SECTION 2

SUMMARY

A conceptual design and economic evaluation has been completed for an industrial complex to mine coal and convert it to SNG, LPGs, naphtha, unleaded gasoline, distillate fuel oil, premium grade coke, and electrical power. The results are summarized in this report.

The work was begun under the auspices of the Major Facilities Project Management Division of the Energy Research and Development Administration - Fossil Energy and completed under the Department of Energy, Office of Assistant Secretary for Energy Technology, Division of Coal Conversion. Their support and guidance are gratefully acknowledged.

The design basis used is the result of the analysis of a number of candidate processes and process combinations. A report describing the predesign analysis results has been published.[8] These predesign analyses indicated that there are incentives for use of certain coal conversion operations that required further development and pilot plant testing prior to commercial plant operation. These operations include pressurized flash pyrolysis and pressurized, entrained, slagging, two-stage gasifiers. Analysis results indicate that these technologies offer economic incentives if they perform as defined in this design. The projected performances are considered practical and attainable if additional development work is successfully completed. The procedures for design, as well as recommendations for the additional development work considered necessary to ensure success in commercial operation, are presented in the report.

The greatest amount of detail is presented for the complex conceived to be located in the Eastern Region of the Interior Coal Province; i.e., Kentucky, Indiana, and Illinois. Projected modifications to this design for the Southern Appalachian Region of the Eastern Coal Province, and the Powder River Area of the Rocky Mountain Coal Province are included as Sections 18 and 19 at the end of this report. The principal summary that follows is based on the Interior Coal Province Case.

The scope of the industrial complex is a grassroots facility consisting of a large captive coal mine capable of producing 60,000 TPD of run-of-mine (ROM) coal. A coal preparation plant will produce approximately 45,000 TPD of clean, washed, sized coal from the ROM feed; the clean coal is fed to the coal conversion and power generation facilities.

The complex will produce the following approximate product slate:

- 150 million scfd of SNG
- 13,000 BPD of C_3- LPG

- 2,000 BPD of C_4-LPG
- 35,000 BPD of unleaded gasoline
- 27,000 BPD of distillate fuel oil
- 1,600 TPD of crystalline coke
- 1,000 MW of electrical power

In addition, about 1,700 TPD of sulfur and 185 TPD of ammonia are produced as byproducts.

Process flow sheets and accompanying heat and material balances are presented based on a typical coal analysis that is intermediate between the extreme analyses that might be encountered during a 20-year project life. The equipment was sized to handle this typical coal.

The process portion of the complex consists of four coal conversion steps and 21 additional processes to recover the products and refine them to marketable grades; also to treat the effluents to meet environmental standards.

The four coal conversion steps consist of:

- Hydroliquefaction using SRC-II technology.
- Pressurized flash pyrolysis.
- Synthesis gas production by gasification of char. The synthesis gas serves as a precursor of the hydrogen required for the coal hydroliquefaction as well as for hydrotreating naphtha and heavy coal-derived liquids.
- Fuel gas production by gasification of coal. The fuel gas, after cleanup, is used as fuel for the power plant and also as fuel for process furnaces.

An important point: This process configuration eliminates the need for filters for removal of coal ash and unconverted coal from the hydroliquefaction product stream; it also recovers a significant amount of liquids as salable fuel products, which are normally associated with the filter cake when filtration is used.

The power plant incorporates an improved configuration of a combined cycle system, which interfaces with the coal mine and process complex. It receives energy-containing streams and converts them to power and steam to supply all the utility requirements of the complex plus approximately 1000 MW of power for sale. Bleed air from the gas turbine compressor supplies approximately 40% of the air required as feed for the oxygen plant; taking credit for the power equivalent of this compressed air results in an efficiency of approximately 43% for conversion of fuel gas to electrical power.

The estimated thermal efficiency for the process portion of the complex is about 74%; this is the predicted efficiency for conversion of coal to products/byproducts plus fuel gas supply to the power plant.

The process plant and power plant complex would occupy about a square mile. The plant population, including the mines, process, and power plants, would be approximately 2,800.

The estimated fixed capital investment for the complex is approximately $2.4 billion; all economics are expressed in mid-1977 dollars. The total capital investment is estimated to be about $2.75 billion, exclusive of construction financing costs. The total capital investment includes the cost of initial raw materials, catalysts and chemicals, land acquisition, startup and initial working capital.

The schedule to design, engineer, and construct the complex is estimated to be 60 months. A probable fund drawdown schedule is also presented.

