proposes to pursue both them and the possibly more expensive coal liquids.

As a separate task, ESCOE is undertaking a comparative analysis of the commercial-scale economics of selected synfuels processes. This analysis focuses upon those coal gasification and liquefaction processes that are receiving financial support under the DOE Fossil Energy Demonstration Program. The DOE's support is helping to ensure the public availability of detailed technical and economic studies. ESCOE is reviewing these studies with regard to the uniformity of project scopes and the comparable handling of major capital and operating costs elements. ESCOE is using a common set of financial parameters to recompute the economic performance of each process over its useful lifetime. The results of this task will be published as a separate ESCOE report, in a form to facilitate economic comparisons.

7.4 ENVIRONMENTAL IMPACTS

The emergence of a synthetic fuels industry has been accompanied by many comprehensive assessments of its health and environmental impacts. The Department of Energy (66,67) and the Congressional Research Service (68) prepared analyses that were made available to the Congress and the public during the legislative deliberations on the synthetic fuels program. Several major environmental impact statements (EIS) have been published (69,70) detailing the environmental, health and safety benefits and risks of synthetic fuels commercialization and of various advanced coal technologies. An EIS has been prepared for the Great Plains Gasification Project (71) and a draft EIS has been prepared for the SRC-II Demonstration Project. (72)* A draft EIS is well along for the Department of Energy's oil shale program. This builds upon the very comprehensive final environmental statement for oil shale leasing. (73) The Office of Technology Assessment (74,75,76) has published comprehensive analyses on coal, oil shale, and enhanced

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* Editor's Note:

Additional EIS's for synthetic fuels projects have been completed subsequent to the original issue date of this report. The final EIS for SRC-II and the draft EIS for SRC-I were both published in January 1981. The draft EIS for the Memphis Gasification Project was issued in October 1980.

oil recovery, including heavy oils. Although the coal assessment deals mainly with the direct use of coal for combustion rather than for synthetic fuels, it does provide a wealth of information about coal mining and transportation with respect to impacts on the environment, public health, occupational safety and health, and the community. The Federal Interagency Committee on the Health and Environmental Effects of Energy Technologies has identified in several reports (77, 78, 79, 80) the health and environmental problems of coal technologies including gasification and liquefaction and of oil shale technology. Thus, environmental and health concerns have been examined repeatedly and in depth.

The common message of these assessments and statements is encouraging. The environmental effects of synthetic fuels plants are sufficiently well understood so that the nation can move prudently to initiate a synthetic fuels industry.

This is not to say that all questions have been answered completely. Uncertainties do exist, of course, as there inevitably are for any technology which does not yet exist at a commercial scale. Many of these uncertainties can only be resolved by proceeding with the construction and operation of synthetic fuels plants. Thus, the initial plants need to include comprehensive environmental monitoring and surveillance systems, for example, to demonstrate completely that all environmental standards are being met. The preponderence of expert opinion is that the environmental impacts have been fully identified, and that control technologies are available to meet the standards of environmental performance which can reasonably be expected.

7.4.1 Laws and Regulations

Synthetic fuels projects are subject to a large body of laws and regulations promulgated to protect human health and the environment. Table 7.2 gives a partial listing of the laws affecting synfuels plants.(81) They cover all major concerns: clean air, clean water, solid wastes management, toxic substances control, worker protection, mining, land policy, and the list goes on. There is no significant area in which the impacts of synthetic fuels plants would go unregulated.

The existence of so many different laws and regulations creates uncertainties as to the time and steps required to satisfy the various administrative requirements. Each application for a permit, a license, or an approval must be submitted at the proper time, follow the prescribed procedures, and include the required supporting data. The timing, procedures, and data in each case are different. No large commercial synfuel project has as yet made it through this maze of regulations, and it is impossible to state with certainty the total length of time required to bring a project on-stream.

