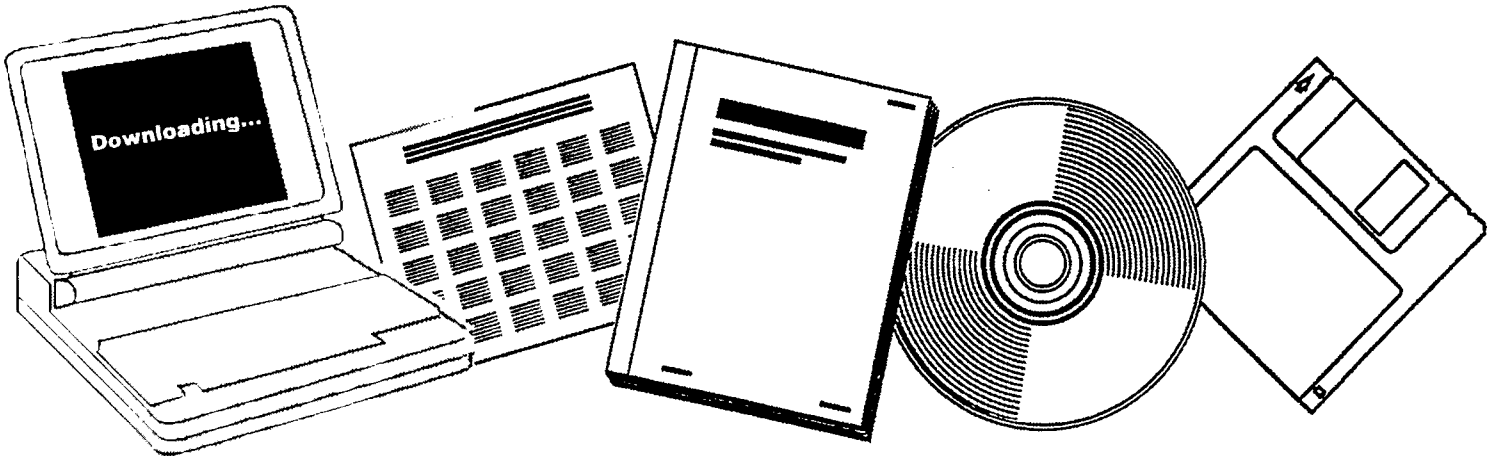
COMMERCIALIZATION STRATEGY REPORT FOR COAL LIQUEFACTION

DEPARTMENT OF ENERGY
WASHINGTON, DC

1979



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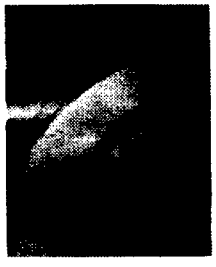

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COMMERCIALIZATION STRATEGY REPORT

FOR

COAL LIQUEFACTION

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PREFACE

This proposed report is one of a series of reports being developed by a task force of Department of Energy personnel to examine new energy technologies for commercialization. Each task force has as its focus a single technology. In this first preliminary review, no attempt has been made to achieve balance or consistency among the several technologies. The Department of Energy has not approved or adopted this proposed report and the report does not represent Department policy.

This specific report is designed to begin to answer questions concerning the commercial readiness of Coal Liquids. The report identifies some of the barriers to be overcome before this technology is ready to be used commercially. The report also identifies possible actions that might be considered to remove specific barriers. The full implications of the various proposed actions have not been fully developed and many actions listed undoubtedly have substantial problems associated with them. Their inclusion here does not constitute an endorsement of their soundness or appropriateness by the Department of Energy.

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PART I

CONCEPT STATEMENT

Hydrocarbon liquids supply roughly half of the energy used in the United States. Increasing consumption coupled with decreasing domestic production have boosted imports of oil to almost half of the amount consumed in the U.S. The level of petroleum importation has two negative impacts; a potential cutoff of supply by producing countries, and a large negative impact on the balance of trade. This report assesses the commercialization of coal liquefaction which is one of the potential solutions to this problem.

CANDIDATE DESCRIPTION

There are two basic processing routes to coal liquefaction as seen in the following two diagrams.

Indirect Liquefaction

In this approach, the coal is first gasified to produce a synthesis gas (hydrogen and carbon monoxide) which is then catalytically converted to liquids. There are two classes of commercially available technologies for converting synthesis gas to liquids. Methanol plants use any of five different licensed processes for this conversion. The methanol industry generates its synthesis gas by steam reforming of methane although coal was used until the early 1950's. The other commercially available technology, Fischer-Tropsch, converts synthesis gas to a variety of hydrocarbon and oxygenated products. This process has been practiced for over 25 years in South Africa. In the Fischer-Tropsch approach the product recovery and purification needs are extensive.

One advantage of indirect liquefaction is that the sulfur, oxygen, and nitrogen in the coal are removed as hydrogen sulfide (H_2S), water (H_2O), and ammonia (NH_3). As a result, the indirect liquefaction liquid products are essentially pollutant free. Thermal efficiency is low, however, roughly 45-60%. Liquid yields are in the range of 1.6-1.7 barrel fuel oil equivalent (FOE)/ton of coal for Fischer-Tropsch and 2.2-2.5 for methanol.

Direct Hydrogenation

In this approach, coal is slurried in a process derived oil and reacted in a hydrogen atmosphere under high temperature and pressure. A feature of this method is a necessary solid-liquid separation step

