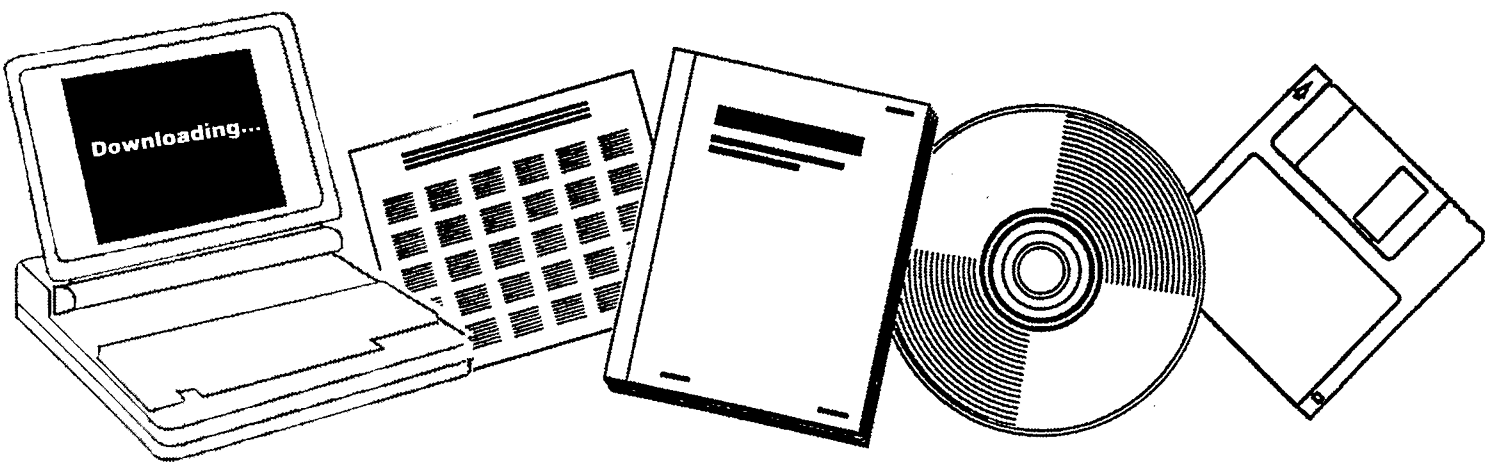
PILOT/PROTOTYPE AND DEMONSTRATION/PIONEER PLANTS FOR THE PRODUCTION OF SYNTHETIC FUELS FROM COAL

USAEC, WASHINGTON, D.C

11 NOV 1974



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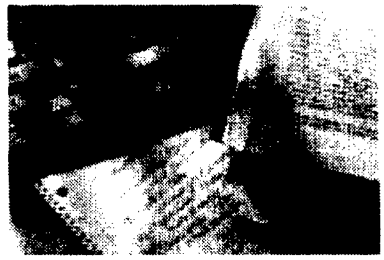

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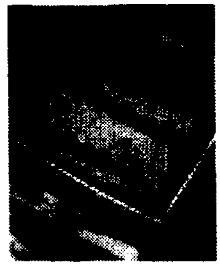

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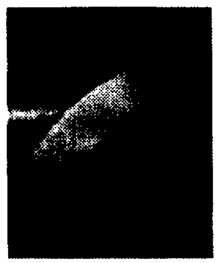

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PILOT/PROTOTYPE AND DEMONSTRATION/PIONEER PLANTS FOR THE PRODUCTION OF SYNTHETIC FUELS FROM COAL

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V. PILOT/PROTOTYPE AND DEMONSTRATION/PIONEER PLANTS FOR THE PRODUCTION OF SYNTHETIC FUELS FROM COAL

SUMMARY

This program topic includes pilot prototype, demonstration, and pioneer projects for the production of clean liquid fuels (e.g., boiler fuels and syncrude), substitute natural gas, and clean solid fuels (e.g., desulfurized and deashed coal) from coal. The projects included in this topic have high visibility and are characterized more by the requirement for management of capital funds, manpower, materials, and resources than for management of pertinent supporting research and development.

Preliminary estimates of the FY 1974 and FY 1975 budgets for these projects are presented in Table 5.1. These projects presently are being funded through the OCR and the Bureau of Mines energy laboratories and, thus, would be transferred to ERDA under HR 11510.

INTRODUCTION

The rapid scaleup and commercialization of promising processes for producing clean gaseous, liquid, and solid fuels from coal is needed to provide energy self-sufficiency. Forecasts of continued high energy growth rates, declining domestic gas and oil reserves with attendent vulnerability to the whims of foreign suppliers, and public-felt fuel shortages have brought demands for rapid technological solutions. The concept of the Pioneer program, a leap over intermediate scales to commercial sized test plants, was one response to this demand.

There is increased support for process development in the pilot/prototype to demonstration/Pioneer size range. This support is shown by an almost fourfold budget increase from FY 1974 to FY 1975.

The large scale process development projects are under contract mainly from the Office of Coal Research. These projects would be transferred to the proposed Coal Programs Division upon the formation of ERDA. The later sections of this chapter will describe currently proposed large scale projects for liquefaction and gasification of coal and present an alternative program that has been proposed by an AEC task force on synthetic fuels.

OBJECTIVES

The purpose of the pilot/prototype and demonstration/Pioneer programs is to develop economical processes for producing clean fuels from coal in a logical, rapid fashion to commercialization. This goal must be met by balancing risks and development costs against benefits from rapid scaleup and acceptance by the nation's energy industries.

SCOPE

This section deals only with the large scale stages of process development. Relationships to support projects and research programs can be found in other sections.

CURRENTLY PROPOSED PROGRAM

Liquefaction

The Office of Coal Research program for coal liquefaction represents a substantial acceleration of effort over previous years. The recent emphasis is on multiproduct coal conversion (rather than a single product process) which can provide a more efficient process with lower unit costs. Clean by-product gas can be used as a fuel for electric generation and also upgraded to pipeline quality gas to supplement natural gas supply. Accordingly, a major objective of the OCR program is its plan for process flexibility - combining complementary processes now being developed separately to emphasize the best features of each component process.