Table 7.2 Environmental Legislation Affecting Synthetic Fuels Plants

Title	Year Enacted or Amended
The Rivers and Harbors Act	1899
Occupational Safety and Health Act	1970
Noise Control Act	1972
Marine Protection Research and Sanctuaries Act	1972
Endangered Species Act	1973
Safe Drinking Water Act	1974
The National Environmental Policy Act	1975 (amended)
Resource Conservation & Recovery Act	1976
Federal Land Policy and Management Act	1976
Toxic Substances Control Act	1976
Clean Air Act	1977 (amended)
Federal Water Pollution Control Act	1977 (amended)
Federal Coal Leasing Act	1977 (amended)
Federal Coal Mine Safety & Health Act	1977 (amended)
Surface Mining Control & Reclamation Act	1977
Endangered American Wilderness Act	1978

The uncertainty is compounded because environmental regulations are continually evolving and expanding. Even if we saw clearly how to navigate through today's maze, tomorrow's course could be different.

Additional environmental regulations are just now being developed or revised in several major areas affecting synfuel plants.(82) In part, these changes are occurring because several of the laws shown in Table 7.2 were only recently enacted or amended. For example, the last several years have seen increased emphasis on the regulation of toxic substances, especially carcinogens, as evidenced by the arrival of the Toxic Substances Control Act (TSCA) in 1976. In other cases, such as ambient air quality standards and new source performance standards, Congress has mandated that the regulations undergo periodic review and revision.

There are many areas where synthetic fuel plants may be affected by emerging regulations. For example, under the Clean Air Act, New Source Performance Standards are established to limit air emissions caused by specific industries or processes. Such standards have not yet been promulgated for synthetic fuel plants. The existing standards for coal preparation plants, petroleum refineries, and fossil-fired boilers are each applicable in part. Standards specific to synthetic fuel plants, however, are not expected until 1983 or later. In the meanwhile, the Environmental Protection Agency (EPA) plans to publish environmental guidance documents which, while not legally binding, are intended to direct the early development of the industry. Oil shale, coal gasification, indirect liquefaction, and direct liquefaction are among the technologies for which guidance will be reported.

Regulations are being developed, also under the Clean Air Act, to prevent visibility degradation. The visibility regulations could lead to more stringent requirements for controlling emissions of fine particulates, sulfates, and nitrogen oxides. These regulations will affect plants located near mandatory Class I areas, which permit very little increase in the ambient concentrations of regulated air pollutants. One-hundred and fifty-six Class I areas have been designated for visibility protection.

In connection with the prevention of significant deterioration (PSD), the EPA is revising the PSD regulations as a result of a June 1979 court decision (Alabama Power Co. vs. Costle) which invalidated key provisions of the earlier regulations. The current thinking is to define a "major" source based on emissions after, rather than before, controls. The revised regulations would also increase the number of pollutants requiring Best Available Control Technology (BACT) and would reduce the level of emissions considered significant. Fugitive dust may be included in assessing the impact of a source. Contamination of groundwater by injected fluids is to be regulated by the Underground Injection Control Program. These regulations could affect liquid disposal procedures at synthetic fuel plants.

Regulations for handling and disposing of solid wastes, under the Resource Conservation and Recovery Act, were proposed in 1978 and 1979. Two parts of the final regulations were issued in February 1980 and in April 1980. Especially significant are the provisions regarding "hazardous" wastes. A waste is classified "hazardous" if the leachate from the waste contains any contaminant whose concentration exceeds 100 times the safe drinking water standard. It appears that the great percentage of synfuel wastes will not be classified as hazardous, but this remains to be confirmed conclusively. Hazardous substances must be handled according to special procedures and disposed of at a permitted hazardous wastes disposal site.

The Toxic Substances Control Act gives EPA authority to regulate toxic chemicals in all areas of commerce. In particular, EPA may require warning lables on toxic chemicals which enter commerce. Other forms of regulation may range as far as banning production or distribution of certain chemicals. Toxic substances regulations have not yet been promulgated, but could not have a major effect on synthetic fuels.