Figure 1

Generalized Indirect Liquefaction Flow Diagram

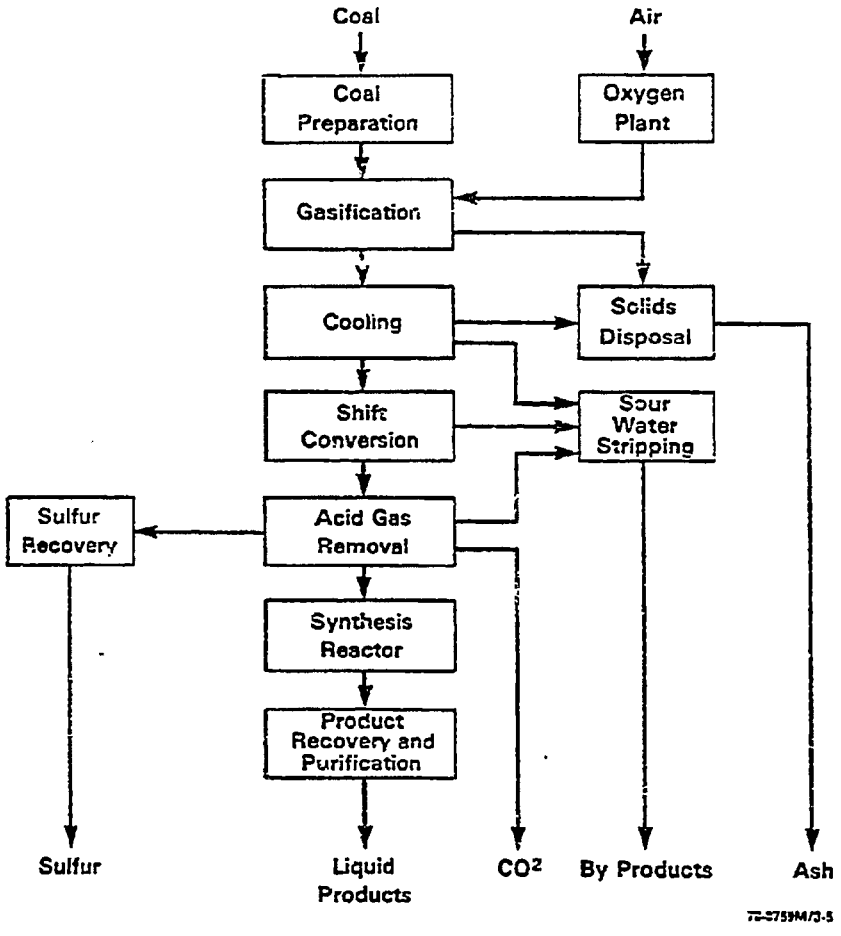
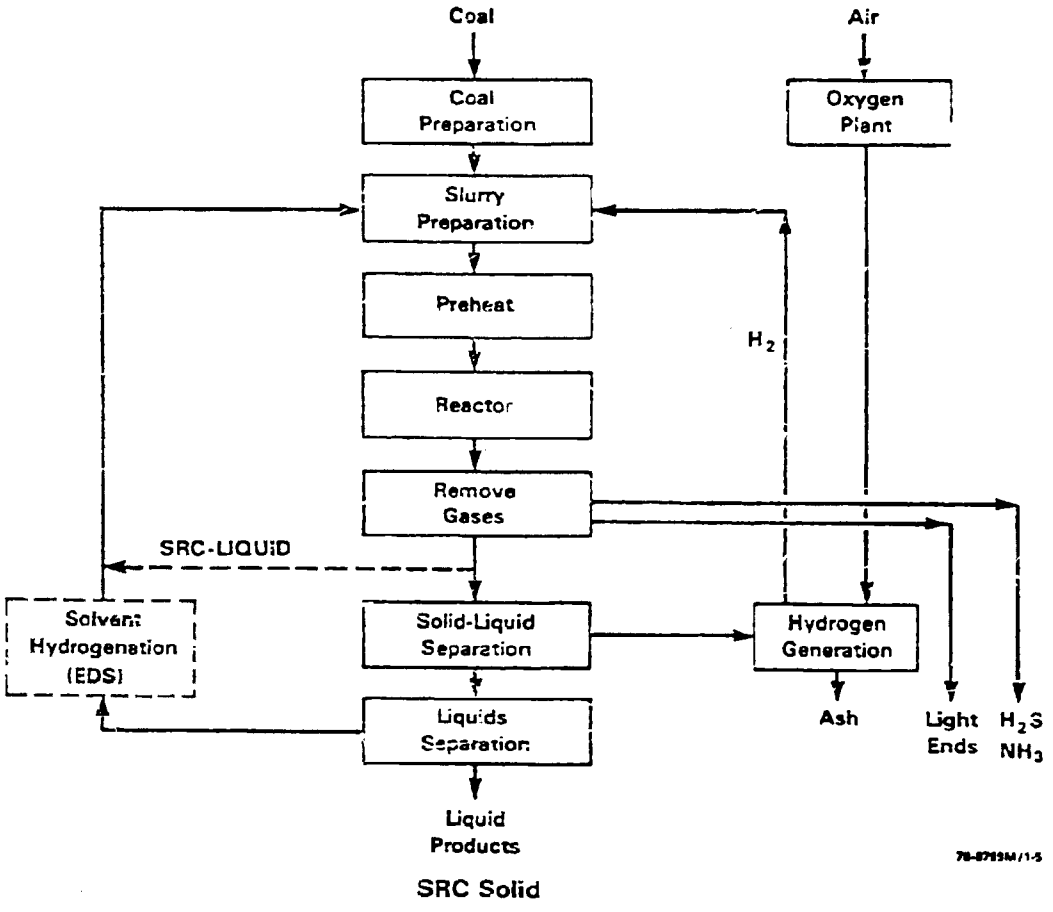


Figure 2

Generalized Direct Liquefaction Flow Diagram



after the hydrogenation reactor to remove unreacted coal and ash. The unreacted coal is gasified in a manner similar to the indirect liquefaction route to provide the required hydrogen. This approach is the major thrust of DOE's liquefaction program. The liquid products from these processes include large amounts of distillate material which should be considered as feedstocks for hydrotreating and production of petroleum-like products.

Sulfur and nitrogen removal is not as great by this route as by the indirect liquefaction route. The thermal efficiencies for direct liquefaction products are in the range of 65-70%. Yields are in the range of 2.5-3 barrel FOE/ton coal. At this point in their development, the greater thermal efficiencies and yields of the direct hydrogenation processes produce products which are less expensive than the indirect processes.

DEVELOPMENT HISTORY

Both direct and indirect liquefaction routes were practiced on a relatively small scale by the Germans and British prior to and during World War II. In the early 1950's a Fischer-Tropsch plant was constructed by SASOL in South Africa. After a difficult start-up period which involved revamping part of the plant, SASOL has been producing liquids from coal for over 25 years. A much larger companion plant based on the original SASOL technology and experience is now being constructed and will start up in 1980-81.

The prime objective of DOE's liquefaction program is to improve performance and economics by operating at less severe conditions and on a larger scale from these earlier efforts. There are six candidate processes which have demonstrated technical feasibility and should be considered in discussions relating to commercialization. These are:

Direct Hydrogenation

- Exxon Donor Solvent (EDS)
- H-Coal
- Solvent Refined Coal (SRC) - Solid
- Solvent Refined Coal (SRC) - Liquid

Indirect Liquefaction

- Methanol
- Fischer-Tropsch

Other processes (e.g., CSF, COED, flash hydropyrolysis, and Synthoil) were considered by this Task Force but deemed not sufficiently developed for early commercialization. Reasons for this decision included early stage of development (flash hydropyrolysis), more suitable as part of gasification plants (COED), and not being actively developed at this time (CSF and Synthoil).

Technical Risks/Open Questions

The ability to scale up any of the processes which are in various stages of development is a potential drawback to commercialization. The successful operation of the large EDS and H-Coal pilot plants as well as the projected SRC demonstration plants will minimize the scale up risk. A major technical uncertainty of all direct hydrogenation processes is the solid/liquid separation step. In the current conceptual designs both solid SRC and H-Coal "boiler fuel" mode depend on filtration for this separation. Current pilot plant tests of other solid/liquid separation schemes might result in improved performance. Filtration is expensive in capital and operating costs, high maintenance costs would be expected, and its reliability on the scale necessary for commercialization is questionable. Resolution of this uncertainty is one of the high priority objectives of current pilot plant operation. The other direct hydrogenation processes are able to use distillation, a more proven technology, for the solid/liquid separation.

Of major concern to this Task Force are questions relative to the health and safety aspects of these plants. While a vigorous program along these lines is part of the demonstration and pilot plant programs, the potential hazards due to exposure and emissions are very real and largely unknown. A well-planned program is required to resolve these concerns.

A major unresolved question is the environmental standards which will regulate these technologies. The products from the processes under discussion are expected to meet existing standards. New air pollution standards being proposed by EPA may prohibit the use of certain coals for the solid SRC process.