OCR believes that a vital objective is the early demonstration of a plant in an effort to save from 2 to 5 years' lead time over a normal development pace prior to commercialization. A vigorous and adequately

Table 5.1 Summary of Proposed FY 1976 & FY 1977 Funding Allocations for Pilot/Prototype and Demonstration/Pioneer Projects for the Production of Clean Fuels from Coal

	Contractor	Agency	Capacity t/d	Funding Obligations by Fiscal Year, $ Millions							
				*1973	1974	1975	1976	1977	1978	1979	75-79
Liquefaction Pilot/Prototype Plants											
1. Engineering Evaluations		OCR		*0.65	2.10	6.0	5.0	5.0	5.0	5.0	26.0
2. SRC Pilot Plant	P & M	OCR	50	6.11	11.75	6.0	10.0	10.0	10.0	-	36.0
3. COED Pilot Plant	FMC	OCR	36	3.25	3.00	3.0	3.0	-	-	-	6.0
4. Multiple Process Pilot Plant (Cresap)	Fluor	OCR	24	-	3.00	5.0	-	-	-	-	5.0
5. Direct Hydrogenation Prototype Plant	HRI	OCR	250-700	-	4.00	8.0	17.0	38.0	20.0	6.0	89.0
6. Extraction/Hydrogenation Prototype Plant	(RFP)	OCR		-	-	-	-	17.0	20.0	3.0	40.0
7. Fischer-Tropsch Prototype Plant	(RFP)	OCR		-	-	-	19.0	25.0	8.0	8.0	60.0
8. Pyrolysis Pilot Plant					-	-	20.0	20.0	8.0	7.0	55.0
TOTAL				10.01	23.85	28.0	74.0	115.0	71.0	29.0	317.0
High Btu Gas Pilot/Prototype Plants											
1. Engineering Evaluations		OCR		0.90	1.33	1.2	4.0	1.0	-	-	6.2
2. Hygas Pilot Plant	IGT	OCR		4.00	4.67	3.0	2.3	2.0	-	-	7.3
3. CO_2 Acceptor Pilot Plant	Consol	OCR		2.73	6.97	2.0	2.0	2.0	-	-	6.0
4. Bi-Gas Pilot Plant	BCR	OCR		6.40	1.33	13.2	8.0	5.0	-	-	26.2
5. Synthane Pilot Plant	USBM	USBM		6.80	7.03	9.6	6.0	6.5	6.5	2.0	30.6
TOTAL				20.83	21.33	29.0	22.3	16.5	6.5	2.0	76.3
Synthetic Fuels Demo/Pioneer Projects											
1. Design Studies[a]		OCR		-	7.0	17.0					17.0
2. Liquid Fuels Demo # 1		OCR		-	-						
3. Liquid Fuels Demo # 2		OCR		-	-						
4. Second Generation SNG Demo		OCR		-	-	0.7	220.	250.	250.	200.	920.7
5. Low Btu Gas Demo		OCR		-	-						
6. Fluid Bed Combustion Demo		OCR		-	-						
7. Pioneer Plant Projects					-	42.1	100.	125.	100.	50.	417.1
TOTAL					7.0	59.8	320.	375.	350.	250.	1354.8
TOTAL PROGRAM				30.84	52.2	116.8	416.3	506.5	427.5	281.0	1748.1

[a] Includes extensive design studies of plants employing candidate processes including (1) extraction/hydrogenation, (2) direct catalytic hydrogenation, (3) methanol synthesis, (4) Fischer-Tropsch Gasoline Synthesis, (5) Pyrolysis, (6) Hydrocarbonization (7) Second Generation SNG processes, and various combinations such as those exemplified by the COG, SRC-COED, and COGAS concepts.

funded program could lead to commercialization in the early 1980s by using appropriate Federal incentives. Low-sulfur, ash-free, clean-burning liquid fuels from coal can provide fuel for existing power plants as well as for new conventional plants and new advanced cycle power plants. Several processes are available for the demonstration-scale plant development for the production of clean solid, gas, and liquid fuels from coal.

The large scale projects currently underway or planned for FY 1975 include (1) operation of the SRC (Tacoma) pilot plant, (2) continued operation of the COED pilot plant, (3) reactivation of the Cresap pilot plant, (4) design and construction of an H-Coal prototype plant, (5) design of a combined SRC/COED demonstration plant, and (6) design studies and pilot plant development in support of a process for production of liquid fuel from synthesis gas.

1. <u>Engineering Evaluations</u> FY 1974 $ 2.1 millions
FY 1975 $ 6.0 millions

Preliminary reviews are to be made of all OCR projects for coal liquefaction, including their suitability for combining under the COG (Coal, Oil, Gas) objective. Preliminary specifications for a COG plant will be prepared as a second-generation pilot plant. As work proceeds in each of OCR's liquefaction projects, it is particularly necessary to maintain a continuous review of technical and economic status as to the commercial plant that can be projected from the research results. This requires detailed engineering studies by independent third parties. Otherwise experimental work costing far more than the evaluations may be undertaken unnecessarily.

An experienced engineering construction firm will be retained to evaluate technical and cost aspects of the alternative processes for production of clean liquids for coal. This activity will provide information for periodic evaluation of the economic viability of alternative processes. The contractor will have access to computer services and will provide cost engineering and process economic studies and services to private industries and to the U.S. Government in a concerted effort to expedite selection of the most promising process at minimal cost.

