

FINAL REPORT OF THE
NATIONAL PETROLEUM COUNCIL'S
COMMITTEE ON SYNTHETIC LIQUID
FUELS PRODUCTION COSTS

February 26, 1953

OFFICE COPY

CHAIRMAN: W. S. S. RODGERS

HEADQUARTERS OFFICE

601 Commonwealth Building
1625 K Street, N. W.
Washington 6, D. C.

Telephone:
Executive 3-5167

FINAL REPORT OF THE
NATIONAL PETROLEUM COUNCIL'S

COMMITTEE ON SYNTHETIC LIQUID
FUELS PRODUCTION COSTS

INTRODUCTION

Your committee on Synthetic Liquid Fuels Production Costs was created by the National Petroleum Council in June 1950 in response to a request from the Secretary of the Interior, Honorable Oscar L. Chapman, to:

1. "review the estimates made by the Bureau of Mines for the cost of producing synthetic liquid fuels and its estimates of comparative costs of producing liquid fuels from crude oil,
2. "prepare independent cost estimates,
3. "make recommendations as to ways and means, if any, for improvement of future cost estimates by the Bureau of Mines."

In subsequent discussions Dr. James Boyd, Director of the Bureau of Mines, advised that the Bureau of Mines was not prepared to submit estimates of the costs involved in the production of liquid fuels from crude oil, therefore no studies were made by your committee on this subject. For a comparison with synthetic liquid fuels production costs, the committee has used the current quoted price for gasoline at the refinery or terminal at four locations in the United States.

COMMITTEE ORGANIZATION

A subcommittee of experts in the synthetic fuels field was established by your committee to assist in analyzing this highly technical problem. This subcommittee, in turn, organized

additional technical subcommittees shown in Attachment 1, comprised of specialists in mining, research, development, engineering and economics. During the two and one-half years of work these men have enlisted the aid of over 150 other technical personnel in their own companies, and have consulted hundreds of outside concerns during the course of the investigation. It is estimated this study has cost the participating companies over \$500,000.

SCOPE OF INVESTIGATION

The work of the Bureau of Mines, which was submitted to your committee for study, is concerned with the manufacture of liquid fuels by:

1. Hydrogenation of coal.
2. Recovery and refining of oil from oil shale.
3. Gasification of coal and conversion of the resultant gas to liquid fuels by a modified Fischer-Tropsch synthesis process.

The report for your committee on the first two processes, coal hydrogenation and oil shale, was presented to the National Petroleum Council on October 31, 1951. This final report includes (1) a further analysis on coal hydrogenation as proposed by the Bureau of Mines and hereafter referred to as the "modernized" case, and (2) the committee's complete study of the Fischer-Tropsch synthesis process.

The Bureau of Mines has under construction at Rifle, Colorado, a large scale gas combustion retort pilot plant for handling oil shale. Data from this plant should be available during the last half of this year. Preliminary cost calculations, based on a Bureau of Mines small scale gas combustion retort pilot plant, indicate that the substitution of this type of retort will cause no significant change

in the previously reported cost of gasoline from oil shale. It is proposed that no further work be done by the National Petroleum Council to evaluate this phase of the project.

DESCRIPTION OF OPERATIONS

COAL HYDROGENATION

The basic processing steps in this study of coal hydrogenation are essentially the same as those used for the work previously reported to the Council on October 31, 1951. For the benefit of the members who were not present at the October 31, 1951 meeting, we will repeat a resume of the process so you will have a more complete description of coal hydrogenation.

Run-of-mine coal is separated into two fractions, a low ash fraction for hydrogenation, and a high ash fraction for fuel and hydrogen production. The clean coal is pulverized, slurried with heavy oil, mixed with catalyst and subjected to hydrogen at a pressure of 10,500 pounds per square inch and a temperature of 900^o F. This treatment substantially liquefies the coal to form gas, naptha, middle distillate, and a heavy oil. The heavy oil is divided into two parts, one for recycle back to the hydrogenation unit as the slurring agent, the other for feed to a coking unit for removal of ash, catalyst, and unreacted coal from the system.

The middle distillates and the naptha are further hydrogenated at the same pressures and temperatures, but over a different catalyst to produce gasoline. Gases from both stages of hydrogenation are processed to recover hydrogen, liquefied

petroleum gas, and the lighter hydrocarbon gases which are used to manufacture hydrogen. Phenolic type chemicals can be recovered from the middle distillates produced from the first stage hydrogenation.