A technical concern not directly related to liquefaction technology is the ability of delivering the required amounts of coal to a plant site. As currently envisioned, coal liquefaction plants will utilize about 10 million tons/year of coal, equivalent to roughly the total capacity from the largest Western strip mines today. Eastern coal mines are considerably smaller. The ability to increase coal production and preparation to meet projected demand requires additional study.

PART II

COMMERCIALIZATION READINESS ASSESSMENT

TECHNICAL READINESS

Operational Status

Table 1 lists prime developers and current status of the processes being considered.

Capital and Operating Cost Experience

The only commercial coal conversion facility producing liquids in the world is SASOL which uses a Fischer-Tropsch synthesis step. DOE has not been permitted to pursue directly with SASOL the projected costs, based on their experience, for such a plant in the United States. Without this direct contact our economic information is based on projections from limited published data. Our data on the other processes are based on projections from the current stages of development. These estimates are felt to be accurate from the viewpoint of design. Areas of technical uncertainty remain, however, which impact on questions of performance (e.g., capacity factors and reliability).

Current Developments

The major concerns about scalability and performance of coal conversion facilities will be answered with the start up of the two large pilot plants. The H-Coal pilot plant construction is scheduled to be completed by the end of this year. The Exxon Donor Solvent pilot plant is expected to start up early in 1980. Contracts have been signed to proceed with both solid and liquid SRC demonstration plants. Thus, the experience gained in the large pilot plants will be available before the construction of the SRC commercial modules begin and the SRC commercial module experience will permit construction of commercial H-Coal and EDS plants without a commercial module first step. The completion of these projects will resolve the technical, economic and environmental uncertainties of these processes.

TABLE I

STATUS OF COAL LIQUEFACTION PROCESSES

PROCESS	PRIME DEVELOPER	OPERATIONAL STATUS*	INITIAL OPERATION
Direct Hydrogenation			
Exxon Donor Solvent	Exxon Research and Engineering	1 TPD PDU (250 TPD Pilot - Construction)	1976 (1980)
H-Coal	Hydrocarbon Research, Inc. Ashland Oil Company	2.5 TPD PDU (600 TPD Pilot - Construction	1973 (1979)
SRC-Solid	Pittsburg & Midway Coal (Gulf Oil Co.) Southern Company Services	50 TPD Pilot - Fort Lewis 6 TPD Pilot - Wilsonville 6000 TPD Demonstration Plant	1973 1974 (1983)
SRC-Liquid	Pittsburg & Midway Coal (Gulf Oil Co.)	30 TPD Pilot - Fort Lewis (modified) 6000 TPD Demonstration Plant	1977 (1983)
Indirect Liquefaction			
Fischer-Tropsch	South African Coal, Oil, and Gas Company, Ltd. (SASOL)	SASOL I - 6000 TPD SASOL II - 30,000 TPD	1953 (1981)
Methanol		Commercial Mobil Methanol to Gasoline: 4BPD PDU	

* TPD = Tons Per Day; PDU = Process Development Unit

MARKET/ECONOMIC READINESS

Market Description

Exxon Donor Solvent, H-Coal, and liquid SRC coal liquefaction processes yield a family of products that will compete mainly for the boiler fuel market. Although we are confident that economic processes will be developed to convert these primary liquefaction products to petroleum-like finished products, the boiler fuel market is and will continue to be large enough to consume the total output of middle and heavy distillates of all the projected facilities through 2000. Methanol will be converted to and marketed as high quality gasoline (M-Gasoline). There is no current market for fuel grade methanol although a potential market exists for limited areas such as gas turbines. Fischer-Tropsch produces a broad product slate comprising SNG, LPG, naphtha, diesel fuel, and 5-10 percent oxygenated chemicals and thus addresses a wide variety of markets currently met by petroleum products. Economics are strongly dependent on finding markets for the product slate. Solid SRC is a "clean" coal intended for use in existing coal-fired boilers. It is low in ash, sulfur and nitrogen and will meet current environmental standards without flue gas scrubbing. Solid SRC can also be further processed to provide carbon for aluminum anodes and metallurgical coke.

Potential Competing Technology

Solid SRC will compete with coal combustion, flue gas desulfurization and fluid bed combustion. Exxon Donor Solvent, H-Coal and liquid SRC will compete in new installations with: unrefined shale oil, medium Btu gas in specific regional markets and environmentally accepted direct combustion of coal, i.e., fluidized bed combustion and flue gas desulfurization. For existing oil fired units, coal liquids will compete with unrefined shale oil and petroleum derived residuals. The suitability of Fischer-Tropsch technology has not been fully analyzed for the U.S. market conditions. It is estimated that distillate and motor fuels produced by Fischer-Tropsch or M-Gasoline currently cost more than their petroleum derived analogs and are likely to cost as much or more than the direct hydrogenation processes in the future.

Cost Comparisons

The cost breakdown and comparison of coal derived liquid boiler fuel and gasoline to petroleum products in 1978 dollars are shown in Figures 3 and 4. The range of costs is due to different processes and uncertainties introduced by unoptimized designs and level of analysis. The ongoing development programs should reduce this

