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Balanced Program Plan

Volume IV: COAL CONVERSION

Analysis for Biomedical & Environmental Research

MAY 1976

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BALANCED PROGRAM PLAN

Volume IV: Coal Conversion

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MAY 1976

Prepared for the Division of Biomedical and
Environmental Research, Energy Research
and Development Administration

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FOREWORD

This document represents the contribution to the ERDA/DBER Balanced Program Plan (BPP) that was coordinated by the Oak Ridge National Laboratory. It is the fourth in a series of eleven that will be published by DBER. Volume 1, "Balanced Program Plan - Overview and Summary," was published in October 1975 as ERDA-116 and is available from the National Technical Information Center. Volume 2 is entitled "BPP: Categorical Research," Volume 3, "BPP: Coal Extraction, Processing, and Combustion," and this, Volume 4, "BPP: Coal Conversion."

The ERDA Assistant Administrator for Environment and Safety (AAES) initiated the Balanced Program Planning activity within the Division of Biomedical and Environmental Research in April 1975. ERDA had just come into existence and the AAES recognized the importance of establishing an environmental health and safety program that would be both responsive to an anticipatory of ERDA's needs as regards R&D and ultimate commercialization of energy-producing technologies. The BPP activity represented a formalization and integration of thinking and interaction with contractor personnel that had taken place for at least a year prior to the formation of ERDA.

Input into the BPP was not limited to ERDA/DBER and contractor personnel. A working session at ORNL in May 1975 on Coal Conversion Technology was attended by representatives of industry, universities, ERDA Energy Research Centers, and the ERDA multipurpose laboratories. Each had valuable inputs to this document. This working session, as well as other activities involved in the preparation of this document, were coordinated by Dr. C. W. Gehrs of the Environmental Sciences Division at Oak Ridge. Dr. C. R. Richmond, Associate Laboratory Director for Biomedical and Environmental Research at Oak Ridge, had overall responsibility for the project. ORNL also participated actively both prior to and during the June 1975 workshop held in Germantown, Maryland. The workshop served the important function of integrating the efforts of the multiprogram laboratories planning activities as regards specific technologies and the ERDA/DBER staff concerning Biomedical and Environmental Research categories. The latter evolved from several environmental planning activities related to national energy problems; for example, the Ray report of December 1973, "The Nation's Energy Future," WASH-1281 and the King-Muir Interagency Study of November 1974, "Report of the Interagency Working Group on Health and Environmental Effects of Energy Use."

The goal of the BPP is to apportion the research activities sponsored by the AAES among the technologies of interest to ERDA and the specific categories of Biomedical and Environmental Research to help ensure that unnecessary duplication is avoided and meaningful programs can be implemented.

The ERDA National Plan for Energy R&D submitted to Congress on June 30, 1975, contains a commitment to protect and improve the nation's environmental quality. We at ORNL are proud to be part of the joint BPP activity with ERDA. We now look forward to the implementation of the BPP so that we can work with ERDA toward honoring its commitment to protecting and improving the quality of our environment as we proceed with the important job of securing the nation's energy future.

ABSTRACT

OAK RIDGE NATIONAL LABORATORY. 1976. Balanced Program Plan. Volume IV: Coal Conversion. ORNL-5123. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 314 pp.

This document contains a description of the Biomedical and Environmental Research necessary to ensure the timely attainment of coal conversion technologies amenable to man and his environment. The document is divided into three sections. The first deals with the types of processes currently being considered for development; the data currently available on composition of product, process and product streams, and their potential effects; and problems that might arise from transportation and use of products. Section II is concerned with a description of the necessary research in each of the King-Muir categories, while the third section presents the research strategies necessary to assess the potential problems at the conversion plant (site specific) and those problems that might effect the general public and environment as a result of the operation of large-scale coal conversion plants.

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INTRODUCTION

The technology for the conversion of coal to liquid and gaseous hydrocarbons for fuel and petrochemicals is being actively developed by ERDA and private industry. The need for this technology is increasing because of dwindling domestic supplies of natural gas and petroleum, and because of environmental requirements for clean desulfurized fuel. The development of this technology should proceed in such a way that conversion processes can be optimized not only economically, but also for maximum protection of human and environmental health. However, experience in the 1950's at a large coal hydrogenation pilot plant demonstrated a variety of industrial hygiene problems. The most serious of these was the incidence of skin cancer resulting presumably from contact with process materials containing polycyclic organic compounds. A careful assessment of potential health and environmental impacts of coal conversion is required as the technology develops so that adequate protection for the industrial workers, for the population in the vicinity of conversion plants, for the general public, and for the environment can be designed and engineered into conversion processes. Health and environmental protection should be important criteria in process development and design selection, comparable in importance to conventional economic considerations.

The purpose of this document is to present the biomedical and environmental research necessary to ensure the development of coal conversion technologies optimized not only economically, but also for maximum protection to man and his environment. The document is divided into three sections, the first of which contains a detailed description of various components of the fuel cycle. It includes descriptions of the various alternative processes of both gasification and liquefaction (Section I.1), a discussion of effluent materials (Section I.2) (both what is currently known and potential biomedical and environmental problems), problems associated with waste management (Section I.3), and information regarding transportation, storage, and final use of products (Section I.4).

Section II is subdivided into two parts. The first includes a brief overview of research necessary in each King-Muir category (scientific discipline) to evaluate any technology. The second part of Section II includes the research problem areas (Problem Definitions) and specific research plans (Program Units) necessary to support a developing coal conversion technology. These include milestones and suggested funding levels for 1977-1981.

There are three parts to Section III. The first is a matrix display by King-Muir categories and selected demonstration and/or commercial plant sites. Included in this is a brief discussion of that research which must be conducted at the specific plant site. The second part of Section III begins with a matrix display of King-Muir categories and fuel cycle components. This includes a discussion of research applicable to the different conversion alternatives but able to be conducted at research facilities removed from specific plant sites. In both of the matrix displays priority rankings for each of the categories (severity, extent, information, and urgency) have been included at each matrix intersect. The final part of Section III includes summary budgetary sheets by Program Units for the first five years of the Program.

One appendix is included, which is composed of chemical composition information of process, product, and effluent streams of the various conversion alternatives.

Coal conversion technologies are young and quickly evolving. Information on biomedical and environmental implications is sparse. The research suggested here has been kept sufficiently flexible to allow rapid response to changing technological priorities.

I. FUEL CYCLE COMPONENTS

I.1 COAL CONVERSION PROCESSES

I.1.1 Introduction

Conversion of coal into clean fuels and into chemical feedstocks is a desirable use for the enormous coal reserves in the United States. In terms of energy, these reserves are estimated to be 80 x 10^{17} Btu, compared to domestic oil reserves at 2 x 10^{17} Btu.[1] Unfortunately, coal is laden with sulfur and ash, both of which are undesirable in fuel combustion and in chemical processing, because coal conversion products must be clean.

Coal pyrolysis (destructive heating) has long been used to produce coke, coal tar, and fuel gases. Rudimentary coal gasification was developed in the late nineteenth century, and Siemans conceived of underground or in-situ gasification as early as 1868. By the 1940's, manufactured gas had peaked as the primary source for the eastern U.S. residential gas market,[2] Lenin had inspired large-scale in-situ gasification projects in Russia,[3] and the Bergius hydrogasification processes and the Fischer-Tropsch hydrocarbon synthesis were meeting major fractions of German needs for hydrocarbon liquids. Nevertheless, these processes were inefficient and/or expensive, so commercial coal conversion in the United States was pre-empted by bountiful supplies of cheap oil and natural gas. Diminishing domestic oil and gas reserves, together with an increased need to use coal reserves in an environmentally safe manner, have prompted renewed interest in coal conversion.

For purposes of technology review, coal conversion processes will be broken into five categories:

(1) Surface gasification
(2) In-situ gasification
(3) Liquefaction - carbonization/hydrocarbonization
(4) Liquefaction - solvation
(5) Liquefaction - catalytic hydrogenation

One example process under each category will be discussed so as to present characteristics of the coal conversion type.

I.1.2 Characterization of Coal Conversion

Coal differences are rooted in the physical processes by which the coal was created. As prehistoric plants died, accumulated, and were gradually buried, subterranean heat and compression combined to drive off volatile fragments from the basically carbon molecular skeletons. The varying degree of this devolatilization produced variations from anthracite (the lowest in volatile content) through bituminous and subbituminous coal, lignite, and peat. Accordingly, these are broad classifications which represent approximations of the differences in coals.

Theories of coal structure produce models such as that in Fig. I.1-1. This diagram shows high-volatile bituminous coal (an intermediate classification) as being composed of aromatic clusters, linked into huge molecules by carbon bridges and by hetero-atom groups like OH, CO, COOH, NH_2, CN, S, and SH. Ignoring water and ash content (a moisture- and ash-free or maf basis), organic matter normally can be 70-90% carbon, 2-6% hydrogen, 1-2% nitrogen, 0.5-6% sulfur, and 2-20% oxygen (by weight). Moisture content of freshly mined coal will depend on ground water, but changes due to transport from mine-mouth to consumption site, open storage, and pretreatment vary widely. Inorganic matter is measured as ash, normally ranging from 3-30%. Ash is primarily oxides of silicon, aluminum, iron, and calcium, but also has important amounts of FeS_2, $FeSO_4$, $CaSO_4$, and trace elements.

The essential nature of many coal conversion processes is production of hydrocarbons, which are enriched in hydrogen as compared to the original coal. Comparison of the atomic ratio of hydrogen to carbon for hydrocarbon fuels (Fig. I.1-2) shows the hydrogen deficiency of coal relative to liquid or gaseous hydrocarbons. Anthracite would have even a lower H/C ratio than bituminous coal, while subbituminous coal and lignite would be approximately the same. Enrichment can be performed by removing the volatile, hydrogen-rich organic content through pyrolysis, leaving a high-carbon char or coke; by adding extra hydrogen to the carbon contained in the coal; or by producing CO and H_2 from the coal and catalytically reacting the molecules to form CH_4 and/or higher hydrocarbons. An important variation from this generalization of conversion as hydrogen enrichment is direct combustion of CO and H_2 from gasification.

Coal conversion routes are summarized by Fig. I.1-3. As shown in the top two lines, coal gasification can produce either a range of low- to high-heating value fuels or synthesis gas (H_2 + CO) for chemical manufacture, depending on the number of steps (and expense) that are applied. High-temperature, low-Btu gas may be the key to increasing coal-generated electricity production from its present 35-40% efficiency up to 60% efficiency.[4] It is low in heating value because of dilution by nitrogen from air, but contains much sensible heat from the high temperatures of gasification. In contrast, by gasifying with oxygen, dilution by nitrogen is prevented, leaving a medium-Btu gas consisting primarily of CO, H_2, and some CH_4. This mixture is suitable either for producing pipeline-quality gas by methanation (reaction of CO and H_2 to form CH_4) or for processes such as Fischer-Tropsch hydrocarbon synthesis, methanol production, and ammonia synthesis.

The bottom three lines represent the three basic coal liquefaction routes. Pyrolysis or carbonization may be carried out under a relatively inert atmosphere, or it may be carried under moderately high hydrogen partial pressure (hydrocarbonization). Dissolution is generally under

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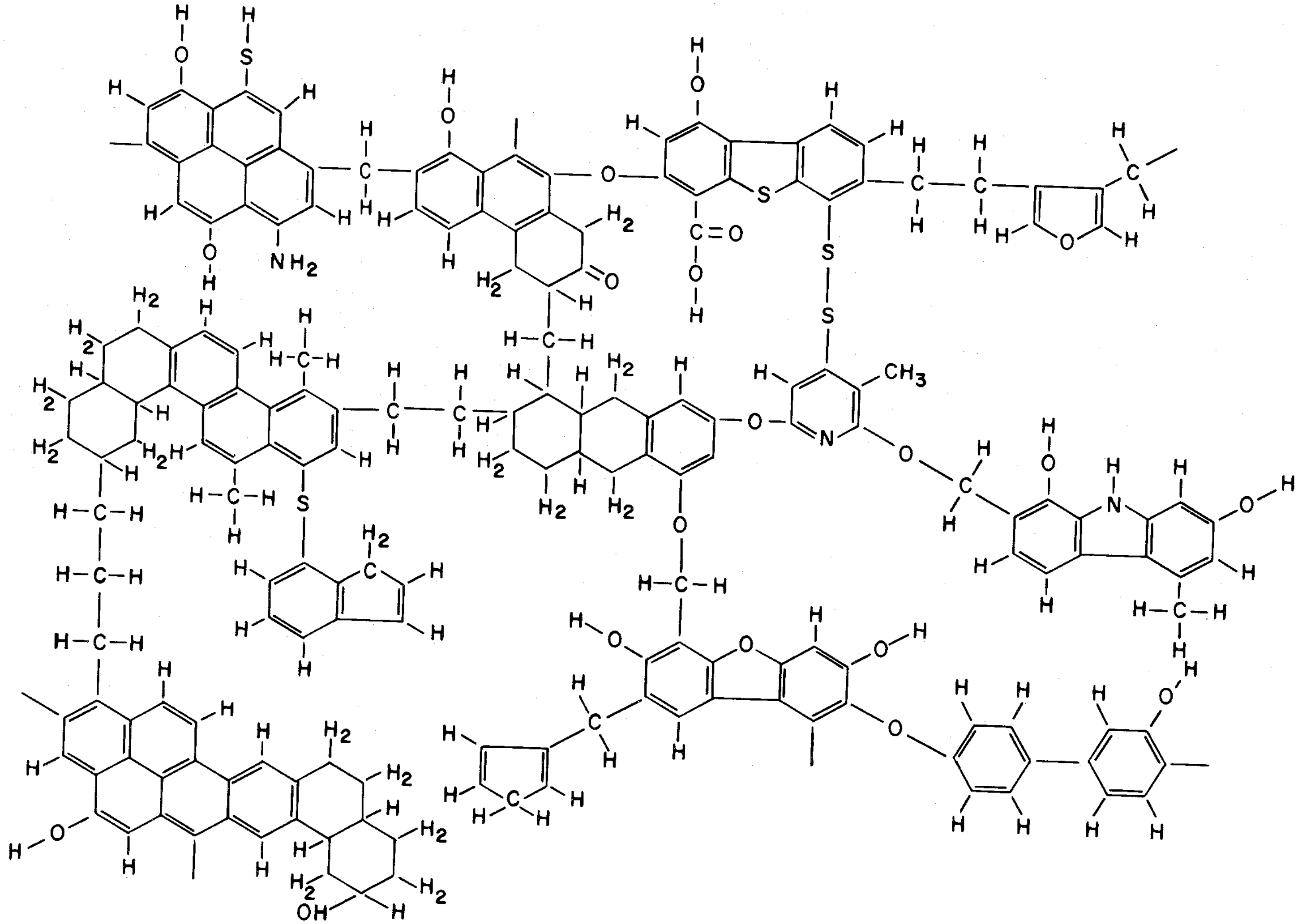

Figure I.1-1. Proposed structure of a high volatile bituminous coal. [Source: W. H. Wiser, "Coal Characteristics and Coal Conversion Processes" (short course), Pennsylvania State University, October 29 - November 3, 1973.]

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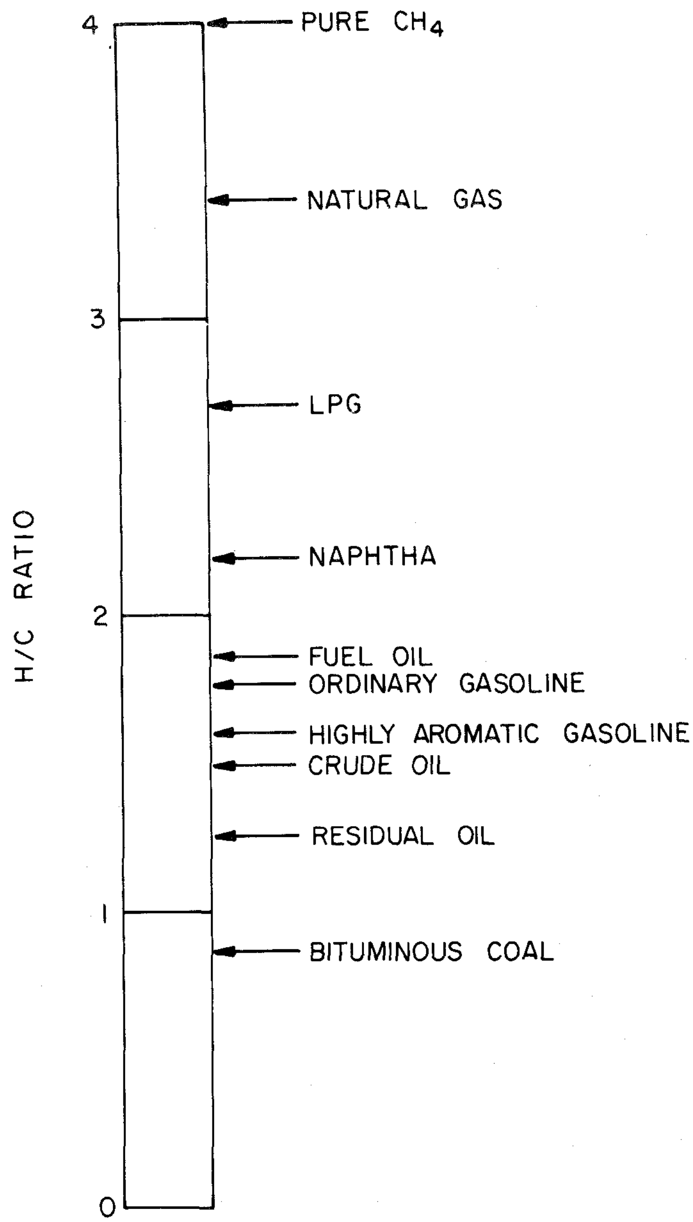


Figure I.1-2. Atomic hydrogen/carbon ratio for various hydrocarbon fuels. [Source: W. H. Wiser, "Coal Characteristics and Coal Conversion Processes" (short course), Pennsylvania State University, October 29 - November 3, 1973.]

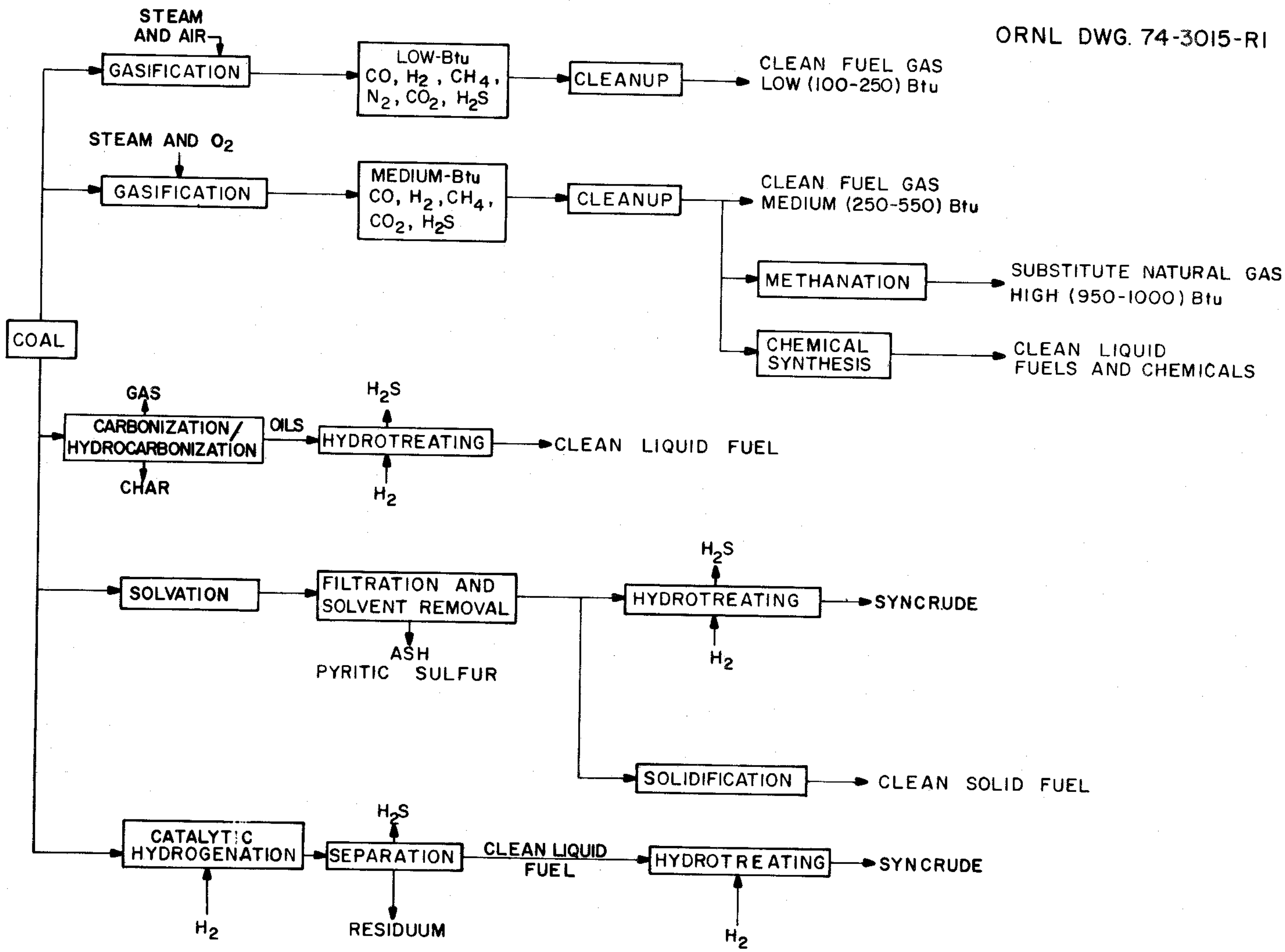


Figure I.1-3. Routes of coal conversion.

moderate hydrogen pressure; depending on the degree of hydrogenation, the product can be quite liquid or virtually solid at room temperatures. Finally, hydrogenation under high hydrogen pressure can take place in the presence of a catalyst, and the extent of hydrogen addition can be controlled to produce liquids ranging from heavy boiler fuels to synthetic crude oils (syncrudes).

Within process types, important differences in product composition can result from changes in process variables. Generalizing, high temperatures and, frequently, high pressures are necessary to convert coal to clean fuels. Temperatures ranges for liquefaction processes are about 400-700°C, and gasification temperatures vary between 600-1500°C. Because of thermodynamic equilibria and kinetic considerations, high pressures are necessary for hydrogenation. Catalysis may be required to increase reaction rates. Other important process variables are coal type as discussed above, coal particle residence time, partial pressures of reactants and products (particularly H_2), and recycle solvent composition for certain processes.

It must be assumed that coal conversion will be called upon to provide clean energy forms for the United States. The magnitude of future commercial production by coal conversion can only be subject to reasonable guesses; however, it will probably be dependent on crude petroleum availability and economics, coal conversion process development, governmental economic supports, and environmental factors. However, assuming a somewhat faster development than the Project Independence "business as usual" case and using estimates from the Department of Commerce Advisory Board, by 1985 a production rate of 1.4 billion cubic feet per day of gas (natural gas equivalent) and 100,000 barrels per day of liquid hydrocarbons (crude oil equivalent) is estimated. Projections for the year 2000 are 8 billion cubic feet per day of gas and 1,000,000 barrels per day of liquids.

I.1.3 Discussion of Specific Processes

Current status of important coal gasification processes is displayed in Table I.1-1, and the status of coal liquefaction development is shown in Table I.1-2. These listings are restricted to processes which are in pilot, demonstration, or commercial plant development for the United States. Possible time of commercialization with respect to 1985 is also noted. No distinction is made between processes likely or unlikely to be commercialized at all beyond 1985. Many other conversion processes have been used abroad or proposed for domestic development, but they are either unsatisfactory or unproven. Other sources discuss the many different process schemes more extensively.[2,4]

For detailed discussion of coal conversion, it is best to describe the best-developed and most-favored processes, chosen as examples of

Table I.1-1. Technological status of coal gasification processes

Process (developer)	Product gas Btu content	Reactor bed type	Number of stages	Pressure/temperature (atm/°C)	Current capacity (t/d)	Possible commercialization
Commercial						
Koppers-Totzek (Koppers GmbH)	Medium	Entrained	1	1/950-2150	850	Available now
Lurgi (Lurgi Mineraloltechnik GmbH)	Medium	Moving	1	20-30/600-750	1000	Available now
Wellman-Galusha (McDowell-Wellman)	Medium	Moving	1	1/600	100	Available now
Winkler (Davy Powergas)	Medium or low	Fluidized	1	1-3/800-1000	1500	Available now
Demonstration						
Lurgi - using agglomerating coals	Low	Moving (stirred)	1	20/500	2000	By 1985
Pilot Plant						
BI-GAS (Bituminous Coal Research)	Medium	Entrained	2	70-100/900-1500	120	By 1985
Cogas (FMC)	Medium	Fluidized	1	2-4/900	53 (char)	Near 1985
CO_2 Acceptor (Consolidated Coal)	Medium	Fluidized	2	10-20/900	40	Near 1985
HYGAS (Institute of Gas Technology)	Medium	Fluidized	2	70-100/700-1000	80	By 1985
SYNTHANE (Pittsburgh Energy Res. Ctr.)	Medium	Fluidized	1	40-70/900	75	By 1985
Union Carbide/Battelle	Medium	Fluidized	1	7/1000	25 (U.C.)	Near 1985
Stirred fixed-bed producer (Morgantown Energy Res. Ctr.)	Low	Moving	1	20/550	20	Near 1985
Combustion Engineering/ Consolidated Edison	Low	Entrained	1	1-10/1150+	120	After 1985
Westinghouse	Low	Fluidized	2	10-16/900-1000 and 1150	14	Near 1985
Pittsburg & Midway Coal Mining	Low	Entrained	2	4-35/1150+	30	Near 1985
U-Gas (Institute of Gas Technology)	Low	Fluidized	1	20/1050	30	After 1985
Laramie Energy Research Center	Low	Underground (in situ)	1	10/?	13-46	Near 1985

Table I.1-2. Technological status of coal liquefaction processes

Process (developer)	Type of hydrogenation	Pressure/temperature (atm/°C)	Current capacity	Possible commercialization
Demonstration (*none operating*)				
Coalcon (Union Carbide, Belleville, Ill.)	Hydrocarbonization	App. 70/500 (estimated)	(Contract let in early 1975; operation expected in 1979 at 2600 t/d)	Near 1985
H-Coal (Hydrocarbon Research, Inc. Catlettsburg, Ky.)	Catalytic	200/450	(Contract let in late 1974; operation expected in 1977 at 600 t/d)	Near 1985
Pilot Plant				
COED (FMC Corp., Princeton, N.J.)	Carbonization	2/315,455,540,870	36 t/d	After 1985
Consol or Project Gasoline (Consolidated Coal, Cresap, W. Va.)	Solvation & Catalytic	25/400 (solvation) 240/400-450 (catalytic)	20 t/d solvation and 13 t/d catalytic shut down in 1970	After 1985
Exxon (Baytown, Texas)	Catalytic	? (like H-Coal, SYNTHOIL)	1 t/d	After 1985
H-Coal (Hydrocarbon Research, Inc., Trenton, N.J.)	Catalytic	200/450	3-8 t/d	Near 1985 (see above)
Solvent Refined Coal or SRC (Pittsburg & Midway Coal Mining Co.)	Solvation	70-150/450	6 t/d (Alabama) and 50 t/d (Washington)	After 1985
SYNTHOIL (Pittsburgh Energy Research Center)	Catalytic	150-300/450	0.5 t/d	After 1985

general categories. Process types and specific processes are listed below:

Surface gasification - Lurgi
In-situ gasification - General description
Carbonization/hydrocarbonization - Coalcon (COED)
Solvation - Solvent Refined Coal
Catalytic liquefaction - H-Coal

Details about Coalcon, the leading candidate in carbonization/hydrocarbonization, are virtually unavailable, while COED, a similar and well-developed process near the demonstration stage, is well-documented; therefore, COED will be discussed instead of Coalcon. No U.S. process for underground gasification is currently slated for a demonstration plant, so discussion will be general, describing the current development efforts.

The above categories also neglect Fischer-Tropsch synthesis. It is not included because, as with ammonia and methanol synthesis, it can operate on any stream of CO and H_2. Fischer-Tropsch synthesis is admittedly linked more logically to coal; while steam reforming of methane to CO and H_2 is practical for producing ammonia or methanol, shortages of natural gas make its conversion to higher hydrocarbons unlikely. As Fig. I.1-4 shows, the Fischer-Tropsch product composition is dependent on temperature, pressure, and catalyst rather than on feedstock. Economics do not favor American use of the process, although a Fischer-Tropsch plant has operated successfully in South Africa since the mid-1950's.[5] In contrast, ammonia and methanol synthesis may well be built for operation on coal feedstock within the next decade.

I.1.3.1 Surface Gasification - the Lurgi Process

Lurgi gasification is in many ways typical of most surface gasification processes. As the oldest of the processes expected to produce gas in the United States, it also exhibits drawbacks which other processes attempt to eliminate.

For understanding of gasification in general, Lurgi gasification chemistry is informative. Among the complex reactions in the gasifier, seven qualitatively describe the process:

Pyrolysis	1.	Coal + heat $\rightarrow$ C + volatile hydrocarbons
Hydrogasification	2.	$C + H_2O + heat \rightleftarrows CO + H_2$
	3.	$CO + H_2O \rightleftarrows CO_2 + H_2 + heat$
Hydrogenation	4.	$C + 2H_2 \rightleftarrows CH_4 + heat$
	5.	$CO + 3H_2 \rightleftarrows CH_4 + H_2O + heat$
Combustion	6.	$C + O_2 \rightleftarrows CO_2 + heat$
	7.	$C + 1/2\ O_2 \rightleftarrows CO + heat$

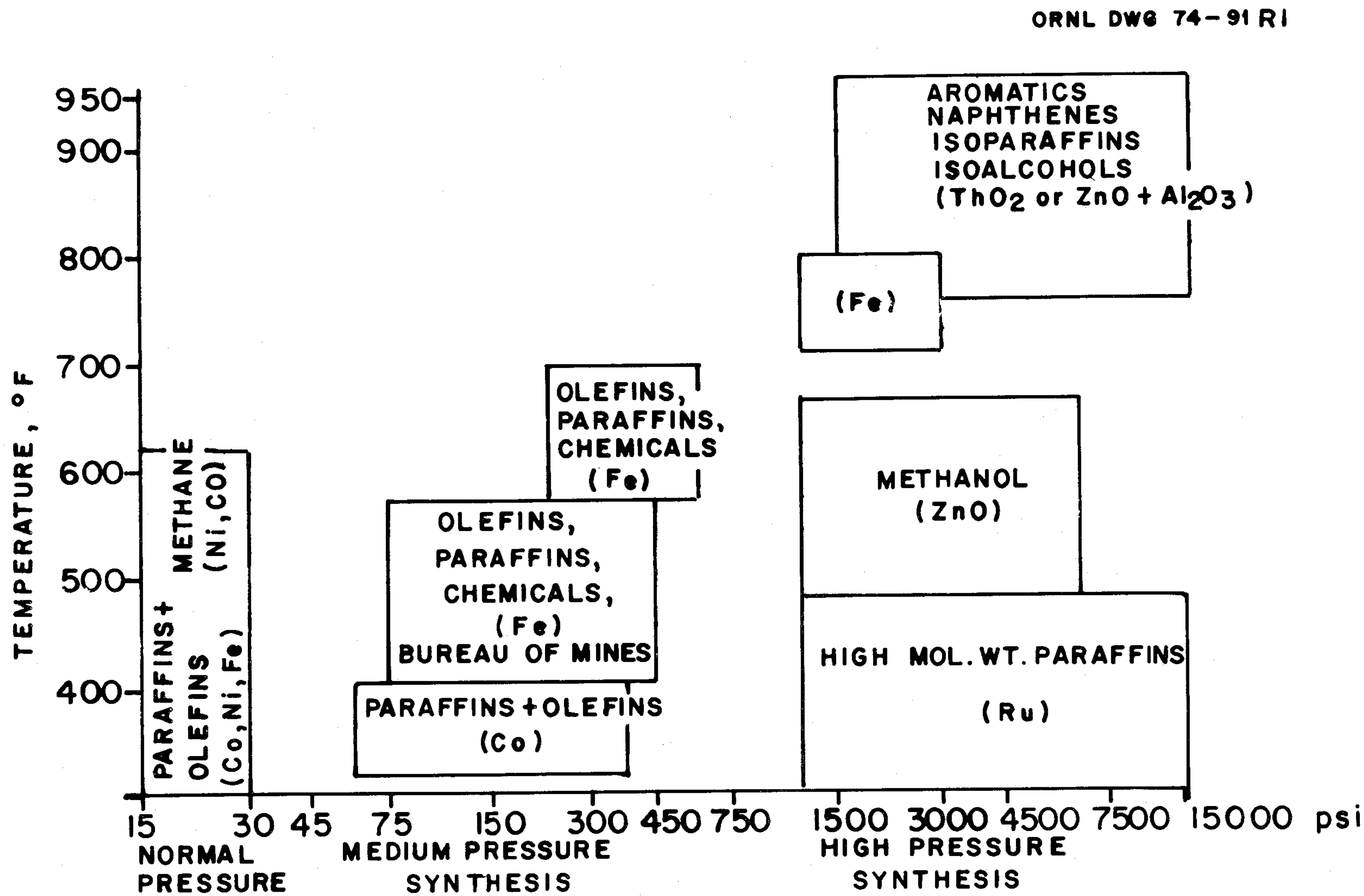


Figure I.1-4. Products of different Fischer-Tropsch synthesis conditions. [Source: Arnold and Keith, Advances in Chemistry Series, No. 5, 128 (1951).]

