supplementing the nation's dwindling reserves of natural gas and oil. But before any of the conversion processes under investigation go commercial, many economic, equipment and other problems must be resolved. A strong recommendation for increased support for research and development in conversion was contained in a study entitled "Energy R and D Strategy" which was prepared under the auspices of the now defunct Office of Science and Technology, under the Executive Office of the President, on November 29, 1972. The study represented a very comprehensive effort to identify promising new opportunities for meeting U.S. energy needs and was prepared by hundreds of experts in many technological areas. The Administration and Congress have recognized the significance of coal conversion, and economic and policy steps have been and are being taken to further its development without delay.

## GASIFICATION

Coal gasification is a chemical process in which pulverized coal is converted into gas. Two kinds of gases are currently being considered for commercial development. They are characterized by their heating value. High-Btu, also referred to as substitute natural gas (SNG), has a heating value of about 1,000 Btu per cubic foot. It has the same chemical and physical properties as, and is completely interchangeable with, natural gas. Low-Btu gas has a heating value in the range of 100 to 200 Btu per cubic foot. It may be used in gas turbines or combined cycle plants for the generation of electricity. When successfully developed, low-Btu gas would replace conventional coal-fired generating plants and permit projected expansion of coal-based electricity generation in the coal-rich areas of the United States.

The coal gasification process is quite simple. Coal is heated in the presence of steam in a gasifier. This causes some of the hydrogen in the steam to unite with the carbon in coal, to form methane. Methane is the main constituent of natural gas, the pipeline gas used for cooking, heating, and other purposes. In the initial gasification step, not all carbon and hydrogen in the steam-coal mixture combine to form methane. Gasification also generates carbon monoxide and hydrogen. A further step called "methanation" is required to convert this initial mixture of gases of relatively low heating value, to a gas of higher heating value. It also reduces the carbon monoxide content to a level where the synthetic natural gas is nontoxic. The methane content in the gas, in essence, determines whether it is of low- or high-Btu quality. Gasification eliminates from coal undesirable impurities such as carbon dioxide, ash, and sulfur.

Several gas demonstration plants, based on U.S. technology, are in operation or under construction. Among these are the Hygas process, developed by the Institute of Gas Technology, the CO Acceptor Coal-Gasification process, developed by the Consolidation Coal Company, the Synthane process, developed by the U.S. Bureau of Mines, and the Bi-Gas process, developed by Bituminous Coal Research, Inc. The projects, with exception of Synthane, are being funded jointly by the American Gas Association and the Office of Coal Research of the Department of the Interior.

Each process differs in important respects. Which one of the processes under investigation may ultimately prove most feasible for commercial application is expected to be determined within the next three years. At that time, the engineering design of a demonstration plant may be drawn up. The plant will use commercial scale equipment and should produce about 80 million cubic feet of high-Btu gas per day from 5,000 tons of coal. If successful, it will provide the basis for industry to begin building and operating full-scale commercial plants based on U.S. technology producing synthetic natural gas from coal by the end of the 1970's. U.S. technologies offer great economic promise. Cost savings for the production of synthetic natural gas are expected to be as much as 20 to 50 percent over foreign technologies.

Exxon, El Paso Natural Gas, Texas Eastern Transmission, Northern Natural Gas, Cities Service Gas, and Michigan Wisconsin Pipeline are among the companies that have announced their intention to build commercial coal gasification plants.

El Paso's project is the furthest along. According to the company, a plant is awaiting construction near Farmington, New Mexico. Congressional approval of the Company's plan to take water from the San Juan River is pending. The El Paso plant will use the Lurgi gasifier, a pro-

cess developed in Germany. It, and others such as Koppers-Totzek and Winkler, were developed in Europe where they were used commercially to produce low-Btu gas.

Economics, men and material to build the plants, the availability of water, and equipment have a significant bearing on the widespread application of coal gasification. Studies show that gasification processes can provide energy at a cost of \$1.50 to \$1.75 per million Btu. Yet, by the time plants are built, inflation could considerably increase the cost. Also, coal prices may increase. The financing of the 20 gasification plants envisioned to be in operation by 1980, presents a problem. Their collective cost has been estimated at \$8 billion. Questions such as "will there be enough men and material to build the plants?" have to be considered. Will there be sufficient water, especially in the arid regions of the Southwest where many of the plants may be located? Can equipment needs such as the construction of gasifiers that gulp 600 to 800 tons of coal per hour be met? These, and others, are mind-boggling problems whose resolution bears heavily on the future viability of huge gasification complexes.