7.4.2 Air Emissions

The principal gaseous emissions from synthetic fuel plants are nitrogen, water vapor, and carbon dioxide, all of which are normal constituents of the earth's atmosphere. Synthetic fuel processes also emit lesser amounts of various pollutants, chiefly sulfur compounds, oxides of nitrogen, particulates, hydrocarbons, and carbon monoxide. The emissions may result from the processing operations or from auxiliary operations, such as on-site steam generation.

Concern has been expressed over the potential increase in atmospheric CO_2 levels which can result from the long-term combustion of fossil fuels and which may eventually affect the earth's climate. The mechanisms of CO_2 accumulation in the atmosphere and the potential for climatic change are poorly understood and are receiving increased research attention. The current state of scientific knowledge in this area is inadequate to make political and societal decisions regarding the acceptable use of fossil fuels, including synthetic fuels.

The chemical and physical operations that constitute a surface synthetic fuel process occur in enclosed vessels, often operating at high temperatures and pressures. For *in situ* processes, these operations occur underground and, in theory, are confined to discrete zones or strata. In either case, the processing vessel or zone is designed to minimize direct gaseous discharges to the atmosphere. Emissions from the process operations result primarily from fugitive leaks and vent gases. Leaks can occur at pump seals, joints, packing, flanges, compressors, and similar locations. Fugitive emissions from a surface process can be a large source of hydrocarbons.(83)

Fugitive emissions can be greatly reduced by a formal program of leak detection and maintenance and such a program can achieve hydrocarbon levels acceptable for occupational safety and environmental protection.

During normal plant operations air emissions arise primarily from the auxiliary parts of the plant, such as the steam boiler, sulfur recovery plant, product storage tanks, or coal handling equipment. The types of auxiliary equipment vary widely among different plant designs. It is not surprising that the literature reports a wide range of estimated air emissions for different synfuel processes. These estimates can not yet be the basis for deciding which processes provide the least emissions, or for determining whether or not a specific process can achieve current or future standards.

Environmental control technologies are available for synfuel plants to meet today's most stringent air emission standards. For example, an examination of controls for Lurgi high-Btu gasification found that satisfactory NO_x control can be achieved through boiler modification, staged combustion, low excess air, or fuel denitrification; the final process offgases from a Claus plant followed by the Beavon process can meet the most stringent SO_x standards; adequate particulate control can be achieved through cyclones and electrostatic precipitators; and commercially proven designs can provide over 90% control of cooling tower drift.(84)

Not surprisingly, previous conceptual designs aimed at less stringent standards may not meet today's more stringent standards.

An examination of alternative environmental controls for low-Btu coal gasification identified more than 100 processes that are available for particulate control, acid gas removal, sulfur recovery, tail gas treating, by-product recovery of NH_3 and phenols, and wastewater treatment.(85) Since environmental standards for low-Btu gasifiers have not been promulgated, standards are inferred from those for coal-fired power plants, coke ovens, and petroleum refineries. Although the costs of controls vary widely, all cases studied are able to meet the inferred emission limits.

The design effort is well along for several of DOE's fossil energy demonstration plants. These designs employ the controls anticipated for acceptable environmental performance. For example, the SRC-I demonstration plant is designed to utilize the best available control technology, and to satisfy the EPA Prevention of Significant Deterioration requirements for air quality and all applicable New Source Performance Standards.

7.4.3 Water Supply and Wastewater

Hydrogen is needed to manufacture synthetic fuels from coal, shale, or tar sands. Water is the usual source of this hydrogen via gasification of carbonaceous materials or by steam reforming. In addition to providing hydrogen, water meets other process needs. Synthetic fuel processes produce waste heat which is discharged into the environment primarily by evaporating water. Also, water is needed to mine and prepare the raw materials and to dispose of the processing residues.

Published estimates vary widely on the amount of water consumed in manufacturing synthetic fuels. One reason for this variation is that different assumptions are made about the amount of water that is used for cooling in the plant, often the prime determinant of total consumption.