The two processes of coal hydrogenation differ distinctly in the methods used in the manufacture of hydrogen. In addition, certain modifications suggested by the Bureau of Mines, after the start of the committee's work, were incorporated. In detail, these differences are:

1. Pressure gasification of coal (450 psig) to manufacture hydrogen replaces conventional gasification at approximately atmospheric pressure.
2. Hydrogen is also manufactured from product hydrocarbon gases by partial combustion with oxygen under pressure instead of the conventional steam-cracking process.
3. The Bureau of Mines has found that a higher concentration of carbon monoxide can be tolerated in the liquid phase hydrogenation step than originally considered. This allows a reduction in hydrogen purification facilities.

The above changes result in lower costs of hydrogen manufacturing facilities as well as lower investment for coal mining, coal preparation, general plant facilities, and utilities. It is to be noted that certain steps in this modernized case are based on a limited amount of pilot plant work and have not been sufficiently demonstrated to insure commercial operability.

FISCHER-TROPSCH OPERATIONS

The reaction of carbon monoxide with hydrogen over catalysts to produce synthetic liquid fuels is generally known as

the Fischer-Tropsch synthesis process, after the German scientists who developed the process in their work in the 1920s. Commercial application of the process began in Germany in the middle 1930s.

There have been many suggested modifications to the methods practiced by the Germans in Fischer-Tropsch plants operated prior to and during World War II. These modifications involve changes in the equipment for the basic Fischer-Tropsch synthesis as well as changes in the method of producing feed gas for the reaction and in the methods of processing of the reaction products.

In summary, the Bureau of Mines modified Fischer-Tropsch process is:

Coal is crushed, partially dried, pulverized, and then gasified with oxygen and steam at 450 pounds per square inch pressure and at about 2700^o F. temperature to produce a gas containing carbon monoxide, hydrogen, carbon dioxide, and impurities. The gas is purified so that it is a mixture of mainly carbon monoxide and hydrogen in the ratio of 1.4 to 1.0.

The gas is then fed to the synthesis unit in which liquid hydrocarbons are produced by the Fischer-Tropsch reaction. This unit employs a technique developed by the Bureau of Mines and consists of two stages to insure completeness of the reaction. Ground iron catalyst is suspended in the reactors by a circulating stream of coolant oil. Feed and recycled gases are bubbled through the oil-catalyst phase at about 500^o F. temperature and 400 pounds per square inch pressure. The circulating oil, synthesis products,

and unreacted gases are disengaged from the catalyst bed and cooled by generation of steam in waste heat boilers. Subsequent equipment, conventional to petroleum refining, separates and processes the above products so that ultimately products for sale are gasoline, No. 2 fuel oil, liquefied petroleum gas, and sulfur, all conforming to present market specifications.

It is possible to recover certain oxygenated chemicals, such as alcohols, acids, esters, and ketones. However, when manufacturing even a moderate percentage of the nation's fuel requirements with this process, the resultant production of these chemicals would be so large compared to the present market demand, their value would be essentially equivalent to liquid fuels. Since the project has been considered as a fuels and not a chemical venture, these compounds were converted to liquid fuels. Sulfur, on the other hand, was recovered since its production rate from these plants is a small percentage of the total demand.

The Bureau of Mines Fischer-Tropsch plant was designed to produce 11,000 barrels of liquid product per calendar day. In order to make the plants more comparable with the coal hydrogenation plants, the subcommittee also made an estimate of the cost of fuels from a plant with a capacity of 27,000 barrels per calendar day. The cost of fuels was computed by identical methods and premises as those used in the committee's report of October 31, 1951. All labor, material, equipment, and financial costs were adjusted to January 1951 levels.

DISCUSSION OF RESULTS

Secretary Chapman requested that the committee "1. Review estimates made by the Bureau of Mines of the cost of producing synthetic liquid fuels--." The Bureau of Mines did not have cost estimates for review on the Fischer-Tropsch process, nor on the final design of the modernized coal hydrogenation case. Consequently, considerable time elapsed as additional laboratory data were obtained by the Bureau of Mines and designs were prepared. The designs that finally evolved were the result of many discussions and conferences between members of the subcommittees and the Bureau of Mines as to the adequacy and interpretation of the laboratory data, the methods of design calculations, and the translation to commercial practices. Details of the estimates and cost calculations have been made available to the Bureau of Mines.

Secretary Chapman requested that the committee "2. Prepare independent cost estimates." Such estimates have been prepared and the conclusions reached represent the combined effort of leading authorities in the petroleum and coal industry.