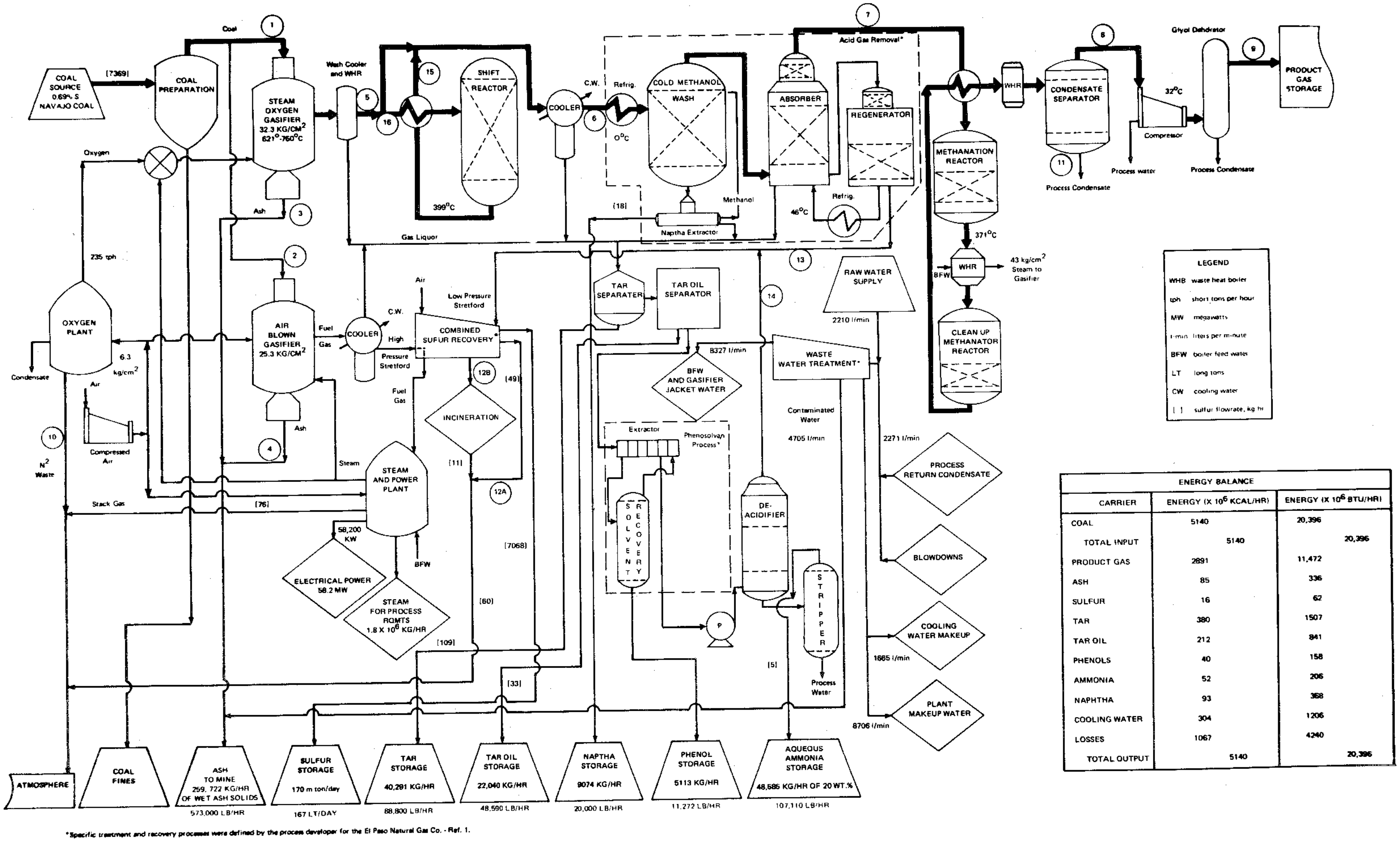
Reactions 2 and 6 are most important in understanding gasification itself. Because reaction 2 is so important yet endothermic, heat must be generated internally. Partial combustion furnishes this heat in the Lurgi process and most others (reactions 6 and 7), also producing CO which can be shifted with steam (reaction 3) to H_2 before methanation. Purified oxygen is used as the oxidizing agent when pipeline gas is produced. For production of a high-Btu gas, hydrogenation (reaction 4) to produce methane is necessary, but insufficient hydrogasification occurs in the gasifier. Instead, CO from reactions 2 and 7 and H_2 from reactions 2 and 3 are formed and then methanated using reaction 5 in a separate catalytic process following the gasifier.

El Paso Natural Gas Company planned to build the first modern, commercial-scale pipeline gas plant in the Four Corners area of New Mexico. Their plans have been delayed,[6] but, although EPNG may not have the first plant, its design is typical of Lurgi development. A detailed Lurgi flowsheet based on their plans is presented in Fig. I.1-5, and some intermediate flow rates and compositions are shown in Table I.1-3. High-Btu gas at 288 million cubic feet per day will be produced at a cost competitive with imported natural gas. Actually, both steam-oxygen gasifiers for product gas and steam-air gasifiers for plant utility generation will be used (see points 1 and 2 on Fig. I.1-5). Tars produced during gasification will be washed out after gasification, followed by a shift reactor (gasification reaction 3), H_2S and CO_2 removal, and finally methanation. Heavy lines mark the main flow of production.

Reactor design details are not included in the flowsheet. Coal is dropped into the top of the Lurgi gasifier from lock-hoppers. At the reactor bottom, steam and oxygen are introduced through a slowly rotating grate, through which ash can fall into an ash receiver. Pyrolysis takes place at the top, thus preserving the high-Btu pyrolysis products, while gasification takes place lower in the moving bed.

Important advantages of the Lurgi method of operation are gasification at pressure (20 atm) and conservation of gas sensible heat. Pressurized operation is valuable both because gas volumes flowing through the process units are minimized and because pressure is necessary to thermodynamically drive methanation reactions. Heating of fresh coal at the bed top by the rising gasification products efficiently uses the heat produced during gasification. This effect contributes to improving overall thermal efficiency, estimated at 72% for the EPNG plant if by-product heating values are included.

Restrictions to sized, noncaking coals and to relatively low feed-rates of coal are the primary disadvantages of the Lurgi route. Fines produced by grinding the coal cannot be used in the gasifier and must be disposed of elsewhere. Development of a Lurgi process to handle caking coals is well advanced; a stirrer is used to break up caked masses formed in the bed. An additional disadvantage is that a single Lurgi



ENERGY BALANCE				
CARRIER	ENERGY (X 10^6 KCAL/HR)		ENERGY (X 10^6 BTU/HR)	
COAL	5140		20,396	
TOTAL INPUT		5140		20,396
PRODUCT GAS	2891		11,472	
ASH	85		336	
SULFUR	16		62	
TAR	380		1507	
TAR OIL	212		841	
PHENOLS	40		158	
AMMONIA	52		206	
NAPHTHA	93		368	
COOLING WATER	304		1206	
LOSSES	1067		4240	
TOTAL OUTPUT		5140		20,396

Figure I.1-5. Lurgi gasification flowsheet. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, under Contract Number G8-02-1358, March 1974.]

Table I.1-3. Stream compositions for Lurgi gasification flowsheet. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards under Contract Number G8-02-1358, March 1974.]

STREAM NAMES	Oxygen Gasifier Coal Feed	Air Gasifier Coal Feed	Oxygen Gasifier Ash	Air Gasifier Ash	Crude Gas	Gas Purification Feed	Methanation Feed	Methanation Effluent	Pipeline Gas	N_2 Waste to ATM	Methanation Condensate	Off Gas to ATM	Off Gas to Incineration	Combined Acid Gas	H_2S From Waste Liquor	Shift Effluent	Shift Feed
STREAM NUMBERS	1	2	3	4	5	6	7	8	9	10	11	12A	12B	13	14	15	16
Gas Components (Vol. %)																	
O_2	---	---	---	---	---	---	---	---	---	0.86	---	2.29	---	---	---	---	---
CO_2	---	---	---	---	28.03	32.36	3.10	1.81	1.81	---	22.58	85.45	64.79	96.12	95.91	36.95	28.03
H_2S, COS, CS_2	---	---	---	---	0.37	0.34	---	---	---	---	---	80ppm	0.06	1.06	4.09	0.32	0.37
C_2H_4	---	---	---	---	0.40	0.39	0.45	---	---	---	---	0.20	0.11	0.22	---	0.35	0.40
CO	---	---	---	---	20.20	11.70	16.91	.01	0.01	---	---	0.15	7.22	0.41	---	5.03	20.20
H_2	---	---	---	---	38.95	43.63	63.49	4.16	4.16	---	---	0.39	9.63	0.76	---	46.80	38.95
CH_4	---	---	---	---	11.13	10.70	14.93	92.93	92.93	---	77.42	0.47	2.10	0.59	---	9.75	11.13
C_2H_6	---	---	---	---	0.61	0.59	0.69	---	---	---	---	0.27	0.16	0.30	---	0.53	0.61
N_2 + As	---	---	---	---	0.31	0.29	0.43	1.09	1.09	---	---	---	---	---	---	0.27	0.31
N_2	---	---	---	---	---	---	---	---	---	99.14	---	10.78	15.93	0.54	---	---	---
FLOW RATES (lb/hr)																	
Total Dry Gas	---	---	---	---	2,280,447	2,450,001	829,704	513,694	513,694	1,577,467	69	1,769,323	46,513	1,670,209	8,853	1,392,164	1,246,945
Water	314,950	67,522	---	---	1,394,960	2,680	---	1,316	66	9,995	314,625	34,569	1,006	10,900	8,870	357,765	762,764
Naphtha	---	---	---	---	20,005	20,005	---	---	---	---	---	---	---	---	---	10,939	10,939
Tar Oil	---	---	---	---	28,007	---	---	---	---	---	---	---	---	---	---	15,314	15,314
Tar	---	---	---	---	7,314	---	---	---	---	---	---	---	---	---	---	3,999	3,999
Crude Phenols	---	---	---	---	9,127	---	---	---	---	---	---	---	---	---	---	4,991	4,991
NH_3	---	---	---	---	17,629	---	---	---	---	---	---	---	---	---	---	9,640	9,640
Coal (MAF)	1,250,310	268,053	19,639	4,209	---	---	---	---	---	---	---	---	---	---	---	---	---
Ash	373,220	80,012	373,220	80,012	---	---	---	---	---	---	---	---	---	---	---	---	---
Total lb/hr	1,938,480	415,587	392,859	84,221	3,757,489	2,472,686	829,704	515,010	513,760	1,587,462	314,694	1,803,892	47,519	1,681,009	17,723	1,794,812	2,054,592
(kg/hr)	(879,530)	(188,560)	(178,250)	(38,210)	(1,704,850)	(1,121,910)	(376,450)	(233,670)	(233,100)	(720,260)	(142,780)	(818,460)	(21,560)	(762,710)	(8,040)	(814,340	(932,210)
Total Gas Flow Rate x 10^6 ft^3/day	---	---	---	---	982.2	1079.7	734.9	288.6	288.6	511.0	---	386.3	11.9	351.3	1.8	612.9	537.1

Table I.1-4. Commercial development of gasification in the United States* [Coal Age 80, No. 3, 94 (1975).]

Controlling company(s)	Site	Number of plants	Coal feed (t/d)	Gas output (million ft^3/day)	Start of operation
El Paso Natural Gas Company	Four Corners area, New Mexico	1	28,250	288	Postponed beyond 1977-1978
Texas Eastern Transmission Corp. and Pacific Lightning Corp. (WESCO)	Four Corners area, New Mexico	4	102,500	1000	1st plant 1978
Panhandle Eastern Pipeline Co.	Eastern Wyoming	1	25,000	270	1978-1980
Natural Gas Pipeline Co. of America	Dunn County, North Dakota	4	108,500	1000	1st plant 1982
American Natural Gas Co.	Bismark, North Dakota	4	-	1000	1982
Northern Natural Gas. Co., Cities Service Gas Co.	Powder River Basin, Montana	4	-	1000	1st plant 1979-1980

*Note: Each project will use Lurgi gasification.

and financial costs could be eliminated. Furthermore, deep, thick reserves as found in the Western United States might be recovered far more completely than by deep mining.

Although first suggested in 1868, development began in the Twentieth century. Russian development was most extensive, operating on a large scale beginning in 1932. An example of Russian production is the year 1956, in which 116 billion ft^3 of gas at 85 Btu/ft^3 were produced.[2] By comparison, this is about the same volumetric production rate as the planned El Paso Natural Gas facility, but at less than 10% of the Btu content. Experimentation was carried out in at least eight countries between 1945 and 1960, including the United States, but control problems and economics precluded further development.

New technology, heightened environmental consciousness, and increased energy needs have spurred further development. ERDA now sponsors three research and development approaches to underground gasification:

(1) Linked vertical-well process - Laramie Energy Research Center (LERC)
(2) Underground packed-bed reactor process - Lawrence Livermore Laboratory (LLL)
(3) Longwall generator process - Morgantown Energy Research Center (MERC)

Potentially these might generate either a medium-Btu gas using oxygen or a low-Btu gas by using air. Process streams would be cleaned and methanated as necessary, much like a surface gasification process except with no coal mining and with a different type of gasifier.

Coal seam preparation most distinctly characterizes the in-situ processes. In the LERC process, partial combustion using high-pressure air or oxygen drives a flame-front through the coal seam from one gas well to another. After this linkage to construct the "reactor," air (or oxygen) and steam are fed to a countercurrently moving gasification front. The LLL process would link the top and bottom of a 50-200-ft-thick coal seam by explosively fracturing the seam. Oxygen and steam would feed a cocurrently moving gasification/pyrolysis zone. In the MERC process, parallel boreholes would be drilled directionally along a coal seam. After further pretreatment, oxygen and steam would be fed into every other hole, driving gasification/pyrolysis zones along the entire hole lengths toward the product gas holes.

The principal advantages of underground gasification are elimination of coal mining problems and improved resource recovery. Manpower requirements would be completely on the surface, and problems of coal transportation and storage would not occur. The second advantage is that deep, thick seams not mineable by stripping or underground mining may be recovered.

Disadvantages are environmental and technical. Only ash will be left in the seam, so that subsidence of the ground surface and leaching by ground water are potential problems. Control of the gasification front and leakage of gaseous product into surrounding rock strata have traditionally been major technical problems, but better instrumentation and wise choice of sites may overcome these difficulties. Finally, the gasifying medium must not bypass the reaction zone, or product gases will contain oxygen.

Field experiments are underway on the LERC process, so that commercialization is possible by 1983. The LLL and MERC processes are preparing for field experiments now, so that successful development might result in commercial production by the late 1980's.

I.1.3.3 Carbonization/hydrocarbonization - COED (Coalcon)

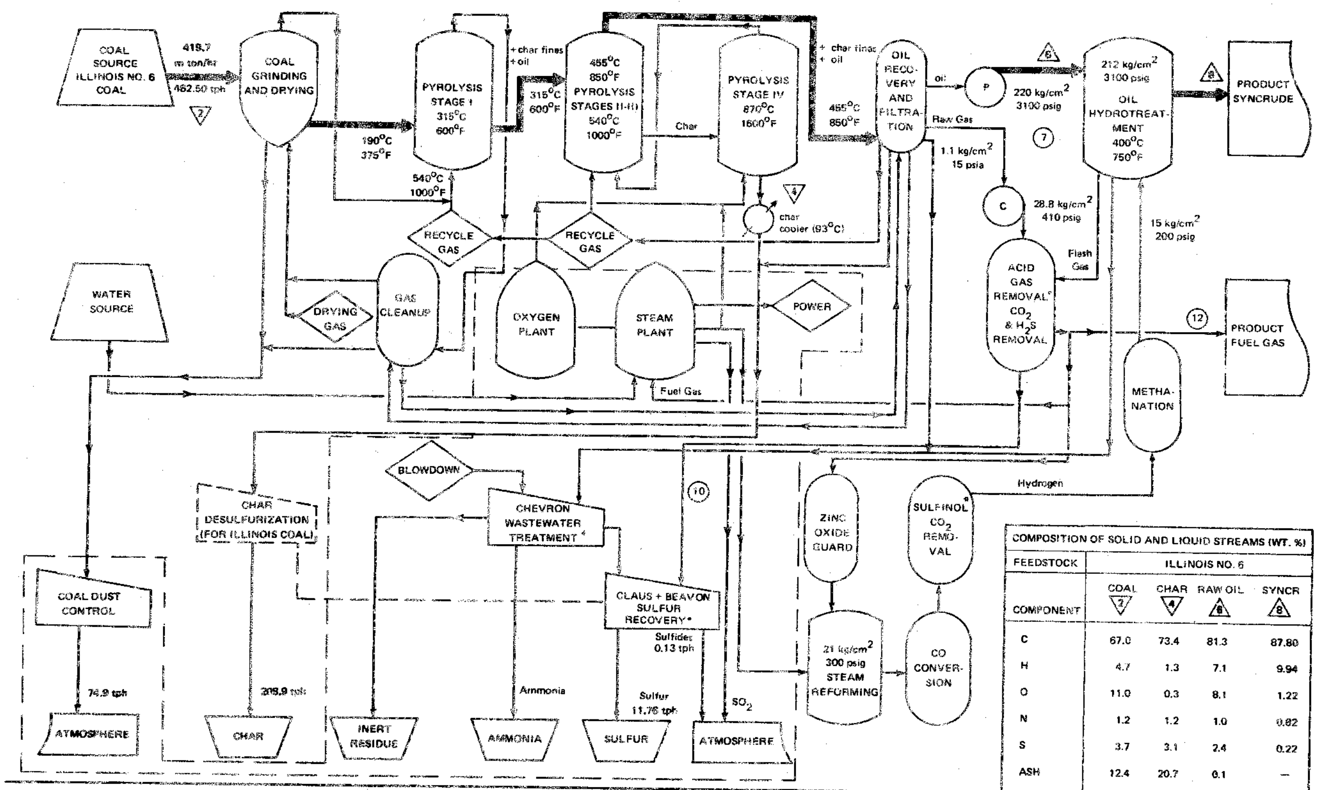
Carbonization or pyrolysis was the original method of producing liquid hydrocarbons from coal. However, yields of liquid product from pyrolysis are limited by the atomic hydrogen/carbon ratio (Fig. I.1-2) and by the corresponding volatile content. In order to convert so-called fixed carbon or refractory carbon, hydrogen pressure must be maintained during the pyrolysis - a hydrocarbonization process.

Coalcon Company, a joint venture of Union Carbide Corporation and General Tire & Rubber Company, will construct a demonstration hydrocarbonization plant under contract with the ERDA Office of Coal Research. Using 2600 tons of coal per day, 3990 barrels/day of clean boiler fuel and 22 million cubic feet/day of pipeline quality gas will be produced.[8] Having been privately developed, this process is not yet well-documented. The COED process, a multi-stage pyrolysis, has been under development at Princeton, N.J., since 1962 by FMC Corporation for the Office of Coal Research. Because COED is the next most promising process with basic similarity to the Coalcon process, the COED process will be discussed.

A typical COED process (Fig. I.1-6) pyrolyses coal in a series of fluidized beds beginning with a low-temperature pyrolysis (315°C), passing it on to a 455° bed, then to a 540° bed, and finally into an 870° bed. Agglomeration of coal ash is prevented by this staged increase in temperature; more or fewer stages may be used, depending on agglomerating tendencies of the particular coal. Heat for the process is generated by partial combustion of char in the final stage. Only slight pressure (10-18 psig) is applied.

COED pyrolysis products are a relatively heavy oil, a medium-Btu gas, and a partially burned char. To convert the oil to a synthetic crude oil, hydrotreatment is required. Hydrogen for the hydrotreating may either be produced by steam reforming of the product gas (as shown in Fig. I.1-6) or by gasification of the product char. Cleaning of the product gas will be necessary in any case, as will treatment of wastewater.

Utilization of char for gasification or combustion is important to development of the COED process. Any liquefaction process must produce



COMPOSITION OF GASEOUS STREAMS (VOL. %)			
COMPONENT	(7)	(10)	(12)
H_2	38.5	1.3	46.3
H_2O	–	–	–
CO	18.4	0.7	22.1
CO_2	13.0	75.3	TRACE
CH_4	12.3	0.4	14.8
C_2H_4	0.6	–	0.7
C_2H_6	10.1	0.3	12.2
C_3H_6	1.6	–	1.9
C_3H_8	0.2	–	0.2
C_4H_8	–	–	–
C_4H_{10}	1.5	–	1.8
C_5^+	–	–	–
O_2	–	–	–
N_2	–	–	–
NH_3	–	–	–
H_2S	3.8	22.0	TRACE
FLOW RATE			
$10^3\ m^3/hr$	98	17	16
$10^3\ ft^3/hr$	3450	595	562

COMPOSITION OF SOLID AND LIQUID STREAMS (WT. %)				
FEEDSTOCK	ILLINOIS NO. 6			
COMPONENT	COAL (2)	CHAR (4)	RAW OIL (6)	SYNCR (8)
C	67.0	73.4	81.3	87.80
H	4.7	1.3	7.1	9.94
O	11.0	0.3	8.1	1.22
N	1.2	1.2	1.0	0.82
S	3.7	3.1	2.4	0.22
ASH	12.4	20.7	0.1	–
TOTAL	100.0	100.0	100.0	100.0
MOISTURE	11.0	–	–	–
short tons/hr (m ton/hr)	462.50 (419.7)	230.20 (208.9)	75.60 (68.6)	65.71 (59.6)

Note: Values for Flow Rates and/or Compositions refer to Illinois No. 6 Coal.

*Specific treatment and recovery processes were defined by the process developer.

Figure I.1-6. The COED process - Illinois No. 6 coal. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, under Contract Number G8-02-1358, March 1974.]

solids, liquids, and gases, but pyrolysis would leave more carbon in its solid product than would other routes. In addition, pyrolysis char would likely be high in sulfur content. Increased conversion of the solid carbon to liquid products is further reason for hydrocarbonization. Desirability of this end is reflected in plans being made for a Coalcon demonstration plant, while plans were being scrapped for a COED demonstration plant because of economics.[10] Other processes are under development, but only COED and Coalcon are ready for demonstration plant construction.

I.1.3.4 Solvation - Solvent Refined Coal

Coal is an organic rock containing inorganic minerals as impurities, so a logical method for separating organic and inorganic constituents is dissolution by organic solvents. The best developed process employing this concept is Solvent Refined Coal or SRC. Pittsburg & Midway Coal Mining Co. has started up a 50-ton/day pilot plant at Fort Lewis, Washington, while Southern Services, Inc. and the Electric Power Research Institute are operating a 6-ton/day SRC system at Wilsonville, Alabama. Differences in the two flowsheets are principally due to differences in their scales of operation.

Figure I.1-7 shows a general flowsheet for a SRC plant using about 11,000 tons/day of coal. Some flows and compositions are included in Tables I.1-5 through I.1-7. In the process, crushed coal and a process-derived solvent are first mixed as a slurry. Hydrogen is added next, and the mixture passes through a preheater and into a dissolver. At 70-150 atm and 440-455°C, mild pyrolysis and hydrogenation take place together with true solvation. Typically 5-10% of the coal will remain undissolved as fine particles, either of ash or of heavy organics such as asphaltenes.

Following dissolution, unreacted hydrogen and product gases are separated from the slurry and desulfurized. Part of the gas is recycled and mixed with fresh hydrogen for the hydrogenation, and the remainder is used to fuel plant utilities. Solids are presently filtered out using precoat filters. Light oils, phenols, and cresylic acid are flashed off and separated from each other. Finally, the remaining liquid product (melting point 150-200°C) is solidified, producing a clean boiler fuel. Hydrotreatment of the heavy liquids is also possible.[11]

Solid-liquid separations and hydrogen consumption are the principal problems in the SRC process. Very small particles (micron and submicron ranges) must be separated from very viscous liquids. Apparently temperatures of 290 to 370°C will be necessary to lower liquid viscosity for filtration at 7-14 atm.[11] This problem is not unique to SRC, but its solution is central to the SRC concept of de-ashing. Furthermore, the mild degree of hydrogenation produces an especially heavy liquid product. In the flowsheet of Fig. I.1-7, nearly 50 million ft^3/day of hydrogen are produced from steam reforming of natural gas for consumption by the

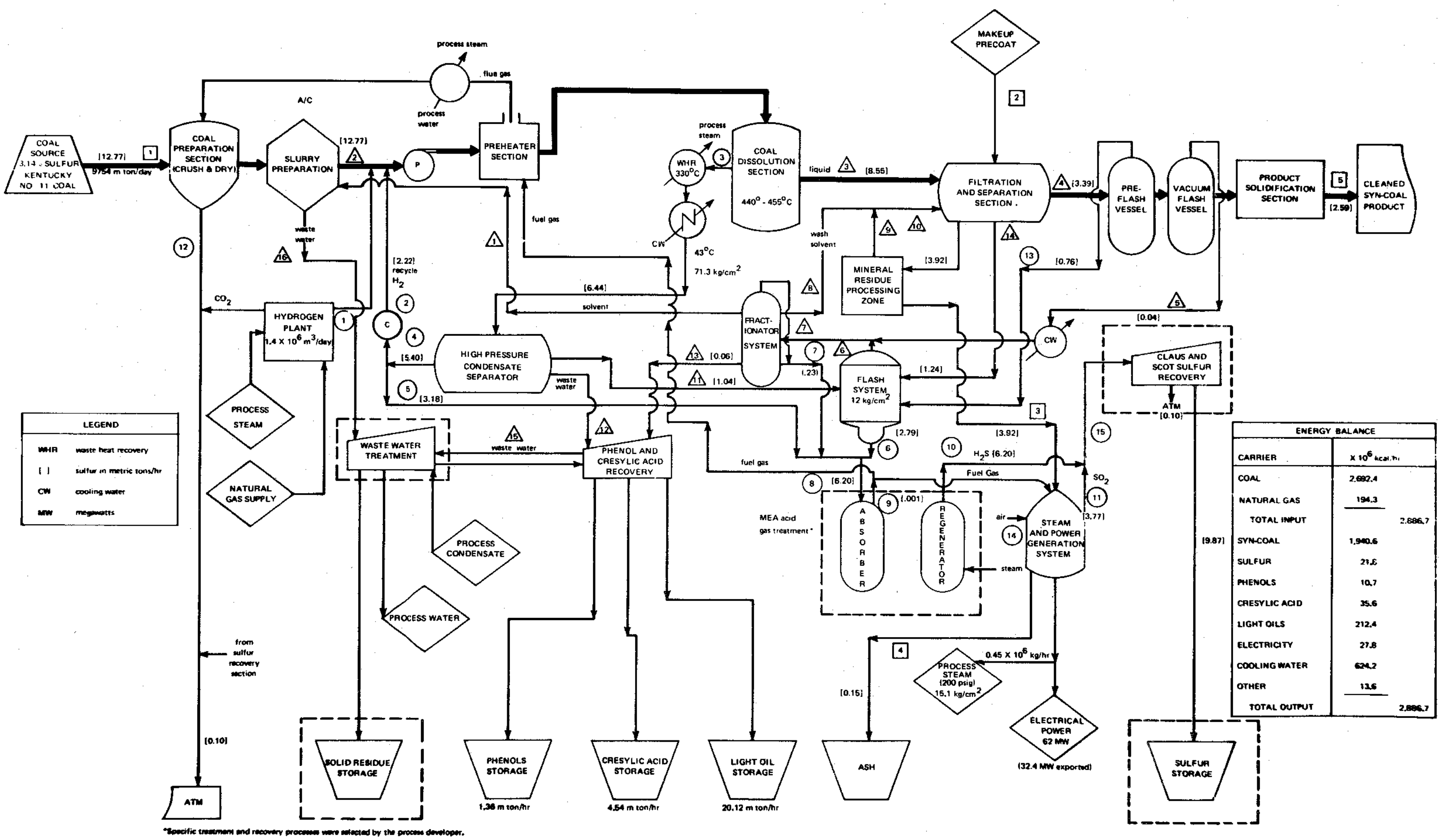


Figure I.1-7. The Solvent Refined Coal process. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, under Contract Number G8-02-1358, March 1974.]

Table I.1-5. Composition of gaseous streams from SRC flowsheet. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards under Contract Number G8-02-1358, March 1974.]

Streams	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)*	(13)	(14)	(15)
Components, mole %															
H_2	100.00	36.73	22.24	36.73	36.73	14.85	1.23	30.95	33.92	— —	— —		9.10		— —
CO_2	— —	2.30	1.49	2.30	2.30	2.83	1.14	2.42	10ppmV	27.55	15.99		2.14		16.55
H_2S	— —	4.38	3.15	4.38	4.38	11.71	19.17	6.35	8ppmV	72.45	— —		16.98		3.55
SO_2	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	2.27		— —		2.16
N_2	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	79.00		— —	79.00	75.14
C_1	— —	43.88	27.54	43.88	43.88	40.84	9.12	42.71	46.81		— —		33.01		— —
C_2	— —	9.50	6.63	9.50	9.50	19.15	23.07	12.02	13.18		— —		21.02		— —
C_3	— —	2.85	2.40	2.85	2.85	9.12	35.22	4.78	5.24		— —		13.71		— —
C_4	— —	0.36	0.42	0.36	0.36	1.50	11.05	0.77	0.85		— —		4.04		— —
H_2O	— —	— —	36.13	— —	— —	— —	— —	— —			— —	100.00			— —
O_2	— —	— —	— —	— —	— —	— —	— —	— —			2.74			21.00	2.60
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
$(Ft^3/hr) \times 10^6$	2.06	1.33	5.34	3.22	1.89	0.62	0.03	2.55	2.33	0.22	4.34	1.14	0.12	4.34	4.56
(Cubic meters/hr) $\times 10^4$	5.83	3.77	15.12	9.12	5.35	1.76	0.08	7.22	6.60	0.62	12.29	3.23	0.34	12.29	12.91
Lb-Moles/hr	5,448	3,500	14,094	8,499	4,999	1,644	82	6,724	6,135	589	11,443	3,013	308	11,443	12,032
(Gm-moles/sec)	(687)	(441)	(1,777)	(1,072)	(630)	(207)	(10)	(848)	(774)	(74)	(1,443)	(380)	(39)	(1,443)	(1,517)
Light oil, lb/hr	— —	1,101	25,138	2,617	1,516	1,261	678	3,455	3,455	—	—	—	19,890	—	—
(kg/hr)	— —	499	11,403	1,187	678	572	308	1,567	1,567	—	—	—	9,022	—	—
Wash solvent, lb/hr	—	—	—	—	—	—	—	—	—	—	—	—	47,017	—	—
(kg/hr)	—	—	—	—	—	—	—	—	—	—	—	—	21,327	—	—
Process solvent, lb/hr	—	—	108,558	—	—	—	—	—	—	—	—	—	209,908	—	—
(kg/hr)	—	—	49,242	—	—	—	—	—	—	—	—	—	95,214	—	—
Phenols, lb/hr	—	—	3,000	—	—	—	—	—	—	—	—	—	—	—	—
(kg/hr)	—	—	1,361	—	—	—	—	—	—	—	—	—	—	—	—

*Only the water vapor content of this stream can be estimated from the source data.

Table I.1-6. Composition of liquid streams from SRC flowsheet. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards under Contract Number G8-02-1358, March 1974.]

Stream	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Components, mole %																
H_2			18.20	8.80		0.81	0.75				2.59			21.33		
CO_2			2.60	2.11	1.04	0.67	0.70				2.87			2.76		
H_2S			11.02	17.24	24.93	14.02	14.89				14.33		8.17	8.94		
C_1			41.34	32.44	15.90	4.98	5.85				30.26		0.73	44.30		
C_2			16.44	21.09	23.23	16.33	16.88				25.42		7.16	14.89		
C_3			8.37	14.04	23.70	40.23	38.91				18.93		44.70	6.49		
C_4			2.03	4.28	11.20	22.96	22.02				5.60		39.24	1.29		
Total			100.00	100.00	100.00	100.00	100.00				100.00		100.00	100.00		
Lb-Moles/hr			1,275	318	11	123	134				503		52	956		
(Gm-moles/sec)			(161)	(40)	(1)	(15)	(17)				(63)		(6)	(121)		
Light oil, lb/hr			31,295	24,462	4,572	47,983	52,555	—	—	—	22,521	—	51,877	6,833	—	—
(kg/hr)			14,195	11,096	2,074	21,765	23,839	—	—	—	10,216	—	23,531	3,099	—	—
Phenols, lb/hr			—	—	—	—	—	—	—	—	—	3,000	—	—	9	—
(kg/hr)			—	—	—	—	—	—	—	—	—	1,361	—	—	4	—
Cresylic acid, lb/hr or kg/hr			—	—	—	—	—	—	—	—	—	—	—	—	100ppmW	—
Wash solvent lb/hr			—	106,979	59,962	54,797	114,759	114,759	94,025	208,784	—	—	—	7,780	—	—
(kg/hr)			—	48,526	27,199	24,856	52,055	52,055	42,650	94,704	—	—	—	3,529	—	—
Process solvent, lb/hr	1,666,667	1,666,667	1,558,109	1,535,074	1,325,166	341,501	1,666,667	—	—	—	108,558	—	—	23,035	—	—
(kg/hr)	756,000	756,000	706,758	696,310	601,095	154,905	756,000	—	—	—	49,242	—	—	10,449	—	—
Coal product, lb/hr	—	—	488,376	488,376	—	—	—	—	—	—	—	—	—	—	—	—
(kg/hr)	—	—	221,527	221,527	—	—	—	—	—	—	—	—	—	—	—	—
Mineral residue, lb/hr	—	—	90,025	—	—	—	—	—	—	—	—	—	—	—	—	—
(kg/hr)	—	—	48,835	—	—	—	—	—	—	—	—	—	—	—	—	—
Water, lb/hr	—	—	—	—	—	—	—	—	—	—	—	91,667	—	—	91,667	8,427
(kg/hr)	—	—	—	—	—	—	—	—	—	—	—	41,580	—	—	41,580	3,822
Feed coal, lb/hr	—	833,333	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(kg/hr)	—	378,000	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table I.1-7. Composition of solids streams from SRC flowsheet. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards under Contract Number G8-02-1358, March 1974.]

Stream	1	2	3	4	5
Components, weight %					
C	65.80		27.01	3.95	88.16
H	4.36		--	--	5.23
N	1.00		--	--	1.54
S	3.14		9.60	0.54	1.17
O	9.56		--	--	3.42
Ash	6.63		63.69	95.51	0.48
Moisture	9.51		--	--	--
Total	100.00		100.00	100.00	100.00
Coal, lb/hr	896,000	--	--	--	488,376
(kg/hr)	406,426	--	--	--	221,527
Precoat, lb/hr	--	250	250	250	--
(kg/hr)	--	113	113	113	--
Mineral residue lb/hr	--	--	90,025	--	--
(kg/hr)	--	--	40,835	--	--
Ash, lb/hr	--	--	--	59,750	--
(kg/hr)	--	--	--	27,103	--
Heating value, Btu/lb	11,924	--	4,191	--	15,768
(kcal/kg)	6,624	--	2,328	--	8,760

process. With natural gas availability dwindling, another source of hydrogen such as coal gasification will have to be used.

I.1.3.5 Catalytic Liquefaction - H-Coal

Catalytic liquefaction routes are logical extensions of solvation processing. Instead of mild hydrogenation of a solvent/coal slurry, more severe hydrogenation is accomplished through heterogeneous catalysis. H-Coal is the most advanced modern catalytic hydrogenation process.