2. <u>Solvent Refined Coal (SRC) Pilot Plant</u> FY 1974 $11.75 millions
FY 1975 $ 6.00 millions

In 1962, the Office of Coal Research awarded a research contract to Spencer Chemical Company to study the technical feasibility of the solvent refined coal (SRC) process. In 1966, a contract was awarded to Pittsburg & Midway Coal Mining Company (successor to Spencer Chemical) to study the commercial feasibility of the SRC process through design, construction, and operation of a pilot plant to process 50 tons of coal per day. The design for the pilot plant was completed by Stearns-Roger Inc. in 1969. In late 1971 Rust Engineering Company was selected through competitive bidding to construct the pilot plant at Fort Lewis (Tacoma), Washington; construction was started in July 1972 and completed in November 1973. Following shakedown, sustained operation of the pilot plant is expected to begin in early FY 1975. A smaller 6-ton/day SRC pilot plant, built by Catalytic Inc. under the sponsorship of Southern Services, Inc. and EPRI, is currently in operation in Wilsonville, Alabama.

In the solvent refining process, coal is dissolved in a heavy aromatic solvent under moderate hydrogen pressure. The solution is filtered (to remove ash and insoluble organic material) and fractionated to recover the solvent. Small quantities of hydrocarbon gases and light liquids are produced, along with heavy organic material. Solvent refined coal has a melting point of about 350°F and contains about 0.1% ash and less than 1% sulfur. Its heating value is about 16,000 Btu's per pound regardless of the quality of the coal feedstock. The solvent refining process removes almost all of the inorganic sulfur and 60 to 70% of the organic sulfur in the coal. The SRC product potentially can be upgraded to a low-sulfur liquid boiler fuel by a second stage of catalytic hydrogenation and desulfurization.

The SRC Tacoma pilot plant will be operated in FY 1975 with goals of (1) developing equipment that will permit feasible scaleup to a larger prototype plant, and (2) producing product for testing in power plant boilers. The future of the process will depend upon the development of a technically and economically viable filtration step.

[Comment: An AEC Task Force on Synthetic Fuels has recommended that the Ft. Lewis pilot plant program be expended to provide for (1) investigation of alternative solid-liquid separation methods, and (2) catalytic hydrotreating of the SRC product to produce boiler fuels and/or syncrude.]

3. Char-Oil-Energy Development (COED) Pilot Plant FY 1974 \$3.00 millions
FY 1975 \$3.00 millions

OCR's project COED pilot plant in Princeton, New Jersey, was completed in 1970 at a capital cost of \$4.5 million. The pilot plant, built and operated by FMC Corp., is designed to process 36 tons of coal per day and hydrotreat 30 barrels of coal-derived oil per day. The plant is fully operational at the throughput capacities of coal and oil for which it was designed.

The COED process converts coal to synthetic crude oil, gas, and char, through four-stage fluidized-bed pyrolysis and subsequent hydrotreating of the coal oil to synthetic crude oil. The volatile products released from the coal in the fluidized-bed reactors pass to a product recovery system for recovering the oil and cooling the gases. The oil from pyrolysis is filtered to remove solids. The solids-free oil is pumped up to pressure and mixed with hydrogen from hydrotreating in a fixed-bed catalytic reactor operating at 750°F and 3000 psi. Hydrotreating removes sulfur, nitrogen, and oxygen from the oil and produces at 25° API synthetic crude oil. The gas from the process can be sold as fuel gas or converted by application of additional technology to pipeline gas or hydrogen. The residual high-sulfur char could be used as power plant fuel, gasified to produce a fuel gas or processed to generate hydrogen, again through the application of further technology.

Two subcontracts were issued by OCR for evaluating the COED hydrotreated oil. The Atlantic Richfield Company is processing distillate fractions of the COED hydrotreated oil to determine yields and product quality and to estimate a dollar value of the COED hydrotreated oil. The American Oil Company is performing analytical and burner tests to determine the suitability of the hydrotreated oil as a fuel oil.

The planned work of the pilot plant in FY 1975 is concentrated to acquiring additional data required to design a commercial plant. Other coals will also be evaluated in the process. A substantial quantity of oil will be supplied to the U.S. Navy for their tests, and research is underway on utilization of by-product chars.

The COGAS Development Company (a consortium of FMC Corp., Panhandle Eastern Pipeline Co., Tenneco Inc., Consolidated Natural Gas Service Co., Republic Steel Corp., and Rocky Mountain Energy Co.) currently is investing $7 million of private funds in a COGAS pilot plant that will use the COED process in conjunction with a char gasifier to produce substitute natural gas (SNG) and a synthetic crude oil (syncrude).

[Comment: Since the COED Process produces very low (< 20%) yields of liquids, it is considered primarily as another second-generation SNG process or as a process that would apply primarily on-site at a power plant. Pyrolysis processes similar to COED are being developed with private funds by the Oil Shale Corporation and Garrett Corporation. Related hydrocarbonization processes, which appear to have greater potential for producing a desulfurized char and/or a higher fraction of desulfurized liquids are being developed by U.S. Steel Corp. and Union Carbide Corp.]

4. Multiple Process (Cresap) Pilot Plant — FY 1974 $3.00 million
FY 1975 $5.00 million

A cooperative OCR and Fluor Corporation program for reactivation of the 24-ton coal/day pilot plant at Cresap, West Virginia, provides for testing of and development of various operations required in coal conversion processes such as coal feeding at high pressure, separation of extracted coal liquids from undissolved materials, and gasification of char. The original plant investment was about $6 million; however, the current cost for construction of an equivalent facility would be in excess of $10 million.

The plant can be converted from the original CSF process by changing the physical location of equipment, making changes to individual items of equipment, and modifying piping. Such changes can be accomplished in considerably shorter time than required for construction of completely new facilities and at much less cost. By testing several processes in one plant, maximum use will be achieved for the existing pilot plant.

The initial phase of the program for Cresap involves rehabilitation of the existing plant with modifications to assure reliable mechanical operation quickly for the basic extraction and hydrogenation operations. The modifications will remedy deficiencies experienced during previous operations and include changes necessary to meet current EPA regulations for environmental protection.

Plant operation after operator training and shakedown will demonstrate that solvent generated from coal at equilibrium operations is satisfactory for coal solution, and following hydrogenation of the extract produces a clean fuel. The product will be tested in various combustion systems to determine that fuel quality is satisfactory. Testing will also include sulfur and nitrogen levels to insure meeting environmental protection standards.