It has been suggested that a 250 million cubic foot per day coal gasification plant can be operated with 4.5 million gallons of water per day.(86) This is equivalent to about 450 acre-feet per year. Such a plant does not waste water, but neither does it minimize water consumption. Other designs for a plant of similar size have water consumption ranging from 900 to 4000 acre-feet per year. The process designer can, at a cost, reduce the consumption of water to a very low level. Thus, the water needed for synthetic fuel plants depends strongly upon economic considerations regarding the value of water and the cost of water-saving technology.

The availability of sufficient water for a synfuel plant depends on more than the physical presence of water. Other critical factors are the economic competition from other users, especially agriculture; the political acceptability of diverting that water for energy; the legal system controlling water rights; and, environmental regulations.

Irrigated agriculture is the major comsumptive water use in the United States. The potential exists for significant reductions in this consumption of water through improved irrigation efficiency. In a dry year, 103 million acre-feet of water are consumed by irrigation, mainly in the West.(75) An estimated 8 million acre-feet of that water could be salvaged by improved irrigation efficiencies.

There are other impediments to water availability in the West, as noted by OTA:

- Water rights remain unadjudicated for many river basins in the West -- particularly in the Northwest. The total allocation of water within many basins remains unknown.
- Indian tribes increasingly exercise their water rights in the West. There is uncertainty about the water quantities that will ultimately be provided for Indian reservations.
- The laws regarding groundwater are inadequate in many states to allocate the resource among competing users and are not resolving the problem of excessive use.(74)

Such impediments are caused by man, not nature. The water resource does exist, both in the West and in the East. Under virgin conditions, the average annual stream runoff in the 11 Western States totals an estimated 427 million acre-feet. Man's cumulative activities have depleted this virgin supply by 83 million acre-feet of consumptive water use annually. This leaves 344 million acre-feet or about 81% of the virgin supply still untapped.

It remains for man to devise solutions for utilizing that water in ways that are equitable and beneficial to all parties.

A synthetic fuel plant generates a variety of wastewater streams. Their quantities and compositions are highly process and site specific. However, the process engineer has a variety of treatment methodologies available to achieve zero discharge or to satisfy all effluent standards.

One major wastewater stream in most synfuel processes is sour water, which is a heavily contaminated stream. Hydrogen sulfide, ammonia, and phenols are the major contaminants in this stream. Cyanides, thiocynate, metals, and trace organics, such as polycyclic aromatic hydrocarbons, are also present in this stream.

Another major waste stream, the cooling tower blowdown, is often comparable in magnitude to the sour water stream. The blowdown contains highly concentrated quantities of the common inorganic constitutents present in the cooling makeup water. In addition, the blowdown contains contaminants such as hexavalent chrominum, which is added to the cooling system for corrosion control.

The remaining wastewater streams come from various sources: runoffs from raw fuel piles or from around the process equipment; sanitary wastes; landfill leachates; oil-bearing wastes; and, filter backwash waters.

The contaminants in the fuel pile runoff are mostly dissolved inorganic solids. The process area runoff contains process liquids, including certain high boiling-point hydrocarbons. The landfill leachates contain organic substances, inorganic salts, and suspended solids. Their compositions and concentrations depend upon the nature of the landfill waste.

Because of their widely varying compositions, the different wastewaters are generally collected and treated initially as separate streams.

"Zero discharge" is an alternative to discharging treated water into a natural stream. Several studies have concluded that synthetic fuels plants will find it practical and economic to design for zero discharge. One observes "returning water to a source is not economic when the water must be cleaned to a quality equal to or better than the source water"(87) and another reported that vendors agreed that treatment of wastewaters for recycling would be easier and cheaper than treating to meet the standards for discharge.(88) The Draft EIS for the coal RD&D program also proceeded on the assumption of zero discharge for the water effluents from synthetic fuel plants.(70)

The SRC-II demonstration plant is being designed for zero discharge of process water.(89) The design employs ammonia and tar recovery units, recycling of process water after evaporation, tertiary treatment of sanitary sewage, and incineration of all sludges. This, however, is not complete zero discharge for all streams. Certain other wastewaters, such as blowdown from the oxygen plant cooling tower, may be discharged under an NPDES permit.