The H-Coal process has been under development by Hydrocarbon Research, Inc. since 1965. In November 1974, the ERDA Office of Coal Research announced partial funding of a 600-ton/day H-Coal demonstration plant to be constructed at Catlettsburg, Kentucky. This plant will have facilities to produce either a heavy fuel oil or a synthetic crude oil.[9]

Figure I.1-8 shows the flowsheet of a conceptual 100,000-barrel/day (29,000 tons/day of coal) H-Coal refinery, including some flow rates. Upstream of the reactor, the process is similar to SRC - coal is slurried with process oil and injected into a reactor with hydrogen at approximately the same temperature and pressure (450°C and up to 200 atm). The heart of the H-Coal process is its reactor, a three-phase fluidized bed or ebullated bed. In it, catalyst pellets are fluidized by the upward flow of solvent, gas, and fine coal particles. Agitation of the bed minimizes catalyst fouling, and the coal/catalyst size differential permits retention of the catalyst pellets within the reactor.[12]

Following liquefaction, gases and light liquids are separated from the heavy oil/solid slurry by flashing and distillation. After solid-liquid separation is accomplished (presently by precoat filtration), liquids are passed on to further refining as necessary, and solids are pyrolyzed and finally burned.

The SYNTHOIL process differs in its reactor design and level of development. resently 0.5 tons/day of coal are slurried and fed to a fixed bed of catalyst maintained at 450°C and 140-280 atm. Hydrogen moves the slurry turbulently through the reactor, preventing the catalyst fouling and accomplishing 94% conversion of coal to oil. A 10-ton/day Synthoil pilot plant is expected to start up in the summer of 1976. Other developing processes using catalytic liquefaction or combination with a solvation route are the Consol process of Consolidation Coal and the Exxon coal liquefaction process.[2]

Similarly to SRC, solid-liquid separations are a problem for catalytic liquefaction, but catalyst attrition and deactivation become important. Hydrocarbon Research has experienced continuing difficulty in separating the fine solids and has investigated magnetic separation. This problem is closely tied to catalyst maintenance because catalyst recovery from separated solids is an economic necessity. By the abrasive nature of coal, attrition and loss of catalyst are likely.

gasifier is limited to about 1000 tons per day of coal, so that 24 gasifiers plus four back-up units will be required for EPNG plant. Such complexity automatically increases capital expenses.[2]

Nevertheless, of all the coal gasification developments, only the Lurgi process is available and suitable for commercial production of high-Btu gas. Table I.1-4 lists U.S. commercial gasification projects now in progress; each will use Lurgi gasification.

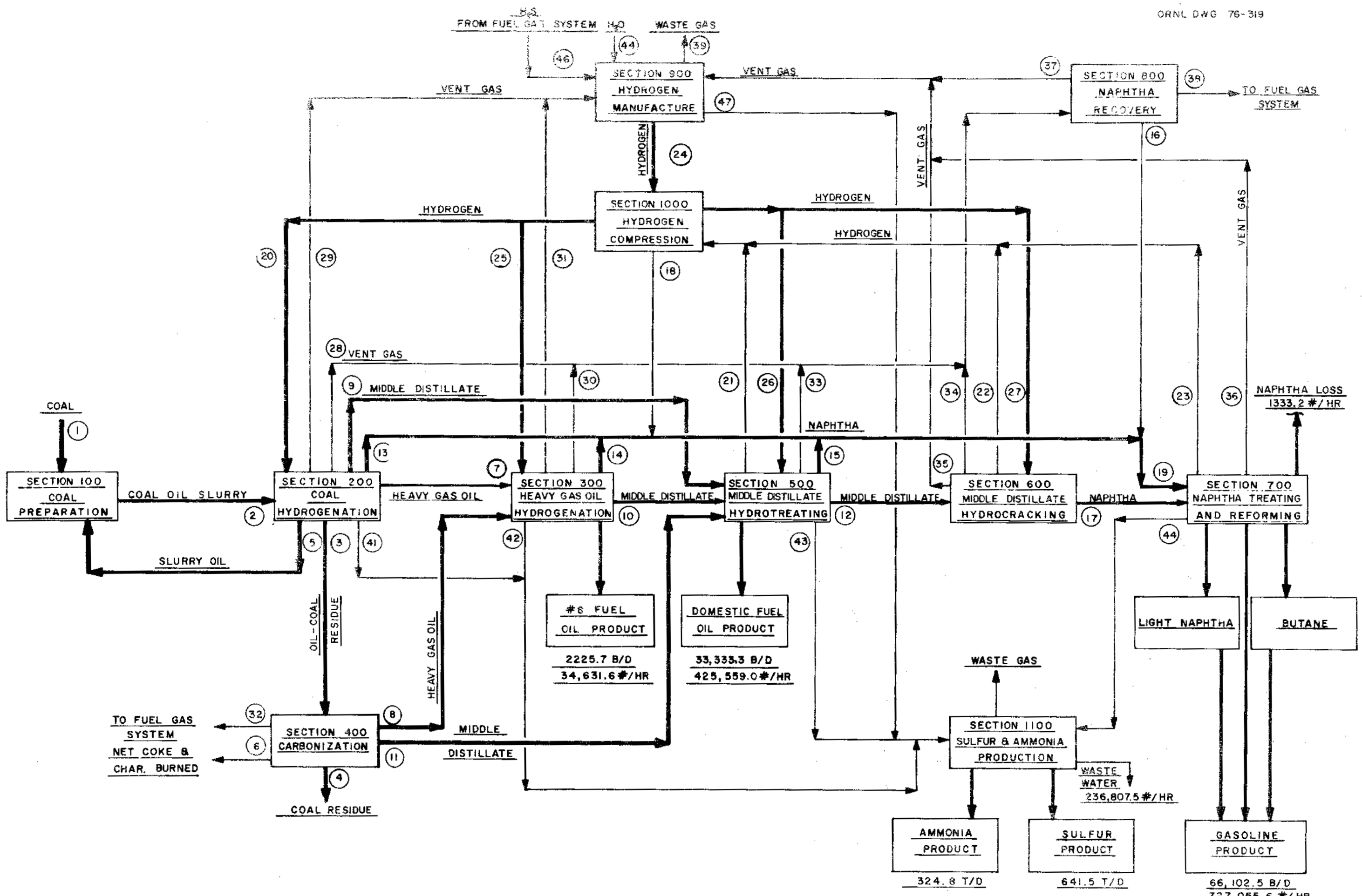
The combined-cycle power plant is an important aspect of gasification development. Clean, low-Btu gas at high temperature and pressure would either be expanded through a gas turbine and combusted to generate steam (an exhaust-fired combined cycle) or combusted before expansion through a gas turbine (a waste-heat-recovery combined cycle). Coal-fired steam plants are technologically limited to 40% maximum efficiency; in contrast, a combined-cycle plant could be approximately 47% efficient with current technology, conceivably nearing 60% in the 1990's 1990's.[7]

Development of combined cycle power plants using low-Btu gasification is now at the demonstration plant level. In the United States, Commonwealth Edison Co. and the Electric Power Research Institute are building a 1400-ton-per-day Lurgi plant consisting of three gasifiers, which would fuel a 120-megawatt combined-cycle generating station. Operation was projected for 1977.[8] Also, in early 1975 Foster-Wheeler Energy Corp. was contracted by the ERDA Office of Coal Research to build and operate a 36-MW combined-cycle pilot plant. The Pittsburg and Midway Coal Mining Co. gasifier will be used.[9]

Certainly the Lurgi process disadvantages can be improved upon, as evidenced by the multiple of other surface gasification processes under development (for example, note Table I.1-1). An oxygen-steam mixture need not be the gasifying medium; oxygen alone can be used to generate a high-CO content gas from coal, or hydrogen alone may be used for direct hydrogasification (HYGAS being the principal example). If an external heat source or a recirculating internal heat transfer medium is used to drive the endothermic steam-carbon reaction, steam alone can be injected for the gasification. Fluidized-bed or entrained flow reactors may be used instead of the Lurgi moving bed. Such reactors would operate at high temperatures, producing fewer pyrolysis tars and phenols. In entrained operation, temperatures are so high that ash must be removed as a molten slag. Staged, entrained, slagging gasifiers such as BI-GAS, and the Pittsburg & Midway low-Btu process are expected to be promising if they can be successfully developed. It is presumed that commercial plants using improvements in technology will be operating by 1985.

I.1.3.2 Underground or In-situ Gasification

In-situ gasification is chemically the same as surface gasification, differing primarily in operation. By eliminating mining of the coal and by operating the gasification "reactor" underground, many environmental



COAL & SLURRY OIL STREAMS			HEAVY GAS OIL STREAMS		MIDDLE DISTILLATE STREAMS		NAPHTHA STREAMS		HYDROGEN STREAMS		VENT GAS STREAMS		H_2O, H_2S, & NH_3 PROCESS STREAMS			
STREAM	#/HR SOLIDS	#/HR OIL	STREAM	#/HR	STREAM	#/HR	STREAM	#/HR	STREAM	#/HR	STREAM	#/HR	STREAM	#/HR H_2S	#/HR H_2O	#/HR NH_3
1	2,393,331.0		7	47,358.6	9	568,903.8	13	327,952.0	20	224,486.9	28	337,475.5	41	34,273.6	220,186.5	23,933.3
2	2,503,396.9	2,503,396.9	8	298,957.7	10	186,270.8	14	98,839.4	21	89,073.5	29	47,749.0	42	1,383.3	6,936.0	1,383.3
3	504,992.8	504,992.8			11	23,425.3	15	4,900.3	22	59,094.9	30	32,374.1	43	320.3	3,893.0	934.4
4	631,662.7				12	354,682.0	16	28,615.6	23	20,419.2	31	5,252.1	44	997.4	5,792.0	817.7
5		2,503,396.9					17	341,278.2	24	244,912.1	32	13,043.3	45		816,762.2	
6	42,896.6						18	5,752.7	25	20,753.3	33	3,334.6	46	19,824.4		
							19	466,059.0	26	104,097.2	34	7,843.2	47	19,824.4		
									27	58,409.6	35	4,875.3				
											36	50,922.1				
											37	335,757.1				
											38	16,634.7				
											39	998,269.9				
											40	3,341.[illegible]				

Figure I.1-8. Design of 100,000 barrel/day H-Coal refinery. [Source: Project H-Coal Report on Process Development, February 1965 through September 1967, Office of Coal Research, R&D Report No. 26.]

I.1.4 Summary

Coal conversion processes are available and being further developed to produce clean fuels and chemical feedstocks as alternatives to petroleum and natural gas. Severe processing conditions are necessary, and some fraction of the coal energy is expended to provide energy for the conversion and supporting processes. Steady improvements in processing are expected to continue.

Surface gasification of coal to produce high-Btu gas will probably contribute first to U.S. energy production by coal conversion. By 1985, operation of the 14 Lurgi gasification plants now planned (Table I.1-4) would produce 4.5 billion cubic feet/day of high-Btu gas. Other surface gasification processes and *in-situ* gasification are likely to be operating commercially by 1985 (Table I.1-1).

If the Coalcon and H-Coal demonstration plants are successful, commercial plants could be onstream in 1985 producing at least the current projection of 100,000 barrels/day. Coalcon and H-Coal are presently expected to be available first because of their advanced states of development, but other liquefaction processes (Table I.1-2) could experience accelerated development and process improvements that would result in early commercial operation.

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I.2 CHEMICAL COMPOSITION AND POTENTIAL HAZARDS OF COAL CONVERSION PRODUCTS, PROCESS STREAMS, AND EFFLUENT STREAMS

The conversion of coal to solid, liquid, and gaseous forms has evolved through the development of many processes to produce fuels and chemical feedstocks as described in the previous section. This discussion will address itself to the chemical composition and potential hazards of products, process streams, and effluent streams. Only a few of the many gasification and liquefaction processes currently under development are considered here. Others are included in Appendix A. Wherever information gaps appear and the need for investigation is indicated, they are identified.

Environments affected by coal-conversion technologies may be divided into two basic types for purposes of considering biohazards associated with particular technologies. These are (1) the immediate environment (i.e., the industry itself) and (2) the surrounding environment.

There appear to be five major process streams or effluents which are of environmental concern. These are:

(1) Water. Each coal-conversion technology will at some stage have water produced by heating and decomposition of the coal (20 to 30 gal/ton coal).[1] This waste is analogous to the ammoniacal liquor waste from the coking industry. The data in Tables I.2-1 through I.2-3 may be considered typical of such aqueous wastes. The major organic compounds appear to be phenolic in nature. The concentration of polyaromatic hydrocarbon compounds (PAH) in such waters is unknown and needs to be investigated. Cyanides are highly toxic and may occur in such waste waters. Thiocyanates are also toxic but apparently do not produce the cyanide effect.[2] Of the trace elements listed only iron, aluminum, selenium, and strontium exceed suggested threshold concentration levels for potable water as reported by Dawson.[3] Identification of the nature of the suspended solids is important. For example, are PAH compounds adsorbed on surfaces? The present effluent limitation guidelines from similar processes (e.g., petroleum refineries and coking plants) are specific for only three chemical compounds: phenol, ammonia, and sulfide.

(2) Air. A variety of process gases will result from coal-conversion technologies, including incinerator gases, stack gases, pyrolysis gas, tail gas from sulfur recovery plants, and ammonia stripping gas. Table I.2-4 contains the national air quality standards for several of the possible emissions from coal-conversion plants. Table I.2-5 lists guidelines for the emissions with possible sources or suspect systems. With respect to toxicity the nature of the particulate pollution may be significant. It has been reported[1] that regulations concerning the allowable size distribution of particulate emissions are important because the small particles currently escaping control appear to be the ones most closely associated with detrimental health effects.

Table I.2-1. Byproduct water analysis from Synthane gasification of various coals, mg/liter (except pH). [Source: A. J. Forney, Wm. P. Haynes, S. J. Gasior, G. E. Johnson and J. P. Strakey, Jr., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Technical Process Report 76, Bureau of Mines, Pittsburgh Energy Research Center, U.S. Department of the Interior.]

	Coke plant	Illinois No. 6 coal	Wyoming subbituminous coal	Illinois char	North Dakota lignite	Western Kentucky coal	Pittsburgh seam coal
pH	9	8.6	8.7	7.9	9.2	8.9	9.3
Suspended solids	50	600	140	24	64	55	23
Phenol	2,000	2,600	6,000	200	6,600	3,700	1,700
COD	7,000	15,000	43,000	1,700	38,000	19,000	19,000
Thiocyanate	1,000	152	23	21	22	200	188
Cyanide	100	0.6	0.23	0.1	0.1	0.5	0.6
NH_3	5,000	8,100[a]	9,520	2,500	7,200	10,000	11,000
Chloride	-	500	-	31	-	-	-
Carbonate	-	6,000[b]	-	-	-	-	-
Bicarbonate	-	11,000[b]	-	-	-	-	-
Total sulfur	-	1,400[c]	-	-	-	-	-

[a]85% free NH_3

[b]Not from same analysis

[c]$S^{=}$ = 400

$SO_3^{=}$ = 300

$SO_4^{=}$ = 1,400

$S_2O_3^{=}$ = 1,000

Table I.2-2. Trace elements in condensate from an Illinois No. 6 coal gasification test. [Source: A. J. Forney, Wm. P. Haynes, S. J. Gasior, G. E. Johnson and J. P. Strakey, Jr., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Technical Process Report 76, Bureau of Mines, Pittsburgh Energy Research Center, U.S. Department of the Interior.]

	No. 1	No. 2	Average (by weight)
Ppm:			
Calcium	4.4	3.6	4
Iron	2.6	2.9	3
Magnesium	1.5	1.8	2
Aluminum	0.8	0.7	0.8
Ppb:			
Selenium	401	323	360
Potassium	117	204	160
Barium	109	155	130
Phosphorus	82	92	90
Zinc	44	83	60
Manganese	36	38	40
Germanium	32	61	40
Arsenic	44	28	30
Nickel	23	34	30
Strontium	33	24	30
Tin	25	26	20
Copper	16	20	20
Columbium	7	5	6
Chromium	4	8	6
Vanadium	4	2	3
Cobalt	1	2	2

Table I.2-3. Ammonia liquor composition (in mg/liter). [Source: Office of Coal Research, Department of the Interior, "Development of a Process for Producing Ashless, Low-Sulfur Fuel from Coal," R & D Report No. 53, Interior Report No. 5.]

Phenolics	300 - 4,000
Free ammonia, as NH_3	1,300 - 2,000
Fixed ammonia, as NH_3	2,600 - 4,000
Carbonate, as CO_3	2,300 - 2,600
Cyanide, as CN	10 - 100
Thiocyanate, as SCN	50 - 500
Oil and tars	20 - 40
Suspended solids	30 - 120
Total dissolved solids	4,000 -13,000

Table I.2-4. National ambient air quality standards. [Source: Office of Coal Research, Department of the Interior, "Development of a Process for Producing Ashless, Low-Sulfur Fuel from Coal," R & D Report No. 53, Interior Report No. 5.]

Contaminant	Averaging Interval	Primary standard $\mu g/m^3$	Primary standard ppm (by vol.)	Secondary standard $\mu g/m^3$	Secondary standard ppm (by vol.)
Suspended particles	1 year	75	--	60	--
	24 hours	260	--	150	--
Sulfur dioxide	1 year	80	0.03	--	--
	24 hours	365	0.14	--	--
	3 hours	--	--	1,300	0.5
Carbon monoxide	8 hours	10,000	9.0	10,000	9.0
	1 hour	40,000	35.0	40,000	35.0
Photochemical oxidant	1 hour	160	0.08	160	0.08
Hydrocarbons (non-methane)	3 hours (6-9 a.m.)	160	0.24	160	0.24
Nitrogen dioxide	1 year	100	0.05	100	0.05

Notes:

1. All values other than annual values are maximum concentrations <u>not to be exceeded more than once per year</u>.
2. PPM values are approximate only.
3. All concentrations relate to air at standard conditions of 25°C temperature and 760 millimeters of mercury pressure.
4. Annual average refers to arithmetic mean for gases and geometric mean for particulates.

Table I.2-5. Guidelines for maximum atmospheric emissions from a commercial SRC plant. [Source: Office of Coal Research, Department of the Interior, "Development of a Process for Producing Ashless, Low-Sulfur Fuel from Coal," R & D Report No. 53, Interior Report No. 5.]

Pollutant	Source category	Maximum emission to the atmosphere	Reference or guideline
Sulfur	Combustion units burning gaseeous fuels (boliers, heaters, flares, etc.)	No more than 0.10 gr/dscf[a] (230 mg/Nm^3) of hydrogen sulfide (H_2S) in the fuel gas being burned.	Proposed EPA new source standards for petroleum refineries.
	Sulfur recovery plant	The lesser of 0.01 lb SO_2 per lb sulfur recovered; or, "best available" control technology.	Ohio State regulations; Federal proposal to prevent significant air quality degradation.
	Combustion units burning solid or liquid fossil fuels	No more than 0.8 lb/10^6 Btu (liquid) or 1.2 lb/10^6 Btu (solid) for heat input rates of 250 million Btu/hr or more.	Federal new source standard for steam generators.
Particulate matter	Process stack emissions	No more than 0.02 gr/dscf (50 mg/Nm^3) of undiluted exhaust.	Proposed Federal new source performance standards for petroleum refineries (fluid catalytic cracking units), lead smelters, brass ingots, and steel plants (basic oxygen furnance); Pennsylvania State regulations.
	Fugitive emissions	No emissions may cross or be visible beyond the property boundary; reasonable care must be taken to prevent fugitive emissions.	Various state regulations.
	Visible emissions	No more than 10 percent opacity, except for 3 minutes in any 1 hour period.	Ohio State regulations; proposed new source standards for steel plants, asphalt plants, sewage treatment plants and petroleum refineries.
	Combustion units burning fossil fuels	No more than 0.10 lb/10^6 Btu, for heat input rates of 250 million Btu/hr or more.	Federal new source standard for steam generators.
Hydrocarbons	Storage vessels	Maximum emissions restricted by requiring the following equipment on storage tanks of 65,000 gallons or more capacity with true vapor pressures at the indicated levels: $\leq$ 78 mm Hg (1.52 psia): Conservation, vent or equivalent. 78 to 570 mm Hg (11.1) psia): Floating roof or equivalent. > 570 mm Hg: Vapor recovery system or equivalent.	Proposed Federal new source performance standards for petroleum refineries.
	Other processes	Volatile organic compounds cannot: (1) Be stored in tanks in excess of 65,000 gallons unless equipped with a vapor-loss control device.	Ohio and other state regulations.

Table I.2-5. (continued)

Pollutant	Source category	Maximum emission to the atmosphere	Reference or guideline
Hydrocarbons (continued)		(2) Be stored in any vessel of more than 500 gallons unless equipped with a permanent submerged fill pipe.	
		(3) Be loaded from a facility loading more than 40,000 gallons per day unless equipped with a vapor collection and disposal system.	
		(4) Be introduced into a water separator which recovers more than 200 gallons/day unless such equipment is filled with a vapor-loss control device.	
		(5) Be discharged at a rate of more than 15 pounds per day or 3 pounds in any one hour from any piece of equipment unless said discharge has been reduced at least 85%.	
		(6) Be disposed of in excess of 1-1/2 gallons per day by any means which will permit evaporation of such material.	
Carbon monoxide	All processes	No more than 0.050 percent by volume, dry basis.	Proposed Federal new source performance standards for petroleum refineries.
Nitrogen oxides	Combustion units (gaseous fuel)	No more than 0.20 lb per million Btu heat input for sources with heat input rates of 250 million Btu/hr or greater.	Federal new source performance standard for gas-fired units; various state regulations.
Odors	All processes	No odors may be detectable beyond the property line; incineration of H_2S before exhaust.	Pennsylvania and West Virginia State regulations.

[a]gr/dscf = grains per day cubic foot at standard conditions.

(3) Solid waste. If chars and tars are burned for fuel during coal-conversion processes they need not be considered as solid wastes (Compositions will be given in process streams section). However, ash and solid residues resulting from incineration (and possible airborne particulate material) may be environmentally significant. Leachate analyses are important. Possible use of ash for recovery of certain metals may be a significant factor. Disposal methods could also be critical.

(4) Process streams. All process streams may possibly be hazardous to workers, but the tars resulting from high temperature processes may be most hazardous in terms of quantity of carcinogens. Table I.2-6 contains typical composition of tars resulting from the Synthane process. Many of the identified constituents may be hazardous.

If the chars resulting from the Synthane process are disposed of in a landfill, as indicated in a published flow sheet[4], they may present a more serious problem than if incinerated and disposed of as ash. Table I.2-7 contains analyses of typical coals and char residues. Information is needed concerning organic constituents, leachate, etc. to evaluate disposal methods for such chars.

Gaseous streams resulting from pyrolysis of coal may contain chemicals of environmental concern. Table I.2-8 contains analysis of gas samples produced in high-pressure, fixed-bed gasifiers. Data in Table I.2-9 show the concentration of minor components of a gas sample produced by the Synthane process.

(4a) Ancillary process streams. Many coal-conversion processes involve ancillary industrial processes such as catalyst preparation and regeneration. In the case of regeneration, organics compounds may possibly pose a regeneration problem. In both preparation and regeneration, metallic wastes or aqueous wastes may be of significance.

Decontamination of process equipment could be of environmental significance particularly to workers but also with respect to disposal of aqueous wastes and solvent materials.

(5) Products. The chemical composition of gasesous and liquid products from coal-conversion technologies is extremely important and may govern the use by consumers. For example, synthetic gasoline with significant PAH concentrations would not be very acceptable for consumer use. Therefore detailed quantitative information concerning chemical compositions of product materials is vitally important. Table I.2-10 displays data on the composition of gas products resulting from use of Lurgi gasifiers followed, in the case of the high-Btu gas, by an adjustment of the gas composition and methanation.

Data on the composition of two samples from an <u>in-situ</u> gasification experiment at Hanna, Wyoming, are presented in Table I.2-11. The differences in composition reflect changes in operating conditions.

Table I.2-6. Mass spectrometric analyses of the benzenesoluble tar, volume-percent. [Source: A. J. Forney, Wm. P. Haynes, S. J. Gasior, G. E. Johnson and J. P. Strakey, Jr., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Technical Process Report 76, Bureau of Mines, Pittsburgh Energy Research Center, U.S. Department of the Interior.]

Structural type (includes alkyl derivatives)	Run HP-1 No. 92, Illinois[a] No. 6 coal	Run HPL No. 94, lignite	Run HPM No. 111, Montana subbituminous coal	Run HP-118 No. 118,[a] Pittsburgh seam coal
Benzenes	2.1	4.1	3.9	1.9
Indenes	8.6[b]	1.5	2.6	6.1[b]
Indans	1.9	3.5	4.9	2.1
Napthalenes	11.6	19.0	15.3	16.5
Fluorenes	9.6	7.2	9.7	10.7
Acenaphthenes	13.5	12.0	11.1	15.8
3-ring aromatics	13.8	10.5	9.0	14.8
Phenylnaphthalenes	9.8	3.5	6.4	7.6
4-ring pericondensed	7.2	3.5	4.9	7.6
4-ring catacondensed	4.0	1.4	3.0	4.1
Phenols	2.8	13.7	5.5	3.0
Naphthols	(b)	9.7	9.6	(b)
Indanols	.9	1.7	1.5	.7
Acenaphthenols	-	2.5	4.6	2.0
Phenanthrols	2.7	-	.9	-
Dibenzofurans	6.3	5.2	5.6	4.7
Dibenzothiophenes	3.5	1.0	1.5	2.4
Benzonaphthothiophenes	1.7	-	-	-
N-heterocyclics[c]	(10.8)	(3.8)	(5.3)	(8.8)
Average molecular weight	212	173	230	202

[a]Spectra indicate traces of 5-ring aromatics.

[b]Includes any naphthol present (not resolved in these spectra).

[c]Data on N-free basis since isotope corrections were estimated.

Table I.2-7. Representative analyses of coals and chars, (in weight-percent). [Source: A. J. Forney, Wm. P. Haynes, S. J. Gasior, G. E. Johnson and J. P. Strakey, Jr., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Technical Process Report 76, Bureau of Mines, Pittsburgh Energy Research Center, U.S. Department of the Interior.]

	Illinois No. 6 coal	Western Kentucky coal	Wyoming subbituminous coal	North Dakota lignite	Pittsburgh seam coal
Coals:					
Moisture	8.3	4.3	18.1	20.6	2.5
Volatile matter	37.5	34.6	31.9	32.9	30.9
Fixed carbon	43.0	44.5	32.0	38.2	51.5
Ash	11.2	16.6	18.0	8.3	15.1
Hydrogen	5.3	4.7	5.4	5.7	4.7
Oxygen	15.9	10.9	30.3	32.6	9.3
Carbon	63.0	62.7	45.2	51.5	68.4
Nitrogen	1.1	1.2	.6	.7	1.2
Sulfur	3.5	3.9	.5	1.2	1.3
Chars (from above coals):					
Moisture	.8	1.2	.5	1.2	1.4
Volatile matter	4.0	4.8	5.1	10.0	1.6
Fixed carbon	69.9	63.3	38.1	50.2	69.3
Ash	25.3	30.7	56.3	38.6	27.7
Hydrogen	1.0	1.0	1.0	.9	1.0
Oxygen	1.3	1.1	1.2	.0	1.7
Carbon	70.4	64.5	40.6	58.9	68.9
Nitrogen	.6	.7	.4	.2	.5
Sulfur	1.4	2.0	.5	2.0	.2

Table I.2-8. Typical gas composition for high-pressure fixed-bed gasification process. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," report prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, under contract number G8-02-1358, March 1974, Table VI-3.]

	Composition of gas produced (volume percent)			
	Steam-oxygen process			
Gas component	Anthracite	Bituminous coal	Lignite	Steam-air process, various coals[a]
CO_2	28.5	27.5	32.2	13.3
CO	21.0	21.0	18.1	13.3
H_2	42.9	41.0	37.0	19.6
CH_4	7.0	8.8	12.0	5.5
N_2	0.4	0.4	0.3	37.5
H_2O	-	-	-	10.1
COS	-	-	-	0.1
H_2S	-	-	-	0.6

[a]Lignite, subbituminous, and noncaking and weakly caking bituminous coals can be used.

Table I.2-9. Components in gasifier gas, (in ppm). [Source: A. J. Forney, Wm. P. Haynes, S. J. Gasior, G. E. Johnson and J. P. Strakey, Jr., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Technical Process Report 76, Bureau of Mines, Pittsburgh Energy Research Center, U.S. Department of the Interior.]

	Illinois No. 6 coal	Illinois char	Wyoming subbituminous coal	Western Kentucky coal	North Dakota lignite	Pittsburgh seam coal
H_2S	9,800	186	2,480	2,530	1,750	860
COS	150	2	32	119	65	11
Thiophene	31	.4	10	5	13	42
Methyl thiophene	10	.4	-	-	-	7
Dimethyl thiophene	10	.5	-	-	11	6
Benzene	340	10	434	100	1,727	1,050
Toluene	94	3	59	22	167	185
C_8 aromatics	24	2	27	4	76	27
SO_2	10	1	6	2	10	10
CS_2	10	-	-	-	-	-
Methyl mercaptan	60	.1	.4	33	10	8

Table I.2-10. Composition of Lurgi process gas

Component	Composition low Btu (mole %)[a]	Intermediate Btu (volume %, dry basis)[a,b,c]	High Btu (volume %)[d]
CO_2	14.86	28.13	1.8
H_2S	0.01	0.01	-
C_2H_4	0.25	0.40	-
CO	17.49	20.27	0.01
H_2	23.31	39.09	4.1
CH_4	5.09	11.17	93.0
C_2H_6	0.38	0.61	-
N_2	38.61	0.31	1.1

[a]Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," report prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, under contract number G8-02-1358, March 1974, Table VI-3.

[b]Figures adjusted for reduction of H_2S from 0.37% to 0.01%.

[c]Draft Environmental Statement, El Pan Gasification Project, for Juan County, New Mexico, p. 1-56. Issued by the Buereau of Declamation, U.S. Department of the Interior, Salt Lake City, Utah (1974).

[d]Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," report prepared for the U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, under contract number G8-02-1358, March 1974, Table VI-1, Column 9 (figures rounded).

Very little information appears to be available on the composition of tar, tar oil, and crude phenol by-products of the Lurgi gasification process but tar products from the Synthane process have been better characterized.[4] Table I.2-6 contains data in the benzene-soluble tar. These data indicate the wide variety of organic compounds found in tar products, many of which have not been screened for carcinogenicity. The composition of coal tar products is known to vary with process conditions.

Table I.2-11. Gas analyses on collection dates. [Source: S. B. King, C. F. Brandenburg and W. J. Lanum, "Characterization of Nitrogen Compounds in Tar Produced from Underground Coal Gasification," presented at the American Chemical Society Spring Meeting, Philadelphia, PA., April 1975.]

	Sample 1 August 4, 1973[a]	Sample 2 December 10, 1973
Hydrogen	9.5	6.14
Argon	1.17	1.01
Nitrogen	55.62	53.84
Methane	9.62	3.74
Carbon monoxide	0.80	6.94
Ethane	0.81	0.28
Carbon dixoide	21.90	17.91
Propane	0.16	0.08
Propene	0.12	0
n-Butane	0.01	0
iso-Butane	0.05	0
Hydrogen sulfide	0.23	0.05
Heating Value	(154 Btu/scf)	(119 Btu/scf)

[a]Values are expressed in mole %.

REFERENCES

1. Office of Coal Research, Department of the Interior, "Development of a Process for Producing Ashless, Low-Sulfur Fuel from Coal," R & D Report No. 53, Interim Report No. 5.

2. The Merk Index, 8th Edition.

3. G. W. Dawson, "The Chemical Toxicity of Elements," BNWL-1815, Pacific Northwest Laboratories.

4. A. J. Forney, Wm. P. Haynes, S. J. Gasior, G. E. Johnson, and J. P. Sharkey, Jr., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Technical Progress Report 76, Bureau of Mines, Pittsburg Energy Research Center, U.S. Department of the Interior.

I.3 WASTE MANAGEMENT

Depending on the degree of environmental control technology applied to the wastes, waste management may or may not be a significant concern.

The largest amount of solid waste generated are the ash from the combustion process and the fly ash removed from the gaseous effluents. Many of the proposed process flow-sheets indicate that this material will probably be returned to the mine from which the coal was extracted. The method of transport is reported to be as a slurry using treated liquid waste effluents. A potential waste management problem with this material may be the possibility of polluting ground or surface waters due to leaching of inorganic and organic materials from the ash. Although chars and tars are also produced, these products will be used as fuels unless markets for sale exist in the surrounding area.

Liquid wastes result from the storage of coal (leaching due to rainfall on the storage pile), from coal washing if required, from coal preparation if wet grinding is used, from wet scrubbers, and from other process operations. These liquid wastes will contain heavy metals and miscellaneous organics. An earlier section (I.2) has described the possible composition of these effluents. Environmental control technology will be applied to these wastes prior to any release to the environment in order to meet effluent standards. Certain of the proposed flow-sheets indicate that treated effluents might be evaporated to dryness, either in lined ponds or in incinerators.

Many liquid effluent streams from coal conversion facilities are expected to be at higher temperatures than ambient natural waters. It is expected that most of the waste heat load will be dissipated to the atmosphere via evaporative cooling towers, or dry cooling towers where there are large amounts of volatile materials present. However, some heat load is expected to remain in waters that are either processed in waste treatment facilities or released to the environment.

Warm waters entering most biological or chemical waste treatment systems may be a benefit to the efficient operation of the system. This is because rates of decomposition usually are faster than at warmer temperatures. Some added heat content to waste streams may thus be viewed as advantageous. Research is required to determine optimum temperatures for the particular waste treatment (which will depend upon chemical composition). Temperature control may thus be used to optimize treatment, using the increased temperature of the waste as the heat source.

Some heat load may be released directly to the environmental by wastes. This release and the ecological effects from it should be evaluated using the abundant information developed over several years for large thermal discharges from steam electric generating stations.

Gaseous wastes are produced during combustion and in various other processing steps. These gases will contain particulates, sulfur compounds, and volatile organics.

I.3.1 Effluent Standards

I.3.1.1 Liquid Wastes

The Federal Water Pollution Control Act of 1972 (PL 92-500) requires that the Environmental Protection Agency establish effluent guidelines and standards that must be achieved by point sources which discharge into navigable waters of the United States. Sections 301 and 304 of PL 92-500 specify achievement by July 1, 1977 of effluent limits using "best practicable technology currently available" (BPTCA). By July 1, 1983, new limitations are promulgated that are based on the use of "best available technology economically achievable" (BATEA). The Act further sets as a national goal the complete elimination of all discharges of pollutants into navigable waters by 1985.