Alternate processes will be tested which by engineering analysis are potentially competitive economically. \$2.5 to \$5.0 million will be made available from non-Government sources to augment the requested appropriation. OCR would expect to operate the plant for 3-5 years, depending on processes to be tested.

5. H-Coal Prototype Plant — FY 1974 \$4.00 million; FY 1975 \$8.00 million

Funds will be used to design and construct a prototype plant to develop on a substantial engineering scale the catalyzed hydroliquefaction of coal to produce clean synthetic crude oil. The prototype plant will use the ebullated bed principle. It will represent a reasonable, low-risk scaleup from a Process Development Unit (PDU). The PDU has been operating satisfactorily since 1966. Scaleup factor amounts to 3-8 tons coal per day for the PDU to 250-700 tons coal per day for the prototype plant for production of synthetic crude from coal. Approximately one-third of the total costs for this project will come from the private sector - a consortium of Hydrocarbon Research, Inc. (HRI) and several petroleum companies.

[Comment: This project is considered important because it is believed that the H-Coal process currently is the most highly developed of the modern coal liquefaction processes and has the highest potential for early commercialization. It is equally important, however, that this project be backed up with a strong program for supporting research and development in process chemistry, process engineering, and health and environmental effects.]

6. Future Prototype Plant Projects

OCR is projecting that three future pilot or prototype scale projects involving (1) Extraction/Hydrogenation, (2) Fischer-Tropsch, and (3) Pyrolysis processes would begin in FY 1976.

[Comment: We would recommend immediate design and construction of an Extraction/Hydrogenation Prototype.]

High Btu Gas

In 1971, OCR and the American Gas Association (AGA) entered into an agreement covering three second generation coal gasification pilot plant projects (Hygas, CO_2-Acceptor, and Bi-Gas) and supporting projects to jointly provide funding (two-thirds by Government and one-third by industry) of $30 million annually beginning with FY 1972. A fourth second generation pilot plant (Synthane) will be operated by the Bureau of Mines. It is estimated that this pilot plant program should lead to demonstration of commercial feasibility of a second generation process for gasification by the end of FY 1979 and FY 1980.

Engineering Evaluations	FY 1974	$1.33 millions
	FY 1975	$1.20 millions

The contractor evaluates proposed research and assists the continuous evaluation of all phases of the high-Btu coal gasification program. It is essential that independent engineering evaluations be made as each process or process step is developed. The contractor will prepare engineering designs and cost estimates for processes and process variations, projecting from these figures a final cost figure for the product-gas. (Additionally, this work will facilitate termination of projects if they do not meet the technical and economic yardsticks established among the alternates.)

A highly qualified, unbiased engineering firm is vital to the program for evaluation of the various processes and components of processes to assist in the decision-making procedure to insure that the best results of the program are selected for commercialization to produce pipeline-quality gas at the lowest possible cost.

Hygas Pilot Plant	FY 1974	$4.67 million
	FY 1975	$3.00 million

The Hygas pilot plant in Chicago for conversion of coal to pipeline-quality gas represents a capital investment of about $10 million. It is designed to convert 75 tons of coal per day to 1.5 million cubic feet of high Btu gas. The Institute of Gas Technology (IGT) gasification program was initiated in 1946 under sponsorship of the American Gas Association. The early origin and continued development of the concept is largely the reason that the Hygas process is the most advanced of the second generation coal-to-gas schemes under development.

In this process, ground, dried coal is pretreated with air, slurried with by-product oil, and fed to a two-stage fluidized-bed hydrogasifier that is to operate at 1000-1500 psia. Hydrogen-rich gas for the reaction is to be furnished by processes using electric energy or oxygen or by the steam-iron process that is under development. The gas from the hydrogasifier is to be purified and methanated to produce 950+ Btu/scf substitute natural gas.

Pilot plant construction began in 1969 and was completed in 1971. Several significant operating runs have been made, the most notable being successful operation at 1000 psi. Concentration of methane in the hydrogasifier effluent exceeded 40%. This corresponds closely to the design concentration. Operating problems with essentially off-the-shelf mechanical equipment delayed initial gas production. Problems are being solved one at a time and semicontinuous operation of the hydrogasifier has been achieved. The gas purification and methanation systems have been checked out and are on standby awaiting continuous operation of the hydrogasifier.

CO_2 Acceptor Pilot Plant	FY 1974	\$6.99 million
	FY 1975	\$2.00 million

The CO_2 Acceptor Coal Gasification process was developed by Consolidation Coal Company and carried through the laboratory stage by 1964 when the Office of Coal Research awarded a contract to complete the bench-scale development of the process. This phase was completed successfully in 1968. Feasibility studies before and after the bench-scale work indicated the process had potential commercial possibilities.

In this process lignite or subbituminous coal is charged to a fluidized-bed devolatilizer and is contacted at 300 psi with hydrogen-rich gas from a fluidized-bed gasifier. Lime or dolomite is added to both vessels where it reacts with carbon dioxide. Regeneration of the lime-dolomite and ash removal ~~are~~ is carried out in an air-blown fluidized-bed regenerator vessel where spent char is combusted. The product gas is to be purified and methanated to produce SNG.

Construction of the $9.3 million pilot plant at Rapid City, South Dakota (capacity 40 tons coal/day), was initiated in January 1970 and completed in November 1971. The pilot plant was constructed and is being operated by Stearns-Roger Inc. under subcontract to Consolidation Coal Company.

At the completion of plant shakedown tests in April 1972, a series of startup attempts was initiated. Each completed startup has generated additional operating data. Each run was terminated due to some mechanical problems which have since been solved. In FY 1975 the pilot plant will be operated with a new methanation stage that is being installed by Blaw-Knox at a capital cost of $1.7 million.