Figure 3

Cost Comparison: Liquid Boiler Fuel

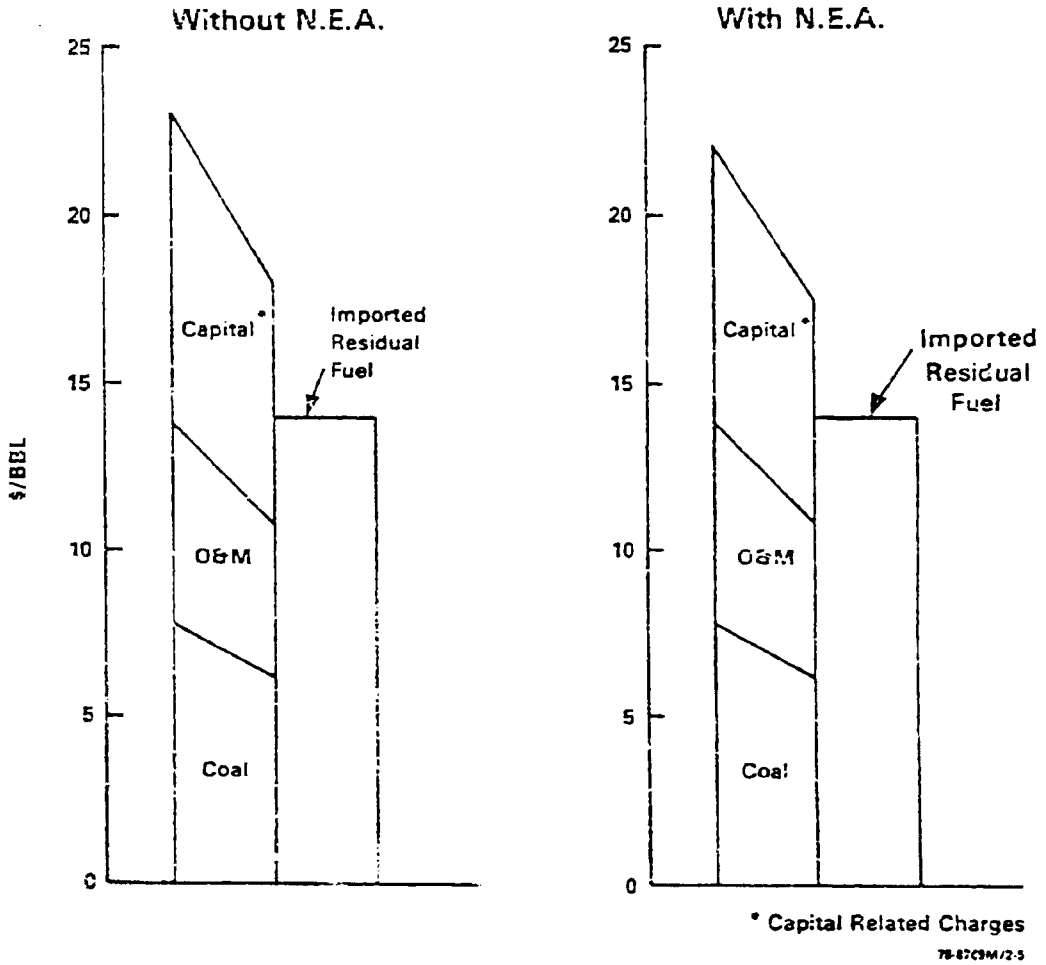
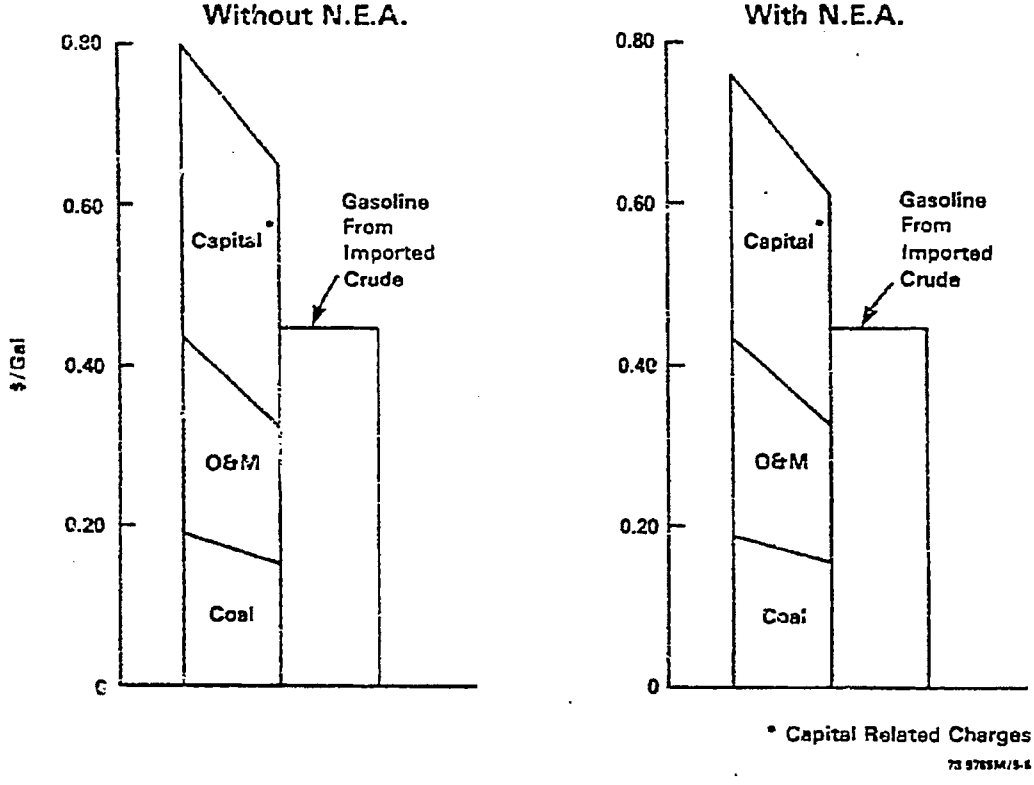


Figure 4

Cost Comparison: Gasoline



uncertainty. Figure 5 projects the expected cost of coal derived liquids compared to anticipated imported crude oil costs. Coal derived liquids should be competitive with petroleum with no or only minor government incentives by the time plants come onstream in the late 1980's. All costs are calculated on a basis consistent with the guidelines used by all Commercialization Task Forces.

Market Penetration

The expected markets for liquid boiler fuel and gasoline are shown on Tables 2 and 3 with the possible penetration by coal-derived products. It should be noted that the potential markets are quite large and penetration of synthetic fuels will be gradual.

Market Barriers

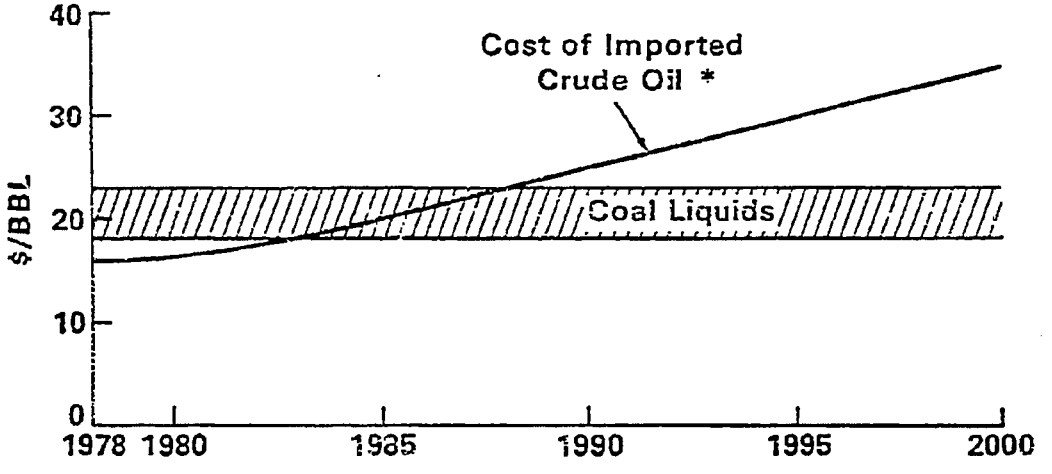
The liquid products from these processes will be inventoried, distributed and consumed through established industrial and commercial channels and, therefore, have no barriers from these areas. Gasoline from methanol will be readily accepted as a high quality motor fuel. The other liquid products do not now meet established commercial specifications, but with refining will meet realistic functional specifications. Products from Exxon Donor Solvent, H-Coal and SRC also will require improved compatibility with their petroleum analogs. These issues may temporarily delay, but not substantially impede, market penetration. Solid SRC as a fuel may be difficult to market and sell as a boiler fuel if more stringent environmental standards are imposed. The most important barrier to commercialization is the anticipated health hazard associated with these liquids, the possible consequential costs to implement the necessary control technology, and the possible institutional barriers to commercialization. Although Fischer-Tropsch may produce some low value by-products, it and gasoline from methanol are not expected to encounter substantial marketing barriers, given acceptable economics.