To date EPA has selected 28 industrial classes of industry as the producers of the most severe water pollution problems. Coal conversion is not one of the industrial categories in which effluent guidelines and standards have promulgated. However, effluent guidelines and standards have been promulgated for the petroleum refining industry (40CFR 419), the iron and steel manufacturing industry (40CFR 420), and steam electric power plants (40CFR 423). It can be anticipated that the guidelines for the first two industries will be similar to those applied to coal conversion if effluent guidelines and standards are developed.

The EPA guidelines may not be as strict as state and local standards in some areas of the country. Individual states may have stricter effluent limitations than those proposed by EPA; however, in no case can they be less stringent.

The appropriate guidelines for consideration in coal conversion are the guides for new sources (these are essentially the same as for existing plants applying "best available technology economically achievable"). Table I.3-1 presents the effluent guidelines for new petroleum refineries (40CFR 419, Subpart E - Integrated Subcategory). Table I.3-2 presents the guidelines for by-product coke production (40CFR 420, Subpart A). In the initial draft of the guidelines for by-product coke a limit was set on BOD-5 (9 lbs per 1000 tons of coke produced); however, this limit was removed in the final set of guidelines. It can be seen that cyanide is included in the coke standard but is not included in the refinery standard. Also, the refinery standards have limits on the amount of organic matter present (as measured by BOD and COD) and include total and hexavalent chromium.

Table I.3-1. Effluent guidelines and standards for petroleum refineries (new sources-integrated subcategory)

Effluent characteristic	Effluent limitations: Maximum for any 1 day	Effluent limitations: Average of daily values for 30 consecutive days shall not exceed
	English units (pounds per 1,000 bbl of feedstock)	
BOD_5	14.7	7.8
TSS	8.7	5.1
COD	104	54
Oil and grease	4.5	2.4
Phenolic compounds	0.105	0.051
Ammonia as N	8.3	3.8
Sulfide	0.093	0.042
Total chromium	0.22	0.13
Hexavalent chromium	0.0047	0.0021
pH	Within the range 6.0 to 9.0	

Note: There are factors to apply to these standards depending on plant size (bbl per day) and process configuration.

Table I.3-2. Effluent guidelines and standards for iron and steel mills (by-product coke production). [Numbers in parentheses are in lb/1000 tons]

Effluent characteristic	Effluent limitations: Maximum for any 1 day	Effluent limitations: Average of daily values for 30 consecutive days shall not exceed
	English units (lb/1000 lb of coke)	
Cyanide (A)	0.0003 (0.60)	0.0001 (0.20)
Phenol	0.0006 (1.20)	0.0002 (0.40)
Ammonia	0.0126 (25.20)	0.0042 (8.4)
Sulfide	0.0003 (0.60)	0.0001 (0.20)
Oil and grease	0.0126 (25.20)	0.0042 (8.4)
TSS	0.0312 (62.40)	0.0104 (20.8)
pH	Within the range 6.0 to 9.0	

Note: Cyanide (A) indicates those cyanides amenable to chlorination.

The effluent guidelines for the petroleum refineries are based on the quantities of raw material processed and the values for coke production on the amount of coke actually produced such that the direct application of either these guidelines requires an assumption of raw material to product ratio for any application to coal conversion. It has been reported that 0.69 tons of coke per ton of coal is a reasonable yield for most coking operations. Thus all figures in Table I.3-2 can be raised by a factor of 1.45 if it is assumed that this type of guideline would be applied to coal conversion technology. In the case in which petroleum standards would be applied it would be necessary to assume a relationship between raw material input and coal consumption.

In the case of liquid effluents from steam electric power plants, effluent guidelines are expressed in terms of maximum daily and 30-day average maximum values. Although nine categories of waste types are described in 40CFR 423, essentially all of the wastes must have concentrations lower than those listed in Table I.3-3. Major variants in the defined waste releases are the requirement for no total suspended solids or oil and grease in fly ash transport water, and the elimination of standards for copper and iron in certain types of waste.

Thus, in order to make any comparisons between coal conversion and coal combustion it is necessary to make assumptions about the equivalent amounts of oil and coal and have available the amounts of waste produced by the various coal conversion processes. In any case it appears that short of "zero discharge," waste materials in liquid form will be discharged into either the aquatic or terrestrial environment.

I.3.1.2 Air Pollution

Much the same problems exist in discussing air pollution standards as were previously described for liquid effluents, namely there have been no effluent guidelines developed for coal conversion technologies. However, guidelines have been established for petroleum refineries, steel mills (basic oxygen furnaces), and steam electric power plants. These guidelines address themselves mainly to particulates, sulfur dioxide, and opacity. A summary of these standards is given in Table I.3-4. It can be seen that sulfur dioxide is not included in the steel standards, and that NO_x and CO are only concerns in the steam electric plants and petroleum industry respectively. Again the problem exists of using different ways of expressing the standards. Since the steam electric standards are on the basis of heat input assumptions will have to be made to determine the air flow through the plant, or the grains/dscf will have to be converted to a Btu basis. In any case there will be emissions from the plant regardless of the control technology applied if either set of standards is applied.

Table I.3-3. Effluent guidelines and standards for new steam electric power plants (large unit subcategory)

Effluent characteristic	Effluent limitations (in mg/liter)	
	Maximum for any 1 day	Average of daily values for 30 consecutive days shall not exceed
TSS*	100	30
Oil and grease*	20	15
Copper, total*	1.0	1.0
Iron, total*	1.0	1.0
Free available chlorine**	0.5	0.2

*Low volume waste sources, bottom ash transport water, metal cleaning wastes, boiler blowdown (See 40CFR 423, Section § 423.15).

**Once through cooling water, cooling tower blowdown (See 40CFR 423, Section § 423.15).

Table I.3-4. Air emissions from various sources - EPA regulations

Source	Particulate matter	Sulfur dioxide	Opacity	Carbon monoxide	NO_x
Petroleum refinery	0.022 gr/dscf[a]	0.10 gr/dscf	<30%[b]	0.050%	-
Iron and steel	0.022 gr/dscf	-	<10%[c,d]	-	-
Steam electric plants	0.10 lb/10^6 Btu	1.2 lb/10^6 Btu	<20%[e]	-	0.7 lb/10^6 Btu

[a] gr/dscf = grains per dry cubic feet at standard conditions.

[b] May be exceeded no more than 3 min in any 1 hr.

[c] May be exceeded no more than 2 min in any 1 hr.

[d] Proposed but not promulgated.

[e] May be allowed to exceed this value up to 40% for 2 min in any 1 hr.

I.3.1.3 Solid Wastes

Residues will be produced both in the conversion processing operation and also in the environmental control equipment. Many of the proposed coal conversion processes are planning to remove this material and place it back into the mined out areas. Whether this operation would be ruled a landfill is not clear, and as a result what guidelines would be applied. The Environmental Protection Agency has issued 40CFR 240, 241 which proposes guidelines for thermal processing and land disposal of solid wastes which would apply to the burial operation. More recently the EPA solid waste program has centered on the hazardous waste disposal problem in the United States, and it is entirely possible that the residues from coal conversion will be classified as hazardous wastes and have specific guidelines applied to them. Fly and bottom ash from steam electric power plants does not appear at this time to have specific guidelines either.

However, both 40CFR 419 (petroleum refinery) and 40CFR 420 (iron and steel manufacturing) include the following statement about solid wastes:

> "(e) SOLID WASTE CONTROL. Solid waste control must be considered. The waterborne wastes from the petroleum (or iron and steel) industry may contain a considerable volume of metals in various forms as a part of the suspended solids pollutant. Best practicable control technology and best available control technology as they are known today require disposal of the pollutants removed from waste waters in this industry in the form of solid wastes and liquid concentrates. In some cases these are nonhazardous substances requiring only minimal custodial care. However, some constituents may be hazardous and may require special consideration. In order to ensure long term protection of the environment from these hazardous or harmful constituents, special consideration of disposal sites must be made. All landfill sites where such hazardous wastes are disposed should be selected so as to prevent horizontal and vertical migration of these contaminants to ground or surface waters. In cases where geologic conditions may not reasonably ensure this, adequate precautions (e.g., impervious liners) should be taken to ensure long term protection to the environment from hazardous materials. Where appropriate the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located."

I.4 TRANSPORTATION AND USE OF PRODUCTS OF COAL CONVERSION

SCOPE

In this section we are concerned primarily with the hazards resulting from the transportation and use of products from coal conversion plants. We will consider only those products that have economic value outside the conversion plant. The wastes produced in the processes and the products that are reprocessed in the plant are thus excluded from this discussion. Furthermore, we are looking only at those hazards which are directly attributable to the coal conversion processes and are not present when the same products come from other sources such as petroleum and natural gas.

I.4.1 Coal Gasification - Lurgi Process

I.4.1.1 General Comments

The primary products of coal gasification, regardless of the process used, can be classified as low and intermediate Btu gas or as high Btu gas. As described elsewhere, low Btu gas (∿ 150 Btu/scf) results from reaction of coal with a steam-air mixture while production of intermediate Btu gas (∿ 300 Btu/scf) requires use of oxygen instead of air. High Btu gas is produced by adjusting the composition of intermediate Btu gas followed by methanation. Table I.2-10 gives data on representative gas compositions for all three gas types produced by the Lurgi Process. This process is emphasized here because the first commercial coal gasification plants presently expected to be built in this decade, those planned by El Paso Natural Gas Company (EPNG)[1] and Western Gas Company (WESCO),[2] both will have Lurgi gasifiers. In either case, the low quality of the gas does not permit transportation of the gas very far from the gasification plant. Pipeline technology is sufficiently advanced that the likelihood of significant leaks during transportation is quite small. If a leak should occur in a populated area, the CO content of the gas could create a health hazard. In addition, there is a hazard due to the potential explosivity of the leaked gas when it is introduced into a confined area. This hazard, however, exists with natural gas pipelines which have been used extensively to transport gas throughout the United States for many years with relatively few explosions reported.

Since the nickel catalyst used in the methanation step in the production of pipeline quality gas is very sensitive to sulfur in the gas, this contaminant must be efficiently removed prior to methanation. Consequently, the substitute pipeline gas (SPG) will contain less of this common contaminant than much of the marketed natural product. Available information on the composition of SPG (see Table I.2-10) does not show the presence of any products that are likely to have significant adverse effects on people or plants exposed to combustion products of the gas. Further, any appreciable differences in composition between SPG and natural gas will be diminished by blending the SPG with larger quantities of natural gas. For example, the initial output of EPNG's Burnham I plant,[1] 288 million ft^3/day, will be fed into their pipeline serving the Southern California market. This line carries approximately 1900 million ft^3/day of gas. Thus the Burnham I output represents only about 15% of the total gas flow. The ultimate output of EPNG's Burnham I and II plants, estimated to be 785 million ft^3/day, represents about 41% of the total pipeline gas flow and impurities in the SPG would be diluted to a smaller extent.

I.4.1.2 Coal Gasification By-Products

While variations occur in the by-products of various coal gasification processes, those produced in plants using Lurgi gasifiers are considered here for the reason stated in the previous section. As indicated in the draft environmental statement for the EPNG project,[1] six by-products are expected to be produced: tars, tar oils, crude phenol, naphtha, sulfur, and 20% ammonia solution. No final disposition of these products can be postulated, pending the results of market studies. If the combustible products such as tars and tar oils cannot be marketed at a profit, they could be used as fuel at the plant site. This is not a very likely mode of disposition for these materials. Since rail and water transportation are not available at EPGN's Burnham plant site, the only viable alternatives for transporting products to markets are pipelines or tank trucks. The latter seem to offer greater probability of loss of these potentially carcinogenic materials to the environment. Table I.2-8 lists compounds likely to be found in these products.[3] These materials will probably require chemical processing to prepare separated products for marketing for uses that have not yet been defined. Such processing will bring the possibility of exposure of plant operators to carcinogenic compounds. The data reported earlier in Table I.2-6 were obtained with tar produced by the Synthane process. Comparable data on Lurgi process material do not appear to be available at present. Variations in processing conditions undoubtedly cause variations in the quantity of tar products and their composition but these changes seem unlikely to modify the above conclusion.

The by-product having next highest potential for environmental effects is the crude phenol material. The mode of transportation and the market for this mixture of compounds also remain to be defined but, in order to be very useful, the crude product will probably need to be refined and thus will require chemical manipulation as in the case of the tars and tar oils. The hazards of processing the crude phenols and the end uses of refined and/or separated products have not been established.

The fourth by-product to be considered here is naphtha. This includes hydrocarbon compounds with molecular weights roughly in the range of natural gasoline but with a higher aromatic content. Use of this material in motor vehicles is a possibility. Since emission of polynuclear aromatic hydrocarbons (PAHs) and phenols in automotive exhaust is a matter of concern,[4-6] the question whether use of by-product naphtha as a substitute for gasoline or as a diluent of the petroleum product will increase the PAH or phenol content of exhaust gases needs to be examined carefully. Since PAH compounds have high molecular weights, they would not be expected to be very volatile and should not present a problem in regard to exposure to vapors during handling or use.

The last two by-products, sulfur and 20% NH_3 solution, should not differ significantly from similar products produced by other methods. Transportation and use of these products would not be expected to present special hazards.

Freudenthal, Lutz, and Mitchell have examined the carcinogenic hazards of coal gasification in a recent report.[7] They state in their conclusions: "The greatest carcinogenic potential probably exists in the early stages of the processes in which the coal passes through a series of structural degradations of complex organic compounds to compounds with simpler chemical structures. It is in these early stages of the gasification processes that leaks and spills must be avoided to minimize the carcinogenic potential that may exist. As the gasifier outputs approach a typical gas composition, the carcinogenicity is eliminated or minimized. However, if besides the typical gas composition, the crude coal gas contains tars of high-boiling oils, the composition must be considered to represent a potential hazard, and safe handling and disposition or destruction are mandatory." This statement is in essential agreement with the above discussion although it considers a processing hazard not addressed in our discussion.

I.4.1.3 In-Situ Coal Gasification

Although underground coal gasification has been investigated in most western countries, it has recently received increased attention because of potential advantages due to greater resource accessibility as well as economic and environmental advantages. In the fall of 1972, the ERDA Laramie Energy Research Center initiated an *in-situ* coal gasification experiment at Hanna, Wyoming.[8] Analyses[9] of two gas samples from this experiment were given earlier in Table I.2-11. The earlier statements on potential environmental effects of this gas product apply equally well here. Some of the products of this process which might be expected to pose environmental or biomedical problems are the coal tars produced along with the product gas. These coal tars are unique in the sense that they are generally low boiling, low molecular compounds which are a potential fuel source or petro-chemical feedstock. The chemical composition of these tars varies with changes in *in-situ* gasification condition using the linked vertical well process. Consequently, the composition of these tars is being investigated in order to assess potential environmental problems.

A number of compounds were identified in the tar base fraction of a sample obtained at Hanna.[9] These include pyridine, 2-, 3-, and 4-picoline, 2, 6-, 2, 4-, 2, 5-, and 2, 3-lutidine, trimethyl and ethyl pyridine, aniline, 2-methylaniline, dimethylaniline, quinoline, and methylquinoline. Other tar fractions have been studied in less detail. Other in-situ experiments soon to be initiated will most likely produce tars of higher molecular weight due to the different processing conditions. Consequently, the tars produced from these forthcoming experiments will also merit investigation. Potential markets for these coal gasification products and modes of transportation to such markets remain to be determined.

I.4.2 Coal Liquefaction

I.4.2.1 General Comments

The hazards presented by coal liquefaction processes are similar to those associated with the by-products of coal gasification previously discussed. However, the quantities of potentially hazardous liquids that must be handled outside the coal conversion plant may be much larger. In coal gasification by the Lurgi process, less than 10% of the coal is converted to liquid organic products and their use outside the gasification plant is probably not an economic necessity. On the other hand, the objective of liquefaction processes is, of course, to produce liquids. These liquids must generally receive further refinement in order to achieve economic status. This upgrading of the primary coal conversion products may occur in the coal conversion plant or the products may be transported to another plant for processing. A combination of these two possibilities may also occur because hydrogenation or other treatment of the primary products may be required in some cases to make them more suitable for shipment.

The number of organic compounds identified in coal conversion products is presently in the hundreds and the number will undoubtedly grow as a greater variety of products is examined with more sophisticated analytical techniques. One principal area of concern, carcinogenicity, was examined in a previously mentioned report.[7] The authors point out that many of the compounds known to be present in coal liquefaction products have not been tested for carcinogenicity but they suggest that, in the absence of medical data, compounds with boiling points above 250°C should be handled with caution. This statement should not be interpreted as implying that compounds with lower boiling points are free of suspicion. The above-mentioned report[7] contains the conclusion that coal liquefaction-hydrogenation processes considered (but not named) in preparing the report yield products that may have considerable carcinogenic potential. It further states that the total products of hydrogenation, the higher-boiling distillates, the centrifuged oils, the char, the centrifuged residues, and the recycled solvent oil are all potentially hazardous materials. Part of these materials will undoubtedly be used only within the coal conversion plant and are thus outside the scope of this section. The destination of the other products and their mode of transportation must be determined in order to evaluate the environmental hazards.

Table I.4-1 gives examples of the products being obtained from some of the liquefaction process now being studied. The Lurgi gasification process is included for comparison.

A more detailed discussion of uses and transportation follows.

I.4.2.2 Refinery Products of Synthetic Crude Oil

In order to estimate the amounts of various refinery products from synthetic crude, we will make the assumption that they will be the same as presently obtained from petroleum crude. This assumption will probably give somewhat low fractions of those compounds that are predominantly aromatic.

The data given in Table I.4-2 illustrates the ratios of the various products that are being obtained from the refining of petroleum.[10] Asphalt and road oil are expected to contain an appreciable fraction of the higher boiling aromatic compounds from the synthetic crude and thus, as was mentioned earlier, can be expected to be carcinogenic.

I.4.2.3 Uses of Petroleum Products

Table I.4-2 gives information about some of the uses and dispositions of refined petroleum products. As mentioned previously those with the higher boiling points such as asphalt, road oil, waxes, and probably residual fuel oil are more likely to contain the carcinogenic components.

Many of the other by-products of coal liquefaction (see Table I.4-2) are similar to those in refinery products or those discussed under coal gasification. The $(NH_4)_2SO_4$, H_2SO_4, and ammonia may be used in the fertilizer industry and are not expected to carry carcinogens.

I.4.2.4 Transportation Hazards of Coal Liquefaction Products

The costs of several methods of transporting liquid petroleum crude and products are quoted[11] to be (in mills per ton-mile): pipeline, 1.5-6; barges, 1.5-3; tankers, 0.5-2; railroad tank car, 30-70; and tank truck, 30-50. Thus it is not surprising that petroleum crude oil is transported to refineries largely by pipeline or by tanker; in 1972, 76.7% of crude oil going to U.S. refineries went by pipeline, 22.1% by water transport, and only 1.2% by tank trucks and tank cars.[10] Thus it seems reasonable to assume that most synthetic crude oil will be transported to a refinery either by pipeline or by water.

Table I.4-1. Commercial products of typical coal conversion processes (tons per 1000 tons coal)

Process/product	COED[a] (Gas reforming)	COED[a] (Char oxidation)	COED[a] (Gas reforming)	SRC[b] (Solvent refined coal)	H-Coal[c] (American Oil Company evaluation)	Lurgi[d]
Type coal % S	Utah A 0.5	Utah A 0.5	Ill. #6 3.7	Ky. #11 3.14	Ill. #6 3.7	Navaho seam 0.69
Fuel gas	$2.04 \times 10^6 \frac{ft^3}{1000\ ton}$	$10.2 \times 10^6 \frac{ft^3}{1000\ ton}$	$1.34 \times 10^6 \frac{ft^3}{1000\ ton}$			265
Naphtha						10
Light oil				49.5		
Motor fuel					282	
Furnace oil					160	
Syncrude	212	212	142			
Sulfur	1.3	1.3	28	24		8
$(NH_4)_2SO_4$					37	
H_2SO_4(60°Be, 77%)					29	
Purified coal				545		
Char	464	243	497			
Coal residue					168	
Tar						45
Tar oil						25
Phenol				3.3		5.8
Cresylic acid				11		
Ammonia	(100%) 2.2	(100%) 2.2		(100%) 2		(20%) 55

[a]Source: A. J. Forney et al., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Bureau of Mines Technical Progress Report 76, January 1974.

[b]Source: Reprint from the Bureau of Mines Mineral Yearbook, "Crude Petroleum and Petroleum Products, "Bureau of Mines, U.S. Dept. of the Interior, Supt. of Documents, Washington, D. C.

[c]Source: "Energy R and D and National Progress," Report prepared for Ali Bulent Chambel, Chairman of the Energy Study Group by Donald F. Hornig, Library Congress Card 65-60087, U.S. Government Printing Office, June 5, 1964.

[d]Source: "Statistical Abstracts of the United States 1973," 94th Annual Edition, U.S. Dept. of Commerce.

Table I.4-2. Yields of refined petroleum products from crude oil in the United States in 1972. [Source: "Summary of Liquid Pipeline Accidents Reported on DOT Form 7000-1 from Jan. 1, 1971 through Dec. 31, 1971," Office of Pipeline Safety, Dept. of Transportation, Washington, D. C., March 15, 1972.]

Finished product	% yield	Uses
Gasoline	46.2	99% for motor use; 1% for aviation
Jet fuel	7.2	(77% kerosine type; 23% naphtha type)
Ethane	0.2	
Liquefied gases	2.8	70% for fuel; 30% for chemical use
Kerosine	1.8	78% for space heating
Distillate fuel oil	22.2	
Residual fuel oil	6.8	52% to electric utilities
Petroleum feedstocks	2.9	
Special naphthas	0.7	Paint thinners, cleaning agents, and solvents
Lubricants	1.5	Over 50% to industry
Wax	0.1	20.5% to paperboard containers; 16% to paper wrappers; 13% to corrugated cardboard; 17% to candles, molded novelties, and decorative items
Coke	2.8	
Asphalt	3.6	77% for paving; 17% for roofing products
Road oil	0.2	
Still gas	3.9	
Miscellaneous	0.4	Absorption oils, medical oils, insecticides, petrochemicals, and solvents

The other liquid products listed in Table I.4-2 are likely to be transported by tank truck and railroad tank car. We can expect the solids to be moved also by truck and railroad car.

Pipeline hazards. The reported volume[11] of crude oil transported by pipeline in 1971 is 1.439 x 10^{12} barrel-miles and the corresponding figure for petroleum products is 1.045 x 10^{12}. The reported losses[12] for the same year are 2.45 x 10^5 barrels for a loss ratio of 0.234 barrels per million barrel-miles. In 1972 and 1973, the last years reported, about 80% of these losses were associated with the pipelines themselves, 10% with pumping stations, and 10% with storage tanks.[13,14] With pipelines we would expect a minimum of contact with the product by the operators, and their exposure would normally be at pumping or valving stations, and at storage yards and distribution points.

Since production of refinery products from synthetic crude oil resulting from coal liquefaction is expected to be a small fraction of that from petroleum refineries, and the synthetic products are likely to be blended with larger volumes of the natural products, the hazard from pipeline losses of synthetic petroleum products seems quite small.

Tanker and tank barge hazards. The U.S. Coast Guard has reported[15] that the total loss of light oil (gasoline, light fuel oil, kerosene, and light crude) amounted to 157,000 barrels in 1972; the corresponding loss of heavy oil (diesel oil, heating oil, heavy fuel oil, heavy crude and asphalt) was 42,000 barrels. These losses included those from tank ships or tank barges and those from other types of vessels and various on-shore facilities.

Since the above losses of light and heavy oils amount to only 3.7 x 10^{-3}% and 0.98 x 10^{-3}% respectively of the total crude oil refined that year,[10] these losses, like those from pipelines, appear to represent no undue hazard.

Railroad tank car hazards. It is reported[10] that in 1971 the weight of petroleum and petroleum products carried by rail was 1.5% of the total of such products carried. This amounts to 25.8 million short tons. An analysis of railroad accidents[16] correlates the probability of an accident with its severity. If we assume than an accident of "minor severity" would not result in an oil spill, but that those of "moderate" and greater severity would, then the probability of a spill is 7.9 x 10^{-8} per vehicle-mile. If the 25.8 million short tons were moved an average of 100 miles, then the expected loss from rail spills would be in the order of 200 tons a year. Again, the losses appear to be a very slight hazard.

Tank truck hazards. An accident analysis[16] of motor carriers carrying hazardous materials found that the probability of a moderately severe accident was 3 x 10^{-7} per vehicle-mile in 1969. The probability of fire being associated with gasoline truck accidents is high.[16] It is reported[10] that motor carriers handled 27.4% of the tonnage of the crude petroleum and petroleum products transported in 1971; most of this was petroleum products and presumably was gasoline being delivered to filling stations. Thus the probability of loss of synthetic oil products in truck accidents is much larger than by other modes of transportation. However, because gasoline contains mainly low boiling hydrocarbons, the carcinogenic potential of spilled products is probably low, but it needs to be carefully evaluated.

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II. KING-MUIR PROBLEM/PROGRAM UNITS

II.0 OVERVIEW OF KING-MUIR CATEGORIES

II.0.1 Characterization, Measurements, and Monitoring (CMM)

For BPP purposes, the objective of the CMM effort is to provide the chemical and physical capabilities and information that are and will be needed to carry out the biological, biomedical, and ecological portions (i.e., effects studies) of the program. In order to meet this overall objective, the CMM activity should (1) assess existing information, (2) utilize a hierarchy of existing chemical and physical techniques, and (3) develop new ones where needed to meet program goals. Moreover, it should (4) establish and maintain chemical support facilities that will provide appropriate quantities of well-characterized materials for use by others, (5) determine optimum sampling and sample preservation/handling protocols, (6) set up a quality assurance program to ensure credible measurements within and among projects and laboratories, and (7) ensure that adequate and reliable measurement and/or monitoring instrumentation is available when needed. Accordingly, much of the chemistry and physics effort of this program falls within the scope of the CMM effort.

CMM research needs to be initiated immediately. Initially the objective will be to assess existing information and capabilities, and to initiate experimental work that gets the overall program off to a good start. In the early stages the research will include inventories of existing materials, support research utilizing existing techniques, and developmental research for techniques considered most critical (i.e., sample storage, quantitative capabilities for selected materials). As the program develops, work will be initiated that will ultimately provide the instrumentation necessary to carry out source (pilot plant)-characterization studies, anticipated later in the overall program.

II.0.2 Health Effects

Proposed Health Effects research in coal conversion can be divided into two parts: (1) effects on industrial workers engaged in the technology, and (2) effects on the general public of the operation and use of the products of the technology.

Industrial workers in coal conversion will represent a relatively small and well-defined population that might be exposed by accident or faulty design to relatively high concentrations of potentially hazardous substances. In this case, the most obvious hazard, from present knowledge, is exposure to potentially carcinogenic hydrocarbons, but there are a number of other, presently less well-defined, hazards. With such industrial groups it may be feasible to carry out a number of tests on most or all members of the population and to monitor them for any clinical symptoms. Acute and chronic toxicity, carcinogenicity, and perhaps for a small fraction, teratogenicity are the important effects to look for. Mutagenicity will likely be of little importance because of the small size of the populations. However, tests for damage to chromosomes and for mutagenicity in laboratory systems may be valuable for identifying and estimating damage to individuals and identifying potentially hazardous substances. It may be possible in such groups to develop and utilize procedures for enhancing biological repair and recovery as protective or therapeutic procedures.

The main known hazard for personnel involved directly in coal conversion is exposure to carcinogenic polycyclicaromatic hydrocarbons (PAH) as discussed in more detail in Section I.2 and Appendix A. However, as these parts of the report point out, there are a number of other materials, including phenols, organosulfur compounds, and others to which such personnel may also be exposed. Our knowledge of the health effects of such substances is in general very limited and needs to be greatly improved. Moreover, there is a very real possibility that there will be both synergistic and antagonistic effects of materials in the complex organic mixtures produced during conversion processes. We know very little about the long-term effects of chronic medium-level exposure to such materials and mixtures. Thus, both rapid screening tests, longer term tests, and quantitative dose-effect determinations will be required to assure that industrial personnel are not being exposed to undue hazards. Medical surveillance and epidemiological studies will certainly be desirable, but as long as coal conversion is in the pilot plant stage the number of exposed individuals will be too small to allow detection of any but the most obvious and ubiquitous effects by such methods. Heavy reliance should be placed on laboratory tests, in any case, to avoid unnecessary exposure to industrial personnel. However, medical surveillance and epidemiological studies with personnel involved in established fossil fuel processes may give valuable information.

Chronic effects of low levels of materials released during coal conversion and during the use of its products will be the principal concern for the general public. This will include the effects included under carcinogenicity, chronic toxicity, mutagenicity, and possibly teratogenicity. Major reliance must be placed on extrapolation from laboratory data to man. However, despite the difficulties imposed by the expected low levels of hazardous substances, epidemiological and clinical studies of groups of individuals, especially those located near coal conversion plants, may be of importance. This is particularly true because the complexity of the products and the low level of the individual effects may make it difficult to really duplicate the situation in the laboratory. As for the industrial workers, the polycyclic hydrocarbons would appear to be at least one hazard of interest, but our present knowledge is too limited to be sure that other materials may not be even more hazardous to the general public.

Little is currently known about the potential hazards to the general public of coal conversion processes. Insofar as the effluents are similar to those produced by coal combustion and the gaseous and liquid products are similar to natural gas and petroleum, the health effects will be the same as for those technologies. However, as pointed out in Section I.2 and Appendix A, the synthetic crude oil produced by coal conversion has a considerably higher concentration of PAHs than does natural crude oil. Insofar as such materials may escape into the general environment during the refinement or use of synthetic crude oil and its products, they represent a potential hazard, especially since there is some indication from work with lower organisms that they may not only be carcinogenic but mutagenic as well. Moreover, there is evidence that aqueous wastes from coal conversion may contain some appreciable amount of PAH. In addition, such waste can contain appreciable amounts of phenols, organosulfur, and other organic compounds as well as some heavy metals. There is essentially no information about the effects of chronic, low-level exposure to such materials. We must conclude that there is no clear information about the potential effects on health of chronic exposures of the general public to the products and effluents from coal conversion technology. However, there is enough known about the composition of these materials to make it essential to carry out further studies.

There are a number of kinds of development and research that are applicable almost equally well to the estimation of health hazards for industrial workers and the general public. These include the development of a variety of laboratory procedures and tests for identifying and quantitatively evaluating the hazards. Also included is research designed to improve our understanding of the way in which potentially hazardous substances produce damage and the way in which biological systems handle such substances and repair or recover from the damage produced. Such information is essential for the development of efficient testing systems and for the interpretation of laboratory tests in terms of human hazards. Such developments and evaluations are particularly important when dealing with complex chemical hazards such as may be expected to result from coal conversion. Our current knowledge in this field is still quite unsatisfactory.

II.0.3 and II.0.4 Environmental Effects and Transport and Physical and Chemical Processes and Effects

The anticipated implementation of massive coal conversion industries in the United States within a decade will result in the introduction of substantial gaseous, solid, and aqueous waste fluxes into the environment. Many of the contaminants produced, particularly from coal liquefaction processes, may have profoundly deleterious effects on aquatic and terrestrial ecosystems, and ultimately, on human life. Research into the environmental effects of effluent compounds will be required to ensure the implementation of environmentally acceptable surface and in-situ coal gasification and coal liquefaction technologies.

The research program outlined proposes parallel investigations of (1) ecological effects and (2) physiochemical and biological transport and transformation of coal conversion effluent constituents. Initial experimentation should emphasize screening procedures to establish a hierarchy of effluent hazards; non-subtle biological effects and major transformations and sinks should be determined for whole effluents, effluent subfractions, and major identified effluent compound classes. Later research should examine quantitatively less significant effluent constituents and individual compounds which are indicated to constitute particular biological or ecological hazards. Investigations should proceed from acute to more subtle, chronic, long-term effects on representative organisms; experimentation should expand to encompass more complex multi-step transport processes and degradation rate studies. Both single-component systems and model ecosystems (microcosms) should be utilized. At each step of the research plan relative ecological hazards of effluent constituents should be re-evaluated and research priorities should be redirected if necessary.

Research areas should initially comprise five major environmental compartments: the atmosphere, biological systems, soil, natural waters, and sediments. Biological effects and transformations should be evaluated initially within each compartment. As fluxes of effluent constituents between compartments are identified and their importance determined, research activities will of necessity cross compartmental lines.

Submodels of transport and transformation pathways and population effects within each environmental compartment should be developed as research program data become available. An objective should be the development of comprehensive models of ecological effluent effects for each of the coal conversion technolgies under development.

Intensive, multi-year field surveys of the environment surrounding representative coal conversion demonstration plants should be conducted concurrently with laboratory programs. Each site chosen should be representative of one of the broad range of climatic, edaphic, and vegetative types in which coal conversion facilities might be expected to be sited. Pre-operational quantification of populations and effluent constituent levels will provide baseline data upon which the effects of plant operation should be superimposed. Sampling and analysis priorities should be adjusted throughout the study to reflect re-evaluations of effluent hazards developed from laboratory research. Field results should be utilized to modify, validate, and test models of effluent behavior. From the accumulated data an evaluation of the ecological hazard of effluents should be determined for each coal conversion technology.

II.0.5 Integrated Assessment of Coal Conversion Technologies

In order to establish a coordinated set of policies and implementation plans for coal conversion technologies, an integrated assessment of technological alternatives, implementation priorities, and a totalized cost/benefit analysis will be established. This program will address the potential energy produced, the form of converted fuel products produced, and the end utilization/substitution for current and projected fuel demands. Implementation plans for various conversion technology scenarios need to be developed which minimize human and environmental health impacts and maximize economic and social benefits. Alternative conversion scenarios should include various methods and mixes of methods for extraction, conversion, distribution, and waste management -- each providing for optimal exploitation of varying resource supplies and for optimal location of plants with a range of options for pollution abatement.

In addition, this program will provide for an integrated assessment of the direct and indirect impacts of the developing technologies and provide a set of policy recommendations for implementation, facility siting, resource supply-demand management, and the fundamental biomedical, environmental, social, and economic research necessary to provide guidelines.

A major thrust of this effort will be to establish fuel product utilization demands and establish the economic costs and incentives necessary to meet the overall goals of Project Independence. This effort will necessitate the assessment of the available coal resources and the alternative extraction processes and conversion processes best suited for maximum efficiency of resource recovery with minimal environmental impact. Alternative technological processes for conversion (i.e., liquefaction, gasification), location of production facilities, and schemes for product storage/distribution/utilization will be studied in detail to optimize coal resource development, transportation development, as well as end-use substitution of conversion products for current and projected energy consumption.