<u>Bi-Gas Pilot Plant</u>	FY 1974	$1.33 millions
	FY 1975	$13.2 millions

The Bi-Gas process, developed by Bituminous Coal Research, Inc., features a two-stage reactor, which operates an entrained bed system, to gasify ground, dried coal at a pressure of 1110 psig. Fresh coal introduced into the upper section of the vessel contacts a rising stream of hot synthesis gas produced in the lower section. The coal is partially converted into methane and more synthesis gas. The residual char is separated from the gas stream and then is transferred into the bottom section where it is completely gasified by reaction with oxygen and steam. This produces the synthesis gas needed in the upper section, as well as the heat required to complete the endothermic reaction of carbon with steam. Slag is periodically removed as granulated particles via a lock hopper system.

Raw gas from the gasifier is freed of dust, passed through a shift converter, its H_2S removed, and then run through a high-pressure CO_2 absorber. Following further purification over iron oxide and activated carbon, a catalytic methanator gives a product which, after drying, is pipeline quality. The Bi-Gas process has potential for very high throughput per unit of reactor volume and apparently will handle all types of coal from lignite to high volatile bituminous.

A fully integrated, 120-ton coal/day pilot plant currently is being constructed by Stearns-Roger Inc. at Homer City, Pennsylvania. Initial startup of this pilot plant, having capital cost of about $25 million, is scheduled for mid-FY 1975.

Synthane Pilot Plant	FY 1974	$ 7.0 million
	FY 1975	$ 9.6 million

In the U.S. Bureau of Mines Synthane process, the caking properties of the dried coal are destroyed by treating with steam and oxygen in a fluidized pretreatment reactor. About one-eighth of the total steam and oxygen required in the process is fed at this stage. The coal, along with any separated volatile matter and excess steam, is then fed to the top of the fluid bed gasifier which operates at about 1000 psia. Here the coal reacts with steam and oxygen to form methane, CO, H_2, and CO_2. Not all of the carbon reacts, however. Char, amounting to about 30% of the heat content of the coal, is removed from the bottom of the reactor and is to be burned to provide process pretreatment step. These impurities are removed in cyclone separators and by water scrubbing.

The cleaned product gas is divided into two streams, one-third going to a shift converter while the remainder bypasses the unit. This step provides the hydrogen needed for methanating the CO contained in the bypass gas stream. The two streams are combined after the one-third from the shift converter has been cooled by heat exchange with the feed gas. Following further cooling and purification, the combined gas stream is charged to the methanator.

This reactor contains a Raney nickel catalyst sprayed on the surface of heat exchange steel tubes. Dowtherm is circulated on the tubes to maintain catalyst temperatures at the desired level. Reaction of the CO and H_2 results in the formation of methane and water vapor. Thus removal of the latter produces SNG of pipeline quality.

A pilot plant, with capacity of 75 tons coal/day, was designed by the Lummus Company and currently is being constructed by Rust Engineering Company in Bruceton, Pennsylvania. This pilot plant, with estimated capital cost of $10 million, is scheduled for initial operation at the beginning of FY 1975. The pilot plant will be used to develop the main steps of the process but is not designed to address the problems of water treatment and char combustion.

Synthetic Fuels Demo/Pioneer Projects

Design Studies

FY 1974 $ 7.0 millions
FY 1975 $17.0 millions

The OCR has initiated several design studies of demonstration plants. The current emphasis is being placed on a single demonstration plant that will incorporate both the SRC and COED since it is stated that these two processes have various components in common and the combined demonstration plant will have significantly lower cost than separate demonstration plants.

The proposed demonstration plant will have capacity for demonstrating the SRC process at a rate of 10,000 tons coal/day, representing a scaleup factor of approximately 200 in capacity relative to the SRC pilot plant in Tacoma, Washington. The prototype plant design will remain flexible with respect to separation and hydrogenation systems until substantive operating data are obtained from the Tacoma pilot plant and the Cresap operation. The demonstration plant is scaled to define economics for producing a No. 5 (0.5% sulfur maximum) fuel oil and a No. 4 (0.2% sulfur maximum) fuel oil. Prototype plant unit costs of $1.25 to $1.50 per million Btu's are indicated utilizing coal priced at 35¢ per million Btu's. Commercial costs for the oil may be 85¢ to 95¢ per million Btu's.

The COED process will be combined with a pressurized boiler, with the following operational objectives: (1) operation of the COED process at pressure to increase throughput rate and liquid yield, (2) consumption of the char in a sophisticated pressurized boiler to provide energy required for the potassium topping cycle for power generation to permit increase in the conversion of thermal energy to electrical energy (50-55%), and (3) control of the sulfur products generated when the char is burned.

[Comment: This project is not recommended by the AEC task force on synthetic fuels because it involves a very high risk scaleup of the yet unproved SRC process in a facility that will cost several hundred million dollars. An alternative project proposed by a consortium led by the Old Ben Coal Company to construct a 900-ton coal/day SRC prototype plant is recommended as a less risky and probably faster way to provide for early commercialization of an extraction/hydrogenation process. This later project, costing about $73 million, would be expected to have substantial private funding.]

Another design study, a project, which would be performed by Vulcan Cincinnati and B&W under OCR sponsorship, has the objective of evaluating the most advanced technology for producing clean liquid fuels from a coal-derived synthesis gas and developing an economic design for a commercial scale plant. This program involves pilot-scale investigation of synthesis gas production from coal as required to demonstrate capability for production suitable for conversion to clean liquid fuel by advanced Fischer-Tropsch processes and methanol production processes. The project includes comprehensive engineering evaluation and conceptual design of an advanced commercial-scale plant for production of clean liquid fuels from synthesis gas generated from coal.

[Comment: The AEC task force questions this project because it may represent a restrictive commitment to a single type of gasifier and synthesis process. It is suggested that this type of project would better be handled with a request for proposals to the several chemical, petroleum, and architect-engineer firms (e.g., Kellogg, Davy Powergas, Continental Oil, Fluor) who have experience in production of synthesis gas from coal and the synthesis of methanol and gasoline.]