ENVIRONMENTAL OVERVIEW 1/

1/ The Task Force included representatives of the Assistant Secretaries for Environment, Energy Technology, and Resource Applications who are experienced with the environmental issues discussed. The material in this section represents a balanced view of the environmental issues considering the practical aspects of commercializing coal liquefaction processes in the mid 1980's. The ASEV is preparing a separate environmental assessment of each Commercialization Task Force area. While no major differences of opinion are expected, some inconsistencies between these two independent efforts may result.

Figure 5

Comparison of Cost of Coal Derived Liquids to Cost of Imported Crude Oil



* Per memo 8/22/78 from Harry Johnson

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TABLE 2

Market Segment: Liquid Boiler Fuel

	Quads		
	1985	1990	2000
Total Market	7.3	7.8	8.8
Available from Coal Liquids	0.003	0.4	1.4
Percent Penetration	0.04	5.1	15.9

TABLE 3

Market Segment: Gasoline

	Quads		
	1985	1990	2000
Total Market	19.0	18.7	18.0
Available from Coal Liquids	0.01	0.3	1.4
Percent Penetration	0.05	1.6	7.8

There appear to be no present environmental barriers facing the coal liquefaction conversion processes under the existing Environmental Protection Agency, Occupational Safety and Health Administration, and Department of Transportation regulations. The solid or liquid fuel products from the processes when burned will have to meet the proposed new source performance standards of 85 percent sulfur removal. The one large-scale solid SRC burn test made to date showed that this sulfur removal requirement can be met by certain coals. The liquid fuel products are not expected to have any problems with sulfur removal.

New regulations are being developed under environmental legislation such as the Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act, Toxic Substances Control Act, and under the Occupation Safety and Health Administration Act. All these are going to affect the amounts of the occupational and the emission control technologies needed for the various liquefaction processes and could have an effect on overall process costs. To resolve the extent of the health and safety hazards of the liquefaction processes and the products, appropriate levels of environmental research and development must be undertaken immediately and the engineering development of the control technologies be also initiated. Without these actions, cost effective and timely resolutions of the environmental parameters for the commercialization of the liquefaction technology cannot be achieved.

Coal liquids contain known carcinogenic compounds and trace metals. These materials pose serious problems to in-plant health and safety as well as end use exposure to products and emissions. The different liquefaction routes pose varying levels of concerns in this area. The indirect route which involves the gasification of the entire coal particle reduces in-plant exposure concerns. First generation gasifiers do produce tar and phenolic by-products which must be carefully handled. The direct hydrogenation processes keep the integrity of the coal structure to a much greater extent. This causes a greater potential problem. Health and safety concerns, however, are largely undefined and point up the need for a vigorous program to insure that effective procedures are developed to handle them. The emission concerns are greatly reduced with effective combustion techniques which will eliminate the potential emissions exposure to carcinogenic materials.

INSTITUTIONAL READINESS

There exist no institutional barriers to the commercialization of coal liquefaction but a number of constraints do exist which need to be addressed. Institutional constraints are the established practices and organizations in a society which may impede, prevent, or delay the commercial scale development of new energy technologies. Applied

to coal liquefaction, institutional constraints depend on the degree of economic risk and the degree to which a timely provision of public facilities and services are a community burden.

Institutional Constraints - non-governmental (private) sector.

Difficulty in obtaining private capital to finance coal liquids plants may be a major constraint. This is caused by uncertainties associated with coal liquids, i.e., long-term market potential, refineability, storability, and government patent policy. Lending institutions by tradition and regulation, do not lend large amounts to ventures which are high cost and high risk. To the extent that coal liquefaction remains a high cost, high risk business, there will be little funds available from this source. Other business practices, such as the mining industry labor/management strife may cause problems. These concerns could reduce productivity at the plant or mine site and influence location choice for coal liquids plants (e.g., the predominance of unionized miners in the East).

Social and cultural organizations and special interest groups offer a new set of problems. Special interest groups can use the public hearings and litigation process to delay approval of environmental impact statements, zoning, siting, and budget approval. Special (public) interest groups may consider government financial support to technology development programs, such as coal liquefaction, an aid to "big business," or more specifically to the oil industry. Given the nature of the products, it is expected that the oil industry will commercialize these technologies.

Institutional Constraints - government (public) sector

Most local governmental procedures for the study, approval, financing, and construction of public facilities such as roads, sewers, etc., are not capable of reacting quickly to sudden population increases such as might accompany the construction of a large coal liquefaction plant. Influxes of new populations to build and operate coal liquids plants may also disrupt existing traditions and life styles in small communities.

A number of political constraints also exist. Fear that oil producing nations could undercut an emerging coal liquids industry obviously inhibits private investment in this capital-intensive industry. On the domestic level, siting decisions are often influenced by local politics, and differing objectives exist between localities, states, and regions for development or nondevelopment.

The largest governmental sector constraint involves legal and regulatory matters. Constantly changing environmental laws and regulations

affect the willingness of private investors and lending institutions to risk the large sums of money required for coal liquefaction projects. Such changes in laws and regulations will affect the costs (additional pollution controls and project location), timing (public hearings, litigation) and siting (accessibility to water, coal, product markets, availability to obtain permits and public approval) of individual projects especially for a technology like coal liquefaction where environmental, health, safety and socioeconomic uncertainties exist. Laws and regulations applying to local growth control, local, state, Federal and Indian water rights, and economic regulations such as the entitlements program will affect the availability of project capital, as well as the ultimate success of the project.

Institutional constraints can be mitigated through Federal financial incentives to reduce project risks (e.g., loan guarantees, price supports, Federal purchase of the coal liquid products) and Federal assistance programs to reduce community impacts. Other relevant mitigating measures include demonstration projects which allay fear of risk and more stabilized regulations.

Manufacturers' Readiness to Produce and Market Coal Liquids

Based upon informal discussions with the major industrial organizations in the coal liquefaction program, the following, possibly biased, conclusions may be drawn. It should be pointed out that in every case the U.S. patent policy may be a hinderance to the commercialization effort.

Exxon Donor Solvent: Exxon feels that their 250 TPD of coal feed pilot plant should be operated through 1982 and that a pioneer plant could begin operation in the late 1980's. Preliminary studies for a pioneer plant could be initiated within the next five years.

H-Coal: The H-Coal pilot plant contractors feel the time is right to begin studies on the feasibility of a commercial plant. They propose a two-phased program (preliminary studies and detailed design, procurement, construction, and operation) leading to a facility operating in approximately five to seven years.

Fischer-Tropsch: A commercial plant has been operated by SASOL on U.S. noncaking coals. U.S. manufacturers continue to show interest in the technology. There have been, however, no announced coal conversion plants in the U.S. based upon this process.

Methanol: Mobil Oil feels the fixed-bed process to produce gasoline from methanol is commercially ready and could be constructed in the same time frame that a conventional coal-to-methanol plant could be built. Making methanol from coal is proven commercial technology.

SRC-Solid: Southern Company Services, Inc., feels the technology is ready for a commercial-scale, first module (6000 tons per day) of a multi-module commercial plant. Their consortium has indicated its willingness to invest about 20% for such a project.