A summary of the data developed in this study is compared (in Table I, attached) with data on oil shale and coal hydrogenation presented in the committee's report of October 31, 1951. It will be noted from this table that the total investment and the cost of gasoline to the wholesale purchaser, at the manufacturing point, by the various methods of processing are:

<u>Process</u>	<u>Plant Investment Millions of Dollars</u>	<u>Gasoline Cost Cents per gallon</u>
Coal Hydrogenation (conventional)		
Single Plant (27,000 B/CD)	533	41.4
Multi-plant (216,000 B/CD)	4,074	43.5
Coal Hydrogenation (Modernized)		
Single Plant (27,000 B/CD)	477	36.3
Fischer-Tropsch Processing of Coal		
Single Plant (11,000 B/CD)	184	35.7
Single Plant (27,000 B/CD)	380	29.4
Oil Shale		
Single Plant (39,700 B/CD)	333	16.2
Multi-plant (201,330 B/CD)	1,518	14.7

In this study the Federal income tax rate has been taken at 50% of income before taxes. No effect has been given to excess profit taxes. The derived product costs do not include sales taxes or marketing expense. Liquefied petroleum gas and a limited amount of chemicals have been credited as by-products.

Housing for construction workers and permanent employees has been included to the extent necessary by the conditions prevailing at the plant sites. The net effect of this housing expense on product cost has been determined with due consideration of money returned to the enterprise through rentals and is negligible for the Eastern locations and adds about 5% to the computed cost of gasoline for the Western locations.

A return of 6% after taxes, on the total investment was used in computing the gasoline cost in order to demonstrate that charges for return on the investment should be included in the calculations. It is very doubtful that capital could be attracted to such a speculative venture at this low rate of return. Although

this committee did not wish to specify the exact investment return required, since such a number would vary with individual situations, most financial authorities agree that an expected return of 12-15% on the total invested capital, borrowed or equity, would be required to attract private capital. For each increase of 1% return on the investment, after taxes, the gasoline costs from the single plant cases would increase by:

<u>Process</u>	<u>Cents per gallon</u>
Coal Hydrogenation (conventional)	3.6
Coal Hydrogenation (modernized)	3.2
Fischer-Tropsch	2.0
Oil Shale	1.3

The following are price quotations (February 1, 1953) for gasoline at the refinery or terminal, for four locations in the United States. These are the prices which synthetically produced gasoline would have to meet in free competition today:

	<u>Regular ¢/Gal.</u>	<u>Premium ¢/Gal.</u>
Los Angeles	11.50	13.00
Denver	12.20	13.20
Salt Lake City	12.40	13.40
St. Louis	12.30	13.30

Secretary Chapman further requested that the committee

"3. Make recommendations as to ways and means, if any, for improvement of future cost estimates by the Bureau of Mines."

It is evident from the scope of the work of this project that the preparation of reliable cost estimates of facilities upon

which there is little commercial experience is a complicated and extensive undertaking. During the course of this study Bureau of Mines representatives have had numerous opportunities to review in detail the methods employed by the industry organizations. With this experience to supplement their own background and with the information available to them in the technical reports made available to them by the subcommittee, the Bureau of Mines personnel should be in a position to prepare comparable cost estimates for any known or new process combination. Certain recent publications of the Bureau of Mines indicate that a large proportion of these recommendations have been adopted.

CONCLUSIONS

As shown by this extensive and conclusive study, all methods of manufacturing synthetic liquid fuels proposed by the Bureau of Mines are definitely uneconomical under present conditions. There is some likelihood of further reducing the cost of synthetic liquid fuels by continued research in oil shale and Fischer-Tropsch processing of coal. In fact, the possibility of commercial operations in oil shale warrants the continued attention of the petroleum industry. Coal hydrogenation, on the other hand, requires drastic improvements in existing methods to permit economic operation. Such developments are not foreseen at the present time. Because of the greater promise of the other methods, further Government work on this process does not appear to be justified.

In view of the findings of other committees of the National Petroleum Council with respect to crude availability, your committee concludes that the need for a synthetic liquid fuel industry in this country is still in the distant future. Since new techniques may be available by then, we question the wisdom of the Government financing large-scale demonstration plants. Such techniques can be developed from well designed pilot plants at a small fraction of the cost of so-called demonstration plants.