Annual operating costs are estimated to be about $305 million. The required revenue for a 12% discounted cash flow (DCF) rate of return with 65% debt at 9% interest is approximately $725 million. The predicted required average fob product fuel and bus bar power selling prices for these financial parameters, after taking credit for sulfur and ammonia byproducts, are:

Electricity Bus Bar Selling Price in mils/kWh	Average Fuel fob Selling Price In $/MM Btu	$/Bbl (6 MM Btu/Bbl)
20	2.50	15.00
30	2.10	12.60
40	1.75	10.50

Required product selling prices for 100% equity and 0% DCF (breakeven) are also presented.

The required product selling prices are most sensitive to fixed capital investment (capital associated costs) and less sensitive to operating and coal costs. Expressed as percent change in required product selling price per % change in parameters, the sensitivities for the 65% debt case are:

Parameter	Sensitivity
Capital Associated Costs	0.8
Operating Costs	0.4
Clean Coal Cost	0.4

Possible product market values were developed based on comparison of the coal conversion product characteristics with conventional crude oil-based products, and on discussions with petroleum, petrochemical, and utility companies. Using the possible product market values developed, the following possible profitabilities, expressed as DCFs resulted:

- For 65% debt/35% equity, the profitability could be 20% DCF after tax on the equity portion.
- For 100% equity, the profitability could be about 13%.

These economic projections indicate that the complex has the potential to be competitive with alternative energy sources based on incorporation of large efficient captive surface mines and performance of the process and power plant portions of the complex as described here.

Most encouraging is the recent successful performance of the DOE Tacoma, Washington, Pilot Plant while operating in the SRC-II mode. Liquid fuels, with sulfur contents in the range projected in this design, have been produced and the pilot plant has operated more than 60 days continuously.

The 3:1 solvent-to-coal ratio of feed to the coal dissolvers in Unit 12 in this design may be conservative. Recent pilot plant data indicate that a ratio as low as 1.5:1 could be used. This lower rate is a potential improvement and could reduce the fixed capital investment and required product selling prices by 3 to 5%.

Methods of scale-up were carefully considered. The scale-up factor from the SRC pilot plant to this conceptual design was of the order of 400. However, the scale-up factor for the critical dissolver, which liquefies the coal by reaction with hydrogen, is approximately 135. The dissolver vessels specified are the largest that can be fabricated with existing materials, fabrication, and code practices. Methods of scale-up were selected to provide efficiency, operability, and process control.

Concurrent with the development of the conceptual design reported here, the DOE Tacoma, Washington, pilot plant was operating using the SRC-II mode of operation. The potential economic impact of the comparison of recent pilot plant data with the POGO commercial coal conversion complex was evaluated. The comparisons are for the Unit 12 (Coal Dissolving) section of the plant; the fixed capital investment for this section is 10 to 15% of the total complex, and changes in the required product selling price are in the ±5% range.

A comparison of recent pilot plant data with the POGO design showed that some factors would reduce and some would increase the fixed capital investment, and also the required product selling prices. The net change for all factors included in the comparison was essentially zero.

Sections 18 and 19 summarize the second-order technical and economic assessments of captive mines and plants at the two alternate locations mentioned on page 2-1. In both alternate cases, experimental data was limited, requiring extrapolations to complete the conceptual designs.

Alternate 1: Southern Appalachian Region of the Eastern Coal Province presents higher cost mining operations and a process plant comparable to that for the base case location with respect to total products. Compared to the base case, coal composition is lower in volatile matter and sulfur content and higher in fixed carbon content. The result is a lower quantity of SNG and higher quantities of liquid fuels. Overall thermal efficiency is comparable to that of the base case plant.

The required product selling price to achieve a 12% annual discounted cash flow is significantly higher than for the base case.

Alternate 2: Powder River Region of the Rocky Mountain Coal Province presents a lower cost mining operation with higher processing costs compared with the base case plant. The sub-bituminous western coal contains a higher inherent moisture content, averaging about 25%, which requires costly drying equipment and a larger steam and power generation system. The coal feed to the processing plant is higher in volatile matter and lower in fixed carbon content. The result is a product mix that contains proportionately less products in the lower and higher molecular weight ranges and more in the middle liquid fuel range. Overall thermal efficiency is appreciably lower because of the energy required for coal drying. Due to the water scarcity in this area, the design contains no cooling tower. Air cooling is extensively used. Moisture from the coal drying operation is recovered for use.

Required selling price for products from this alternate, for a 12% annual discounted cash flow, is higher than for the base case.