II

INTRODUCTION

The United States dominated the world petroleum market and was a net exporter on a large scale until the late 1940s when the country's supply and demand were about in balance. In the early 1950s, the United States became a net importer of petroleum liquids, with the fraction of total consumption coming from imports increasing each year.

U.S. domestic crude oil production dropped from 9.4 million barrels per day in 1973 to 8.6 million barrels per day in 1975 and is expected to be about 8.1 million barrels per day in 1976. Present evidence suggests that this decline will continue with the loss of about 0.5 million barrels per day annually. Additional liquid fuel obtained from processing natural gas amounts to 1.6 million barrels per day, and refinery operations contribute another 500,000 barrels as the crude oil is converted to lighter products. Thus, in 1976 total domestic supply is expected to amount to about 10.2 million barrels per day, which falls far short of the expected demand of 17.4 million barrels. The difference between demand and domestic production of about 7.2 million barrels per day is filled by imports.

In the third quarter of 1976, imports reached 7.6 million barrels per day. During 1977, imports are expected to average about 8 million barrels per day at an annual cost approaching $40 billion.

Although offshore drilling and production grew rapidly during the 1960-1975 period, this source has been unable to counter the loss in onshore production. Alaskan oil, which is scheduled to begin to be delivered in 1977 and to reach 2 million barrels per day in the early 1980s, will not make up production decreases in the contiguous 48 states during the next 5 years. Over half of the projected 1990 domestic oil production will have to come from reserves yet to be discovered if the nation's reliance on imported oil is not to substantially exceed 50 percent.

Conservation measures and restrictions of demand, primarily by price increase, have restrained growth of energy demand from the pre-1972 rate of 5 to 7 percent per year to 3 to 4 percent per year in 1975. Future restrictions must be carefully planned and programmed if adverse effects

on the industrial and economic activity of the country are to be avoided.

The need to supply an increasing portion of the energy demand from domestic resources and to decrease dependence on foreign oil has brought to the fore the direct use of coal to replace oil or gas and the development of processes to produce liquids and gas from coal. In the United States this is of particular significance because of the nation's well-distributed large reserves (over 80 percent of total* U.S. known fossil fuel reserves) of minable coal.

Identified U.S. coal reserves, as defined by the U.S. Geological Survey,[1] are estimated at 1.7 trillion tons of coal occurring to depths of 3,000 feet and in thicknesses of 14 inches. Present economic factors limit application of available mining methods to about 1,000 feet for beds 28 inches or more in thickness, and the amount of coal recoverable is estimated at 232 billion tons.[2] Coal production in 1975 was approximately 600 million tons, and at this rate of use the nation has sufficient reserves for about 400 years. However, assuming that annual production will triple or quadruple to meet additional power plant and synthetic liquid and gas requirements, the minable reserve ultimately may be sufficient for less than 100 years. Because of both the need for and the advantages of fuels in the liquid form for many applications, it is highly desirable that the nation develop economically viable processes for converting some of this vast reserve of solid fuel to liquid fuel. Processes to produce liquid fuels from coal have been known for over 50 years, but these processes have never been economically competitive with the large supplies of relatively cheap liquid fuels from petroleum.

A major important difference between coal and oil is the hydrogen content of each. The ultimate compositions of a Pennsylvania bituminous coal and a Texas crude oil before and after the elimination of impurities are shown in Table 1. Coal typically contains about half as much hydrogen (6 percent vs. 12 percent by weight), several times as much oxygen, and about twice as much nitrogen impurities as oil. Conversion of coal to a liquid product requires addition of considerable hydrogen to the liquefied fraction and removal of ash and moisture; oxygen, sulfur and nitrogen can be removed from the liquefied coal as water, hydrogen sulfide, and ammonia in much the same manner as from crude oil.

Coal liquefaction processes generally add hydrogen in amounts ranging from about 2 weight percent of the coal when converting coal to a refined solid product to greater than 8 percent when the end product, after further refining, is gasoline. To achieve these conversions requires feeding coal to a system at pressures in the range of 500 to 4,000 psi, temperatures in the range of 400 to 550 °C, and usually the presence of a catalyst. The resultant processes are complex and expensive in both capital and operating costs. In addition, the costs of generating the large amounts of hydrogen typically needed are very high.

*Not including oil shale.

TABLE 1 Compositional Comparison of Bituminous Coal with Oil
Weight Percent

	With Impurities		Without Impurities	
	Coal	Oil	Coal	Oil
Carbon	67.5	84.8	93.49	88.67
Hydrogen	4.7	10.8	6.51	11.33
Oxygen	6.2	2.0		
Sulfur	4.2	1.6		
Nitrogen	1.2	0.6		
Ash	10.6	0.2		
Water	5.6	0.0		
	100.0	100.0	100.0	100.0

The purpose of this report is to examine the processes for the liquefaction of coal to determine:

1. The current status and their technical development

2. Their potential for development to an industrial scale and their possible contribution toward the production of several million barrels of synthetic oil a day in the United States

3. The environmental and resource requirements

4. Material, equipment, and lead time requirements for such production by the various processes as compared to the nation's capacity for producing these materials

5. Capital requirements, operating costs, and product costs

6. Research and development needs to support this development and areas for potential significant improvement in new or revised process concepts

REFERENCES

1. P. Averitt, *Coal Resources of the United Stated, January 1, 1974*, Geological Survey Bulletin 1412 (Washington, D.C.: U.S. Government Printing Office, 1975).

2. National Research Council, Committee on Processing and Utilization of Fossil Fuels, Ad Hoc Panel on Coal Mining Technology, *Coal Mining* (Washington, D.C.: National Academy of Sciences, 1977).