#### LIQUEFACTION

Coal liquefaction is the process of converting pulverized coal to synthetic liquid fuel. According to U.S. Energy Outlook, a publication by the National Petroleum Council, production of synthetic liquids from coal will depend upon further technological developments in the hydrogenation of coal or coal-derived material. According to the Council, the key step required to bring coal liquefaction within reach of practical economics in the U.S. involves the development of efficient catalysts for use under the high pressure

needed for the process.

The coal liquefaction program, under the Office of Coal Research, has received less attention than their processes to make gas. The investigations underway are in the area of direct hydrogenation of coal and hydrogenation of coal extract. It is expected that they will produce the technology for converting coal to fuel oil that will meet all projected air quality regulations.

Three pilot plants test variations of the coal liquefaction process. The West Virginia plant was designed originally to produce high octane gasoline from coal. But work was abandoned when a National Academy of Engineering evaluation study and other engineering surveys concluded that the pilot plant needed extensive modifications to improve mechanical reliability. The successful operation of the first stages of the gasoline process, however, appear to promise that the plant can be successfully converted to a testing ground for coal liquefaction processes. A liquefaction project in New Jersey has been under development since 1962. It produces a tar-like oil which must be treated with hydrogen to remove the sulfur and make it more liquid; gas with a heating value of 500 Btu's after cleanup; and a residual char which can be gasified to produce additional gas, burned, or used to produce hydrogen for treating the oil.

The Solvent Refined Coal pilot plant in the state of Washington produces a heavy organic material that has a low ash content, less than 1 percent sulfur, and a heating value of about 16,000 Btu's per pound, regardless of the quality of the original coal feedstock. Solvent refined coal is a good potential source of solid fuel for power plants and industrial installations that now burn coal.

Unfortunately, there does not appear to be a published work showing a thorough and reliable estimate of the time and effort needed to develop

any of the coal liquefaction processes to commercial readiness. A cost estimate made by a Task Force working under the auspices of the National Petroleum Council is \$418 million for a commercial size liquefaction plant that will produce 60 to 100 thousand barrels of oil per day. The earliest estimated feasible target date for a commercial size liquefaction plant is 1982. A contract was recently awarded by the Office of Coal Research to perform engineering and technical evaluation services for the Office's liquefaction program. This includes development of conceptual designs for commercial plants.

On the side of industry, considerable effort has been expended by the Gulf Research and Development Company to produce liquid products from coal. Emphasis has been on the development of a process which will be mechanically simple, yet produce a liquid product which, when properly burned, will meet anticipated air pollution regulations. The process is called the Gulf Catalytic Coal Liquids Process and a small pilot unit has been in operation for a number of years. According to company spokesmen, the objective to construct a commercial catalytic coal liquids plant may be realized by 1979 or 1980, if required materials delivery occurs on schedule.

#### FUNDING

The President's Energy Message of January 23, 1974, included \$427 million for coal research and development in the 1975 budget. This represented an increase of \$262 million or 160 percent over 1974. Research and development will focus on liquefaction, low- and high-Btu gasification as well as advanced combustion, and improved coal extraction and reclamation techniques. The high-Btu gasification program was to receive \$65.3 million, low-Btu \$50.7 million, and liquefaction \$108.5 million in fiscal year 1975.



In the Special Energy Research and Development Appropriations Bill, 1975, passed on April 30, 1975, the House Committee on Appropriations authorized funds almost identical (except for high-Btu gasification) to those presented in the Presidential Energy Message. According to the bill, the Bureau of Mines and the Office of Coal Research are to receive \$57 million for high-Btu gasification, \$49 million for low-Btu gasification, and \$107 million for liquefaction.

The Atomic Energy Commission Chairman, Dr. Ray, has recommended that all three programs receive \$915 million over the period from 1975 to 1979:

#### LEGISLATION

##### S. 1283 (Jackson)

The bill proposes to establish a national program for research, development, and demonstration in fuels and energy and for the coordination and financial supplementation of Federal energy research and development. Section 102 of the bill encourages the conservation of limited energy resources and seeks to maximize the efficient development, production, conversion, and use of nonrenewable and limited primary energy resources. The measure passed the Senate on December 7, 1973. It was referred to the House Committee on Interior and Insular Affairs where hearings were held on Dec. 10, 1973. The measure has since passed to the Committee's Subcommittee on Environment. Markup sessions were begun on Feb. 4, 1974. On March 18, 1974, Mr. Udall introduced H.R. 13565 as the House version of this measure. It was not reported as of May 1, 1974.