Demonstration Plant Projects FY 1975 $ 0.7 millions

Several types of demonstration plant projects are planned to be initiated in FY 1976 on the basis of Requests for Proposals and 50-50 cost sharing of government and industrial funds. The planned demos include those for (1) liquid boiler fuels, (2) liquid fuel by a Fischer-Tropsch variation, (3) production of SNG with a second generation process, (4) low Btu gas, and (5) fluidized bed combustion.

[We will comment on this and recommend an alternative strategy in the last section of this document.]

Synthetic Fuels Pioneer Program FY 1975 $42.1 million

The Synthetic Fuels Pioneer Program is an as-yet poorly defined new line item - budgeted for $42.1 million in FY 1975 - that OCR plans to use to stimulate the rapid commercialization of synthetic fuels processes that require relatively minimal modifications of existing technologies. As originally described in the Dixy Lee Ray report to the President, it was contemplated that $355 million of government funds would be expended over a five-year period to subsidize industrial development, design, construction, and operation of two commercial-sized plants that would produce methanol and gasoline by coupling existing first generation coal gasification processes (e.g., Lurgi, Koppers-Totzek, Winkler) with existing processes for production of methanol (e.g., ICI process) and gasoline (e.g., Sasol Fischer/Tropsch) from synthesis gas. The preliminary indications are that OCR may plan to fund a variety of projects that will boost the development of several of the most advanced second generation liquefaction and gasification processes.

[Comment: There is a basic conflict in the definition of "Pioneer Plant" as used in the Dixy Lee Ray report and as used in the OCR budget documents. In the Ray report a Pioneer plant was a first commercial plant employing a given process (and generally which could be built immediately using existing technology.) In the OCR budget documents a "Pioneer plant" is generally a "piggyback" application to an existing plant - which we would prefer to call a "demonstration."]

An alternative synthetic fuels pioneer program recently was proposed by an AEC task force on synthetic fuels that examined several alternatives in response to Project Independence. These recommendations are discussed in the following section.

RECOMMENDATIONS OF AEC TASK FORCE ON SYNTHETIC FUELS FROM COAL

The proposed $10 billion energy R&D program, recommended to the President on December 1, 1973, was concerned with the structuring of an orderly and well balanced effort aiming to support near term objectives while maintaining both mid-term and long-term objectives in perspective. This program recommended several large-scale projects to further develop the production of synthetic fuels from coal, including: (1) an 80 million ft^3/day second generation high-Btu gas demonstration plant operational by 1980, (2) two advanced liquefaction prototype plants operational by 1978, and (3) two commercial scale pioneer plants using existing liquefaction technology for operation by 1980.

In response to more recent developments, this section provides background information in support of a proposed supplementary synthetic fuels demonstration program which is a recommended next step of an urgent national program to build productive capacity for massive quantities of liquid and gaseous fuels from coal. In view of the transportation fuels crisis and because commercial scale production of high- and low-Btu gas from coal is already being planned by several utilities, production of liquid fuels is assigned high priority.

It is the judgment of many experts that synthetic natural gas (SNG) from coal can and should be produced on a commercial scale using the existing first generation technology. Second generation processes for SNG production potentially will improve the economics (perhaps by about 20%) but these technologies are not directly required to respond to the need for increased productive capacity. It is also a general consensus that the economics of existing processes for liquefaction of coal (e.g., Bergius and Fischer-Tropsch) are so unfavorable with respect to those of the developing processes (e.g., H-Coal and SRC) that it will be preferable to build an industry based upon the new technology while conducting a co-current program to complete the necessary research and development.

The recommended synthetic fuels demonstration program would create a government-industry management system with the specific goal of providing the commercial scale development that will be required for a massive synthetic fuels production industry in the 1980s. Specific aspects of this program include: (1) removal of governmental and other obstacles and provision of incentives to accelerate the present and follow-on commercial projects for the production of high-Btu gas from coal, (2) acceleration of the synthetic fuels pioneer program with higher government funding to compensate for the higher risk, and (3) expansion of the liquefaction prototype plant and synthetic fuels pioneer programs to increase the probability of technological success. The technology exists for extraction of the coal that would be required as a raw material for a synthetic fuels industry. Work is required, however, to minimize the impact of coal mining on the environment and to provide the necessary manpower, materials, equipment, and services for rapid expansion of the mining industry.

Tables 5.2 and 5.3 present a summary of many of the important physical and economic characteristics of four types of liquefaction processes that are believed to have significant potential for industrial-scale implementation by the early 1980s. Several conclusions have been drawn from these data, together with other considerations expressed in the previous sections:

1. The processes for production of syncrude or boiler fuel by direct catalytic hydrogenation or extraction-hydrogenation appear to have significant potential for commercialization with relatively low technical and economic risk. For each type of process the recommended next scale of development would be a prototype plant with a capacity of 300 to 1000 tons/day of coal. The prototype scale of development could begin immediately for these two types of processes (and perhaps one other, depending on results of further studies) since:

   a. Such projects already have sponsors who will provide a substantial fraction of private funds.

   b. Machinery exists within the government to begin projects of this scale.

   c. The prototype plants constitute a logical next step in scale before pioneer full-scale commercial plants, but are sufficiently small to minimize environmental impacts, permit flexibility in design, and reduce the consequences of technological failure.

Table 5.2. Comparison of Processes Considered for Production of Synthetic Fuels from Coal

All costs expressed in 1973 dollars.