SRC-Liquid: Gulf Oil Corporation feels the technology is ready for a commercial-scale, first module (6000 tons per day) of a multi-module commercial plant. Gulf is willing to risk up to $100M for such a project.

General: Some major industrial organizations experienced in coal liquefaction development feel that the lowest risk liquefaction process is production of methanol from coal via a coal gasification route. Conoco, ARCO, and Chevron feel that H-Coal and EDS should be tested at the pilot plant scale before being considered for scaling to commercial size.

BENEFITS ANALYSIS

Energy Impacts

Solid SRC is a form of purified coal and in some instances under current environmental standards competes with coal beneficiation and flue gas desulfurization. Indirectly, solid SRC competes with imported petroleum. Liquid SRC, Donor Solvent, and H-Coal are similar and compete with residual oil. When hydrotreated, they will compete with products from petroleum. Methanol is a suitable clean turbine fuel and would compete with light petroleum distillates from petroleum. Fischer-Tropsch produces a broad product slate whose characteristics, with the exception of SNG and LPG, do not match their petroleum derived analogs without significant upgrading. A Fischer-Tropsch plant without upgrading units would produce products which could probably be used as blending stock by refiners, thereby displacing imported petroleum. Virtually all coal liquefaction processes also produce by-product SNG which could be used to supplement gas supplies.

Recipients of Benefits

Solid SRC would be most useful for new and retrofit industrial and utility coal fired boilers. The liquid products are involved in the petroleum marketing cycle. Subject to concerns about product compatibility, the present users of petroleum derived products would be the recipients of benefits in the form of assured supply.

Cost Impacts

At the present time, the price differential between coal and oil is not great enough to support an economic private sector coal liquefaction industry. The economic incentives available include loan guarantees and possible price supports. In the event that the future coal-oil price differential augmented by these incentives are insufficient, there will be no private industry. To the extent that the loan guarantees are used, it is arguable that the U.S. Treasury may be underwriting the cost differential between high-rated bonds (resulting from Federal loan guarantees) and the anticipated low rating that would be applied to bonds for first-of-a-kind plants. Preliminary estimates are that in today's market this could account for two percent (absolute) difference in cost of capital, which would be broadly shared by most taxpayers. Alternatively, it also may have the effect of withdrawing venture capital from the marketplace that might otherwise be available.

We have determined that the government's regulatory apparatus will allow coal liquefaction plant operators to obtain an adequate return for the byproduct SNG output of these facilities.

READINESS ASSESSMENT CONCLUSIONS

- Coal liquids will address a major segment of energy economy; namely, petroleum and petroleum derived products.
- Technology readiness:
  - methanol and Fischer-Tropsch are technically ready but economically uncompetitive, at present.
  - scale up of direct hydrogenation processes to verify commercial feasibility requires major government funding.
- Federal assistance will probably be required for all first-of-a-kind commercial facilities.
- Coal liquids will be economically competitive with imported petroleum by late 1980's or early 1990's.

PART III

COMMERCIALIZATION STRATEGY

ACTIONS

In order that significant capacity for synthetic fuels be built by private industry, it is necessary that the various concerns as discussed in Part II be addressed. Although the economic projections as indicated in this paper suggest that synthetic fuels from coal would be economically competitive with imported petroleum in the late 1980's, large areas of uncertainty remain. Existing development efforts, most being cost shared with industry, are needed to better define commercial facilities. Uncertain regulatory climate, particularly on environmental matters, also adds to potential cost increases. Beside these more design oriented concerns are the added elements of risk introduced by inflation and world oil prices. Being capital intensive facilities, synthetic fuel plants would be somewhat protected from inflation. World oil prices, however, are subject to changing political considerations which make future planning very difficult.

In order to insure that private industry is stimulated to initiate a synthetic fuels industry in spite of these uncertainties, strong government action is needed. This Federal role is needed to: (a) provide support for the existing development programs to bring these technologies to the stage of large scale commercialization; (b) overcome the financial risk from the uncertainties relative to capital and operating costs and the uncompetitive nature of coal derived liquids based on current prices; and (c) encourage industry to construct and operate commercial facilities.

COMMERCIALIZATION PROFILE

The commercialization profile for the two markets addressed by this plan are shown in Exhibits 1 and 2. Detailed descriptions of the specific barriers appear in Appendix A to this report. For both the boiler fuel/refinery feedstock and transportation fuel markets the major barrier remains technical/economic. In most succinct form, it must be shown that these products can be made on a large scale and at a cost which will make them competitive with petroleum derived products.

For boiler fuel/refinery feedstock, the demonstration plant program and large pilot plants will demonstrate the ability to scale up these processes as well as the viability of operation at commercial scale. In the event that the world price of oil does not behave as predicted

EXHIBIT 1
COMMERCIALIZATION PROFILE FOR
Boiler Fuel/Refinery Feedstock

	Technical/Economic			Initial Deployment			Environment			Resource Availabilit			Institutional		
Barrier Importance	5	5	5	3	3	2	5	3	4	2	3		3	3	2
	Scalability and Reliability	Product Cost	Price Competitiveness	Product Quality and Commatibility	Distribution System	Market Structure	Health Hazards (System)	Plant Effluents	User Effluents	Coal Availability	Siting		Permitting requirement of new mines and plants	Uncertain Environmental Penalations	Capital Formation
Federal Actions															
Information															
R & D	2	1	1	3	1	1	5	1	2	1	1		1	1	1
Demo	5	3	1	3	3	1	3	5	5	1	1		1	2	3
Tech. Trans.	3	2	1	4	3	1	3	3	3	1	1		3	2	2
Fin. Incentives															
Price Guar.	3	1	4	2	1	1	1	1	1	1	1		1	1	5
Loan Guar.	1	2	2	1	3	1	1	1	1	1	1		1	1	5
Tax Credits	3	2	3	1	1	1	1	1	1	1	1		1	1	5
Taxes & Penaltie															
Taxes	1	1	5	1	1	4	1	1	1	1	1		1	1	3
Tariffs	1	1	3	1	1	3	1	1	1	1	1		1	1	3
Penalties	1	1	2	1	1	4	1	1	1	1	1		1	1	3
Regulation															
Entitlements	1	1	2	1	1	1	1	1	1	1	1		1	1	2
Mandated Usage	1	1	5	1	1	4	1	1	1	1			1	1	4
Environmental	2	3	2	1	1	1	1	4	3	2	4		4	5	1

EXHIBIT 2
COMMERCIALIZATION PROFILE FOR
Transportation Fuel

*Gasoline and Diesel/Methanol

	Technical/Economic			Initial Deployment			Environment			Resource Availability			Institutional		
Barrier Importance	3	5	5		*1/5	*1/5		3	*	2	3		3	3	2
	Scalability and Reliability	Product Cost	Price Competitiveness		Distribution System	Market Structure		Plant Effluents		Coal Availability	Siting		Permitting requirement of new lines and plants	Uncertain Environmental Regulations	Capital Formation
Federal Actions															
Information															
R & D	1	2	2		1	1		1		1	1		1	1	1
Demo	5	2	2		*1/5	*1/2		5		1	1		1	2	3
Tech. Trans.	3	1	1		1	*1/2		3		1	1		3	2	2
Fin. Incentives															
Price Guar.	3	1	4		*1/3	*1/3		1		1	1		1	1	5
Loan Guar.	1	2	2		*1/3	1		1		1	1		1	1	5
Tax Credits	3	2	3		*1/3	1		1		1	1		1	1	5
Taxes & Penalties															
Taxes	1	1	5		1	4		1		1	1		1	1	3
Tariffs	1	1	3		1	3		1		1	1		1	1	3
Penalties	1	1	2		1	4		1		1	1		1	1	3
Regulation															
Entitlements	1	1	2		1	1		1		1	1		1	1	2
Mandated Usage	1	1	5		1	4		1		1	1		1	1	4
Environmental	2	3	1		1	1		4		2	4		4	5	1

then Federal action will be required to insure the competitiveness of coal liquids with the spectrum of imported energy sources ($14/bbl imported crude to $30/bbl for LNG in FY 1978). It is suggested that taxation policies on petroleum products or mandated usage of coal liquid products are the most effective means of insuring this competition. Financial incentives, particulatly price guarantees, may also be effective for this purpose.