##### H.R. 9694 (McCormack)

The bill establishes a Coal Liquefaction Corporation to develop coal liquefaction processes by establishing a Government-industry program to

demonstrate commercial methods of producing synthetic liquid petroleum products from coal. The measure was referred to the House Committee on Science and Astronautics on July 30, 1973. The Subcommittee on Energy has requested comments from various agencies. On May 1, 1974, executive comment was received from the General Accounting Office.

H. R. 11480 (Carter)

The Energy Management and Conservation Corporation Act states that the Federal Government has the responsibility to accelerate the use of coal and oil shale to produce liquid and gaseous fuels by conducting and assisting research, development, and demonstration of technologies for producing such fuels from these sources. The bill also has a provision for designing, building, and operating commercial plants to demonstrate these technologies. The measure was referred to the House Committee on Interior and Insular Affairs. It is now in the Subcommittee on Environment where markup sessions began on December 17, 1973.

H. R. 11728 (Conte)

This measure establishes an energy research management project. It was referred to the House Committee on Interior and Insular Affairs on November 30, 1973. The Subcommittee on Environment began consideration and markup sessions on February 4, 1974.

H. R. 14434 (Mahon)

A measure to appropriate funds to enable the Bureau of Mines to perform research and development programs relating to the extraction, processing, and utilization of energy resources without objectionable social and environmental costs; and to foster and encourage private enterprise in the development of energy resources. Also, to appropriate funds to the Office of Coal Research to encourage and stimulate the production and

conservation of coal in the United States through research and development.

The measure passed the House on April 30, 1974. It was referred to several Senate committees for further consideration and action.

## HEARINGS

- U.S. Congress. House. Committee on Appropriations. Subcommittee on Department of the Interior and Related Agencies. Department of the Interior and related agencies appropriations for 1974. Part 3. Hearings, 93rd Congress, 1st session. Washington, U.S. Govt. Print. Off., 1973. 1125 p.
- U.S. Congress. Senate. Committee on Commerce. Council on energy. Hearings, 93rd Congress, 1st session. Washington, U.S. Govt. Print. Off., Feb. 7 and 8, 1973. 223 p.
- U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Energy. Energy research and development and space technology. Hearings, 93rd Congress, 1st session. Washington, U.S. Govt. Print. Off., 1973. 570 p.
- U.S. Congress. Senate. Committee on Interior and Insular Affairs. Subcommittee on Minerals, Materials, and Fuels. The developments in coal gasification and S. 1846, a bill to establish a coal gasification development corporation. Hearing, 92nd Congress, 1st session. Washington, U.S. Govt. Print. Off., November 18, 1971. 122 p.

## REPORTS

- U.S. Congress. House. Committee on Appropriations. Special energy research and development appropriations bill, 1975. Report to accompany H.R. 14434. Report No. 93-1010. 93rd Congress, 2nd session. Washington, U.S. Govt. Print. Off., April 30, 1974. 38 p.
- U.S. Congress. House. Committee on Ways and Means. Briefing on energy situation. Briefing of the Committee on the energy situation by: Dr. Earl T. Hayes, former Chief Scientist, Bureau of Mines, Department of the Interior. 93rd Congress, 2nd session. Washington, U.S. Govt. Print. Off., Jan. 31, 1974. 23 p.
- U.S. Congress. Senate. Committee on Interior and Insular Affairs. Energy research and development -- problems and prospects; report pursuant to S. Res. 45, A National Fuels and Energy Policy Study. 93rd Congress, 1st session. Washington, U.S. Govt. Print. Off., 1973. 175 p. (93rd Congress, 1st session, Senate. Report No. 93-21)
- U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Science, Research, and Development. Energy research and development. 92nd Congress, 2nd session. Washington, U.S. Govt. Print. Off., 1972. 404 p.

CHRONOLOGICAL EVENTS

Gasification

05/23/74 -- The Office of Coal Research issues five technical reports:

1. Phase III and Phase IV - a, -- Design and Construction of the Consolidation Synthetic Gas Pilot Plant, Rapid City, South Dakota.
2. Production of Electricity Via Coal and Coal-Char Gasification.
3. Removal of Sulfur from Coal by Treatment with Hydrogen.
4. Liquid Phase Methanation.
5. Advanced Coal Gasification System for Electric Power Generation. U.S. Department of the Interior News Release, Office of Coal Research.

05/03/74 -- C-E Unit Gets Coal Gasification Contract.