Process or Plant	Direct Hydrogenation		Extraction/Hydrogenation		Fischer-Tropsch		ICI		WESCO	El Paso
Principal Product	Syncrude		Boiler Fuel		Gasoline		Methanol		CH3	
Type of Plant	Prototype	Commercial	Prototype	Commercial	Commercial	Commercial	Commercial	Commercial	Commercial	Commercial
Type of Coal	Bituminous[a]	Bituminous[a]	Bituminous[a]	Bituminous[a]	Subbit.[b]	Subbit.[b]	Subbit.	Subbit.	Navaho	Navaho
Type of Gasifier	Advanced	Advanced	Advanced	Advanced	Lurgi	Advanced	KT	Lurgi	Lurgi	Lurgi
Input										
As-received coal, tons/day	1,040	35,300	1,144	43,800	148,000	97,500	40,800	25,950	25,620	25,950
Electricity, kW	7,450	257,000		400			-	-	28,500	-
Water, gpm	405	14,100		14,500	160,000	111,000	14,800	6,200	5,100	5,000
Total energy, 10^9 Btu/day	23.2	782	27	1,000	2,600	1,710	724	461	440	460
Output										
High Btu fuel gas, 10^9 Btu/day	-	110	6.2	-	-	-	-	176	238	238
Liquid fuel, bbl/day	2,260	82,510	2,100	101,520	100,000	100,000	154,000	38,700	-	-
, tons/day				18,520	12,600	12,600	20,000	5,000	-	-
, 10^9 Btu/day	13.8	470	11.5	627	576	574	391	98	-	-
By-products, tons/day	18	1,566		1,280	8,600	8,600	400	2,200	1,580	
Waste gases, tons/day				77,720	30,700	20,300	-	-	17,400	
Waste water, gpm	130	4,900	100	4,260	28,100	18,500	12,000	1,000	1,000	
Solid wastes, tons/day	120	4,100	150	2,040	30,100	19,900	2,000	4,700	6,400	
Total Capital Investment, $ Millions	60.5	685	62	832	2,293	1,490	752	521	456	455
, $\$/10^6$ Btu/yr	13.3	3.58	10.5	4.02	12.1	7.91	5.83	5.78	5.82	5.80
Annual Operating Cost, $ Millions[c]	9.78	143	7.23	175	261	211	89	47	60.9	49.3
, $\$/10^6$ Btu	2.15	0.75	1.24	0.65	1.38	0.97	0.69	0.52	0.78	0.63
Fuel Production Costs										
High-Btu gas, $\$/10^6$ Btu	-	1.57	-	-	-	-	-	-	1.53	1.51
Liquid fuel, $\$/10^6$ Btu	5.3	1.57	3.70	1.79	4.58	3.07	2.06	1.87	-	-
, \$/bbl	32.1	8.94	20.3	11.0	24.2	16.2	5.60	5.08	-	-
Process Efficiency, %	60	74	65	63	22.1	33.5	45	59	67	63
Manpower										
Engineering, my	96	930	96	1100					635[d]	
Construction, my	390	3,710	390	4500					5,700	
Operation, my/yr	200	840	300	930					612	
Steel for Construction, 10^3 tons	10	96	11	150					50-60	

[a] Midwestern Bituminous Coal at \$7.50/ton.

[b] Western strip-mined subbituminous coal at \$3.00/ton.

[c] Including by-product credits.

[d] Mine requires 96 my for engineering, 3500 my for construction, and 40,000 tons steel.

Table 5.3. Estimated Effects of Type of Process, Type of Coal, Cost of Coal, and Capital Fixed Charge Rate on the Cost of Producing Several Synthetic Fuels from Coal

Product	Process	Coal Type	Coal Cost $/Ton	Capital Fixed Charge Rate %	Product Cost $/10^6 Btu	Product Cost $/bbl
Syncrude[a]	H-Coal	Bituminous	7.50	23.4	1.57	8.94
		Bituminous	8.50	23.4	1.63	9.30
		Bituminous	7.50	17.9	1.37	7.77
		Subbituminous	3.00	23.4	1.59	8.93
		Subbituminous	4.00	23.4	1.68	9.44
		Subbituminous	3.00	17.9	1.36	7.63
Boiler Fuel	SRC, Consol	Bituminous	7.50	23.4	1.79	11.0
		Bituminous	8.50	23.4	1.86	11.5
		Bituminous	7.50	17.9	1.56	9.65
Gasoline	FT-Lurgi	Subbituminous	3.00	23.4	4.58	24.16
		Subbituminous	4.00	23.4	4.87	25.70
		Subbituminous	3.00	17.9	3.85	20.34
	FT-BiGas	Subbituminous	3.00	23.4	3.07	16.20
		Subbituminous	4.00	23.4	3.26	17.20
		Subbituminous	3.00	17.9	2.60	13.70
Methanol	KT-ICI	Subbituminous	3.00	23.4	2.06	5.60
		Subbituminous	4.00	23.4	2.16	5.88
		Subbituminous	3.00	17.9	1.74	4.72
	Lurgi-SNG	Subbituminous	3.00	23.4	1.87	5.08
		Subbituminous	4.00	23.4	1.97	5.35
		Subbituminous	3.00	17.9	1.67	4.54
SNG	Lurgi	Subbituminous	b	23.4	1.93	
		Subbituminous	b	17.9	1.61	
		Subbituminous	b	16.7	1.54	

[a] Gasoline produced from this material would be higher in cost by about $2.0 to 2.5/bbl.

[b] Capital and operating costs of mining operation included with gasification plant.

2. It appears that the Fischer-Tropsch process for production of gasoline will be too expensive and too wasteful of energy to arouse industrial interest.

3. The data indicate that methanol from coal as a substitute automotive fuel will be less expensive than gasoline from Fischer-Tropsch but probably will be more expensive than gasoline derived from syncrude produced by catalytic hydroliquefaction of coal. The most important advantage of methanol from coal is that the required technology is available now. Thus production on an industrial scale could proceed with a minimum of delay.

Recommended Demonstration Program. - The recommended schedules and incremental funding for a joint government-industry program to demonstrate liquefaction technology are presented in Tables 5.4 and 5.5. Specific objectives of this program are as follows:

1. Conduct joint programs from July 1974 to July 1977 to design, construct, and shakedown three prototype (capacity 300 to 1000 tons coal/day) plants - H-Coal Syncrude, SRC-Hydrogenation for boiler fuel, and a third type (a modified CSF or hydrocarbonization). These plants are believed to represent the optimum size to provide the fastest and minimum risk path from present development work to commercial plants. Such prototype plants are generally favored by industry and substantial (perhaps 1/3) investment of private funds can be expected because of the relatively low (about $60 million) capital costs of these plants.