Complete zero discharge is the design concept for the Illinois Coal Gasification Group demonstration plant.(90) The energy costs of the design are high. Almost 2% of the coal feed is consumed to provide energy to the wastewater treatment system. Evaporation is by far the most energy intensive step.

Zero discharge is under evaluation for the SRC-I demonstration plant.(91) The evaluation is considering (1) technical feasibility, including safe disposal of the water-soluble solid wastes; (2) economics; (3) energy consumption; and, (4) overall environmental impacts.

7.4.4 Solid Wastes

Several types of solid wastes result from a synthetic fuels plant. The largest quantity is the mineral residue from the coal, shale or tar sand feedstock. Other major solid wastes include metal-bearing sludges (mainly from physical-chemical treatment processes), and biological treatment sludges. If the plant includes flue gas scrubbing, then a sulfate-sulfite sludge must be disposed of. In addition, there are minor quantities of other solid wastes, including oily sludges, spent catalysts, and spent activated carbon. A plant designed for zero wastewater discharge produces an inorganic salt cake.

The chemical composition and physical structure of the mineral residue depend greatly upon the process. The residue may range from a powder or granular ash to a glass-like slag. The residue may contain unreacted carbon and various organic compounds. The quantity of residue, its composition, and its structure affect whether or not it may be a useful by-product. If it cannot be used in applications such as construction, road-building, or as a soil amendment, it must be sent to a disposal site.

The classification of solid wastes from synthetic fuel processes is uncertain. According to the Resource Conservation and Recovery Act (RCRA), solid wastes must be tested and classified according to the RCRA procedures established by the EPA. Wastes classified as "hazardous" require additional safeguards over "nonhazardous" wastes. The technology exists to dispose of hazardous wastes in an environmentally acceptable fashion, but the costs are much higher. Neither hazardous nor nonhazardous wastes are permitted to be a source of groundwater contamination.

Coal gasification residues are being tested to provide classification data.(92) Residues from CoGas, British Gas/Lurgi, U-Gas, Grace-Ebasco, and SRC-II processes have been tested, and plans are to test SRC-I residues. Leaching tests indicate that, according to the RCRA criteria, these wastes would not be classified as "hazardous." Other tests on residue from the Exxon Donor Solvent Liquefaction Process conclude that wastes from Flexicoking can be classified as "nonhazardous."(93)

The Laramie Energy Technology Center is conducting a complementary program to sample and characterize solid wastes from oil shale and other fossil energy processes.(94) This program, which is in an early stage, plans to characterize both combustion and synthetic fuel wastes.

Leaching data for wastewater treatment sludges are generally not available. The sludges from physical-chemical treatment may well be classified "hazardous" because of their metal content. The biological sludges may or may not be hazardous.

7.4.5 Health and Safety

Many toxic materials are formed or are used in synfuel process operations. These include materials with carcinogenic or mutagenic properties. For example, polynuclear aromatic hydrocarbons, present in most synfuel liquids, can produce cancer in animals by skin painting or injection. Further, skin cancers have been found in workers who had physical contact with coal hydrogenation streams.(95)

There is considerable evidence that the carcinogenic and mutagenic properties are found only in the high boiling-point fractions. This is not surprising because high boiling recycle oil from petroleum catalytic cracking contains similar carcinogenic properties. Current data indicate that synthetic gas products and lower boiling-point fractions of coal liquids present minimal hazards.