Human health assessment will begin at the earliest stage for conversion processes deemed feasible in the next decade. This research will also address potential health problems associated with final domestic utilization of products. Environmental transport pathways and ecological impacts research will utilize information gained from early chemical characterization and toxicity screening of pollution effluents and monitoring programs. The variety of environmental pathways, differing modes of human population exposure, and the array of ecological system responses to effluents from the mix of technological alternatives will be integrated into an analysis scheme for the optimal siting of conversion facilities.

An integrated assessment program has therefore been provided in the following pages to provide for the sound management of this nation's coal resources and the analysis of technological alternatives for economically utilizing these resources in response to trade-offs with other electrical energy and fossil fuel production technologies. The scope of this program plan identifies the current state of knowledge and information gaps critical to an integrated assessment and provides recommendations for both (1) a basic research plan for implementation of an integrated assessment program and (2) the development of necessary data analysis and information research requirements to support this program.

The scope of the integrated assessment program will require a regional perspective and will need to be supported by a well-defined information system including the following:

Resource Management - assessment of the composition and availability of coal reserves, and air, land, and consumable water resources necessary to support conversion technologies.

Control Technology - evaluation of the feasible control technologies that can be implemented to enhance the health acceptability of various conversion processes.

Environmental Transport - characterization of the modes of entry and transport of technology effluents and identification of environmental reaction products and their critical pathways of transport to man and sensitive biota.

Health Effects - evaluation of the occupational health problems and potential exposures of general population, including toxicological and epidemiological biomedical research.

Ecological Effects - identification of sensitive ecological systems (both natural and agricultural) and quantification of both acute and chronic, long-term, low-level exposure impacts on terrestrial and aquatic environments.

Social and Welfare Effects - evaluation of the social, political, economic, and cultural impacts of the environmental effects of coal conversion and pollution control technologies.

Cost/Risk/Benefit Analysis - analysis of the cost/risk/benefit trade-offs of energy production and pollution control alternatives, whether similar or different, in all regions and environments of the nation.

II.0.6 Environmental Control Technology

II.0.6.1 Introduction

Conversion of coal into clean fuels and/or chemical feedstocks will undoubtedly result in gaseous, liquid, and solid waste which must be controlled and managed in an economically and environmentally acceptable manner. Although the basic coal conversion processes have been known and even used on a large scale (see Section I.1), information concerning the nature and quantities of the wastes produced is far from complete. Obviously, the nature and quantities of the wastes produced will depend very strongly upon the content of undesirable material in the coal used in the process. The content varies greatly depending on the source of the coal. Another factor which affects the nature and quantities of wastes is the coal conversion process itself. Recognizing these variations, in general terms the environmental control and waste management problems associated with various process steps can be described as follows:

Process Operation	Problem
I. Coal Preparation, Feeding, Storage, and Handling	
A. Unloading	Dust
B. Storage of raw coal	Water*, Dust, Fire
C. Washing	Water, Solids
D. Drying	Water, Dust
E. Crushing and Pulverization	Water, Dust, Noise
F. Slurry Preparation and Pumping	Organic Vapors Carcinogens
II. Coal Conversion	
A. Coal Convertors	Organic Vapor Leaks Accidental Release of Coal Derived Liquids Spent Catalysts
B. Hydrogen Generation	
C. Gas Purification	
1. Water Wash	Waste Water, Gases
2. Oil Wash	Waste Oil, Gases
3. Amine Scrub	Waste Amine, Gases
4. Sulfur Recovery	Waste Gases
D. Solids Separations and Oil Recovery	Organic Vapors, Solid Wastes Water
E. Solvent Recovery	Vapor Leaks Waste Heat Cooling Water

Process Operation	Problem
III. By-product Recovery	Water, Vapor Leaks
IV. Product Utilization	Carcinogens (?)
V. Waste Management and Disposal	Char Ash (Dust and Water Solubles) Waste Liquids

*All water effluents will probably contain significant quantities of phenols, polynuclear aromatic hydrocarbons, acids, and other harmful soluble compounds unless stringent controls are applied.

II.0.6.2 Control Technology

The magnitude of the control technology problem associated with coal conversion is so great that a detailed discussion of the necessary research and development is not warranted here. However, the general requirements and approach will be discussed with some specific points where information on environmental and health effects of the coal conversion technologies is needed to obtain the ultimate objective, which is to develop and demonstrate economical technologies required to minimize or eliminate completely all unacceptable emissions, effluents, etc., from any coal conversion technologies implemented.

Research and development of environmental control technology is required to ensure that adequate systems and methods of control are available for application upon commercialization of coal conversion technologies in a manner which is most cost effective (i.e., to prevent the necessity of extensive retrofit application of control devices, but rather be able to integrate the technologies and control systems prior to commercial plant installation). A schematic of the approach to this required research and development program is shown in Fig. II.0.6-1. As is obvious from Fig. II.0.6-1. early identification of pollutants, emission, and their health and environmental effects is essential to the timely development of control technology. Although some of this information is available (enough to permit initiation of some control technology research and development), a significant effort is needed to identify the major pollutants and their effects, as well as minor pollutants with major effects. It would be very unfortunate to set effluent standards, establish control technology equipment performance specification, or make economic evaluations of conversion processes without a better definition of the potential environmental problem than currently exists. Problem and Program Units have not been included here. A separate document on Control Technology has been produced by DBER. This summary has been included to show the internal part control technology should play in the evaluation of Coal Conversion technologies.

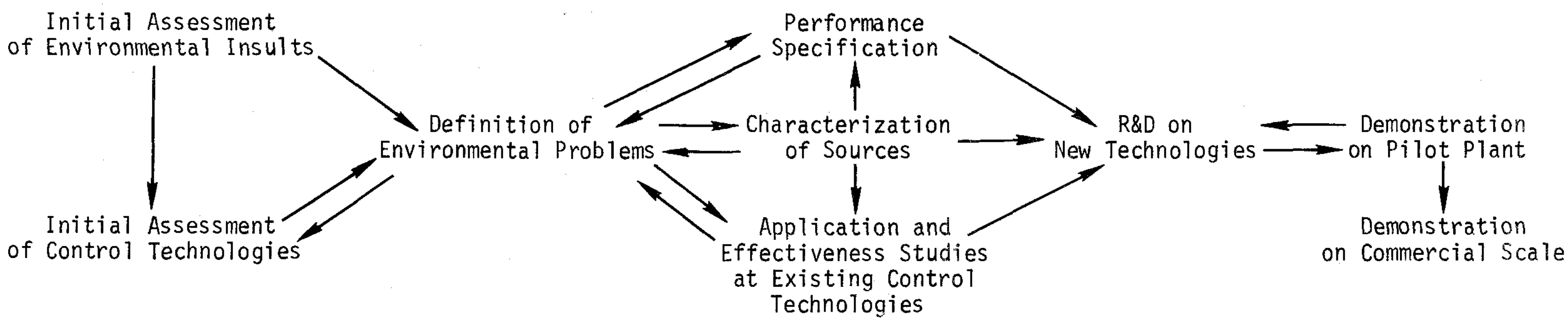

Figure II.0.6-1. Schematic flow chart of environment control technology for Coal Conversion Research and Development Program

II.1 PROBLEM AND PROGRAM UNITS

II.1.1 Characterization, Measurements, and Monitoring

II.1.1.0 Studies of Sample Acquisition and Metamorphosis

(1.1.1 Production of well-characterized materials for environmental and health research)

(1.1.2 Development of sampling methodology and devices)

(1.1.3 Determination of sample stabilities)

(1.1.4 Determination of methods for sample preservation)

II.1.2.0 Methodology

(1.2.1 Inventory of techniques/expertise)

(1.2.2 Separation technology)

(1.2.3 Screening methods)

(1.2.4 Methods development for specific constituents)

(1.2.5 Class analysis)

(1.2.6 Methods for in-situ samples from biological environmental studies)

(1.2.7 Defined exposure systems for biological/ environmental studies)

II.1.3.0 Chemical and Physical Characterization of Coal Conversion-Derived Materials

(1.3.1 Establish quality assurance system)

(1.3.2 Characterization of process streams and products)

(1.3.3 Characterization of airborne discharges)

(1.3.4 Characterization of aqueous discharges)

(1.3.5 Characterization of solid waste)

II.1.4.0 Monitoring

(1.4.1 Inventory of techniques and expertise)

(1.4.2 Occupational monitoring)

(1.4.3 Environmental monitoring)

(1.4.4 Specialized instrumentation)

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Characterization, Measurements, and Monitoring

Problem Title: Studies of Sample Acquisition and Metamorphosis (II.1.1.0)

Objectives: A considerable effort is required to establish standardized procedures for acquiring and preserving representative samples from various points within a coal conversion plant and in the environment affected by the plant. Sampling locations include: process streams; product streams; plant air and water supplies; environmental air, water, soils and sediments; and biosphere components. Methods to preserve the chemical and physical composition of samples prior to characterization constitute a substantial portion of the study.

Priority: High

Program Unit Titles:

1.1.1 Production of well-characterized materials for environmental and health research

1.1.2 Development of sampling methodology and devices

1.1.3 Determination of sample stabilities

1.1.4 Determination of methods for sample preservation

BER Balanced Program Plan

Program Unit

1.1.1 Production of well-characterized materials for environmental and health research

Program Unit Objective: To establish a centralized facility for support of biological and environmental studies related to coal conversion technologies. Materials will be produced, fractionated, characterized, and supplied to other researchers.

Scope: The purpose of this work is to establish a central facility to provide direct support for research at various laboratories engaged in the health and environmental aspects of coal conversion technologies. No such facility exists today. Direct services will include (a) the supply of crude samples and fractions thereof, (b) the supply of pure compounds when purchase is not possible, and (c) the identification and quantification of chemicals constituting crude samples and fractions. To provide these capabilities, it will be necessary (a) to study sampling methodology, (b) to define the chemical stability of samples and to devise means to preserve them, (c) to devise methods for separating crude samples into reproducible fractions on both analytical and preparative scales, (d) to carry out in-depth chemical characterization (identities and quantities) of crude samples and fractions, and (e) to provide other chemical and ecological researchers.

The existence of a central facility will ensure that results obtained by various research teams can be confidently inter-compared because comparable samples will be used in their studies. Should technical limitations preclude direct support (e.g., if sample instability negates sample shipping), then the standardized methodologies developed in this work could be implemented in other laboratories. A central facility combining direct service and some chemical research will provide an economical core activity upon which biologists, industrial hygienists, and environmentalists can draw for chemical support.

Technology Development Time Frame: Should begin immediately so as to be available as biological and environmental research programs mature. Should begin at high level initially to establish facilities and methodologies, and continue at modest level when operation becomes routine.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $2,900,000

2. Per Year -

FY 1977	$	800,000
FY 1978	$	800,000
FY 1979	$	500,000
FY 1980	$	500,000
FY 1981	$	300,000

BER Balanced Program Plan

Program Unit

1.1.2 Development of sampling methodology and devices

Program Unit Objective: Devices will be developed for reliable and, in some instances, automatic collection of samples.

Scope: An inventory of sampling apparatus, both commercial and experimental, is included in this unit. Devices will be developed and tested for long-term, reliable performance in the field. Work outlined in this unit must be done concomitantly with the development of sample methodology.

Milestones:

1. Demonstration of reliable sampling devices for process and product streams.
2. Demonstration of a reliable device for collecting whole air samples (may include particulate-gas separation).
3. Demonstration of reliable devices for collecting aqueous samples.
4. Demonstration of reliable devices for collecting soil and sediment samples.

Technology Development Time Frame: Work should be initiated in Year 2 and continue through Year 7. Additional work will be determined by programmatic needs.

Program Unit Priority: High initially, becoming moderate after Year 5.

Estimated Program Unit Cost:

1. Total $935,000
2. Per Year - FY 1977 $ 60,000
   FY 1978 $200,000
   FY 1979 $225,000
   FY 1980 $225,000
   FY 1981 $225,000

BER Balanced Program Plan

Program Unit

1.1.3 Determination of sample stabilities

Program Unit Objective: Following sampling, rates of change in chemical and physical composition will be measured to determine if any special handling procedures will be required prior to analysis.

Scope: Studies will include rough screening tests to determine the effects of various transport and storage conditions upon sample stability. A data inventory of physical and chemical properties of specific substances can preclude some tedious work. Stability studies may include addition of sought-for substances to real samples.

Milestones:

1. Determination of sample stabilities in various matrices as required.

Technology Development Time Frame: Work should be initiated in Year 1 and continue at a modest level through Year 5. Additional work may be required depending upon programmatic needs and results.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $390,000

2. Per Year - FY 1977 $ 60,000
FY 1978 $ 90,000
FY 1979 $ 90,000
FY 1980 $ 90,000
FY 1981 $ 60,000

BER Balanced Program Plan

Program Unit

1.1.4 Determination of methods for sample preservation

Program Unit Objective: Knowledge accrued through sample stability studies will provide a basis for the development or adaptation of methods for the preservation of samples.

Scope: Studies will include effects of physical conditions such as moisture, air, heat, and light on the samples. The effect of container material used for transportation and storage will also be characterized.

Milestones:

1. Determination of optimum physical conditions for storage and handling.

2. Development of passive container materials.

Technology Development Time Frame: Work should be initiated in Year 1 and continue throughout the ten-year period at a modest level.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		\$360,000
2.	Per Year -	FY 1977	\$ 30,000
		FY 1978	\$ 90,000
		FY 1979	\$ 90,000
		FY 1980	\$ 90,000
		FY 1981	\$ 60,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Characterization, Measurements, and Monitoring

Problem Title: Methodology (II.1.2.0)

Objectives: To provide the chemical methodology that will be needed to carry out the ecological and health portions of the program. To meet this objective will require an assessment of existing information, techniques, and capabilities followed by a systematic approach to the development and application of chemical separation and analysis technology to both classes of chemical compounds and to suspect individual compounds. Finally, the assessment of impact on biological and environmental systems will require the development of methods for the determination of the chemical form and quantity of very small amounts of individual compounds that invade such systems. Such impact assessment will initially require the development of model systems that provide well-defined exposures for biological or environmental experiments.

Priority: High

Program Unit Titles:

1.2.1 Inventory of techniques/expertise

1.2.2 Separation technology

1.2.3 Screening methods

1.2.4 Methods development for specific constituents

1.2.5 Class analysis

1.2.6 Methods for in-situ samples from biological/environmental studies

1.2.7 Defined exposure systems for biological/environmental studies

BER Balanced Program Plan

Program Unit

1.2.1 Inventory of techniques/expertise

Program Unit Objective: To compile existing information about chemical methodologies applicable to coal conversion processes; to ascertain and locate the current capability for utilizing this information; and to continually update this information as additional methodology is developed.

Scope: Available literature must be assembled and organized in a manner that makes it useful and available. Summaries of known information and techniques should be compiled and continually updated in order to prevent wasteful duplications of effort. As useful methodologies are isolated and summarized, those scientists most familiar with the details of the methodologies should be listed with the summaries.

Milestones:

1. Establishment of information categories appropriate to methodology should be completed immediately.
2. Existing literature should be reviewed and organized into the established categories during Year 1.
3. Summaries of available information should be prepared during Years 1-2.
4. Milestones 2 and 3 should be a continuing activity for current developments.

Technology Development Time Frame: Activity must begin immediately and remain a small but ongoing activity for entire period.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$210,000
2. Per Year -	FY 1977	$ 60,000
	FY 1978	$ 60,000
	FY 1979	$ 30,000
	FY 1980	$ 30,000
	FY 1981	$ 30,000

BER Balanced Program Plan

Program Unit

1.2.2 Separation technology

Program Unit Objective: Methods will be adapted, improved, or developed for the quantitative separation of specific compounds and classes of compounds from complex sample matrices on both preparative and analytical scales. The objective is to provide defined, reproducible samples for analysis, for detailed characterization, and for studies of compound and sub-fraction biotoxicity, mutagenicity, carcinogenicity, and ecological behavior.

Scope: The development of highly effective and reproducible separations methods for the complex sample matrices represented by effluents and products of coal conversion processes is extremely important. Approaches will include liquid adsorption chromatography, liquid ion exchange chromatography, solvent extraction, and the use of gas chromatography employing packed and wall-coated open tubular columns. Both preparative- and analytical-scale separations methods will be required. Areas needing development work include flow monitors, preparation of uniformly sized small particle (2 to 10 μm) separations media, and techniques for coating capillary glass columns with uniform thickness, thermostable, polar liquid phases.

Milestones:

1. Development of high-resolution separations procedures for coal tars and high-boiling residuals.

2. Development of "clean" separations for heteroatom-containing compounds.

3. Preparation of defined, reproducible fractions for study of biotoxicity, mutagenicity, carcinogenicity, and ecological behavior.

Technology Development Time Frame: This activity should begin immediately, stressing existing capabilities. Emphasis shifts toward improvement in efficiency and capabilities via R/D after initial start-up (i.e., after Year 2). Should continue as total program matures to meet specific needs.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $1,680,000

2. Per Year -

FY 1977	$ 480,000
FY 1978	$ 480,000
FY 1979	$ 240,000
FY 1980	$ 240,000
FY 1981	$ 240,000

BER Balanced Program Plan

Program Unit

1.2.3 Screening methods

Program Unit Objective: Methods will be developed for rapid, high-resolution screening-type analysis of product and effluent streams from coal conversion processes. The primary objective is rapid analysis of samples in complex matrices.

Scope: Rapid, high-resolution screening methods of analysis are important to process and effluent control for purposes of minimizing environmental insults. Approaches generally will entail use of low-voltage high-resolution mass spectrometry and high-efficiency glass capillary columns for gas chromatographic analysis. A matrix of reliable sensitivity factors and associated programming will need to be developed for quantification of mass spectral data. Improved methods for coating glass capillary columns with polar liquid phases to produce highly efficient, thermostable columns will be developed.

Technology Development Time Frame: Should be initiated immediately so as to be available for use as bioenvironmental research matures. Should commence at high level and decrease to modest level at approximately Year 4.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$1,440,000
2.	Per Year -	FY 1977	$ 360,000
		FY 1978	$ 360,000
		FY 1979	$ 360,000
		FY 1980	$ 180,000
		FY 1981	$ 180,000

BER Balanced Program Plan

Program Unit

1.2.4 Methods development for specific constituents

Program Unit Objective: Specific and sensitive analytical methods will be developed for those constituents which are found to be hazardous to the environment or population. Methods and instrumentation will, in general, be designed for analysis in the field or for use in on-line process applications.

Scope: Methods and instrumentation development resulting from this program will generally be dependent on definition of target compounds by other groups studying biotoxicity, mutagenicity, and carcinogenicity of product and effluent streams. After target compounds are identified, rapid, specific methods and portable analyzers will be developed to measure these compounds in the field. Continuous monitoring systems for process effluent streams will be designed and constructed.

Technology Development Time Frame: Should be initiated at modest level immediately, stressing constituents already known to be hazardous (Years 1-2). Should continue as bioenvironmental research activities mature, to meet specific needs (Years 3-10). Specific instrumentation and monitor development will be based upon the results of this work to a large degree.

Program Unit Priority: Medium initially, medium to high after Year 2.

Estimated Program Unit Cost:

1.	Total		$1,020,000
2.	Per Year -	FY 1977	$ 240,000
		FY 1978	$ 240,000
		FY 1979	$ 180,000
		FY 1980	$ 180,000
		FY 1981	$ 180,000

BER Balanced Program Plan

Program Unit

1.2.5 Class analysis

Program Unit Objective: Develop analytical methods where entire classes of compounds are segregated for analysis (e.g., nitrogen- or sulfur- containing organics, polycyclic aromatics, C_nH_{2n-14} series).

Scope: Identify unique character of target class of compounds and attempt to use detector systems as filters to obtain measurements of only the target class (e.g., thermionic detector for nitrogen-containing compounds). Employ chemical reactions or interactions to separate the desired class, (e.g., interaction of sulfide-containing organics with cation exchange resin in the Cu^{+2} form or the formation of charge transfer complexes between polycyclic aromatics and 2, 4, 7-trinitrofluorenone). This work will blend with Program Units 2.2 and 2.3.

Technology Development Time Frame: Work should be initiated immediately at a modest level, and should be completed by Year 5. Work beyond Year 5 may be required if bioenvironmental research results so indicate.

Program Unit Priority: High initially; decreasing to medium after Year 3; decreasing to low after Year 5.

Estimated Program Unit Cost:

1. Total		$900,000
2. Per Year -	FY 1977	$180,000
	FY 1978	$180,000
	FY 1979	$180,000
	FY 1980	$180,000
	FY 1981	$180,000

BER Balanced Program Plan

Program Unit

1.2.6 Methods for in-situ samples from biological environmental studies

Program Unit Objective: To develop methodology for the determination and characterization of insulting chemicals in samples from living systems and ecological systems and to investigate possible methodology for evaluating molecular changes that may have taken place within the system as a consequence of the invading chemical.

Scope: Methodology for trace amounts of suspect chemicals and their metabolites must be adapted to or developed for complex samples such as blood, serum, urine, tissue extracts, soil, plants, natural water, etc. Such methodology must deal with ultra-trace amounts and with extremely varied sample interferences. Initially, tracer analysis must play a primary role in this activity; however, studies must be directed toward development of other approaches of high sensitivity such as immunoanalytical techniques, specific electrodes, and chromatographic techniques involving sensitive detectors such as fluroescence and electron capture.

Milestones:

1. Develop general approach for tracing fate of suspect compounds.
2. Develop approach to preparing antibody reagents for specific small organic molecules.
3. Develop approach for extracting traces of insulting chemicals from small samples of tissue, blood, serum, etc.
4. Develop sensitive measuring methodology for trace amounts of specific organic molecules in complex natural mixtures derived from living or ecological systems.

Technology Development Time Frame: General approaches to problems must be started immediately; however, specific development for suspect chemicals must be carried out as a joint chemistry-ecology or chemistry-biology effort. Thus, the level of the effort will increase as needed to support health and ecology studies.

Program Unit Priority: High, decreasing to medium after Year 5.

<u>Estimated Program Unit Cost:</u>

1.	Total		$720,000
2.	Per Year -	FY 1977	$ 60,000
		FY 1978	$120,000
		FY 1979	$180,000
		FY 1980	$180,000
		FY 1981	$180,000

BER Balanced Program Plan

Program Unit

1.2.7 Defined exposure systems for biological/environmental studies

Program Unit Objective: To develop exposure systems that allow laboratory exposures which are relevant to exposures occurring in nature; and to be able to monitor such systems so that the amount of exposure is defined and the dose obtained can be determined.

Scope: For laboratory experiments involving exposure to foreign substances it is often not practical to closely duplicate natural exposures. Natural exposures may involve very dilute insults whose chronic effects would take very long periods to evaluate; therefore, exposure systems are needed which are a relevant simulation of the exposures really occurring. Development of such exposure systems will require a synthetically prepared exposure mixture whose relative chemical make-up approaches the real world exposure. (Because of synergistic effects, emphasis should be placed on mixtures.) After making such mixtures, they must be generated into an exposure system where the fate of one or more constituents can be monitored. Fate of exposure components must be monitored in two ways. Firstly, the remains of the exposure mixture must be analyzed for depletion of one or more constituents. In addition, one or more of the constituents depleted in the exposed system must be located. Many of the methods in CMM Program Unit 2.6 will be utilized.

Milestones:

1. Using data from other CMM work and working with either biologists or ecologists synthetic exposure mixtures must be prepared.

2. Suitable exposure systems for the synthetic mixtures must be designed.

3. Methodology to monitor the exposure must be developed.

4. Methodology to evaluate impact (dose to animals, changes in exposed ecosystem, etc.) must be developed. (See CMM Program Unit immediately proceeding this unit).

Technology Development Time Frame: This effort must be collaborative--involving chemistry and environmental science of health studies with the time frame matching animal testing and laboratory ecosystem development. However, studies should begin immediately to develop synthetic mixtures and to elucidate the possible problems of increases in concentration of suspect chemicals effecting chemical changes in the exposure mixture.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $510,000

2. Per Year - FY 1977 $ 60,000
FY 1978 $120,000
FY 1979 $120,000
FY 1980 $120,000
FY 1981 $ 90,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Characterization, Measurements, and Monitoring

Problem Title: Chemical and Physical Characterization of Coal Conversion-Derived Materials (II.1.3.0)

Objectives: The objective of this problem area is to define the chemical composition and physical characteristics of coal conversion-derived materials. The product of this work is to be used to identify appropriate bioassay models, appropriate environmental transport and transformation studies, and likely industrial health concerns and to interpret the results of environmental and health studies. Existing and newly developed methodologies are to be applied to coal conversion-related samples in order to establish and expand the chemical/physical data base required to lead and support other research. Concerns include process streams and products, in-plant environments, and general environmental release. An appropriate data management/dissemination system and a quality assurance system are integral parts of this problem area.

Priority: High

Program Unit Titles:

1.3.1 Establish quality assurance system

1.3.2 Characterization of process streams and products

1.3.3 Characterization of airborne discharges

1.3.4 Characterization of aqueous discharges

1.3.5 Characterization of solid waste

BER Balanced Program Plan

Program Unit

1.3.1 Establish quality assurance system

Program Unit Objective: To ensure that characterization work within the program is internally consistent and of adequate reliability to meet programmatic needs.

Scope: A wide variety of chemical, biological, and physical tests and measurement instrumentation will be utilized and developed within this program, and they will be used by people in a variety of laboratories. In this program unit, a program of quality assurance will be established whereby reference materials are generated and circulated, suitable measurement methodologies are identified, and inter-laboratory comparisons are conducted. This unit also serves as a disciplinary communicative device among workers in the program.

Milestones:

1. Existing quality assurance data is assessed.
2. Reference materials are prepared.
3. Acceptable procedures and instrumentation are identified.
4. Inter-laboratory comparison programs are initiated.

Technology Development Time Frame: Should be initiated as part of the inventory (Nos. 2.1, 3.1, and 4.1) assessment activities, approximately one year into the program; established operation by end of Year 4; routine thereafter.

Program Unit Priority: Medium.

Estimated Program Unit Cost:

1.	Total		$480,000
2.	Per Year -	FY 1977	$ 60,000
		FY 1978	$120,000
		FY 1979	$120,000
		FY 1980	$120,000
		FY 1981	$ 60,000

BER Balanced Program Plan

Program Unit

1.3.2 Characterization of process streams and products

Program Unit Objective: To define the chemical composition and physical characteristics of products and process stream samples.

Scope: The chemical and physical characteristics of the products and of samples at various stages in the process stream will be defined in order to (a) obtain source data indicating the maximum possible environmental release, (b) to establish the characteristics of material to be transported and processed further, and (c) to provide the data required to suggest engineering modifications to reduce environmental and health insults. Inorganic and organic constituents will be determined and physical properties (e.g., volatility) which relate to environmental release will be established. All liquefaction and gasification processes will be considered with priority attention given to representative and best technologies.

Milestones:

1. Sampling sites and protocols established.
2. Inorganic constituents measured.
3. Organic constituents characterized qualitatively and quantitatively.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $1,080,000
2. Per Year -

FY 1977	$	240,000
FY 1978	$	240,000
FY 1979	$	240,000
FY 1980	$	240,000
FY 1981	$	120,000

BER Balanced Program Plan

Program Unit

1.3.3 Characterization of airborne discharges

Program Unit Objective: To define the chemical composition and physical characteristics of airborne discharges.

Scope: Materials discharged to the atmosphere will be chemically and physically characterized in order to estimate the respirable and skin deposition health hazards associated with coal conversion and the airborne environmental release. Concerns include gases, semi-volatiles (fumes), solid particulates, and liquid particulates released in-plant, out of plant but onsite, and to the surrounding environment. Sources to be examined include stacks, ash and other solid waste depositories, process stream contact points, and products. Inorganic and organic chemical constituents and physical properties (e.g., particle size distribution) will be considered. All liquefaction and gasification processes will be considered with priority attention being given to representative and best technologies.

Milestones:

1. Sampling sites and protocols established.
2. Inorganic constituents determined.
3. Physical characteristics determined.
4. Organic constituents characterized.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$1,080,000
2. Per Year -	FY 1977	$ 240,000
	FY 1978	$ 240,000
	FY 1979	$ 240,000
	FY 1980	$ 240,000
	FY 1981	$ 120,000

BER Balanced Program Plan

Program Unit

1.3.4 Characterization of aqueous discharges

Program Unit Objective: To define the chemical composition and physical characteristics of aqueous discharges.

Scope: Product water and aqueous discharges will be chemically and physically characterized in order to estimate the pollutant effect on potable water and the release of pollutants to the aquatic environment. Concerns include aqueous scrubbers, streams into which effluents are directly released, leachate from solid wastes, and settling ponds. Source and field samples will be considered. Both dissolved and suspended organic and inorganic constituents will be determined. Physical properties (e.g., temperature) will also be determined. All liquefaction and gasification processes will be considered with priority attention being given to representative and best technologies.

Milestones:

1. Sampling sites and protocols established.
2. Inorganic constituents determined.
3. Organic constituents characterized.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $1,080,000

2. Per Year -

FY 1977	$	240,000
FY 1978	$	240,000
FY 1979	$	240,000
FY 1980	$	240,000
FY 1981	$	120,000

BER Balanced Program Plan

Program Unit

1.3.5 Characterization of solid waste

Program Unit Objective: To define the chemical composition and physical characteristics of solid wastes.

Scope: Solid wastes will be chemically and physically characterized in order to define their potential hazard as a source for airborne particulates and leachable pollutants. Inorganic and organic constituents and physical properties will be considered. All liquefaction and gasification processes will be considered with priority attention being given to representative and best technologies.

Milestones:

1. Sampling sites and protocols established.
2. Inorganic constituents determined.
3. Organic constituents characterized.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$720,000
2.	Per Year -	FY 1977	$180,000
		FY 1978	$180,000
		FY 1979	$180,000
		FY 1980	$ 90,000
		FY 1981	$ 90,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Characterization, Measurements, and Monitoring

Problem Title: Monitoring (II.1.4.0)

Objectives: Systems are needed to monitor the exposure of workers, members of the public, and the environment to potentially hazardous materials that arise from coal conversion operations. Work in this program will assess present technology and support developmental work to provide adequate monitoring capabilities to assure that operations are carried out in compliance with all health and safety standards and regulations.

Priority: High

Program Unit Titles:

1.4.1 Inventory of techniques and expertise

1.4.2 Occupational monitoring

1.4.3 Environmental monitoring

1.4.4 Specialized instrumentation

BER Balanced Program Plan

Program Unit

1.4.1 Inventory of techniques and expertise

Program Unit Objective: The program will determine to what extent existing technology can provide adequate monitoring capabilities for coal conversion operations. It will recommend needed additional work to develop such capabilities.

Scope: This work will survey existing monitoring instruments and systems in conjunction with health and safety requirements of coal conversion technology. This activity will also provide a registry of names of specialists and installations where particular areas of expertise exist. The program will address all phases of health-protection monitoring for both occupational and offsite exposures.

Milestones:

1. Complete survey and compile registry.
2. Recommend needed monitoring R&D programs.
3. Reduce activity to keep registry current and continually reevaluate R&D needs.

Program Unit Priority: High initially, medium after Year 2.

Estimated Program Unit Cost:

1. Total $390,000
2. Per Year -

FY 1977	$120,000
FY 1978	$120,000
FY 1979	$ 60,000
FY 1980	$ 60,000
FY 1981	$ 30,000

BER Balanced Program Plan

Program Unit

1.4.2 Occupational monitoring

Program Unit Objective: To design prototype monitoring equipment for in-plant use for the protection of occupational workers.

Scope: Fixed instrumentation for area monitoring and portable equipment for surveying and personnel monitoring will be developed. Stress will be placed on equipment to assess hazardous gaseous substances, airborne particulates, and toxic surface contamination. The nature of the instrumentation and the degree of development required will be determined by information on toxicity from work in the Health Effects category, from information on the levels of hazardous substances present in coal conversion plant samples, and from the assessment of existing instrumentation and expertise carried out in Program Unit 4.1.

Milestones: Recommendations from Program Unit 4.1--Inventory of techniques/expertise--are needed before specific milestones are set.

Technology Development Time Frame: Work should be initiated near end of Year 2 and continue throughout the ten-year period, depending directly upon programmatic needs and results.

Program Unit Priority: High initially, becoming moderate after Year 5.

Estimated Program Unit Cost:

1. Total			$2,100,000
2. Per Year -	FY 1977	$	-0-
	FY 1978	$	300,000
	FY 1979	$	600,000
	FY 1980	$	600,000
	FY 1981	$	600,000

BER Balanced Program Plan

Program Unit

1.4.3 Environmental monitoring

Program Unit Objective: To design and construct monitoring equipment for the assessment of ambient and integrated offsite levels of toxic substances produced by coal conversion plants.

Scope: The program will be concerned with three areas: (1) design of prototype instrumentation for nonnuclear plant use to assess total plant discharges to the environment; (2) in conjunction with Problem Title 4.1 "Sample Definition" and Problem Title 4.2 "Methodology", the provision of standardized reliable equipment for the collection of environmental samples and the provision of standarized methods for the measurement of contamination levels within these samples; and (3) design and construction of prototype portable equipment for rapid, on-the-spot assessment of ambient contamination levels within the environment with a view to providing means for a rapid assessment of environmental levels in the event of an accidental release of contamination.

Milestones: Recommendations from Program Unit 4.1--Inventory of techniques/expertise--are needed before specific milestones are set.

Technology Development Time Frame: Work should be initiated near end of Year 2 and continue throughout the ten-year period, depending upon programmatic needs and result.

Program Unit Priority: High initially, becoming moderate after Year 5.

Estimated Program Unit Cost:

1.	Total		$2,100,000
2.	Per Year -	FY 1977	$ -0-
		FY 1978	$ 300,000
		FY 1979	$ 600,000
		FY 1980	$ 600,000
		FY 1981	$ 600,000

BER Balanced Program Plan

Program Unit

1.4.4 Specialized instrumentation

Program Unit Objective: This activity will support the development of new monitoring instrumentation required for biomedical and environmental research programs for coal conversion technology.

Scope: It is expected that some specialized instrumentation will be needed for monitoring exposures in biological and environmental research programs. This work will support the development of needed monitoring systems.

Milestones: Specific milestones will have to be developed in response to the needs of the over-all biomedical and environmental research programs.