C. E. Lummus, a subsidiary of Combustion Engineering, Inc., was awarded a contract for engineering, procurement, construction and startup assistance for American Natural Gas Co.'s full-scale coal gasification plant to be built in North Dakota. According to the contractor, the plant is scheduled for start-up in the late 1970's and will convert North Dakota lignite to clean-burning gas by the Lurgi process. Plant capacity will be 250 million cubic feet a day. (Coal News)

04/26/74 -- Exxon Corporation let a contract to engineer and build a previously announced coal gasification pilot plant at Baytown, Texas. The plant will cost more than \$40 million and will convert 500 tons of coal daily into gas that can be up-graded to pipeline quality.

Exxon said in March, 1974, that the gasification plant was being designed as part of the company's plan to spend about

\$200 million over the next six years on coal-based synthetic fuel research and development, which also includes design of a large liquefaction pilot plant. (Coal News)

04/19/74 -- Fourteen U.S. companies have agreed to sponsor a new coal gasification project at Westfield, Scotland, at a cost of nearly \$10 million. The project is aimed at commercial-scale testing of the high-pressure slagging process of gasifying coal developed by the British Gas Corp.

If successful, the process is expected to reduce substantially the cost of producing "coal gas" compared with established methods. (Coal News)

04/05/74 -- The U.S. Department of the Interior spells out a 5-year \$4.6 billion research program aimed at shifting the nation's energy base from oil and natural gas toward coal. (Dallas News, Friday, April 5, 1974).

03/08/74 -- The Exxon Corporation announced that it plans to spend about \$200 million over the next six years on research and development programs for coal conversion processes.

01/18/74 -- The American Gas Association this week unveiled a \$2.3 billion five-year research plan for the natural gas industry that would allocate three-quarters of the program funds to development of synthetic natural gas from coal and other sources. (Coal News)

01/18/74 -- El Paso Natural Gas Co. claims that failure to receive necessary authorization from the U.S. government has led to cancellation of its 1972 contract to purchase a billion cubic feet a day of liquefied natural gas from Algeria.

- 01/11/74 -- The Department of the Interior has received a patent for the Bi-Gas coal gasification process developed by Bituminous Coal Research, Inc., under contract with the Office of Coal Research. The process will be used in a pilot plant being built at Homer City, Pa., as part of the \$120 million coal gasification research program of Interior and the American Gas Association. (Coal News)
- 12/07/73 -- A vastly expanded federal energy research program that would funnel \$2.175 billion into coal research in the next five years was proposed to President Nixon in a report submitted by Atomic Energy Commission Chairman Dixy Lee Ray. (Coal News)
- 11/21/73 -- Old Ben Coal Corp., subsidiary of Standard Oil Co., announces plans for a \$73 million, multi-company project to test the commercial potential of a process for converting coal to a low-sulfur, clean-burning fuel. (Coal News)
- 11/16/73 -- Peoples Gas Company has mapped plans to build at least four coal gasification plants, each to produce 250 million cubic feet of gas a day and to cost \$370 million, under its Dunn Center Coal Gasification Project. (Coal News)
- 10/19/73 -- Scientists at the National Coal Association Conference in Washington, D. C. recommend international coal research commission. (Coal News)
- 09/05/73 -- The Carter Oil Company confirms that a company task force will be studying a possible commercial coal gasification project in northeast Wyoming over the next 18 months.
- 03/22/73 -- The Office of Coal Research awards contract to develop high-Btu synthetic natural gas to Chem Systems. (Department of the

Interior news release)

- 02/23/73 -- The Office of Coal Research awards a contract to develop an economical method for producing synthesis gas from coal, one step away from a quality pipeline gas, to Battelle Laboratories.
- 02/09/73 -- Office of Coal Research awards contract for development of entrained coal gasification process for production of low-Btu gas. (Department of the Interior news release)
- 01/15/73 -- The Department of the Interior announces award of low-Btu gas contract to Westinghouse. (Department of the Interior news release)
- 07/21/72 -- The Department of the Interior invites bids on a contract to build pilot-plant facilities near Pittsburgh, Pa., for the Synthane coal gasification process. (Department of the Interior news release)
- 07/17/72 -- Eleven U.S. companies in various areas of the energy field have joined Continental Oil to build the first commercial-scale demonstration of methanation of gas from coal. The project has the cooperation of the British Gas Council and the Scottish Gas Board, and will cost about \$6 million. It will turn out 2.6 million cubic feet of gas a day with a heating value about equal to that of natural gas. Construction contractor is Woodall-Duckham, Ltd., an English firm, which will build the plant in Scotland. (Chemical and Engineering News)
- 07/14/72 -- The Federal Power Commission approved the application of El Paso Algeria Corp. to import one billion cubic feet a day of liquefied natural gas from Algeria under a 25-year contract.