In biomedical studies on SRC-II liquefaction materials, heavy distillate — a high boiling-point material — showed significant mutagenic activity, but lower boiling-point fractions were inactive. Chemical characterization studies suggested that 3- and 4-ring primary aromatic amines are responsible for a large fraction of the mutagenic activity of the heavy distillate. A significant reduction of bioactivity was experienced after the SRC-II samples were subjected to mild hydrotreating. One postulated mechanism is the removal of primary amine groups from multi-ring aromatic compounds.(96)

Modern methods of industrial hygiene are adequate to minimize exposure to hazardous materials and to protect worker health. This was not always the case. The less rigorous hygiene practices of the past allowed excessive worker exposure to coal-derived materials.(97) Statistical studies showed a greater incidence of cancer among coke-oven workers employed during the 1950's and early 1960's. The degree of risk depended upon the level and duration of exposure to coke-oven emissions. Workers in the low-exposure areas around the coke-ovens, however, experienced little or no cancer above normal. Since the exposure levels in a modern coal conversion facility would be greatly below even the cleanest areas of a 1950's coke-oven plant, coal conversion workers are not expected to encounter health risks.

A comprehensive analysis of the impacts of synthetic fuels, conducted by the Assistant Secretary for Environment of the U.S. Department of Energy, concluded that occupational health and safety is not a constraining factor in synthetic fuels development.(67) However, many questions must be answered regarding worker exposure to process-associated materials. An intensive testing program is underway to study process mixtures and individual fractions for mutagenicity and carcinogenicity. These efforts will take full advantage of pilot and demonstration plant operation as well as worker health data available from other industries and coal conversion sites abroad.

The potential hazards to the public health must also be considered. Public exposure to synthetic fuel materials may take one of two forms. Exposure may come through low-level pollutants in air or water, or it may come from accidental releases from transportation systems, waste disposal facilities, or product user facilities. Plant environment control systems are expected to maintain routine air and water emissions at acceptable and safe levels. The risk of accidental releases can be minimized by proper process design and operation. The extent and severity of public exposure, should an accident occur, can be limited by proper containment and clean up techniques.

7.4.6. Socioeconomic Impacts

Major societal impacts can result from synthetic fuels development, particularly in the West. A synthetic fuels industry requires a large number of people for mining, plant operations, and associated support and service activities. Many persons with different values and orientations could move into rather small communities, rapidly expanding the population.

The ability of a region to absorb socioeconomic stresses depends upon the size and the quality of the existing infrastructure and the magnitude of the stresses. Communities in the sparsely populated Western coal and oil shale regions have small bases from which to handle rapid population growth. An annual 5% growth rate appears to be the maximum that can be comfortably absorbed. Boom-town type growth occurs when annual increases approach 7 to 10%. Sustained yearly population increases in excess of 10% would, almost certainly, require the creation of new towns.

Even the most carefully planned new development may represent an undesirable change in lifestyle for existing residents. The existence of new communities in close proximity to older communities could create conditions for resentment and social strife. Of course, there also will be opportunities for enrichment and a higher standard of living.

The issue of socioeconomic impacts has been analyzed in several recent assessments and environmental statements relating to coal and oil shale utilization.(67,69,70,75) As discussed in these studies, options exist for minimizing the adverse socioeconomic impacts.

In summary, a synthetic fuels industry will change the social and economic lifestyles of many people. These changes will bring both benefits and drawbacks. Adequate planning and preparation for the inevitable changes, increased public understanding of what is occurring and why, broader participation by citizens in decisions affecting them, and fair compensation for damages are measures that can enhance the benefits and minimize the drawbacks.

7.4.7 Environmental Conclusion

The environmental, health, and safety impacts of synthetic fuels technology have been analyzed repeatedly and in depth. The impacts are neither so trivial as to be ignored, nor so large as to preclude the start of a synthetic fuels industry. Engineering judgment states that synfuel plants can be built and operated in compliance with all existing standards. The optimization of environmental safeguards and the evolution of additional standards are areas of uncertainty. Such uncertainties can be best resolved through a comprehensive program of environmental research and surveillance to accompany the initiation of the synfuels industry. Formation of this industry will encourage improved environmental controls.

7.5 GENERAL COMPARISONS

Table 7.3 is a composite comparison of the available synguel technologies. Even though development work continues for all categories, each is at a state where commercialization is feasible.

It is the market needs that will dictate the generic process which best suits the requirements. After this determination is made, there are competing process licensors and contractors for each of the technologies.