Technology Development Time Frame: This work should be initiated in Years 1 or 2 and continue on an *ad hoc* basis throughout the ten-year period.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total		$330,000
2. Per Year -	FY 1977	$ -0-
	FY 1978	$ 90,000
	FY 1979	$ 90,000
	FY 1980	$ 90,000
	FY 1981	$ 60,000

II.2.1 Health Effects

II.2.1.0 Determine Materials from Coal Conversion Technology that are Potentially Toxic

(2.1.1 Review information from CM&M from the point of view of health effects and make recommendations for further action)

(2.1.2 Determine potential for health effects by sensitive and pertinent biological test systems)

(2.1.3 Develop, improve, and evaluate methods for Programs 2.1.1 and 2.1.2)

II.2.2.0 Determine Dose-Effect Relationships in Laboratory Models and in Humans and Develop Methods for this Purpose

(2.2.1 Develop chemical and biochemical methods to determine the metabolism, fate, and dose for potentially toxic materials)

(2.2.2 Determine acute and chronic dose-effect relations in laboratory organisms and, if possible, in selected groups of people)

(2.2.3 Use previously established dose-effect relations to develop biological indicators of dose)

II.2.3.0 Develop and Apply Laboratory, Clinical, and Epidemiological Methods for Medical Surveillance of Personnel Involved in Coal Conversion Technology

(2.3.1 Develop and apply biochemical, cytological, and physiological indicators of subclinical effects from exposure)

(2.3.2 Evaluate utility of appropriate methods for detection of disease resulting from exposure)

(2.3.3 Determine what clinical parameters or preexisting diseases and what environmental factors may cause hypersensitivity in personnel)

(2.3.4 Carry out epidemiological studies of exposed personnel)

II.2.4.0 Develop a Comprehensive Industrial Hygiene and Safety Program to Assure Adequate Protection of Personnel

(2.4.1 Develop monitoring techniques for chemical and physical agents)

(2.4.2 Monitoring for skin and equipment surface contamination for polynuclear aromatic hydrocarbon)

(2.4.3 Investigate protective devices and measures)

(2.4.4 Develop emergency procedures for accidental large exposures)

II.2.5.0 Develop and Apply Methods for Clinical and Epidemiological Studies on Segments of the General Public that Could Have Been Exposed to Coal Conversion Related Materials

(2.5.1 Develop and apply appropriate biochemical, cytological, and physiological tests for clinical studies with exposed populations)

(2.5.2 Develop and apply epidemiological procedures to clinical and public health data to look for effects)

(2.5.3 Develop maximum credible accident concepts to given situations)

II.2.6.0 Develop and Apply Knowledge of the Ways in Which Deleterious Effects of Coal Conversion Materials are Produced in Living Systems and of the Ways in Which Such Systems Recover From or Repair These Effects

(2.6.1 Develop knowledge of how deleterious effects are produced and utilize this knowledge to design testing procedures and predict potential hazards)

(2.6.2 Develop knowledge of how biological systems recover from or repair potentially deleterious effects and utilize this knowledge to develop remedial and protective procedures)

(2.6.3 Utilize knowledge of the action deleterious agents and of repair and recovery processes to improve extrapolation from laboratory tests to humans)

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Health Effects

Problem Title: Determine Materials from Coal Conversion Technology that are Potentially Toxic (II.2.1.0)

Objectives: A study is needed to identify the materials that may arise from coal conversion technology that are potentially hazardous to human health. This will require review of the information from CM&M with special regard to potential health hazards and making recommendations for further biomedical research or for industrial hygiene and health procedures. It will involve carrying out laboratory testing to identify hazards as well as identification, where possible, on the basis of past information.

Priority: High

Program Unit Titles:

2.1.1 Review of information from CM&M from the point of view of health effects and make recommendations for further action

2.1.2 Determine potential for health effects by sensitive and pertinent biological test systems

2.1.3 Develop, improve, and evaluate methods for Programs 2.1.1 and 2.1.2.

BER Balanced Program Plan

Program Unit

2.1.1 Review information from CM&M from the point of view of health effects and make recommendations for further action

Program Unit Objective: The primary purpose of this program is to acquire and evaluate health effects information from CM&M on coal conversion materials. This information will then be used to identify already known hazardous materials, to set priorities for laboratory testing, or to make recommendations for further CM&M.

Scope: Data on the materials produced by coal conversion technology and the use of its products will be obtained from CM&M and correlated with existing information on health effects. The correlated information will then be reviewed by experts in various aspects of health effects to make recommendations for action. Such actions might include a change in design, an industrial hygiene or medical surveillance program, the development of new safety guidelines, the initiation of laboratory tests to determine if a potential hazard exists, or the judgment that there is little if any probability of a hazard. Priorities for the various alternatives would be recommended. Review might be by individuals, groups, or workshops.

Milestones:

1. Initiate correlations between information on materials with health effects immediately.

2. Within six months or less make information available to experts for review.

3. Institute first workshop on information within a year after start.

4. Prepare annual update of information.

5. Institute further workshops or review at appropriate intervals.

Technology Development Time Frame: Can be initiated immediately but rate of progress depends upon rate at which information becomes available.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Five-year Total $4,550,000

2. Per Year -

FY 1977	$1,000,000
FY 1978	$ 800,000
FY 1979	$ 850,000
FY 1980	$ 900,000
FY 1981	$1,000,000

BER Balanced Program Plan

Program Unit

2.1.2 Determine potential for health effects by sensitive and pertinent biological test systems

Program Unit Objective: The materials from coal conversion technology and its uses need to be screened for potential health effects whenever these cannot be determined from previous work. Various laboratory testing and screening procedures will be selected, depending on the health effects judged to be most important. Chemical composition can be used as a guide to priorities and testing procedures when possible. The final result should be a determination that a potential hazard does or does not exist and/or that further investigation is needed to determine the magnitude of the hazard.

Scope: Whenever appropriate, rapid, sensitive, and as definitive as possible tests with mammals will be used. However, it may often be desirable to carry out preliminary screening with microorganisms and other lower organisms to set priorities for more expensive and time consuming tests. The exact kinds and sequences of tests will depend on a variety of considerations such as the nature of the materials to be tested, the most likely route of exposure, the level and duration of the exposure, the number of people that might be exposed, etc. The exact set of procedures to be used must depend on the best judgment of the investigator, taking into account existing tests and standard procedures.

Milestones:

1. Initiate tests as soon as enough information about materials and processes becomes available.

2. On basis of test results, decide whether a potential risk to health exists.

3. Make recommendations for further testing or dose-effect relation determinations if those seem desirable.

Technology Development Time Frame: Testing of actual materials from coal conversion processes depends on such materials being available.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$10,200,000
2. Per Year -	FY 1977	$ 1,000,000
	FY 1978	$ 2,000,000
	FY 1979	$ 2,200,000
	FY 1980	$ 2,400,000
	FY 1981	$ 2,600,000

BER Balanced Program Plan

Program Unit

2.1.3 Develop, improve, and evaluate methods for Programs 2.1.1 and 2.1.2

Program Unit Objective: A vigorous program to improve existing procedures and to introduce new and better ones is needed because many of the present procedures are relatively long and expensive whereas more rapid, less expensive procedures are less generally accepted as definitive tests for human risks. The multiplicity of materials associated with coal conversion technology makes it especially important that this situation be improved.

Scope: Methods for collecting data concerning materials from coal conversion technology and correlating them with previous information concerning health effects will be reviewed and improved as more experience is obtained. Procedures for making judgments based upon this correlated information will also be reviewed and improved as additional experience is gained. Improvement of old testing procedures and development of new ones will be emphasized. The goal needs to be the most rapid and the cheapest testing procedures possible that retain a high level of pertinence to humans. Test improvement can begin with materials already available, including model substances related to materials from coal conversion.

Milestones:

1. Initiate review of given testing procedures and attempts to improve these procedures or develop new ones. This should be done immediately.

2. Initiate periodic review of procedures for collecting information on materials and health effects.

3. Periodic reviews should be made of the success of the recommendations.

Technology Development Time Frame: Test development and information system development can be begun immediately.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$4,200,000
2.	Per Year -	FY 1977	$ 600,000
		FY 1978	$ 800,000
		FY 1979	$ 850,000
		FY 1980	$ 950,000
		FY 1981	$1,000,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Health Effects

Problem Title: Determine Dose-Effect Relationships in Laboratory Models and in Humans and Develop Methods for this Purpose (II.2.2.0)

Objectives: In order to make quantitative estimates of the magnitude of any potential hazard, especially for use in cost-benefit analyses, it is necessary to obtain quantitative data on dose-effect relations. Such quantitative estimates will be especially important for potentially hazardous materials that are impractical to completely eliminate. Such quantative relationships will also be important for planning and evaluating surveillance and epidemiological programs.

Priority: High

Program Unit Titles:

2.2.1 Develop chemical and biochemical methods to determine the metabolism, fate, and dose for potentially toxic materials

2.2.2 Determine acute and chronic dose-effect relations in laboratory organisms and, if possible, in selected groups of people

2.2.3 Use previously established dose-effect relations to develop biological indicators of dose

BER Balanced Program Plan

Program Unit

2.2.1 Develop chemical and biochemical methods to determine metabolism, fate, and dose for potentially toxic materials

Program Unit Objective: The objectives of this program are to investigate the metabolism and fate of potentially hazardous materials associated with coal conversion and to use this information to estimate doses to the tissues of interest. This information will be needed for dose-effect studies and for developing protective and prophylactic measures.

Scope: Methods will be developed to investigate the metabolism of potentially toxic materials in the body and in various culture systems. Whenever possible methods for obtaining quantitative measures of the interaction with important cell and tissue constituents will be obtained. Comparative studies on a variety of systems will be carried out to determine the systems that are suitable for extrapolation to humans. Model systems will be used to investigate factors that influence metabolism and fate, such as routes of administration, levels of exposure, durations of exposure, and special conditions influencing the sensitivity of the individual. This information will be used to provide quantitive measurements for dose-effect studies and to aid in developing protective and prophylactic measures.

Milestones:

1. Begin use of available systems and model compounds to develop an understanding of fate and metabolism.
2. Initiate search for new procedures and methods of measuring dose to tissues.
3. Provide quantitative dose estimates for dose-effect experiments.
4. Provide information for designing protective and prophylactic measures.

Technology Development Time Frame: Can be started immediately but will have to be continued as the technology develops.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $16,400,000

2. Per Year -

FY 1977	$ 2,000,000
FY 1978	$ 3,000,000
FY 1979	$ 3,500,000
FY 1980	$ 3,800,000
FY 1981	$ 4,100,000

BER Balanced Program Plan

Program Unit

2.2.2 Determine acute and chronic dose-effect relations in laboratory organisms and, if possible, in selected groups of people

Program Unit Objective: The objective is to establish quantitative dose-effect relations for both acute and chronic exposures. Information on dose to cells and tissues will be used whenever possible. In general, these determinations will have to be made in laboratory organisms, but rare cases of inadvertent human exposure should be used when possible. Efforts should be made in the laboratory experiments to duplicate human exposures as much as possible. The ultimate aim is to provide the quantitative data needed for cost-benefit analysis.

Scope: Whenever possible, laboratory animals that metabolize the material as similarly as possible to humans will be used and the route of exposure will be chosen to mimic potential human exposures. Various endpoints depending on the circumstances of potential human exposure will be used. These might include short-term toxicity, various aspects of chronic toxicity, mutagenicity, and, if unborn fetuses might be exposed, teratological alterations. Studies on cultured cells and organs may yield valuable results for extrapolation, especially when cultured human cells can be used. The end result should be a quantitative estimate of the magnitude of risk likely to be met by humans.

Milestones:

1. Determine the materials, conditions of exposure, etc. that require quantitative dose-effect relations and decide on appropriate experimental designs.

2. Carry out the experimental protocols and decide whether the information is adequate for the purpose.

3. If not, design new protocols; otherwise make recommendations for safety purposes.

Technology Development Time Frame: Work should begin immediately and will probably have to continue during the whole development of the technology.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $26,000,000

2. Per Year -

FY	1977	$ 3,000,000
FY	1978	$ 5,000,000
FY	1979	$ 5,500,000
FY	1980	$ 6,000,000
FY	1981	$ 6,500,000

BER Balanced Program Plan

Program Unit

2.2.3 Use previously established dose-effect relations to develop biological indicators of dose

Program Unit Objective: The purpose of this unit is to use previously established dose-effects relations to develop methods to assess biologically or biochemically the amount of damage produced by specific exposures. Such methods will be of value in the laboratory, but their primary value will be to estimate the dose received by humans either as a result of routine or accidental exposure. The objective will be to use this information to monitor for unduly high exposures and to plan therapeutic measures in case such exposures occur.

Scope: So far this method of estimating exposures to humans has had limited use. An example is the use of the frequency of chromosomal aberrations in peripheral leukocytes to estimate dose in cases of accidental exposure to radiation. In principal, however, it should be possible to develop a variety of such tests for exposures to chemicals. Confirmitory tests on humans will depend upon the existence of exposed individuals, but laboratory work should bring the tests to a stage where there is every reason to believe that they would apply to humans.

Milestones:

1. Existing tests, such as those for chromosomal aberrations, need to be standardized for some of the materials that present the most likely hazards to humans.

2. Initiate research to improve existing tests and develop new ones, using model substances.

3. Apply to humans, if instances of suspected high exposure occur.

Technology Development Time Frame: Laboratory development will take time but is independent of technology.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $3,760,000

2. Per Year -

FY 1977	$	600,000
FY 1978	$	700,000
FY 1979	$	760,000
FY 1980	$	820,000
FY 1981	$	880,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Health Effects

Problem Title: Develop and Apply Laboratory, Clinical, and Epidemiological Methods for Medical Surveillance of Personnel Involved in Coal Conversion Technology (II.2.3.0)

Objectives: The objective is to apply procedures for the clinical and epidemiological surveillance of personnel engaged in various aspects of coal conversion technology. Existing methodology is partially satisfactory for this purpose, but new methods need to be developed for adequate and effective surveillance. Method development can go on, in part, prior to the time many individuals are engaged in the technology followed later by actual surveillance.

Priority: High

Program Unit Titles:

2.3.1 Develop and apply biochemical, cytological, and physiological indicators of subclinical effects from exposure

2.3.2 Evaluate utility of appropriate methods for detection of disease resulting from exposure

2.3.3 Determine what clinical parameters or preexisting diseases and what environmental factors may cause hypersensitivity in personnel

2.3.4 Carry out epidemiological studies of exposed personnel

BER Balanced Program Plan

Program Unit

2.3.1 Develop and apply biochemical, cytological, and physiological indicators of subclinical effects from exposure

Program Unit Objective: Sensitive techniques of various kinds are needed for application at the clinical level to provide objective indicators of potentially harmful exposures to personnel under medical surveillance. In part, existing methods can be used, but new and sensitive methods developed for this purpose will also be required.

Scope: Indicator systems should be noninvasive and consist of biochemical analyses of blood and excretory specimens, exfoliative cytology and cytogenetic procedures, and physiologic studies focused on detecting decrements in gastrointestinal and respiratory function before systematic diseases develop.

Milestones:

1. Initiate review of existing procedures for applicability to the program.
2. Initiate laboratory work to develop new procedures.
3. Begin application to personnel when pilot plants start operation.

Technology Development Time Frame: Test development can start immediately; application to personnel when pilot plants begin operation.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $3,200,000

2. Per Year -

FY 1977	$	500,000
FY 1978	$	600,000
FY 1979	$	650,000
FY 1980	$	700,000
FY 1981	$	750,000

BER Balanced Program Plan

Program Unit

2.3.2 Evaluate utility of appropriate methods for detection of disease resulting from exposure

Program Unit Objective: Methods for diagnosis of diseases of lung, G.I., and urinary systems need improvement to differentiate the natural diseases of these systems from those resulting from occupational exposures and to evaluate the clinical course and response to therapy.

Scope: Etiologic and pathogenic information obtained from animal studies will be used to identify any unique biologic endpoints that can be measured biochemically, physiologically, or microscopically and equated objectively with disease of occupational origin.

Milestones:

1. Initiate animal experimentation to obtain the desired information.
2. As opportunity arises, apply to the acute clinical situation.

Technology Development Time Frame: Can be started immediately.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $2,500,000
2. Per Year -

FY 1977	$	400,000
FY 1978	$	450,000
FY 1979	$	500,000
FY 1980	$	550,000
FY 1981	$	600,000

BER Balanced Program Plan

Program Unit

2.3.3 Determine what clinical parameters or preexisting diseases and what environmental factors may cause hypersensitivity in personnel

Program Unit Objective: To protect persons hypersensitive to materials from the coal conversion process, it is necessary to determine what factors, such as preexisting disease, environmental agents, etc., may cause hypersensitivity and to identify personnel who may be hypersensitive for such causes.

Scope: Appropriate clinical procedures need to be developed on the basis of preexisting information and new information to identify hypersensitive individuals. For this purpose various causes of hypersensitivity, preexisting disease, genetic predisposition, exposure to special environmental agents such as tobacco smoke, etc., need to be investigated both in laboratory models and, whenever possible, clinically. On the basis of these studies appropriate protective procedures, including proper job assignments, need to be developed for such personnel.

Milestones:

1. Initiate model laboratory studies to develop appropriate tests and criteria for hypersensitivity.
2. Start application to personnel of pilot plants.
3. Full-scale application when full-scale plants come on-line.

Technology Development Time Frame: Laboratory work to begin immediately. Application to start when pilot plants exist.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $2,500,000
2. Per Year - FY 1977 $ 400,000
   FY 1978 $ 450,000
   FY 1979 $ 500,000
   FY 1980 $ 550,000
   FY 1981 $ 600,000

BER Balanced Program Plan

Program Unit

2.3.4 Carry out epidemiological studies of exposed personnel

Program Unit Objective: Once considerable numbers of people become involved in coal conversion technology, efforts should be made to carry out standard epidemiological studies on them in addition to regular medical surveillance of those presently employed. Among other things, this program would have the goal of keeping track of any delayed or late effects such as the appearance of tumors, lung disorders, etc.

Scope: Attempts will be made to keep track of those who are or have been employed in coal conversion technology and accumulate epidemiological information about them. Some development of methods may be necessary to do this satisfactorily.

Milestones:

1. Initiate planning for effective epidemiological studies.
2. Initiate actual studies once sufficiently large groups of personnel become available.

Technology Development Time Frame: Planning need not start immediately. Actual studies can be done effectively only after technology is operating.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$3,300,000
2. Per Year -	FY 1977	$ 400,000
	FY 1978	$ 500,000
	FY 1979	$ 600,000
	FY 1980	$ 800,000
	FY 1981	$1,000,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Health Effects

Problem Title: Develop a Comprehensive Industrial Hygiene and Safety Program to Assure Adequate Protection of Personnel (II.2.4.0)

Objectives: There is a need to establish a comprehensive industrial hygiene and safety program to protect personnel involved in coal conversion technology from undue exposure to potentially hazardous materials. This should include surveillance procedures to detect potential hazards before undue exposure has occurred, the application of protective devices and measures, and the development of emergency procedures for accidental large exposures.

Priority: High

Program Unit Titles:

2.4.1 Develop monitoring techniques for chemical and physical agents

2.4.2 Monitoring for skin and equipment surface contamination for polynuclear aromatic hydrocarbon

2.4.3 Investigate protective devices and measures

2.4.4 Develop emergency procedures for accidental large exposures

BER Balanced Program Plan

Program Unit

2.4.1 Develop monitoring techniques for chemical and physical agents

Program Unit Objective: To characterize exposures in the work environment and develop control techniques to minimize exposures. Monitoring data will be correlated with medical findings and toxicological data.

Scope: An attempt will be made to identify all chemical and physical stresses. Techniques for monitoring will be applied and data will be evaluated in light of existing or proposed standards. Specific detailed procedures will be developed for substances such as chlorinated hydrocarbons, coal, dust, polynuclear aromatic hydrocarbons, etc. Background data on physical stresses such as noise and radiant heat at the site will be developed.

Milestones:

1. Detailed, uniform procedures for identifiable stresses - 6 months.
2. Background data on specific stresses - 9 months.
3. Evaluation of work environment - 1-3 years.
4. Interpretation of data - 1-3 years.
5. Correlation of industrial hygiene data with medical and toxicological findings - 2-3 years.

Technology Development Time Frame: Initial planning can be done immediately. Actual carrying out of procedures depends on timing of technology.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$2,500,000
2.	Per Year -	FY 1977	$ 300,000
		FY 1978	$ 400,000
		FY 1979	$ 500,000
		FY 1980	$ 600,000
		FY 1981	$ 700,000

BER Balanced Program Plan

Program Unit

2.4.2 Monitoring for skin and equipment surface contamination for polynuclear aromatic hydrocarbon

Program Unit Objective: Identify operations and equipment which result in skin contamination with carcinogenic materials.

Scope: The extent of skin and equipment will be determined initially using the black light technique. The data are needed to identify operations and/or equipment which result in skin contamination with polynuclear aromatics. Modification in engineering design and/or operating procedures will be effected as the data indicate.

Milestones:

1. Determine extent of the problem in pilot plants as they come on-stream.
2. Relate findings to design of commercial-size plants.
3. Survey commercial plants in similar manner.

Technology Development Time Frame: Some planning can be done prior to pilot plants coming on-stream but main operations afterwards.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$675,000
2.	Per Year -	FY 1977	$ 50,000
		FY 1978	$100,000
		FY 1979	$150,000
		FY 1980	$175,000
		FY 1981	$200,000

BER Balanced Program Plan

Program Unit

2.4.3 Investigate protective devices and measures

Program Unit Objective: Investigate and identify areas where protective equipment and measures are required to prevent exposures to various chemical and physical stresses.

Scope: Protective clothing, devices, equipment, barrier creams, and skin cleansers will be evaluated to optimize protection of personnel.

Milestones:

1. Institute programs to minimize skin contamination.
2. Evaluate various commercial barrier creams in minimizing skin contamination.
3. Evaluate skin cleansers.
4. Determine effectiveness of respiratory protective devices.
5. Summarize findings and recommend minimum effective program for personnel protection.

Technology Development Time Frame: Some evaluation can be begun before technology on-line.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total			$1,425,000
2. Per Year -	FY 1977	$	200,000
	FY 1978	$	250,000
	FY 1979	$	300,000
	FY 1980	$	325,000
	FY 1981	$	350,000

BER Balanced Program Plan

Program Unit

2.4.4 Develop emergency procedures for accidental large exposures

Program Unit Objective: Establish medical and industrial hygiene protocols to be followed in the case of accidental large exposures.

Scope: With medical, industrial hygiene, and toxicology input, define protocol to be followed for massive skin exposures to materials with carcinogenic potential. Evaluate protocol in animal model.

Milestones:

1. Decide on protocol.
2. Test in animal model.

Technology Development Time Frame: Some work can be initiated before technology begins.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total		$510,000
2. Per Year -	FY 1977	$ 50,000
	FY 1978	$100,000
	FY 1979	$110,000
	FY 1980	$120,000
	FY 1981	$130,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Health Effects

Problem Title: Develop and Apply Methods for Clinical and Epidemiological Studies on Segments of the General Public that Could Have Been Exposed to Coal Conversion Related Materials (II.2.5.0)

Objectives: The objective is to develop and apply procedures for detecting the consequences for the general public of chronic exposure to materials in effluents, wastes, etc., which may be widely spread as a result of coal conversion itself and the use of its products. Methods and procedures for this purpose are very limited at present; consequently, a research program is needed to develop such methods. Safety guidelines need to be developed for the general public.

Priority: Medium

Program Unit Titles:

2.5.1 Develop and apply appropriate biochemical, cytological, and physiological tests for clinical studies with exposed populations

2.5.2 Develop and apply epidemiological procedures to clinical and public health data to look for effects

2.5.3 Develop maximum credible accident concepts to given situations

BER Balanced Program Plan

Program Unit

2.5.1 Develop and apply appropriate biochemical, cytological, and physiological tests for clinical studies with exposed populations

Program Unit Objective: The general purpose of this program is to develop and apply sensitive tests that might be able to detect the consequences for the general public of increased exposure to materials associated with coal conversion. This would have the advantage over laboratory testing of measuring the effects of the combination of factors that might affect the general public. It should, however, be considered a back-up and extension of detailed laboratory testing.

Scope: The emphasis at the beginning will be upon laboratory development of the sensitive methods that will be required. These methods, once developed, might be tested on special segments of the general public or some industrial personnel before coal conversion technology becomes sufficiently advanced to warrant applying them to segments of the general public that might have been exposed to materials from coal conversion. Some emphasis should be given to the detection of mutations and chromosomal changes since such effects may be the most important ones for low-level exposures of large numbers of people.

Milestones:

1. Initiate laboratory work to devise tests with the requisite sensitivity.

2. Evaluate under controlled laboratory conditions.

3. Initiate field trials with appropriate groups of people.

4. Institute regular use when coal conversion technology becomes commercially developed.

Technology Development Time Frame: Laboratory and trial phases will probably require several years.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $2,025,000

2. Per Year -

FY 1977	$	300,000
FY 1978	$	350,000
FY 1979	$	375,000
FY 1980	$	400,000
FY 1981	$	600,000

BER Balanced Program Plan

Program Unit

2.5.2 Develop and apply epidemiological procedures to clinical and public health data to look for effects

Program Unit Objective: The purpose of this unit is to apply epidemiological procedures to clinical and public health data for groups of people judged to have been exposed to materials associated with coal conversion technology. Since such groups do not presently exist, the intermediate objective will be to develop plans and perhaps use existing groups that have been exposed to similar materials from other technologies. This program would be initiated with the view that such studies will eventually be necessary to assure public health and therefore should be initiated fairly early.

Scope: The initial effort will be to develop and improve plans for eventual use. This may best be done in conjunction with other technologies such as coal, gas, and oil that involve somewhat similar materials. Eventual application specifically to populations that could have been exposed to materials from coal conversion would be made when such populations become available.

Milestones:

1. Initiate planning and methodology improvement efforts.
2. Trial procedures on whatever pertinent populations exist.
3. Initiate studies with populations actually exposed to coal conversion-related materials.

Technology Development Time Frame: A moderate planning effort might be initiated immediately and gradually built up to a larger scale effort as technology develops.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $1,145,000
2. Per Year - FY 1977 $ 100,000
   FY 1978 $ 150,000
   FY 1979 $ 170,000
   FY 1980 $ 325,000
   FY 1981 $ 400,000

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Program Unit

2.5.3 Develop maximum credible accident concepts to given situations

Program Unit Objective: This program is aimed at evaluating the consequences to the general public of accidental releases of considerable amounts of harmful materials into the environment. For this purpose it will be necessary to develop estimates of health effects for the general public of maximum credible accidents and remedial procedures for handling the health consequences.

Scope: Information from dose-effect and other studies, primarily laboratory ones, will be brought together for those materials judged to be most likely to produce major health effects as a result of accidental releases. On the basis of estimates of the magnitude of the possible effect, safety procedures to avoid such accidents should be recommended and remedial procedures developed in case, despite precautions, such an accident occurs.

Milestones:

1. Initiate studies of maximum credible accidents.
2. Complete estimations of magnitude of health effects.
3. Make safety recommendations.
4. Develop and recommend remedial procedures to be taken if such an accident occurs.

Technology Development Time Frame: Existing information can be used for preliminary estimates, but some years may be required before sufficient quantitative data are available.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total		$400,000
2. Per Year -	FY 1977	$ 50,000
	FY 1978	$ 50,000
	FY 1979	$ 75,000
	FY 1980	$100,000
	FY 1981	$125,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Health Effects

Problem Title: Develop and Apply Knowledge of the Ways in Which Deleterious Effects of Coal Conversion Materials are Produced in Living Systems and of the Ways in Which Such Systems Recover From or Repair These Effects (II.2.6.0)

Objectives: The major objective is to provide the fundamental understanding of the biological effects of materials associated with coal conversion. This is important because existing information is inadequate to give confidence in predictions from chemical structure to living systems, and from laboratory tests to humans. It is also important for the development of protective and remedial procedures.

Priority: High

Program Unit Titles:

2.6.1 Develop knowledge of how deleterious effects are produced and utilize this knowledge to design testing procedures and predict potential hazards

2.6.2 Develop knowledge of how biological systems recover from or repair potentially deleterious effects and utilize this knowledge to develop remedial and protective procedures

2.6.3 Utilize knowledge of the action deleterious agents and of repair and recovery to improve extrapolation from laboratory tests to humans

BER Balanced Program Plan

Program Unit

2.6.1 Develop knowledge of how deleterious effects are produced and utilize this knowledge to design testing procedures and predict potential hazards

Program Unit Objective: The major purpose of this program is to acquire and systematize knowledge of the ways in which potentially hazardous materials act. This is important because such knowledge is presently very limited. It can be used to improve the reliability and efficiency of testing and measuring procedures and to improve the ability to predict from chemical structure and simple laboratory tests.

Scope: Laboratory studies will be initiated with model compounds and, when available, with materials from coal conversion technology to determine the molecular and biological action both separately and in combination (synergistic effects). By use of several biological test systems and a variety of chemically related compounds, attempts will be made to find out what effects are general for many systems and what are specific to one or a few systems. These results will be used to design simpler and more reliable testing systems and to attempt to develop generalizations that might make it possible to make predictions from limited information such as chemical composition or simple laboratory tests.

Milestones:

1. Initiate studies with model compounds to determine molecular and biological action.

2. Initiate work with materials from coal conversion, including mixtures.

3. Attempt to generalize to larger classes of materials.

4. Attempt to design improved testing procedures.

Technology Development Time Frame: At least 5 years, possibly more, may be required to develop really broad generalizations though useful generalizations will be available earlier.

Program Unit Priority: Medium

<u>Estimated Program Unit Cost:</u>

1. Total $9,100,000

2. Per Year -

FY 1977	$1,000,000
FY 1978	$1,500,000
FY 1979	$2,000,000
FY 1980	$2,200,000
FY 1981	$2,400,000

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Program Unit

2.6.2 Develop knowledge of how biological systems recover from or repair potentially deleterious effects and utilize this knowledge to develop remedial and protective procedures

Program Unit Objective: The main objective is to develop knowledge about how the body and its tissues and cells can recover from or repair the deleterious effects of materials from coal conversion. This knowledge will then be used to better understand the action of such potentially harmful materials and to develop protective and remedial procedures.

Scope: Various ways in which biological systems can recover from or repair potentially deleterious effects will be studied. These will include such diverse mechanisms as repair of DNA, recovery of cells from sublethal injury, replacement of damaged cells by undamaged cells, regeneration of injured tissues, immune responses, etc. Much of the work will have to be done with model compounds judged to be type examples of the compounds found in materials from coal conversion. Various types of injury will be considered, ranging from changes in the DNA to trauma to tissues and organs. On the basis of the insights provided by this work attempts will be made to develop protective and remedial procedures for humans exposed to such materials.

Milestones:

1. Identify specific repair and recovery processes for specific types of compounds.
2. Attempt to understand the detailed processes involved.
3. Attempt to systematize to a variety of compounds and biological effects.
4. Suggest or design protective and remedial procedures.

Technology Development Time Frame: At least 5 years, possibly more, will be required for broad generalizations, but useful information will be available earlier.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $9,100,000

2. Per Year -

FY 1977	$1,000,000
FY 1978	$1,500,000
FY 1979	$2,000,000
FY 1980	$2,200,000
FY 1981	$2,400,000

BER Balanced Program Plan

Program Unit

2.6.3 Utilize knowledge of the action deleterious agents and of repair and recovery processes to improve extrapolation from laboratory tests to humans

Program Unit Objective: The objective of this program is to use knowledge of the ways in which deleterious effects are produced by materials from coal conversion and of the ways in which recovery and repair occur to increase the confidence with which laboratory test results can be extrapolated to humans. This is necessary because at present too little is known to place firm reliance in the extrapolatibility of such tests.

Scope: Among the methods that can be used to increase reliability are comparisons of results with model compounds in a number of test systems to see how general the results are, quantitative comparisons between systems to detect trends that might also apply to humans, and comparisons between results with cultured human cells and cultured cells from standard laboratory test organisms. Efforts are needed to extrapolate not only qualitative results (e.g., positive or negative) but also quantitative information. Any cases of known human exposure could be used to further increase the reliability of the extrapolations. The end result should be a better evaluation of the extrapolatibility of testing systems and possibly a reduction in the margins of safety and the number of tests required.

Milestones:

1. Initiate comparative studies with model compounds, including comparisons of existing tests.

2. Develop recommendations about testing procedures and qualitative and quantitative extrapolations to humans.

3. Examine safety regulations from this point of view.

Technology Development Time Frame: At least 5 years, possibly more, will be required for broad generalizations, but useful information will be available earlier.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $3,500,000

2. Per Year -

FY 1977	$	500,000
FY 1978	$	600,000
FY 1979	$	700,000
FY 1980	$	800,000
FY 1981	$	900,000

II.3.1 Environmental Effects and Transport

II.3.1.0 Acute Effects Studies

(3.1.1 Aquatic organism acute effects)

(3.1.2 Terrestrial organism acute effects)

II.3.2.0 Chronic Effects Studies

(3.2.1 Several-generation studies on short-lived test organisms)

(3.2.2 Long-term studies on selected representative species)

II.3.3.0 Effects Model Development

(3.3.1 Population dynamics modeling of affected representative and important species)

(3.3.2 Ecosystem dynamics modeling for microcosms and field ecosystems)

(3.3.3 Verification of models through critical comparison with subsequent laboratory and field data)

II.3.4.0 Microcosm Studies of Coal Conversion Effluents

(3.4.1 Assessment of direct effects of effluent compounds in a multi-organism, multi-level system)

(3.4.2 Assessment of indirect effects of coal conversion effluents on the environment)

II.3.5.0 Determination of Routes, Transformations, and Sinks of Coal Conversion Effluent Constituents

(3.5.1 Transport, distribution, and bioaccumulation of effluent constituents and transformation products within terrestrial systems)

(3.5.2 Retention, transformations, and mobility of effluent constituents in soils)

(3.5.3 Transport, distribution, and bioaccumulation of effluent constituents and transformation products in aquatic ecosystems)

(3.5.4 Accumulation and transformation of effluent constituents in sediments of aquatic ecosystems)

II.3.6.0 Formulation of Transport Models of Coal Conversion Effluents

(3.6.1 Formulation of biotransformation model)

(3.6.2 Formulation of soils and sediments model)

II.3.7.0 Ecosystem Effects of Operating Coal Conversion Facilities

(3.7.1 Preoperational and operational studies at each coal conversion facility)

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Environmental Effects and Transport

Problem Title: Acute Effects Studies (II.3.1.0)

Objective: To determine which effluents, effluent fractions, leachates, combinations of effluent constituents, and transformation products are directly toxic, otherwise lethal, or obviously damaging to representative organisms and life stages at concentrations or dosages anticipated to be released, over relatively short exposure times (24, 48, and 96 hr). These tests would provide initial screening for purposes of establishing priorities for waste management engineering or setting procedures for handling spills. Testing components singly and in typical combinations would establish synergistic/antagonistic properties.