Respectfully submitted,

W. S. S. Rodgers, Chairman
K. S. Adams
H. H. Baker
Max W. Ball
Bruce K. Brown
R. L. Foree
J. M. Lovejoy
R. S. Shannon
R. H. Taylor
L. S. Wescoat
R. E. Wilson

ATTACHMENT 1 - PAGE 1

NATIONAL PETROLEUM COUNCIL COMMITTEE ON
SYNTHETIC LIQUID FUELS PRODUCTION COSTS

W. S. S. RODGERS Chairman	The Texas Company, New York
K. S. ADAMS	Phillips Petroleum Company, Bartlesville, Oklahoma
HINES H. BAKER	Humble Oil & Refining Company, Houston
MAX W. BALL	Washington, D. C.
*BRUCE K. BROWN	Pan American Southern Corporation, New Orleans
**ROBERT L. FOREE	Texas Independent Producers and Royalty Owners Association, Dallas
JOHN M. LOVEJOY	Seaboard Oil Company of Delaware, New York
R. S. SHANNON	Pioneer Oil Corporation, Denver
REESE H. TAYLOR	Union Oil Company of California, Los Angeles
***J. ED WARREN	Independent Petroleum Association of America, c/o Carl B. King Drilling Company, Midland, Texas
L. S. WESCOAT	The Pure Oil Company, Chicago
ROBERT E. WILSON	Standard Oil Company (Indiana) Chicago
J. W. FOLEY Secretary	The Texas Company, New York

* Mr. Brown resigned November 22, 1950. He was reinstated
May 29, 1952.

** Mr. Foree resigned November 26, 1951. He was reinstated
December 23, 1952.

*** Mr. Warren resigned April 1, 1952.

NATIONAL PETROLEUM COUNCIL SUBCOMMITTEE ON
SYNTHETIC LIQUID FUELS PRODUCTION COSTS

*A. P. FRAME Chairman	Cities Service Research and Development Company, New York
E. AYRES	Gulf Research and Development Company, Pittsburgh
F. E. FREY	Phillips Petroleum Company Bartlesville, Oklahoma
* *L. C. KEMP, JR.	The Texas Company, New York
E. V. MURPHREE	Standard Oil Development Company New York
A. C. RUBEL	Union Oil Company of California Los Angeles
A. L. SOLLIDAY	Stanolind Oil and Gas Company Tulsa
***H. G. VESPER	California Research Corporation San Francisco

*Mr. Frame resigned from the committee on March 1, 1951

**Mr. Kemp was appointed chairman on March 1, 1951

***Mr. Vesper joined the committee on July 11, 1951

NATIONAL PETROLEUM COUNCIL SUBCOMMITTEE ON
SYNTHETIC LIQUID FUELS PRODUCTION COSTS

RAW MATERIALS SUBCOMMITTEE

A. L. SOLLIDAY, Chairman
P. R. SCHULTZ, Alternate

Stanolind Oil and Gas Company
Tulsa

Oil Shale

TELL ERTL, Chairman

Department of Mine Engineering
Ohio State University, Columbus

I. N. BAYLESS

Union Pacific Coal Co., Omaha

P. R. SCHULTZ

Stanolind Oil and Gas Company
Tulsa

Eastern Coal

JOSEPH PURSGLOVE, JR.
Chairman

Pittsburgh Consolidation Coal
Company, Pittsburgh

CLAYTON BALL

Paul Weir Coal Co., Chicago

STEPHEN KRICKOVIC

Eastern Gas and Fuel Associates
Pittsburgh

I. S. SALNIKOV

Standard Oil Co. (New Jersey)
New York

Western Coal

I. N. BAYLESS
Chairman

Union Pacific Coal Company
Omaha

R. L. BALDNER

Stanolind Oil and Gas Co., Tulsa

J. H. POORE

Northern Pacific Railway Co.
St. Paul

PROCESS SUBCOMMITTEE

E. V. MURPHREE, Chairman
E. J. GOHR, Alternate

Standard Oil Development Company
New York

Coal Hydrogenation

L. E. CARLSMITH
Chairman

Standard Oil Development Company
New York

NATIONAL PETROLEUM COUNCIL SUBCOMMITTEE ON
SYNTHETIC LIQUID FUELS PRODUCTION COSTS

PROCESS SUBCOMMITTEE (Cont.)

Coal Hydrogenation (Cont.)