The next most serious concern relative to commercialization in the boiler fuel/refinery feedstock market is the environment. A vigorous research and development program to define and explore potential health hazards is an essential part of this commercialization plan. It is known that some liquefaction process streams and products are carcinogenic in nature and must, therefore, be handled and used with care. A continuing program is needed to lessen the risks associated with the technology to insure its environmental acceptability.

The transportation fuel market poses a different set of constraints. The technology in this area, mainly the indirect liquefaction processes, is more advanced than in the other market. As a result, while large scale demonstration on American coals is needed, the need for demonstration is not as pronounced. Product cost, however, is still a major drawback. The conventional products, gasoline and diesel, are quite marketable and in fact offer some advantage over petroleum products as they are lower in pollutants. Since the product cost is higher than petroleum products, mandated usage, taxation of petroleum products or tax relief of synthetic products would be required for wide scale production.

An added problem must be considered for the use of methanol by itself or in gasoline blends as a transportation fuel. Although this option has received a lot of attention, there currently exists no market. As a result the major barriers to commercialization, along with cost, involve the development of such a market, necessary engine modifications and support structure. Legislative initiatives which mandate the use of methanol or make its use economically attractive are essential.

RECOMMENDED STRATEGY

The direct hydrogenation processes have products that can be considered as substitutes for petroleum derived liquids or coal. This represents a potentially enormous market with many, varied products. Due to market demand, however, the initial commercialization of the middle and heavy distillates should be addressed toward boiler fuel. Each of the direct hydrogenation processes have products that could be considered as potential feedstocks for further processing. In this aspect, the ultimate products would be petroleum-like finished

products. For reasons of market demand for boiler fuel, required increased complex construction, siting problems near existing refineries, and lack of demonstration of technical feasibility, upgrading of coal liquids is not considered at this time. A more complete view of the upgraded product spectrum appears in Appendix B.

Current economic projections indicate that the products from these plants will be competitive with imported crude oil by the time they come onstream or close enough so that only relatively minor government incentives may be required. Early federal assistance will be needed to verify the commercial feasibility of these processes.

Indirect liquefaction processes produce light liquids suitable for the transportation fuels market and the potential turbine fuel market. These processes are the most advanced technically since they have been demonstrated on a commercial scale. The products, although marketable, are also more expensive than their petroleum counterparts. Significant government incentives would be needed for this approach, but the technology is ready for large scale commercialization. Much work remains to be done before the Fischer-Tropsch route could be adapted for commercialization in the United States. As practiced at SASOL this process is not suited for American markets. It may have potential if combined with the Mobil technology to convert oxygenated hydrocarbons to high octane gasoline.

A major aspect of this commercialization approach is the substituting of coal liquids for petroleum. More petroleum would be available for processing to products for which it is well suited, especially transportation fuels. This is possible by displacing petroleum products from lower priority applications for which minimally processed coal derived liquids can be substituted. Coal liquids provide an assured, at-hand supply, mitigating reliance on imported crude and the corresponding balance of payments debits. Coal liquids would contribute to continuing environmentally acceptable operation of the in-place Eastern industrial and electric utility establishment.

GOALS

To address the boiler fuel/refinery feedstock market, the development program outlined in the attached schedule is required. In this fashion it would be possible to construct a commercial facility which would start up in 1988. The size of the H-Coal and EDS pilot plants is such that after the completion of their programs it will be possible to proceed with a commercial sized facility. With a new facility coming on stream every two years, the market penetration as shown in Table 2 is possible. Since many of the same resources and infrastructure will be used for the commercialization of coal liquids, gasification, and shale, the rate of market penetration in any one area may

be even more restricted than is currently projected. Careful planning will be needed to insure the maximum benefit for the country.

Since the technology is more advanced for addressing the transportation fuels market, the objective of the commercialization plan in this area is the evaluation of ways to make the indirect liquefaction processes more economically attractive and the encouragement of commercial ventures. Using largely demonstrated technologies and use of Federal incentives, the market penetration in Table 3 is possible.

ACTIVITIES

The major actions for FY 79 are indicated in Table 4 by process, products and markets. The schedule through 1984 is shown in Figure 6. The major Federal activity is a program to develop the indicated direct hydrogenation processes so that commercial plants can be constructed in the late 1980's. As was previously indicated, it is expected that coal liquids will be economically competitive by the late 80's or early 90's. This is predicated, however, on the world price of oil escalating at a rate greater than the general rate of inflation. If the world oil price does not behave as expected, then Federal actions as indicated on the Commercialization Profile should be initiated by the early 1980's. These legislative initiatives will be needed to insure that the commercial interests will undertake the larger projects required after the government role has diminished.

The secondary activity of this plan involves the evaluation of the indirect liquefaction routes. While a plant has been operated for some time in South Africa using Fischer-Tropsch technology, a direct application to the United States coals and markets does not seem to be attractive. A variation of this process using Mobil technology would greatly reduce the size of the product spectrum as well as byproduct production. Such an approach needs to be evaluated and if SASOL is not involved, a new development effort would need to be established. While such a program may delay the initial commercialization of Fischer-Tropsch, it would insure the economic competitiveness once a plant is built.