Priority: High, where no literature data are available; moderate, where only confirmatory testing is necessary.

Program Unit Titles:

3.1.1 Aquatic organism acute effects (including freshwater and estuarine)

3.1.2 Terrestrial organism acute effects (including major habitat types - arid, humid, etc.)

BER Balanced Program Plan

Program Unit

3.1.1 Aquatic organism acute effects

Program Unit Objective: To determine which aqueous effluents, effluent fractions, leachates, combinations of effluent constituents, and transformation products are directly toxic, otherwise lethal, or obviously damaging to representative aquatic organisms (freshwater, marine, estuarine) and life stages at concentrations or dosages anticipated to be released, over relatively short exposure times (24, 48, and 96 hr).

Scope: For effluent components for which adequate literature data are not available, acute effects testing should be done as an initial screening to establish priorities for waste management engineering or to set procedures for handling spills. Tests should include endpoints of direct death, behavioral abnormalities (such as loss of equilibrium), or related acute debilitations. Representative and important aquatic organisms should be tested from example habitats--freshwater, marine, and estuarine--or specific habitats near proposed coal conversion facilities. Results will be useful in optimizing plant sitings, designs, and operations.

Milestones:

1. Definition of effluents or components, etc., to be screened, including arrangements for sampling bench scale, pilot, or demonstration plant aqueous effluents (by FY 1978 for existing facilities, and continuing for new facilities).
2. Determine effects of major aqueous effluents complexes from pilot or demonstration plants.
3. Determine effects of effluent fractions.
4. Determine effects of selected effluent components as they are characterized by CMM activities.

Technology Development Time Frame: Initial screening should begin immediately in order to set priorities for establishing priorities for further research and for setting procedures for handling spills.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $2,625,000

2. Per Year -

FY 1977	$	625,000
FY 1978	$	500,000
FY 1979	$	500,000
FY 1980	$	500,000
FY 1981	$	500,000

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Program Unit

3.1.2 Terrestrial organism acute effects

Program Unit Objective: To determine which atmospheric effluents, effluent fractions, leachates, combinations of effluent constituents, and transformation products are directly responsible for necrosis or damaging impairment of organism function for representative life stages of terrestrial organisms (animal, plant, microbial) at concentrations or dosages anticipated to be released over relatively short exposure times (1-hr, 3-hr, 8-hr, and 24-hr average concentrations).

Scope: For effluent components for which adequate literature data are not available, acute effects testing should be done as an initial screening for purposes of establishing priorities for waste management engineering and identification of potential hazards from accidental spills, leaks, etc. Tests should include threshold dosage determinations for direct necrosis and damaging impairment of organism function. Representative and important terrestrial organisms should be tested from example habitats, or specific habitats anticipated to be impacted by coal conversion process facilities. Results should be in a form usable for plant siting, design, and operational decisions.

Milestones:

1. Definition of effluents or components, etc., to be screened, including arrangement for sampling pilot demonstration plant atmospheric effluents. (By FY 1978 for existing facilities, and continuing for new facilities).

2. Determine effects of major atmospheric effluents and effluent fractions from pilot or demonstration plants.

3. Determine effects of selected individual effluent components as they are characterized by CMM activities.

Technology Development Time Frame: Initial screening should begin immediately in order to set priorities for future research.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $2,625,000

2. Per Year -

FY 1977	$	625,000
FY 1978	$	500,000
FY 1979	$	500,000
FY 1980	$	500,000
FY 1981	$	500,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Environmental Effects and Transport

Problem Title: Chronic Effects Studies (II.3.2.0)

Objective: To determine concentrations necessary to produce measurable effects over prolonged time spans of effluents, effluent fractions, leachates, combinations of effluent constituents or materials accumulated or transported through environmental processes or biotransformation for effects on normal life functions of representative and important organisms throughout their normal life cycle (including life span, reproduction, fecundity, growth, maturation, and productivity), in the presence of typical background environmental factors (habitat, water chemistry, other pollutants of regional importance, etc.).

Priority: High where effluents cannot be treated and are released to the environment even in low quantities. Low where effluent treatment is effective and where only occasional spills may be encountered (in which case acute studies will be more important).

Program Unit Titles:

3.2.1 Several-generation studies on short-lived test organisms

3.2.2 Long-term studies on selected representative species

BER Balanced Program Plan

Program Unit

3.2.1 Several-generation studies on short-lived test organisms

Program Unit Objective: To determine sub-acute effects of effluents, effluent fractions, leachates, combinations of effluent components or materials accumulated or transported through environmental processes or biotransformation on normal life functions of selected short-lived test organisms through several generations of their normal life cycle.

Scope: For effluent components identified as causing acute effects, chronic effects testing should be initiated immediately thereafter for purposes of establishing levels of waste control necessary for incorporation into process engineering. Effluent components not identified as being of acute importance should be evaluated on the basis of the best information available on biological and environmental transformations and accumulation. From such information, components of identified importance should also be studied for purposes of identifying process areas of priority concern to waste management engineering. Tests should include threshold dosages for effects on normal life functions (including life span, reproduction, fecundity, growth, maturation, and productivity) throughout a series of complete life cycles of selected short-lived test organisms from example habitats (aquatic, terrestrial), or specific habitats near proposed coal conversion facilities. Results will be useful in optimizing plant sitings, designs, and operations.

Milestones:

1. Definition and screening of effluent components of primary importance - those causing acute effects and most likely to be of chronic influence.

2. Definition and screening of effluent components and complexes of anticipated chronic importance due to environmental and biological transport, transformation, and accumulation.

3. Identification of dosage levels necessary for effects on organismic and population characteristics (life span, reproduction, age class structure, growth, etc.) throughout a series of life cycles of selected short-lived test organisms from representative habitats (continuing, beginning as early as inputs from (1) and (2) are available).

Technology Development Time Frame: Initial testing should begin immediately as acute effects inputs become available in order to provide feedback to process engineering on effluent levels of chronic concern.

Program Unit Priority: Moderate initially, high as information on acute toxicities, transport, transformations, and accumulation become available.

Estimated Program Unit Cost:

1.	Total		$5,400,000
2.	Per Year -	FY 1977	$ 600,000
		FY 1978	$1,200,000
		FY 1979	$1,200,000
		FY 1980	$1,200,000
		FY 1981	$1,200,000

BER Balanced Program Plan

Program Unit

3.2.2 Long-term studies on selected representative species

Program Unit Objective: To determine threshold concentrations or dosages over prolonged time spans of effluents, effluent fractions, leachates, combinations of effluent constituents, or material accumulated or transformed through environmental processes or biotransformation for effects on normal life functions of representative and important species throughout their normal life cycle (including life span, reproduction, fecundity, growth, maturation, productivity, and age class structure), in the presence of typical background environmental factors (this can be regional habitat, water chemistry, other pollutants of importance, etc.).

Scope: This program unit is distinct from other studies conducted on standard laboratory organisms in that it is directed specifically at site-related organisms and their life-cycle requirements.

Milestones:

1. Select representative and important species for long-term studies of chronic effects (to accompany site selection).

2. Establish appropriate experimental systems for the selected species (this may be available in the literature for some species, but requires considerable development for others).

3. Establish acceptable levels of pollutants for single generation success (1-5 years, depending upon species).

4. Establish threshold levels of pollutants for multiple generation success (1-20 years, depending upon species).

5. Establish and monitor reproducing populations of representative and important species in actual effluent streams (this will blend with plant monitoring activities), to be done during plant operation.

Technology Development Time Frame: Initial results are needed as soon as possible for short-lived organisms to serve as indices for establishing the necessity for extensive treatment of low-level wastes. Tests with longer-lived organisms should be initiated rapidly so that results can be obtained before major damage is done.

Program Unit Priority: High, for testing of effluents that will contain low-level wastes unless extraordinary and expensive treatment is undertaken (i.e., chronic tests will be needed to do an adequate cost/benefit assessment for extraordinary and expensive waste treatment facilities).

Estimated Program Unit Cost:

1. Total $3,780,000

2. Per Year -

FY 1977	$	-0-
FY 1978	$	-0-
FY 1979	$	900,000
FY 1980	$1,440,000	
FY 1981	$1,440,000	

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Environmental Effects and Transport

Problem Title: Effects Model Development (II.3.3.0)

Objective: To synthesize experimental information on acute, chronic, and microcosm effects and field information on ecosystem effects at operating conversion facilities, along with information on transport and accumulation in order to better define interrelationships, to identify outstanding gaps in knowledge and to allow interim predictions of population and ecosystem responses for purposes of long-range planning for siting, design, and operation of coal conversion facilities. Computer modeling techniques should be useful for simulating population and ecosystem effects that may result from local or short-term impacts.

Priority: Medium in the short term; high in the long term.

Program Unit Titles:

3.3.1 Population dynamics modeling of affected representative and important species

3.3.2 Ecosystem dynamics modeling for microcosms and field ecosystems

3.3.3 Verification of models through critical comparison with subsequent laboratory and field data

BER Balanced Program Plan

Program Unit

3.3.1 Population dynamics modeling of affected representative and important species

Program Unit Objective: To synthesize experimental information on acute and chronic microcosm effects, and field information on population dynamics of important species at projected or actual coal conversion sites through the use of computer modeling techniques in order to better define the levels of damage (in time and location) to populations of the species in the area.

Scope: Detailed population dynamics models may be necessary for determining acceptable levels of damage to species of high importance where waste management facilities are expected to be of unacceptable cost or technologically unfeasible. Output is to be formulated to provide management options for the population and the coal conversion facility.

Milestones:

1. Aggregation of all pertinent effects data and life cycle data for the selected species (this must await data, if they are not yet available).

2. Development of the population dynamics model.

3. Test runs of the model, using example and realistic levels of damage to portions of the life cycle (e.g., reduced reproductive success, slower growth, etc.) in order to predict the success of the population (using an appropriate measure such as yield to a fishery) over the time span of operation of the plant and a recovery period thereafter.

4. Formulation of management options for decision makers.

Technology Development Time Frame: Basic population dynamics models of species likely to be affected can begin immediately in order to be ready for incorporation of effects data. The complete impact models must, however, await effects data and thus may have to be several years away (2-3 years, minimum).

Program Unit Priority: Low for first 1-3 years; probably high for later years, depending upon effects results and costs of extensive waste treatment.

Estimated Program Unit Cost:

1. Total $900,000

2. Per Year -

FY 1977	$ -0-
FY 1978	$ -0-
FY 1979	$300,000*
FY 1980	$300,000*
FY 1981	$300,000*

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*Based on three representative species.

BER Balanced Program Plan

Program Unit

3.3.2 Ecosystem dynamics modeling for microcosms and field ecosystems

Program Unit Objective: To synthesize information from experimental microcosms and field locations on the ecosystem effects of effluents, both primary effluents and as these are transported and/or transformed by ecosystem components, in order to better define relationships of the effluent materials to various components of ecosystem structure and function and to simulate ecosystem effects in order to develop interim predictions for purposes of long-term planning for siting, design, and operation of coal conversion facilities.

Scope: Ecosystem effects models may be of several types, depending upon the aspect of structure or function of most concern at a particular site or with reference to particular effluent materials. Species diversity, energy flow, carbon flow, trophic biomass, and others are available. Both experimental ecosystem results and data from field locations will be used. Transport and transformation phenomena will have to be incorporated to some extent in order to model secondary effects of transported and transformed materials realistically. In some cases, joint transport and effects models may be feasible. The models will be useful for defining acceptable levels of effluents when treatment costs are extraordinarily high or the technology not available.

Milestones:

1. Aggregation of ecosystem effects information and site-specific ecosystem survey information as well as existing ecosystem models that may be usable.

2. Development of appropriate ecosystem model(s) for representative ecosystems and for site in question.

3. Use of models to simulate potential ecosystem responses to released effluents.

4. Formulation of management options to decision makers.

Technology Development Time Frame: Modeling will necessarily come after acquisition of much effects data, but development of models can proceed simultaneously as an aid to directing ecosystem research.

Program Unit Priority: Medium in first 2-3 years; high thereafter.

Estimated Program Unit Cost:

1.	Total		$900,000
2.	Per Year -	FY 1977	$ -0-
		FY 1978	$ -0-
		FY 1979	$300,000*
		FY 1980	$300,000*
		FY 1981	$300,000*

*Based on three representative ecosystems.

BER Balanced Program Plan

Program Unit

3.3.3 Verification of models through critical comparison with subsequent laboratory and field data

Program Unit Objective: To evaluate ecosystem and population dynamics models developed earlier with respect to their validity for particular sites and with particular effluent materials when compared to measured parameters of population and system function for sets of specific laboratory and field data collected from acute and chronic effects studies, microcosm studies, and preoperational and operational field studies at existing coal conversion facilities.

Scope: Both ecosystem dynamics and population dynamics models developed to model the behavior of effluents of concern within populations and ecosystems of concern will be compared in performance to field and laboratory data obtained for analogous populations and ecosystems exposed to similar conditions. Such comparisons should allow validation not only of direct effects models, but also transport and transformation models, and finally, integrated transport and effects models. The model verification will establish the feasibility of using such models for defining acceptable levels of effluents in terms of populations and ecosystem dynamics and function.

Milestones:

1. Aggregation of laboratory and field data available for use in model verification.

2. Comparison of model outputs to field data and validation/nonvalidation of model.

3. Formulation of management options to decision makers.

Technology Development Time Frame: To develop coincident with models.

Program Unit Priority: Medium in first 2-3 years; high thereafter.

Estimated Program Unit Cost:

1. Total $1,500,000

2. Per Year -

FY 1977	$	-0-
FY 1978	$	-0-
FY 1979	$	500,000*
FY 1980	$	500,000*
FY 1981	$	500,000*

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*Based on five models.

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Environmental Effects and Transport

Problem Title: Microcosm Studies of Coal Conversion Effluents (II.3.4.0)

Objectives: To determine the role of acute and chronic effects on individual organisms as they relate to multi-level organism interactions. These tests would provide a bridging mechanism between interpretation of organism acute and chronic effects, and the later modeling and post-operation field studies.

Priority: High

Program Unit Titles:

3.4.1 Assessment of direct effects of effluent compounds in a multi-organism, multi-level system

3.4.2 Assessment of indirect effects of coal conversion effluents on the environment

BER Balanced Program Plan

Program Unit

3.4.1 Assessment of direct effects of effluent compounds in a multi-organism, multi-level system

Program Unit Objective: To evaluate the direct effects of effluent fractions or components determined to be of importance in acute and chronic effects studies on laboratory microcosms of varying levels of complexity in order to identify sites of accumulation of chemicals and to assess the importance and rates of complementary and competitive processes in the system.

Scope: As effluent fractions and compounds are identified in acute and chronic effects studies to be of potential environmental importance, microcosm experiments should be established to allow evaluation of the behavior of these compounds and mixtures under heterogeneous environmental conditions and with a diversity of organisms. Such complex microcosms will serve as a useful tool for the integration of multiple biotic-abiotic interactions, and provide a mechanism for screening and identifying the potential fate of effluents of concern for future study. Tests should duplicate heterogeneous environmental conditions and organism diversity typical of habitats likely to be impacted by coal conversion effluents.

Milestones:

1. Determination of effluents and compounds of primary concern from acute and chronic effects studies.

2. Identification of sites of accumulation of effluent chemicals, and the direct effects of that accumulation both on the individual trophic level and on the associated food chain.

Program Unit Priority: Low in the short-term; high as the necessary background information becomes available.

Estimated Program Unit Cost:

1. Total $1,440,000

2. Per Year - FY 1977 $ -0-
   FY 1978 $ 360,000
   FY 1979 $ 360,000
   FY 1980 $ 360,000
   FY 1981 $ 360,000

BER Balanced Program Plan

Program Unit

3.4.2 Assessment of indirect effects of coal conversion effluents on the environment

Program Unit Objective: Assessment of effluent compound transport, transformations, and accumulation in multi-level systems, and to evaluate the long-term, indirect effects of these inputs on the system.

Scope: Effluent compounds of acute and chronic environmental importance identified in acute and chronic effects studies should be tested in microcosm experiments to integrate biotic and abiotic interactions and identify sites of accumulation and potential fate of effluent compounds introduced into the system. Simplified microcosms should be used to verify pathways of chemical transport and measure the corresponding rates of transfer.

Milestones:

1. Identification of effluent compounds of primary interest from acute and chronic effects studies.

2. Identification of processes and pathways involved in accumulation of effluent compounds.

3. Measurement of rates of processes involved in accumulation of effluent compounds.

Program Unit Priority: Low in the short-term; high as the necessary background data become available.

Estimated Program Unit Cost:

1. Total $1,800,000

2. Per Year -

FY 1977	$	-0-
FY 1978	$	-0-
FY 1979	$	600,000
FY 1980	$	600,000
FY 1981	$	600,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Environmental Effects and Transport

Problem Title: Determination of Routes, Transformations, and Sinks of Coal Conversion Effluent Constituents (II.3.5.0)

Objective: Determination of rates of biological accumulation and degradation of effluent constituents is necessary to predict effluent mobilities, environmental residence times, and ultimate fates in ecosystems. Initial links in environmental transport chains will be predicted from previously completed effluent characterization studies (e.g., solubility and initial compound form). Kinetics of metabolism and bioaccumulation will be investigated utilizing target organisms identified as possessing susceptibility to identified contaminants. Metabolites released into the environment will be identified for further toxicity and effluent studies. Information obtained will be utilized in models of degradation and fate of coal conversion effluent constituents. Research results generated within each program unit will allow evaluation of the relative environmental hazard of the effluent constituent investigated.

Priority: High for effluent constituents whose removal efficiency from waste effluent streams by standard procedures is less than complete.

Program Unit Titles:

3.5.1 Transport, distribution, and bioaccumulation of effluent constituents and transformation products within terrestrial systems

3.5.2 Retention, transformations, and mobility of effluent constituents in soils

3.5.3 Transport, distribution, and bioaccumulation of effluent constituents and transformation products in aquatic ecosystems

3.5.4 Accumulation and transformation of effluent constituents in sediments of aquatic ecosystems

BER Balanced Program Plan

Program Unit

3.5.1 Transport, distribution, and bioaccumulation of effluent constituents and transformation products within terrestrial systems

Program Unit Objective: Characterization of the distribution of the various effluents and their transformation products in components of representative ecosystems. Identification of components of these systems which accumulate these pollutants.

Scope: Following atmospheric deposition or land disposal of solid wastes, effluents are transported (cycled) within terrestrial systems. This cycling can lead to accumulation in some components, such as soils in the case of trace metals. The present effort would characterize the distributions of effluents in ecosystem components by analyzing components for their effluent contents and comparison with corresponding biomass distributions. The information acquired will interface with terrestrial effects programs by identifying components which accumulate given effluents and by supplying data on the magnitude of this accumulation.

Milestones: - at different sites representative of vegetation distributions:

1. Summarize data on the distribution of biomass and organic detritus in the systems.

2. Detailed process studies to identify transformation products and bioaccumulation of materials.

3. Analyze ecosystem components for concentrations of pollutants and transformation products.

4. Merge biomass and concentration data to yield quantified distributions; use these as the basis for assessing sites of accumulation.

Technology Development Time Frame: Should proceed as composition of process streams and effluents becomes known.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total			$1,680,000
2. Per Year -	FY 1977	$	-0-
	FY 1978	$	240,000
	FY 1979	$	480,000
	FY 1980	$	480,000
	FY 1981	$	480,000

BER Balanced Program Plan

Program Unit

3.5.2 Retention, transformations, and mobility of effluent constituents in soils

Program Unit Objective: Evaluation of the interactions of coal conversion-related contaminants with soils and determination of the affinity, persistence, and transformation products of designated contaminants. Those substances identified as toxic or carcinogenic will require detailed study to ascertain the potential mechanisms affecting transfers to biota from contaminated soils.

Scope: Soils are major sinks for contaminants released to the terrestrial environment. The behavior and fate of recognized organic contaminants in soils will be evaluated by assessing: (1) the capacity of soil organisms to catabolize the substance(s) to innocuous forms; (2) the physicochemical interactions between contaminant and soil constituents, and the manner in which such interactions affect persistence, leaching, and volatilization; and (3) the routes of biological transfer which can lead from soil to important food chains. Mobility, persistence, and biological availability parameters will be integrated into a determination of the relative hazard of the substance in comparison with existing, recognized health hazards. The results of this task will be integrated into the design of microcosms which test transfers and bioaccumulation factors in more complex biological communities.

Milestones:

1. Identification of soil types to be tested; testing of analytical scheme(s).

2. Persistence evaluation (including catabolites); determination of side effects on soil microbes (i.e., nitrifying bacteria); determination of degradation potential in soil.

3. Adsorption, leaching, and volatility testing. Determination of the most probable routes of physical transport.

4. Biological availability tests. Determination of factors affecting availability to plants.

5. Integration of experimental observations in order to: (1) classify hazard potential; (2) provide input into microcosm design.

Technology Development Time Frame: Concurrent with pilot plant development.

Program Unit Priority: Medium, precede assessment of chronic effects.

Estimated Program Unit Cost:

1. Total $1,330,000

2. Per Year -

FY 1977	$	150,000
FY 1978	$	280,000
FY 1979	$	340,000
FY 1980	$	280,000
FY 1981	$	280,000

BER Balanced Program Plan

Program Unit

3.5.3 Transport, distribution, and bioaccumulation of effluent constituents and transformation products in aquatic ecosystems

Program Unit Objective: Determination of rates of uptake, bioaccumulation, metabolism, and excretion of coal conversion effluent constituents by flora and fauna in aquatic ecosystems.

Scope: The kinetics of uptake and metabolism of representative effluent constituents by components of aquatic ecosystems will be investigated. Initial target organism will be identified on the basis of effluent constituent form; metabolites will be quantified and identified when feasible. Effects of other water constituents, temperature and pH, and other variables on bioaccumulation rates will be assessed. Transformation through individual steps in representative aquatic food chains will be investigated to provide a basis for later multi-component model ecosystem studies.

Milestones:

1. Selection of representative effluent constituents of known or suspected environmental concern.

2. Prediction of initial target organisms based upon knowledge of form of effluent constituent.

3. Evaluation of uptake, bioaccumulation, metabolism, and excretion rates of effluent components by target organisms.

4. Determination of transformation rates through individual stages in food chains.

5. Measurement of transformation and bioaccumulation rates in representative ecosystems.

Technology Development Time Frame: Concurrent with initial pilot plant development.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$1,200,000
2.	Per Year -	FY 1977	$ 150,000
		FY 1978	$ 150,000
		FY 1979	$ 300,000
		FY 1980	$ 300,000
		FY 1981	$ 300,000

BER Balanced Program Plan

Program Unit

3.5.4 Accumulation and transformation of effluent constituents in sediments of aquatic ecosystems

Program Unit Objective: Assessment of sediments as sinks for compounds in coal conversion effluents.

Scope: Based upon knowledge of effluent components form and initial data of bioaccumulation potential, effluent components which are likely to interact with sediments (either directly or through sedimentation of dead organisms) will be examined. Adsorption behavior will be assessed as a function of sediment type. Benthic bioaccumulation and microbial degradation kinetics will be determined under oxidizing and reducing conditions; final degradation products and excreted metabolites will be identified. Effects of mixtures (e.g., toxic metals and selected organic compounds) on degradation of compounds will be assessed. Degradation rates and rates of accumulation in sediments will be used later, both in design of model ecosystem (microcosm) experimentation and in model formulation.

Milestones:

1. Identification of representative effluent constituents predicted to interact with sediments and considered hazardous to biota.

2. Evaluation of sediment adsorption kinetics and volatility potential from water.

3. Evaluation of bioaccumulation by benthic invertebrates.

4. Evaluation of degradation by microbial and chemical mechanisms; identification of degradation products.

5. Evaluation of effect of effluent mixtures on degradation rates.

6. Integration of data for hazards assessment.

Technology Development Time Frame: Concurrent with pilot plant development.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $840,000

2. Per Year -

FY 1977	$ -0-
FY 1978	$120,000
FY 1979	$240,000
FY 1980	$240,000
FY 1981	$240,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Environmental Effects and Transport

Problem Title: Formulation of Transport Models of Coal Conversion Effluents (II.3.6.0)

Objective: Assembly of a model of effluent constituent transport integrating rates of biotransformation, degradation, and bioaccumulation determined in previous program units. Pathways of effluent transport, degradation, and accumulation will be outlined. Rates of effluent movement will be coupled to source fluxes to permit generalization of transport behavior. Model formulation will interface with parallel efforts in "ecological effects"; an overall goal will be the development of a unified transport/effects model which will permit realistic evaluation of both local and regional effects of effluents produced by a full-scale commercial plant. Data obtained during an ongoing field monitoring program will be utilized to refine and validate the model.

Priority: High when necessary transport and effects data become available from previous research; earlier activities (consisting of evaluating applicability of existing transport models) moderate in priority.

Program Unit Titles:

3.6.1 Formulation of biotransformation model

3.6.2 Formulation of soils and sediments model

BER Balanced Program Plan

Program Unit

3.6.1 Formulation of biotransformation model

Program Unit Objective: Synthesis of previously determined kinetic data of biological transport and transformation of effluent compounds into a model of compound movement in aquatic and terrestrial ecosystems.

Scope: Transformation, bioaccumulation, metabolism, and degradation rates obtained in previous single and multicomponent studies will be modeled. Information from environmental effects research will be integrated to permit evaluation of synergistic and antagonistic interactions between inorganic and organic effluents. Transformations in aquatic, terrestrial, and atmospheric systems will be evaluated; compartmental levels measured in field surveys will be utilized to modify and verify model predictions. Sensitivity analyses will be utilized to assess variations in source fluxes and to determine the significance of pollutant abatement measures.

Milestones:

1. Initiate integration of physicochemical and biological transport kinetic data to yield biotransformation fluxes.
2. Verification of model by analysis of field survey data.
3. Determination of the significance of effluent abatement measures.

Technology Development Time Frame: Basic modeling initiated concurrent with transformation research; verification stage follows site selection and field survey.

Program Unit Priority:

Estimated Program Unit Cost:

1. Total $480,000
2. Per Year - FY 1977 $ -0-
   FY 1978 $ -0-
   FY 1979 $100,000
   FY 1980 $180,000
   FY 1981 $200,000

BER Balanced Program Plan

Program Unit

3.6.2 Formulation of soils and sediments model

Program Unit Objective: Development of a submodel with synthesized extant data on physicochemical, macrobiological, and microbial transformation of coal conversion effluent constituents in soils and sediments.

Scope: Data on kinetics associated with biotransformation, metabolism, and bioaccumulation of significant effluent compounds obtained from transformation and microcosm experiments will be incorporated into existing model frameworks (where applicable). Emphasis will include predictions of ultimate sinks, steady-state levels in biotic and abiotic soil and sediment compartments, and availabilities of intermediates to other organisms. Site-specific data from field surveys will be used to modify and validate the submodel.

Milestones:

1. Review of existing models for organic transformations in soils.
2. Development of initial soil and sediment transformation models.
3. Incorporation of data into model.
4. Evaluation of model.
5. Incorporation of transport model into integrated assessment.

Technology Development Time Frame: Concurrent with pilot plant operation.

Program Unit Priority: Moderate in humid and xeric soil environments.

Estimated Program Unit Cost:

1. Total		$900,000
2. Per Year -	FY 1977	$ 60,000
	FY 1978	$120,000
	FY 1979	$240,000
	FY 1980	$240,000
	FY 1981	$240,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Environmental Effects and Transport

Problem Title: Ecosystem Effects of Operating Coal Conversion Facilities (II.3.7.0)

Objectives: To determine environmental effects of operating a coal conversion facility. This will include baseline ecological data and measurement of accumulation and transformation rates of effluent constituents within an ecosystem surrounding a representative coal conversion pilot plant facility. Preoperational sampling studies will be undertaken to determine composition of ecosystems and initial levels of contaminants in representative compartments of terrestrial and aquatic systems in the surrounding region. Sampling and analysis will continue through the initial start-up period and for a sufficient period to observe transport due to steady-start effluent fluxes. Survey procedures will be developed in conjunction with CMM groups. Research will be designed to determine environmental effects (population, community, or ecosystem level) from operating demonstration or commercial plants and to trace the effects to the particular physical and chemical source(s), with the objective of mitigating the damages through corrective engineering. This presumes adequate preoperational information to serve as a basis for comparison.

Priority: High

Program Unit Titles:

3.7.1 Preoperational and operational studies at each coal conversion facility

BER Balanced Program Plan

Program Unit

3.7.1 Preoperational and operational studies at each coal conversion facility

Program Unit Objective: To determine ecosystem effects, if any, from each operating demonstration, pilot, or commercial coal conversion plant, and to trace the effects of the particular physical and chemical source(s), with the objective of mitigating the damages through corrective engineering. This presumes adequate preoperational information to serve as a basis for comparison.

Scope: Each coal conversion facility, whether demonstration, pilot, or commercial, shall have a research, monitoring, and assessment program consisting of:

(a) Preoperational ecological survey, emphasizing those portions of the ecosystem most likely to be affected by the particular facility (e.g., aquatic system for liquid effluents).

(b) Preoperational and operational chemical/physical characterization and measurements to monitor actual discharges. Samples of air, water, soils, sediments, and representative species of aquatic and terrestrial flora and fauna will be collected. Chemical analyses will be adapted by "Chemical Measurement and Monitoring" researchers, and will be undertaken for those compounds and elements which are identified by previous research as comprising significant environmental hazards. Methods of sample preservation will be optimized to ensure the capability of retrospective baseline analysis of effluent constituents identified later in laboratory or field investigations. Sampling will be continued for at least a year prior to pilot plant start-up to allow determination of seasonal variations.

(c) Operational ecological surveys and assessment for a minimum of five years following start-up to observe any changes in the overall ecosystem. Sampling of ecosystem compartments and analysis of effluent components, initiated in (b), will be continued after initiation of plant operation. Sampling will be spatially extended outward until effluent constituent concentrations observed do not significantly exceed background levels. Levels of metabolites and other transformation products will be determined when their ecological significance is confirmed by parallel laboratory research ("Acute Effects", "Chronic Effects", and "Environmental Transport and Transformation" investigatory groups). Other effluent constituents will be investigated if unanticipated ecological effects (e.g., population shifts and variations in species diversities) are observed in the field ecosystem. Routine monitoring of key ecological parameters will be continued to permit a realistic assessment of long-term operation of coal conversion facilities.

(d) Continued monitoring of a small number of key elements (physical, chemical, biological) of the ecosystem for the life of the plant to indicate any long-term changes.

Milestones: As noted under Scope, the principal milestones of the study of each facility will be preoperational studies, operational measurements and characterization, operational ecological surveys and assessment, and continued monitoring of key elements of the ecosystem for the life of the plant.

A long-term milestone would be reduction in site survey requirements at later facilities when corrective engineering and waste treatment at early plants have reduced the potential for ecological damage significantly.

Technology Development Time Frame: Initial pilot and demonstration facilities should be studied carefully in order to minimize the potential for damages at later, larger facilities (see Section III).

Program Unit Priority: High for each facility.

Estimated Program Unit Cost:

1. Total		$14,500,000
2. Per Year -	FY 1977	$ 2,500,000*
	FY 1978	$ 3,000,000*
	FY 1979	$ 3,000,000*
	FY 1980	$ 3,000,000*
	FY 1981	$ 3,000,000*

*Based on five representative facilities.

II.4.1 Physical and Chemical Processes and Effects

II.4.1.0 Evaluation of Atmospheric Dispersal, Transformation, and Deposition of Effluent Constituents on Terrestrial Landscapes

(4.1.1 Atmospheric dispersal, transformations, and deposition of effluent constituents on terrestrial landscapes)

(4.1.2 Formulation of dispersion/distribution model)

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Physical and Chemical Processes and Effects

Problem Title: Evaluation of Atmospheric Dispersal, Transformation, and Deposition of Effluent Constituents on Terrestrial Landscapes (II.4.1.0)

Objective: Determination of transport, conversion, and deposition of atmospheric pollutants. Field aspects of this research need to be coupled with demonstration or commercial-size plants where sufficient materials are produced for measurement. This initially would involve Lurgi-type gasifier plants (both high and low Btu) and catalytic and carbonization-hydrocarbonization liquefaction. Target compounds will be selected from results of CMM. They will be based on quantitative results, known and expected environmental effects, and similarities of effluents between conversion types (i.e., if one group of compounds is produced in all alternative processes, priority of research may be directed here).

Priority: High

Program Unit Titles:

4.1.1 Atmospheric dispersal, transformations, and deposition of effluent constituents on terrestrial landscapes

4.1.2 Formulation of dispersion/distribution model

BER Balanced Program Plan

Program Unit

4.1.1 Atmospheric dispersal, transformations, and deposition of effluent constituents on terrestrial landscapes

Program Unit Objective: Determination of atmospheric transport, transformations, dispersal, and deposition of effluent constituents.

Scope: Time-variant atmospheric movement of effluent constituents away from the source will be estimated on the basis of initial effluent form and particle size distribution. Chemical and photolytic transformations will be determined and reaction rates measured. Meteorologic and physicochemical factors affecting the removal of effluents and transformation products will be assessed. From the data obtained deposition rates on specific landscapes and long-term regional atmospheric compositions of effluent constituents and transformation products will be determined, and relative hazard potentials of effluent constituents will be evaluated.

Milestones:

1. Characterize atmospheric effluent streams quantitatively and qualitatively (in conjunction with CMM group).
2. Determine atmospheric transformation and process rates.
3. Measure effects of meteorologic variables (air turbulence, stability, etc.) on deposition velocities for effluent constituents on different vegetation covers (i.e., grass, forest types, etc.).

Technology Development Time Frame: Simultaneous with development to permit preoperational siting criteria for commercial-scale plants.

Program Unit Priority: High for conversion processes which produce significant fluxes of atmospheric contaminants whose environmental transport is poorly understood; moderate for relatively intensively studied effluent constituents.

Estimated Program Unit Cost:

1.	Total		$1,680,000
2.	Per Year -	FY 1977	$ 240,000
		FY 1978	$ 360,000
		FY 1979	$ 360,000
		FY 1980	$ 360,000
		FY 1981	$ 360,000

BER Balanced Program Plan

Program Unit

4.1.2 Formulation of dispersion/distribution model

Program Unit Objective: Incorporation of knowledge of effluent character and form and atmospheric and hydrologic criteria into a submodel of effluent dispersal in aquatic and terrestrial ecosystems.

Scope: Effluent component forms will be evaluated from previous research. Existing atmospheric and aquatic dispersal models with necessary modifications will be utilized where available. As specific locations of pilot plant operation are pinpointed, site-specific micro-climatic data will be incorporated. Effluent distributions obtained in the field monitoring survey will be used to test and modify the submodel as required.