C. HOLLOWAY	Gulf Research and Development Co. Pittsburgh
B. J. MAYLAND	Girdler Corporation, Louisville
J. SEEBOLD	Standard Oil Company (Indiana) Whiting, Indiana

Coal Synthesis

L. P. GAUCHER, Chairman	The Texas Company, New York
R. H. CROSBY	Shell Oil Company, New York
*K. J. NELSON E. J. GORNOWSKI	Standard Oil Development Company Linden, New Jersey
S. WALKER	Stanolind Oil and Gas Company Tulsa
*H. L. MALAKOFF	Cities Service Petroleum, Inc. New York

Shale Oil

C. BERG, Chairman	Union Oil Company of California Wilmington, California
J. HIRSCH	Gulf Research and Development Co. Pittsburgh
J. E. LATTA	Stanolind Oil and Gas Company Tulsa
H. J. OGORZALY	Standard Oil Development Company Linden, New Jersey
G. D. GOULD	California Research Corporation San Francisco

* Resigned

ATTACHMENT 1 - PAGE 5

NATIONAL PETROLEUM COUNCIL SUBCOMMITTEE ON
SYNTHETIC LIQUID FUELS PRODUCTION COSTS

ENGINEERING SUBCOMMITTEE

L. C. KEMP, JR., Chairman The Texas Company, New York

J. C. NEYLAND, JR., Alternate

Coal Hydrogenation

J. S. CLARKE Standard Oil Development Company
Linden, New Jersey

J. C. NEYLAND, JR. The Texas Company, New York

WARREN A. ROE, JR. Gulf Oil Corporation, Pittsburgh

O. L. WHITE Standard Oil Development Company
*G. J. DOLL Linden, New Jersey

Coal Synthesis

R. G. ATKINSON Phillips Petroleum Company
Bartlesville, Oklahoma

J. C. NEYLAND, JR. The Texas Company, New York

J. B. WILLIS Sinclair Rubber, Inc., Houston

L. P. EVANS Socony-Vacuum Laboratories
Paulsboro, New Jersey

Off-Site Facilities

E. H. ROY Cities Service, New York

J. D. SNAKENBERG American Petrochemical Corp.
New York

E. O. PATTERSON, JR. Stanolind Oil and Gas Company
Tulsa

**G. B. BURLISON Stanolind Oil and Gas Company
Tulsa

* Resigned

** Deceased

NATIONAL PETROLEUM COUNCIL SUBCOMMITTEE ON
SYNTHETIC LIQUID FUELS PRODUCTION COSTS

ENGINEERING SUBCOMMITTEE (Cont.)

Shale Oil

H. REED, Chairman	Brea Chemical Company, Inc. Los Angeles
L. P. ELLIOT	California Research Corp. San Francisco
R. A. BAKER	General Petroleum Corporation Los Angeles
C. K. VILAND	Tidewater Associated Oil Co. San Francisco
F. W. CURTIS	Shell Oil Company Wilmington, California
FRANK FONTANA	Richfield Oil Corporation Los Angeles

ECONOMICS SUBCOMMITTEE

P. R. SCHULTZ, Chairman	Stanolind Oil and Gas Company Tulsa
R. G. ATKINSON	Phillips Petroleum Company Bartlesville, Oklahoma
F. T. BARR	Standard Oil Development Co. Linden, New Jersey
J. HIRSCH	Gulf Research and Development Company, Pittsburgh
T. R. MOORE	The Texas Company, New York
C. F. PARKER	Union Oil Company of California, Los Angeles
J. D. SNAKENBERG	American Petrochemical Corp. New York

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON 25, D. C.

C
O
P
Y

Dated
April 21, 1950
as per F. McCormick

My Dear Mr. Hallanan:

During and immediately after World War II when the problem of adequate supplies of liquid fuels was uppermost in the minds of Government and industry and while there was uncertainty as to whether this country possessed an adequate supply of petroleum in the event of another emergency, the Bureau of Mines, of the Department of the Interior, was charged by Congress with the responsibility for investigating and developing processes for producing synthetic liquid fuels from oil shale and coal.

One of the requirements was to construct and operate demonstration plants to enable Government to furnish industry with the necessary cost and engineering data for the development of a synthetic liquid fuels industry.

Since the Bureau of Mines experimental work is sufficiently advanced to enable it to furnish some of the data called for, the Bureau would now welcome a critical study of its cost data by the National Petroleum Council and will cooperate fully in furnishing its data for such a study.

Therefore, I request that the National Petroleum Council create a committee to: (1) review the estimates made by the Bureau of Mines for the cost of producing synthetic liquid fuels and its estimates of comparative costs of producing liquid fuels from crude oil, (2) prepare independent cost estimates, and (3) make recommendations as to ways and means, if any, for improvement of future cost estimates by the Bureau of Mines.

Sincerely,

/s/ Oscar L. Chapman

Secretary of the Interior

Mr. Walter S. Hallanan, Chairman
National Petroleum Council
1625 K Street, N. W.
Washington 6, D. C.