There are indications that commercial methanol ventures are seriously being discussed by industry. The product is intended mainly for the combustion turbine market (peak sharing electricity production) and chemicals market. Such facilities if built, however, would help the entire coal liquids program since it would stimulate the entire infrastructures and capital formation areas. The Department should undertake an aggressive commercial development study to determine

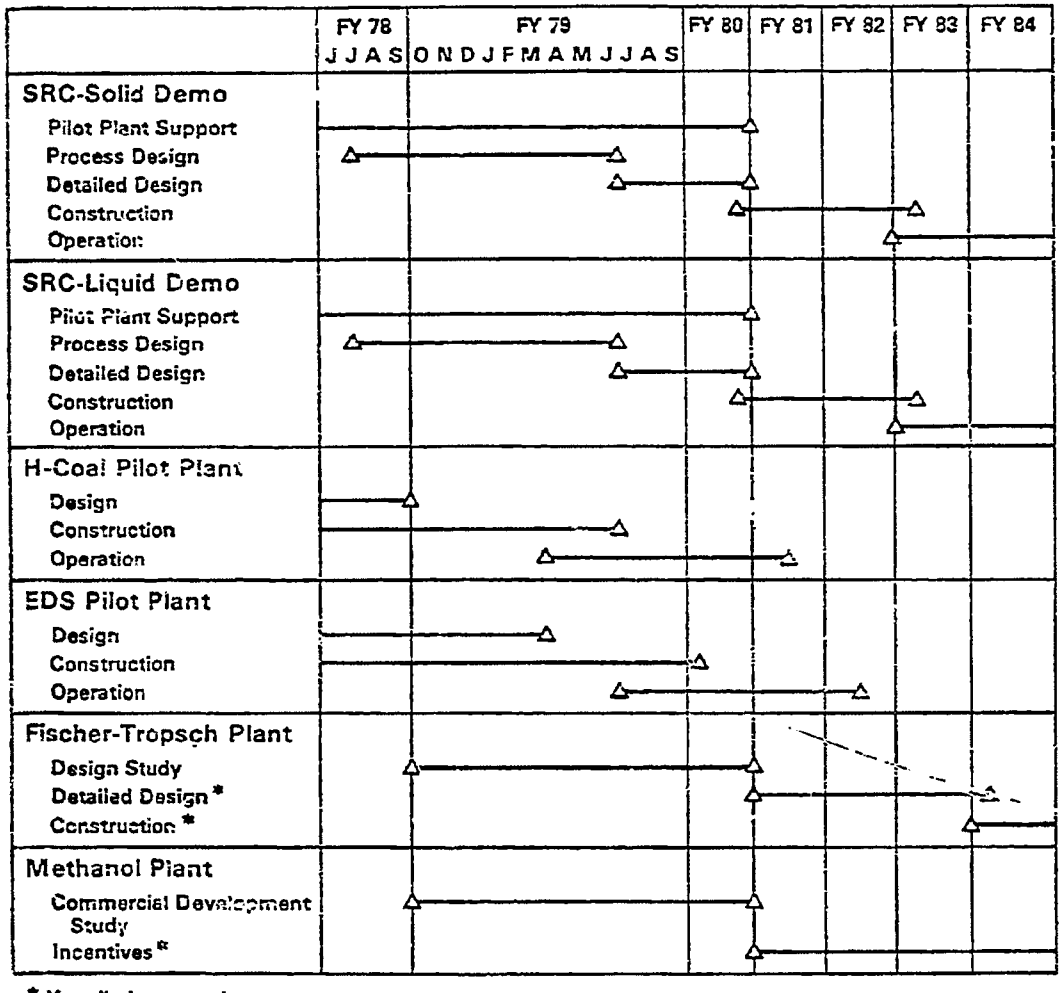
Table 4

Federal Actions in FY 1979

Process	Products	Market	Action
Exxon Donor Solvent	synthetic natural gas naphtha distillate fuel oils	boiler fuel/ refinery feedstock	construction of pilot plant
H-Coal	synthetic natural gas naphtha distillate fuel oil	boiler fuel/ refinery feedstock	operation of pilot plant
Fischer-Tropsch	synthetic natural gas liquefied petroleum gas gasoline diesel fuel residual fuel oil	transportation fuel	process evaluation study
Methanol	methanol gasoline	transportation fuel	commercial development study (including use in gas turbines)
SRC-Solid	SNG LPG naphtha distillate fuel solid boiler fuel	boiler fuel	construction of first module of commercial plant
SRC-Liquid	SNG LPG naphtha distillate fuels	boiler fuel/ refinery feedstock	construction of first module of commercial plant

Figure 6

Schedule for Coal Liquids



* If preliminary study warrants.

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which Federal actions would encourage these projects. After determining the best incentive, the Department should pursue the necessary legislation to insure its timeliness.

APPENDIX A

DESCRIPTION OF COMMERCIALIZATION BARRIERS

Technical/Economic

Scalability and Reliability - capability to design and operate facilities at a commercial scale.

Product Cost - required revenue to cover operating, raw material and maintenance costs as well as retire the incurred debt and give an adequate return to equity holders.

Price Competitiveness - effect of current or projected market price of petroleum derived products on capability of coal-derived products to penetrate the same markets.

Initial Deployment

Product Quality and Compatibility - ability to meet current market specifications and to be used interchangeably with petroleum products.

Distribution System - infrastructure to get products from plant gate to consumer.

Market Structure - manner in which products are sold.

Environment

Health Hazards - potential risks to health and safety from coal mine to end use.

Plant Effluents - air and water emissions from mine and producing facility.

User Effluents - air emissions from end user.

Resource Availability

Coal Availability - development of enough mines of sufficient size to produce required amounts of coal and the necessary transportation system to deliver coal to the plant.

Siting - locations which afford enough land and water with proximity to coal reserves.

Institutional

Permitting Requirements of New Mines and Plants - necessary approvals to proceed with new ventures.

Uncertain Environmental Regulations - unknown and changing Federal requirements.

Capital Formation - ability to raise sufficient funds for construction.

APPENDIX B

UPGRADED PRODUCT SPECTRUM

While coal liquids from the direct hydrogenation process will make an environmentally acceptable boiler fuel, these products can also be treated as intermediates and processed to other fuels or chemical products. Several possibilities are indicated below:

- o methane rich gas to pipeline quality methane;
- o ethane, propane, and light hydrocarbons and paraffins from naphtha-treating to ethylene;
- o raw naphtha to phenol (by extraction) and to high octane gasoline blend stock and BTX, especially xylene;
- o middle distillate to stationary gas combustion turbine fuel, medium speed diesel fuel, such as used by railroad locomotives and some marine applications, in addition to industrial boiler fuel.

Table 5 gives an indication of the potential product breakdown from an SRC-Liquid plant of 30,000 tons/day coal capacity. The naphtha stream would require pretreatment, mainly for nitrogen removal, before it could be fed to a refinery. The indicated product slate is directed toward minimal processing for saleable products rather than severe hydrocracking. In this regard, the coal liquids product should be considered as an intermediate to petroleum-like finished product rather than a synthetic crude oil.

Other market possibilities are less likely to occur. SRC fuel oil, for example, could be converted to automotive diesel fuel or aviation turbine fuel but not without considerable incremental expense. For this reason, SRC fuel oil products are aimed at specific economically promising markets which do not require substantial further processing of the SRC products.

TABLE 5

POTENTIAL PRODUCTS FROM A COMMERCIAL SRC-II PLANT

SRC Plant Intermediates	Max Volume Per Plant	Secondary Products Volume
Methane	157 x 10^6 SCFD	Pipeline Gas
Ethylene	1.0 x 10^9 lb/yr	Polyethylene 45% Ethylene glycol, oxide 20% Styrene 10% Vinyl Chloride 15%
Raw Naphtha	12,000 B/D	Phenol 200 x 10^6 lb/yr Gasoline 10,000 B/D Xylene 50 x 10^6 gal/yr
Middle Distillate	15,000 B/D	Industrial Boiler Fuel Medium Speed Diesel Fuel Stationary Gas Combustion Turbine Fuel
Heavy Distillate	27,000 B/D	Utility Boiler Fuel

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