The FPC also stipulated that the imported gas be sold under separate rate schedules to customers willing to pay extra cost. National Coal Association President Carl E. Bagge said that this decision could adversely affect the continued pursuit of coal gasification processes by government and industry. He felt that it could have severe repercussions on millions of energy consumers who are looking to the producers of coal and other forms of energy to solve a gas supply crisis of major proportions. It was asked that the Commission hold a rehearing of its ruling. (Coal News)

03/16/72 -- The Bureau of Mines feels that Synthane natural gas from coal is low-pollution auto fuel. (Department of the Interior news release)

03/06/72 -- The Institute of Gas Technology has put a part of its pilot Hygas coal gasification plant on stream. In an "encouraging" eight-day trial run, the hydrogasification reactor produced gas containing at most about 20 percent methane. Says an IGT spokesman: "It was sort of like Wright brothers' first flight; they didn't fly very far, but they proved something." IGT expects that the reactor will ultimately convert coal into gas with a heating value of 650 Btu per cubic foot; further treatment in methanation section will result in a 950-Btu final product. (Chemical and Engineering News)

03/03/72 -- Dr. Edward David, director of the President's Office of Science and Technology, outlines coal research plans. (Coal News)

02/25/72 -- Bureau of Mines invites comments on draft environmental statement for proposed Synthane Pilot Plant. (Department of

the Interior news release)

- 12/20/71 -- The \$5 million slash by Senate-House conferees in the Office of Coal Research's fiscal 1972 budget will delay five coal gasification studies in support of three OCR-funded pilot projects. OCR had counted on a \$20 million budget backed by \$10 million from industry. Now down to \$15 million from the Government, OCR will "have to play catchup in fiscal year 1973," says OCR's Ed Larson. (Chemical and Engineering News)
- 11/22/71 -- The Bi-Gas coal gasification process being developed by Bituminous Coal Research, Inc., will be tested in a 120 ton per day pilot plant to be constructed at Homer City, Pa. The process uses a two-stage high-pressure reactor, followed by passage of the gas over a catalyst to produce additional methane. Koppers Co. is doing design and engineering work for the plant, which is funded by a \$24,830,000 grant from Interior's Office of Coal Research. The pilot plant is scheduled to begin operations in 1973. (Chemical and Engineering News)
- 11/01/71 -- Latest addition to the list of coal gasification plans involves Pacific Lighting Service Co., Utah International, Inc., and Texas Eastern Transmission Corp. The three firms have begun feasibility studies for building a 250 million cubic foot per day gas plant in northwestern New Mexico. The plant would use the coal gasification process of Lurgi Gesellschaft fuer Waerme und Chemotechnik, GmbH. (Chemical and Engineering News)

Liquefaction

- 04/12/74 -- The Office of Coal Research awards a \$245,006 contract to determine preliminary costs for building and operating a commercial plant converting coal to liquids for use in chemical production. The contract is to run 24 months. The contractor will evaluate the technical and economic feasibility of three liquefaction processes to determine which could most effectively feed a chemicals complex for producing useful compounds. The three processes, developed to the pilot stage by the Office of Coal Research in cooperation with private industry are solvent refined coal, H-coal hydrogenation and char-oil-energy development (COED) pyrolysis.
- 11/22/73 -- Synthetic oil from coal makes seagoing history. A U.S. Navy destroyer sailed out of a Philadelphia port and thereby added a page to seagoing history by burning synthetic oil from coal for the first time. (Navy Legislative Liaison Office)
- 09/05/73 -- Exxon Corporation announced two promising processes for converting coal to synthetic fuels and an intensified multi-million dollar development effort to demonstrate the commercial practicability of the processes.
- 03/03/73 -- The Office of Coal Research issues a final report on development of arc-coal process to produce acetylene from coal. (Department of the Interior)
- 07/30/71 -- The Interior Department's Bureau of Mines reported that high-sulfur bituminous coal has been experimentally converted into a pollution-free fuel. (Department of the Interior)

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- Coal gasification offers one key to energy independence. Commerce Today. vol. IV, no. 7. January 7, 1974: p. 4.
- Federal Power Commission. The supply-technical advisory task force -- synthetic gas-coal. Final report, prepared by Synthetic Gas-Coal Task Force, for the Supply-Technical Advisory Committee National Gas Survey. April 1973: A11-7 p.
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When will synthetic fuels begin flowing from coal? Engineering, January 9, 1974: p. 35.

U.S. Department of the Interior. Bureau of Mines. Clean energy from coal -- new developments. Irving Wender, Research Director, Pittsburgh Energy Research Center, Pittsburgh, Pennsylvania. April, 1974. 22 p.

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