The present plan is that these prototype plants would be built at sites that are already highly industrialized (petroleum refineries, petrochemical complexes, or large power plants) and, thus, will have small incremental environmental impact. These sites will have (a) trained personnel, (b) technical services, (c) supplies of coal and/or other raw materials, and (d) facilities for testing of the products.

2. Conceptually design, collect base line data on sites, and prepare generic environmental impact statements for two pioneer hydroliquefaction plants (~50,000 tons coal/day) in the period July 1974 to July 1976. Design, construct, and shakedown these two pioneer plants in the period

Table 5.4. Incremental Government Funding for the Recommended Program for Demonstrating the Production of Synthetic Fuels from Coal.

	Fiscal Year Costs, $Millions					
	1975	1976	1977	1978	1979	Total
ER & D Program for Coal						
Coal Liquefaction	75	75	75	75	75	375
R&D, Other Operating Expenses	(57)	(45)	(43)	(46)	(55)	(246)
Construction-SRC Pilot Plant	(4)	-	-	-	-	(4)
Direct Hydrogenation Prototype Plant	(8)	(20)	(18)	(3)	-	(49)
Advanced Process Prototype Plant		(2)	(8)	(23)	(20)	(53)
Multiple Process Pilot Plant	(6)	(8)	(6)	(3)	-	(23)
Two Synthetic Fuel Pioneer Plants	100	100	55	50	50	355
High Btu Gasification	35	75	92	81	57	340
R&D, Other Operating Expenses	(14)	(25)	(47)	(49)	(53)	(188)
Construction-Hygas Pilot Plant	(2)	(2)	(4)	(2)	-	(11)
- CO_2 Acceptor Pilot Plant	(2)	-	-	-	-	(2)
- Synthane Pilot Plant	(8)	(7)	(2)	-	-	(17)
- Bi-Gas Pilot Plant	(9)	(12)	-	-	-	(21)
- Demonstration Plant		(28)	(39)	(30)	(4)	(101)
Mining	45	57	64	77	82	325
Direct Combustion	30	35	40	44	51	200
Low Btu Gasification	30	37	42	48	43	200
Environmental Control Technology	70	50	42	45	53	260
Supporting R&D	20	22	24	27	27	120
	405	451	434	447	438	2175
Recommended Incremental Funding for Synthetic Fuels Demonstration Program						
Construction a/						
Direct Hydrogenation Prototype Plant	2	5	-13	-3		-9
Extraction/Hydrogenation Prototype Plant	10	25	5			40
Third Prototype Plant	10	23	-3	-23	-20	-13
Methanol Pioneer Plant	0	0	0	0	0	0
Second Pioneer Plant	0	0	150	0	0	150
Third Pioneer Plant	0	0	150	0	0	150
Fischer-Tropsch Design Studies	5	15	-	-	-	20
First Generation SNG Production	5	20	20	10	10	65
Supporting R&D, Operations	30	45	77	100	95	347
	62	133	386	84	85	750

a/ Assumes government provides 2/3 and 20% of capital for prototype and pioneer plants, respectively.

Table 5.5 Recommended Schedules

	Fiscal Year						
	1974	1975	1976	1977	1978	1979	1980
Task 1. H-Coal Syncrude Production							
Process Develop. Unit (3 tons/day)							
Operation							
Prototype Plant (300-700 tons/day)							
Conceptual Design and Review							
Engineering and Procurement							
Construction and Shakedown							
Operation							
Pioneer Commercial Plant							
Conceptual Design and Review							
Engineering and Procurement							
Construction and Shakedown							
Operation							
Task 2. SRC Boiler Fuel Production							
Wilsonville Pilot Plant (6 tons/day)							
Complete Construction, Shakedown							
Operation							
Tacoma Pilot Plant (50 tons/day)							
Complete Construction, Shakedown							
Retrofit for Hydrogenation							
Operation							
Prototype Plant (900 tons/day)							
Conceptual Design and Review							
Engineering and Procurement							
Construction and Shakedown							
Operation							
Pioneer Commercial Plant							
Conceptual Design and Review							
Engineering and Procurement							
Construction and Shakedown							
Operation							
Task 3. Alternate Liquefaction Process							
Prototype Plant							
Conceptual Design and Review							
Engineering and Procurement							
Construction and Shakedown							
Operation							
Task 4. Fischer-Tropsch							
Pioneer Commercial Plant							
Conceptual Design							
Title I Engineering							
Task 5. Methanol							
Pioneer Commercial Plant							
Conceptual Design and Review							
Fuel Application Demonstration							
Engineering and Procurement							
Construction and Shakedown							
Operation							
Task 6. Substitute Natural Gas							
Promote Industrialization							
Task 7. Siting, Health, and [illegible]							

July 1976 to July 1979. Government funding of about 20% of the capital costs of these plants may be required because there is some risk that engineering funds would be wasted since the engineering would begin before operation of the prototype plants. It may also be necessary to waive the formal environmental impact review for these plants.

3. After detailed conceptual design and siting studies, engineer, construct, and shakedown a pioneer commercial (~5000 tons MeOH/day) plant in the period January 1975 to January 1979.

4. Conceptually design and perform Title I engineering of a commercial Fischer-Tropsch gasoline plant in the period July 1974 to July 1976 for reference and standby construction.

5. Accelerate the pace of supporting research and development of liquefaction as a coordinated extension of the $10 billion energy R&D program.

The recommended synthetic fuels development program also includes provisions for accelerating the development of the industry for the production of SNG from coal. The recommended activities include (a) engineering development of a slagging Lurgi gasifier, (b) engineering development of a high-pressure Koppers-Totzek gasifier (to permit wider use of coals), (c) site studies (collecting base line data on potential commercial sites), (d) preparation of generic environmental impact statements, (e) accelerated research in environmental effects, (f) development of advanced materials, catalysts, and equipment components, (g) additional development of the methanation step, (h) institutional research, (i) development of services and capabilities for process vessel manufacturing, and (j) development of standards to minimize the routine design requirements.

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