In addition to the needs of the local market, the available resource is of prime interest since it will be a major factor determining capital investment and product cost.

The entries in Table 7.3 are very general. All of the synfuel processes shown have a strong advantage in offering energy cost stability if the proper assurances of resource supply are established. A healthy U.S. synfuels industry will likely make some use of all of the entries in the table.

Table 7.3: Synfuel Comparisons

Synfuel Process	Technology Status	Products	Market Potential	Risks & Constraints	Resource Utilization	Economic Factors
Coal:						
Pyrolysis /Gasification (COGAS)	(B)	Gas, Oil	Good	Economic	Good	Market Risk
Coal-Oil Mixtures	(B-A)	Boiler Fuel	Good	(A)	High	Attractive Where Applicable
Direct Liquefaction	(B)	Refinery Feed or Boiler Fuel	Good	(B)	Good	Product Cost
Indirect Liquefaction	(A)	Light Liquids Gases	Good	(A)	Good	Market Risk
High Btu Gasification	(A)	SNG	Good	(B)	High	Product Cost
Medium Btu Gasification	(A)	MBG	Good	(A)	High	Market Risk
Low Btu Gasification	(A)	LBG	Good	(A)	High	Market Risk
In Situ Gasification	(C)	LBG	(C)	(C)	Poor	(C)
Magnetohydrodynamics	(C)	Electric Power	Good	(C)	High	(C)
Oil Shale:						
Surface Retorting	(B)	Refinery Feed Gas	Good	Economic	Good	Product Cost
Modified In Situ	(C)	Refinery Feed Gas	Good	Economic Technological	Fair	Product Cost
In Situ	(C)	Refinery Feed Gas	Good	(C)	Poor	Product Cost
Tar Sands:						
Surface Recovery	(A)	Refinery Feed	Good	(A)	High	Product Cost
In Situ Recovery	(B)	Heavy Oil	Good	(C)	(C)	(C)

Notes:
(A) Few risks, experience full developed
(B) Development work fairly complete but commercial scale experience lacking
(C) Many unknowns still exist, much remains to be proven

ABBREVIATIONS TABLE

API	American Petroleum Institute
ARCO	Atlantic Richfield Company
B/D	Barrels Per Day
BACT	Best Available Control Technology
BTU	British Thermal Unit
CFD	Cubic Feet Per Day
COED/COGAS	An Integrated Pyrolysis Gasification Combustion Process
COM	Coal-Oil Mixture
CONAES	Committee on Nuclear and Alternative Energy Systems
CONOCO	Continental Oil Company
DOE	Department of Energy
EDS	Exxon Donor Solvent
EIS	Environmental Impact Statement
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration
ESA	Energy Security Act
ESCOE	Engineering Societies Commission on Energy
FSI	Free Swelling Index
GPT	Gallons Per Ton
H-COAL	Trade Name of Process Developed by Hydrocarbon Research, Inc.
HRI	Hydrocarbon Research, Inc.
ICGG	Illinois Coal Gasification Group
IGT	Institute of Gas Technology
LBG	Low Btu Gas
LCFFC	Lummus Clean Fuels From Coal
LPG	Liquified Petroleum Gas
MBG	Medium Btu Gas
MHD	Magnetohydrodynamics
MIS	Modified In-Situ
MMSCFD	Million Standard Cubic Feet Per Day
MWe	Megawatt Electric
MWt	Megawatt Thermal

NEP	National Energy Plan
NO_x	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
OCR	Office of Coal Research
OPEC	Organization of Petroleum Exporting Countries
ORNL	Oak Ridge National Laboratory
OTA	Office of Technology Assessment
PDU	Process Development Unit
PPM	Parts Per Million
PSD	Prevention of Significant Deterioration
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
SFC	U.S. Synthetic Fuels Corporation
SNG	Synthetic Natural Gas
SO_x	Sulfur Oxides
SRC	Solvent Refined Coal
TIS	True In-Situ
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
USGS	U.S. Geological Survey

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