Milestones:

1. Effluent form characterization.
2. Formulation of general submodels.
3. Adaptation of submodel to specific sites.

Technology Development Time Frame: Initial modeling concurrent with technical development; site-specific modeling at time of pilot plant siting.

Program Unit Priority: Moderate

Estimated Program Unit Cost:

1.	Total		$780,000
2.	Per Year -	FY 1977	$ 60,000
		FY 1978	$120,000
		FY 1979	$200,000
		FY 1980	$200,000
		FY 1981	$200,000

II.5.1 Integrated Assessment

II.5.1.0 Environmental and Biomedical Research Information Integration

(5.1.1 Coordination and management system for coal conversion R&D programs)

(5.1.2 Coordination of environmental data acquisition)

(5.1.3 Computing facilities for coal conversion R&D programs)

(5.1.4 Environmental information data base for coal conversion technologies)

(5.1.5 National geoecology data base)

(5.1.6 Source terms and effects data base for coal conversion technologies)

(5.1.7 Data processing, analysis, display, and reporting support)

(5.1.8 Synthesis and policy analysis methodology)

II.5.2.0 Onsite Physical Environmental Impacts

(5.2.1 Determine the land area required for alternative coal conversion processes)

(5.2.2 Determine the topographic (i.e., geological, soil) considerations pertinent to siting coal conversion facilities)

(5.2.3 Identifying competing land-use requirements for potential sites of coal conversion facilities)

(5.2.4 Determine the impacts of a coal conversion facility on existing land-use applications contiguous to the site)

(5.2.5 Identify and categorize the accessibility requirements of coal conversion facilities)

(5.2.6 Determine the total onsite demands for alternative coal conversion processes)

(5.2.7 Identify the institutional environmental constraints relative to coal conversion facilities)

(5.2.8 Identify coal resource locations and assess the applicability of various coal conversion options thereto)

II.5.3.0 Off-Site Physical Environmental Impacts

(5.3.1 Determine the land-use demands of the supporting facilities prompted by coal conversion facilities)

(5.3.2 Determine the size and time-phasing of the land area requirements of the construction and operating work force of coal conversion facilities)

(5.3.3 Determine the total population trends associated with the size of the construction and operating populations)

(5.3.4 Determine the impacts of the increased population on the physical environment of regional recreational areas)

(5.3.5 Determine population land-use impacts on indigenous wildlife habitat and activities)

(5.3.6 Determine the cumulative water requirements of the residential and commercial developments attributable to the coal conversion industry)

(5.3.7 Identify the human, commercial, and industrial waste handling and disposal requirements and the resultant environmental impacts)

(5.3.8 Determine the direct and secondary impacts off-site commercial, residential and industrial developments on the air shed)

(5.3.9 Determine the accessibility requirements necessary to support plant, community and supporting facilities)

II.5.4.0 Social and Demographic Effects

(5.4.1 Public information program)

(5.4.2 Methodology for determining the structure of construction and operating populace)

(5.4.3 Evaluation of existing political structure)

(5.4.4 Evaluating community service capabilities)

(5.4.5 Social-cultural impacts assessment)

II.5.5.0 Regional, National and International Economic Impacts of Coal Conversion Facilities

(5.5.1 Assessment of major coal regions capacity to supply coal conversion facilities)

(5.5.2 Determination of optimal number and mixture of coal conversion facilities)

II.5.6.0 Local Economic Impacts Associated with Siting of Coal Conversion Facilities

(5.6.1 Identification and quantification of local economic structures and multiple effects)

(5.6.2 Local costs and benefits associated with siting coal conversion facilities)

(5.6.3 Impacts on local tax structures of siting coal conversion facilities)

(5.6.4 Study of capital investments associated with coal conversion facilities and local impacts)

II.5.7.0 Siting Coal Conversion Facilities

(5.7.1 Siting criteria for coal conversion facilities)

(5.7.2 Multi-scale geographic base file for siting analysis)

(5.7.3 Siting variables at the regional scale (county-level data))

(5.7.4 Screening for candidate siting areas)

(5.7.5 Siting at the local scale within candidate siting areas)

(5.7.6 Fine screening for candidate areas within candidate counties)

(5.7.7 Comparison of the number and capacity of suitable sites for coal conversion)

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Integrated Assessment

Problem Title: Environmental and Biomedical Research Information Integration (II.5.1.0)

Objectives: The overall objective is to manage, integrate, and analyze environmental and biomedical research information so that energy technology alternatives can be properly evaluated and compared. This capability is essential to merge research results and assessment capabilities developed in each Program Unit area in all King-Muir categories.

Priority: High

Program Unit Titles:

5.1.1 Coordination and management system for coal conversion R&D programs

5.1.2 Coordination of environmental data acquisition

5.1.3 Computing facilities for coal conversion R&D programs

5.1.4 Environmental information data base for coal conversion technologies

5.1.5 National geoecology data base

5.1.6 Source terms and effects data base for coal conversion technologies

5.1.7 Data processing, analysis, display, and reporting support

5.1.8 Synthesis and policy analysis methodology

BER Balanced Program Plan

Program Unit

5.1.1 Coordination and management system for coal conversion R&D programs

Program Unit Objective: To develop, implement, and operate a system to assist in coordinating and managing the various tasks in the coal conversion technology, utilizing time lines and critical paths between projects.

Scope: The various R&D tasks will be cataloged with time lines, milestones, and relationships between tasks defined. Updating research progress will allow current developments to be displayed and future progress or slippage to be forecasted. Critical paths between programs will be established to allow analysis of scheduled tasks to determine those projects which may cause subsequent delays in the overall effort. The system will utilize interactive processing to permit quick response times of queries to the system.

Milestones:

1. Select and implement a user-oriented, interactive system to store, retrieve, and report management information.

2. Catalog research projects and establish time lines, milestones, and functional relationships.

3. Generate periodic status reports based on updated project reports.

4. Provide interactive access to status of projects.

Technology Development Time Frame: Greatest benefit would be obtained from this unit if it were utilized in the initial funding of proposals.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $1,600,000

2. Per Year - FY 1977 $ 350,000
FY 1978 $ 350,000
FY 1979 $ 300,000
FY 1980 $ 300,000
FY 1981 $ 300,000

BER Balanced Program Plan

Program Unit

5.1.2 Coordination of environmental data acquisition

Program Unit Objective: To coordinate the acquisition of environmental information and data related to the energy technology programs, including format, identification, experimental design, sampling, etc., to ensure compatability and completeness.

Scope: Both descriptive information and numeric data need to be accumulated and organized to allow ready retrieval and analysis. It is essential to establish guidelines and management policies early in the program to obtain data sets of uniform high quality without excessive editing or reformatting of data or duplication of efforts. The user community must contribute to defining information needs and forms of reports and displays most useful to them.

Milestones:

1. Survey information needs and define overall objectives.
2. Produce documentation of standard guidelines for information collection and submission to data center.
3. Provide continual consultation on sampling and evaluation of research results.

Technology Development Time Frame: This activity must be initiated immediately and continued to ensure appropriate data will be available for integrated assessment.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$1,050,000
2.	Per Year -	FY 1977	$ 200,000
		FY 1978	$ 250,000
		FY 1979	$ 200,000
		FY 1980	$ 200,000
		FY 1981	$ 200,000

BER Balanced Program Plan

Program Unit

5.1.3 Computing facilities for coal conversion R&D programs

Program Unit Objective: To establish and operate a computer facility to provide interactive access to data files and analysis programs, using a telecommunications network.

Scope: Computers are essential tools for accomplishing the integrated assessment goals. A computer facility dedicated to providing quick access to large mass storage files and maintaining a library of appropriate analysis programs utilizing a national network of interactive teleprocessing terminals would allow efficient retrieval, display, and evaluation of environmental information. This capability is not currently available within the national laboratories to handle the volume of information anticipated in the energy R&D programs or to provide a national telecommunications network with adequate response times. This capability is needed and should be developed by the Integrated Assessment efforts across the various technologies.

Milestones:

1. Define computational needs and select computing facility to provide the required services.

2. Establish network communications and promote use of the facility.

3. Operate facility to provide uninterrupted services and access to the system during normal working hours.

Technology Development Time Frame: This capability must be developed early in the overall program so that computing will not be a limiting factor in accomplishing the goals of the program.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$1,900,000
2.	Per Year -	FY 1977	$1,000,000
		FY 1978	$ 300,000
		FY 1979	$ 200,000
		FY 1980	$ 200,000
		FY 1981	$ 200,000

BER Balanced Program Plan

Program Unit

5.1.4 Environmental information data base for coal conversion technologies

Program Unit Objective: To develop and maintain an environmental data base from literature, R&D reports, and other sources to maximize the availability and usefulness of existing information related to coal conversion technologies.

Scope: Existing information from literature, R&D reports, bibliographic information files and other sources will be organized to provide a state-of-the-knowledge report on coal conversion technology. This data base will be constantly updated and will be accessably in an interactive mode to allow searching for specific types of information. In compiling the information, gaps may be identified that require additional research.

Milestones:

1. Compile existing information.
2. Publish state-of-the-knowledge report.
3. Update files and provide information services as required.

Technology Development Time Frame: State-of-the-knowledge reports are required as soon as the information can be compiled to aid in guiding research plans.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $950,000
2. Per Year - FY 1977 $300,000
   FY 1978 $200,000
   FY 1979 $150,000
   FY 1980 $150,000
   FY 1981 $150,000

BER Balanced Program Plan

Program Unit

5.1.5 National geoecology data base

Program Unit Objective: To develop and maintain a comprehensive data bank providing background geographic and environmental characteristics of standard geopolitical units for the entire country.

Scope: A highly structured file based on a standard geopolitical unit such as the county will be created for the USA. Information on the terraine, climate, natural resources including plant and animal inventories, land use, economic characteristics, human population census, etc., will be compiled at comparable scales of resolution. Display and reporting programs will be devised to summarize selected information based on standard units or aggragates of units. Maps will be generated to show regional patterns of the data and projections of future patterns developed.

Milestones:

1. Create data base of most essential characteristics.
2. Develop retrieval, display, and analysis capabilities.
3. Provide information as required in integration and synthesis.
4. Expand subject areas included in files.

Technology Development Time Frame: This activity needs to be initiated immediately so that data will be available for siting facilities (II.5.7.0).

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $1,850,000
2. Per Year -

FY 1977	$	400,000
FY 1978	$	450,000
FY 1979	$	400,000
FY 1980	$	300,000
FY 1981	$	300,000

BER Balanced Program Plan

Program Unit

5.1.6 Source terms and effects data base for coal conversion technologies

Program Unit Objective: To accumulate and organize data, defining source-term parameters and related potential ecologic and health effects.

Scope: The integrated assessment requires access to R&D results from the CMM, transport processes, health effects, and ecological effects categories for use in evaluation and comparison of alternative energy technologies. An important part of creating this data base will be coordinating data input (standard format, units, identification) and identifying information gaps.

Milestones:

1. Obtain information from King-Muir R&D projects, maintaining lists of gaps and needed information.
2. Publish directories and descriptions of the contents of the data bank and promote the use of the data.
3. Update and maintain the files, providing data as requested.

Technology Development Time Frame: This unit must be initiated immediately to accumulate available and identify missing source terms from the literature. Subsequent activity will include updating files and providing data to integrated assessment projects.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $300,000
2. Per Year - FY 1977 $100,000
   FY 1978 $100,000
   FY 1979 $100,000
   FY 1980 $ -0-
   FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.1.7 Data processing, analysis, display, and reporting support

Program Unit Objective: To provide data processing, statistical analysis, data management, data display, and reporting support, utilizing interactive processing and a telecommunications network.

Scope: An essential part of providing analysis support is to make available analysts and statisticians to consult with research investigators on all aspects of data handling and evaluation. In addition, a common library of computer programs will be accumulated to provide necessary computational capabilities for analysts and investigators in the coal conversion program. In providing this support, data of uniformly high quality must be readily available for inclusion into data banks as required by the integrated assessment effort.

Milestones:

1. Compile and implement existing programs and publish manuals on their capabilities and use.

2. Provide consultation services as needed.

Technology Development Time Frame: This support activity must be made available at the start of the program to assist in designing experiments that are statistically valid and that use a minimum of resources. Analysis activities will depend on the completion of research.

Problem Unit Priority: Medium

Estimated Program Unit Cost:

1.	Total		$1,200,000
2.	Per Year -	FY 1977	$ 300,000
		FY 1978	$ 400,000
		FY 1979	$ 200,000
		FY 1980	$ 150,000
		FY 1981	$ 150,000

BER Balanced Program Plan

Program Unit

5.1.8 Synthesis and policy analysis methodology

Program Unit Objective: To develop and apply information synthesis and regional policy analysis methods to aid in selecting energy technology alternatives.

Scope: Methods are needed to compare potential advantages (benefits) and disadvantages (risks and costs) of alternative energy technologies. Mathematical models, including effects, transport, regional planning and economic models, and statistical procedures may allow derivation of comparative indices for various technologies for specific sites or regions. The various data bases, computational support capabilities, and a library of mathematical models will be required to accomplish these objectives. Additional efforts in revising or creating mathematical models may be required, utilizing a team of ecologists, biomedical scientists, engineers, economists, regional planners, statisticians, and others.

Milestones:

1. Define synthesis methods, including information requirements.

2. Obtain, catalog, and implement existing computer programs to perform synthesis.

3. Synthesize information and produce impact statements comparing alternative technologies as required for various sites.

Technology Development Time Frame: Development of methodology must be started immediately to allow the analysis to be performed as soon as sufficient data are available for evaluating technologies.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $1,800,000

2. Per Year -

FY 1977	$	500,000
FY 1978	$	500,000
FY 1979	$	300,000
FY 1980	$	300,000
FY 1981	$	200,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Integrated Assessment

Problem Title: Onsite Physical Environmental Impacts (II.5.2.0)

Objectives: A systematic study is needed to identify and characterize the environmental effects on the site and to include all components of the process of a coal conversion facility. These will include the adverse impacts on the land, hydrology, plants/animals, and humans. A determination of the immediate and long-term (e.g., the effects of pollutant buildup and/or concentration) impacts of all onsite effluents from the conversion process.

Priority: High

Program Unit Titles:

5.2.1 Determine the land area required for alternative coal conversion processes

5.2.2 Determine the topographic (i.e., geological, soil) considerations pertinent to siting coal conversion facilities

5.2.3 Identifying competing land-use requirements for potential sites of coal conversion facilities

5.2.4 Determine the impacts of a coal conversion facility on existing land-use applications contiguous to the site

5.2.5 Identify and categorize the accessibility and requirements of coal conversion facilities

5.2.6 Determine the total onsite demands for alternative coal conversion processes

5.2.7 Identify the institutional environmental constraints relative to coal conversion facilities

5.2.8 Identify coal resource locations and assess the applicability of various coal conversion options thereto

BER Balanced Program Plan

Program Unit

5.2.1 Determine the land area required for alternative coal conversion processes

Program Unit Objective: The primary purpose of this program is to determine the land area requirements for coal conversion facilities.

Scope: The various conversion options will be analyzed in order to determine their land-use requirements. An effort will be made to assess various configurations of the components of each option to develop efficient land-use plans. Land-use requirements for a range-of-sizes of each type facility will be developed. Specific objectives are: examination of pilot in-situ gasification and coal liquefaction plants for land area and water consumption onsite and in the near vicinity; determination of land-area demands for proposed demonstration plants; and assessment of the total area of potential impact determined for each type of facility proposed.

Milestones:

1. Initiate efforts to determine the land area requirements for the various coal conversion processes.

2. Develop land-use guidelines.

Technology Development Time Frame: Should begin as soon as plant characterizations are available.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $100,000

2. Per Year - FY 1977 $ 50,000
FY 1978 $ 50,000
FY 1979 $ -0-
FY 1980 $ -0-
FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.2.2 Determine the topographic (i.e., geological, soil) considerations pertinent to siting coal conversion facilities

Program Unit Objective: Careful consideration of topographical features best suited for each coal conversion facility.

Scope: The determination of the best possible site for a coal conversion facility with regard to topography is essential. Consideration will be given to such topographical elements as geology, soil characteristics, and drainage basins. The objective is to determine through careful screening of topographical features the best-suited location for the siting of a coal conversion facility.

Milestones:

1. Geologic requirements for gasification and other types of conversion facilities.

2. Topographic and geomorphological requirements determined.

3. Location of geologic and topographically suitable areas for the siting of coal conversion facilities.

Technology Development Time Frame: Should begin immediately in order to provide criteria for future siting.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $500,000

2. Per Year - FY 1977 $300,000
FY 1978 $200,000
FY 1979 $ -0-
FY 1980 $ -0-
FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.2.3 Identifying competing land-use requirements for potential sites of coal conversion facilities

Program Unit Objective: The identification of competing land-use requirements and the comparison of these land-use options with the use of the sites for a coal conversion facility.

Scope: The competing land uses of potential coal conversion sites must be considered. These will include the necessity of present usage and/or potential future usage of high priority. Where possible the cost-benefit values for these competing options will be determined and compared to that of the use as a site for a conversion facility. The identification of sites not to be considered for a conversion facility will be the end product of this work.

Milestones:

1. Case study of pilot plants proposed.

2. Case study of future demonstration plants.

3. Development of quidelines for future commercial plants.

Technology Development Time Frame: Should be timed to coincide with site selection work.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $180,000

2. Per Year -

FY 1977	$ 60,000
FY 1978	$ 60,000
FY 1979	$ 60,000
FY 1980	$ -0-
FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.2.4 Determine the impacts of a coal conversion facility on existing land-use applications contiguous to the site

Program Unit Objective: For potential sites, determine the impact that a coal conversion facility would have on existing land-use applications contiguous to each site.

Scope: The impacts of various conversion options on-going activities contiguous to potential sites will be assessed. In this manner, the particular option having minimal impact on these activities can be identified. Conversion options, or changes in the conversion scheme and/or facility organization that might enhance these activities, will be determined.

Milestones:

1. Case study of pilot plants (existing and proposed).
2. Case study of demonstration plants.
3. Development of guidelines for future commercial plants.

Technology Development Time Frame: Essential for impact statement. Should begin once sites are selected.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $220,000

2. Per Year -

Per Year -	FY 1977	$ 60,000
	FY 1978	$ 60,000
	FY 1979	$100,000
	FY 1980	$ -0-
	FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.2.5 Identify and categorize the accessibility requirements of coal conversion facilities

Program Unit Objective: The identification and categorization of the accessibility requirements of coal conversion facilities and a correlation of these requirements with those (existing and future) of potential conversion sites.

Scope: The requirements of the conversion facilities for roads, power lines, pipelines, sewers, etc., will be determined. The availability of rail lines, airports, and product distribution systems and other accessibility requirements to potential conversion sites will be identified. Accordingly, the requirements of each conversion option can be compared with these availability determinations in siting analyses.

Milestones:

1. Identify and characterize transportation and service requirements for each technology at site.
2. Inventory existing and proposed transportation systems (highways, pipelines, power lines, etc.) near sites.
3. Determine areas which meet the needs of specific coal conversion facilities for transportation.
4. Develop siting guidelines.

Technology Development Time Frame: These studies should proceed in unison with the development of demonstration plants. Criteria for siting must be developed.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $260,000
2. Per Year - FY 1977 $100,000
   FY 1978 $100,000
   FY 1979 $ 60,000
   FY 1980 $ -0-
   FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.2.6 Determine the total onsite demands for alternative coal conversion processes

Program Unit Objective: The primary purpose of this program unit is to determine the total water-use requirement for each coal conversion facility.

Scope: The total water requirements of each coal conversion option will be determined. This will include the requirements of the extractive phase (e.g., for strip mining, the water needed for dust control, reclamation, etc., will be included). In addition, the water requirements for the work force will be included. An assessment of the distribution of this water as to consumptive vs recyclable usage will be made. Determination of the water quality and resultant clean-up systems required for the waste water streams will be undertaken.

Milestones:

1. Determine water needs of various proposed and existing coal conversion facilities.

2. Develop data base of existing supplies of water suitable and available for coal conversion use.

3. Factor in pollution control requirements and develop siting criteria for each type of coal conversion facility.

Technology Development Time Frame: Must begin immediately for siting constraint assessment.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $470,000

2. Per Year - FY 1977 $150,000
   FY 1978 $100,000
   FY 1979 $100,000
   FY 1980 $ 60,000
   FY 1981 $ 60,000

BER Balanced Program Plan

Program Unit

5.2.7 Identify the institutional environmental constraints relative to coal conversion facilities

Program Unit Objective: The identification of institutional environmental constraints applicable to potential siting regions.

Scope: As assessment of the national and state environmental regulations concerning the various coal conversion techniques will be conducted. The regulatory/licensing structure governing each conversion option will be identified. An effort will be made to identify ways to streamline policy formulation and the regulatory structure governing these processes. Areas wherein inter-jurisdictional problems may exist will be identified. This work will depend heavily upon research into the ecological pathways and effects associated with coal conversion.

Milestones:

1. Assess existing constraints to land, water and air use for potential siting regions.
2. Make estimates of changes in land, water, and air quality relative to development of coal conversion facilities.
3. Develop siting criteria with varying technologies of pollution control and abatement to meet federal, state and local requirements.

Technology Development Time Frame: Institutional problem assessments must be assessed early in order to mitigate the local and regional impacts of large technology events.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$400,000
2. Per Year -	FY 1977	$200,000
	FY 1978	$100,000
	FY 1979	$100,000
	FY 1980	$ -0-
	FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.2.8 Identify coal resource locations and assess the applicability of various coal conversion options thereto

Program Unit Objective: The primary purpose of this program unit is to identify by region the accessible coal resources and to utilize this information to evaluate the potential coal conversion sites.

Scope: Coal resources will be identified on a regional basis. The various coal conversion options will be considered in regard to the resource location, the unique characteristics of the conversion options, and other resource utilization/developments in the region. A matrix of coal resource location and conversion options will be completed to indicate a ranking of conversion processes for each area.

Milestones:

1. Existing inventories of coal resources and locations will be examined and included in a spatial data base.

2. Deficiencies in the data base will be corrected as information on exploitability of coal seams is available.

3. Data merged with economic supply demand analysis to provide siting criteria for future plants.

Technology Development Time Frame: Should begin immediately in order to assess the availability of coal resources throughout the U.S. which are available and suitable for coal conversion use.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $870,000

2. Per Year - FY 1977 $300,000
FY 1978 $300,000
FY 1979 $150,000
FY 1980 $ 60,000
FY 1981 $ 60,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Integrated Assessment

Problem Title: Off-Site Physical Environmental Impacts (II.5.3.0)

Objectives: A detailed, systematic study is needed to identify and characterize the off-site environmental effects caused by a coal conversion facility. The study should include an assessment of the adverse effects on the land, hydrology, plants/animals and people in the vicinity of the facility. This assessment will capitalize upon the research results of the ecological pathways and effects research at various ERDA Laboratories.

Priority: High

Program Unit Titles:

5.3.1 Determine the land-use demands of the supporting facilities prompted by coal conversion facilities

5.3.2 Determine the size and time-phasing of the land area requirements of the construction and operating work force of coal conversion facilities

5.3.3 Determine the total population trends associated with the size of the construction and operating populations

5.3.4 Determine the impacts of the increased population on the physical environment of regional recreational areas

5.3.5 Determine population land-use impacts on indigenous wildlife habitat and activities

5.3.6 Determine the cumulative water requirements of the residential and commercial developments attributable to the coal conversion industry

5.3.7 Identify the human, commercial, and industrial waste handling and disposal requirements and the resultant environmental impacts

5.3.8 Determine the direct and secondary impacts off-site commercial, residential and industrial developments on the air shed

5.3.9 Determine the accessibility requirements necessary to support plant, community and supporting facilities

BER Balanced Program Plan

Program Unit

5.3.1 Determine the land-use demands of the supporting facilities prompted by coal conversion facilities

Program Unit Objective: The main goal is to determine the land-use requirements of the supporting facilities for a coal conversion plant.

Scope: The total land-use requirements of the supporting facilities of a coal conversion system must be identified and categorized. This should include residential, institutional, and commercial land-use demands. Areas for schools, hospitals, banks, roads, etc. must be accounted for, as well as areas required for recreation in the communities. This is a basic research task which should begin immediately.

Milestones:

1. Attending agglomerative industries which will be attracted to coal conversion facilities determined.

2. Size of employment and attending land-use demand determined.

3. Assessment of proposed sites capability to meet land-use demands determined.

4. Siting criteria determined.

Technology Development Time Frame: Should begin in FY 1978 once the siting feasibility of various coal conversion scenarios is known.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $260,000

2. Per Year - FY 1977 $ -0-
   FY 1978 $200,000
   FY 1979 $ 60,000
   FY 1980 $ -0-
   FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.3.2 Determine the size and time-phasing of the land area requirements of the construction and operating work force of coal conversion facilities

Program Unit Objective: Consideration will be given to determine the size of both the construction and operating work forces of a coal conversion facility and their combined effect on the physical environment.

Scope: The size of the construction force and the operating force will be determined. The time phasing of the buildup of the construction force will be projected, and its impact on the environment relative to its size will be considered. The transition from a large construction population to that of the operating personnel will be considered. And options for accomplishing this transition with minimum impact on the physical environment will be identified.

Milestones:

1. Develop time-frame for construction of various types of coal conversion facilities with estimates of employment based on size of facility.

2. Develop time-frame of demand for housing and services.

3. Assessment of community's ability to supply land and services determined.

Technology Development Time Frame: Should begin early with demonstration plants.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$240,000
2. Per Year -	FY 1977	$ 60,000
	FY 1978	$ 60,000
	FY 1979	$ 60,000
	FY 1980	$ 60,000
	FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.3.3 Determine the total population trends associated with the size of the construction and operating populations

Program Unit Objective: The primary purpose is to determine the population trends associated with the size of the construction and operating work forces in order to assess the social, environmental, cultural, and institutional impact of a coal conversion facility on a community.

Scope: An assessment of the total population associated with, direct and indirect, the coal conversion facilities is required. Numbers of workers, dependents, including school age children, must be adequately identified for each conversion process. This will influence the social, environmental, cultural and institutional impacts of the technology and is basic to determining the physical environmental impacts. This research is supplemental to other socio-economic research.

Milestones:

1. Potential multiplier effects based on technology and size of plant determined.

2. Land-use requirements for construction and operation population determined.

3. Develop guidelines which will minimize land-use impacts.

Technology Development Time Frame: Studies of the types of employment and multiplier effects should begin early.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $180,000

2. Per Year - FY 1977 $ 60,000
   FY 1978 $ 60,000
   FY 1979 $ 60,000
   FY 1980 $ -0-
   FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.3.4 Determine the impacts of the increased population on the physical environment of regional recreational areas

Program Unit Objective: The primary purpose of this program unit is to determine the environmental and recreational impact of an increased population and to suggest possible solutions to minimize any potential disturbance of the environment due to this increased population.

Scope: The impacts of the increased population associated with coal conversion facilities on the area's recreational facilities must be carefully assessed. This is particularly important in regard to national/state/local recreational resources such as national/state parks and monuments, wilderness areas, lakes and streams. Potential problems will be identified and possible solutions carefully addressed.

Milestones:

1. Total and time-phased population impacts determined.
2. Existing recreational resources near proposed sites determined.
3. Future demands predicted and supplies assessed.

Technology Development Time Frame: Should begin late in the development of demonstration plants and at the time commercial plants are proposed.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $120,000
2. Per Year - FY 1977 $ -0-
   FY 1978 $ -0-
   FY 1979 $ 60,000
   FY 1980 $ 60,000
   FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.3.5 Determine population land-use impacts on indigenous wildlife habitat and activities

Program Unit Objective: Careful consideration will be given to determine the impact of increased land-use on indigenous wildlife imposed by the construction and working forces of a coal conversion facility.

Scope: The effects of population growth or redistribution contiguous to coal conversion facilities and the resultant impacts on wildlife will be carefully evaluated. Of particular importance are those species of either economic or recreational value. For example, the effects of a large development on the deer population will be considered as well as the effects of decreased water quality on native fish species.

Milestones:

1. Total potential land area expansion associated with each type of coal conversion facility and varying size determined.
2. Results of terrestrial impact research merged into a spatial model.
3. Wildlife habitat and population impacts determined.
4. Siting criteria developed.

Technology Development Time Frame: Should begin early in order to provide siting criteria.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1.	Total		$260,000
2.	Per Year -	FY 1977	$100,000
		FY 1978	$100,000
		FY 1979	$ 60,000
		FY 1980	$ -0-
		FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.3.6 Determine the cumulative water requirements of the residential and commercial developments attributable to the coal conversion industry

Program Unit Objective: This program will determine the water-use requirements of the residential and commercial developments attributable to a coal conversion facility and will determine if this increased water-use will have a deleterious effect on the allocation of a community's water supply.

Scope: The water requirements of the community and associated commercial and institutional facilities attributable to the development of a coal conversion facility must be determined. This is to include consumptive and recyclable water needs. This information will be of particular importance when considering conversion facilities in areas of restricted water availability. The impacts of these requirements on alternative uses, i.e., agriculture, must be assessed. This research will be integrated with the land-use demand research.

Milestones:

1. Determine the amounts and qualities of water necessary to supply construction and operating populations as well as agglomerative industries.

2. Develop siting criteria.

Technology Development Time Frame: Generic assessment should begin immediately to provide information as to competing water resource demands.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $220,000

2. Per Year -

FY	1977	$ 80,000
FY	1978	$ 80,000
FY	1979	$ 60,000
FY	1980	$ -0-
FY	1981	$ -0-

BER Balanced Program Plan

Program Unit

5.3.7 Identify the human, commercial, and industrial waste handling and disposal requirements and the resultant environmental impacts

Program Unit Objective: Consideration is necessary to identify the human, commercial, and industrial waste handling and disposal requirements of the community and the conversion facility. This is essential to determine if there will be a deleterious impact on the environment as a result of an over-extended waste handling and disposal system.

Scope: The requirements for the handling, processing and disposal of waste generated by the community and the coal conversion facility must be determined. This will include such items as sewage treatment and disposal, sanitary land fill or incineration requirements, and industrial waste disposal needs. The size, number, and life span of the areas will be determined and the resultant environmental impacts will be identified and categorized.

Milestones:

1. Determination of volumes and types of wastes to be handled.

2. Synergistic waste disposal impacts determined.

3. Land area needed to properly dispose and decontaminate waste determined.

Technology Development Time Frame: These studies should begin as soon as plant employment figures are determined and the multiplier effects on support employment are determined.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $120,000

2. Per Year -

FY 1977	$ -0-
FY 1978	$ 60,000
FY 1979	$ 60,000
FY 1980	$ -0-
FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.3.8 Determine the direct and secondary impacts off-site commercial, residential and industrial developments on the air shed

Program Unit Objective: The primary purpose of this program is to predict the impact of offsite commercial, residential, and industrial developments on the air shed and to evaluate the environmental impact of the potential buildup of air pollutants originating from these offsite developments.

Scope: The cumulative impacts of these developments on the air shed - short and long term - must be identified. The potential of the buildup of NO_x, SO_2 and other air pollutants will be assessed. Total effluent releases into the air will be predicted and local and regional environmental impacts identified.

Milestones:

1. Development of air shed models will accept multiple point source data on SO_2, NO_x etc. and potential deposition rates.

2. Results of ecological impacts of air pollution factored into spatial models.

3. Terrestrial and aquatic impacts predicted for various coal technology facilities at various locations.

Technology Development Time Frame: These studies should begin immediately to determine the air quality impacts of a large number of coal conversion facilities on local ambient conditions.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$280,000
2. Per Year -	FY 1977	$100,000
	FY 1978	$ 60,000
	FY 1979	$ 60,000
	FY 1980	$ 60,000
	FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.3.9 Determine the accessibility requirements necessary to support plant, community and supporting facilities

Program Unit Objective: This program will determine the accessibility requirements necessary to support plant, community, and supporting facilities and the environmental impact of providing these requirements.

Scope: The accessibility of the community and facilities to transportation routes, power transmission lines, pipelines, etc., must be analyzed. Requirements for roads, streets, sewers, powerlines, airports, etc., must be determined, and the environmental effects of providing these facilities must be determined.

Milestones:

1. Regional transportation requirements, based upon regional and national economic impacts, determined.

2. Secondary and tertiary impacts on regional transportation demands determined including the distribution and use of coal conversion products (i.e., pipelines, waterways, rail, etc.).

Technology Development Time Frame: This should begin and continue after potential candidate sites have been identified throughout the country in order for ERDA to plan for the development of support activities for coal conversion facilities.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $240,000

2. Per Year - FY 1977 $ -0-
FY 1978 $ 60,000
FY 1979 $ 60,000
FY 1980 $ 60,000
FY 1981 $ 60,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Integrated Assessment

Problem Title: Social and Demographic Effects (II.5.4.0)

Objectives: A comprehensive program for determining direct and indirect social effects of coal conversion technologies is needed. This program should include a basic set of standardized measurement techniques applicable to siting in a generic sense. Additionally, acceptable methods must be developed for application on a site by site basis, taking cognizance of widely varying extant social characteristics. Overall, the assessment method must include both near-field (site and immediate environs) and far-field (regional and beyond) capabilities, featuring provisions for incorporating all aspects of existing and/or competing technologies.

Priority: High

Program Unit Titles:

5.4.1 Public information program

5.4.2 Methodology for determining the structure of construction and operating populace

5.4.3 Evaluation of existing political structure

5.4.4 Evaluating community service capabilities

5.4.5 Social-cultural impacts assessment

BER Balanced Program Plan

Program Unit

5.4.1 Public information program

Program Unit Objective: To develop and implement a comprehensive program for (1) informing relevant "publics" about the proposed technology and its likely effects, and (2) channeling early and relevant citizen inputs into the site selection and development process.

Scope: A comprehensive program is needed for informing local citizenry concerning the various technical aspects of a proposed project, and for inputting citizen concerns to the site selection and development process. The program methodology would incorporate various techniques for reaching the local populace based on the particular social makeup of that population, and would provide sufficient information for personal judgment on the part of people themselves, as to what the proposes project might mean to their community and culture.

Milestones:

1. Plan development and elaboration.
2. Establish variety of interfaces with local and state officials and opinion leaders, and general public.
3. Disseminate assessments and information about proposed plant and technology through news media, special bulletins, public meeting.
4. Solicit, organize, and record citizen input on site selection process.
5. Evaluate effectiveness of information efforts through baseline and time series surveys, and other means.

Technology Development Time Frame: As new technology is brought on-line, public acceptance of the impacts and hazards which may be associated with conversion of coal must be addressed. This work should begin immediately and proceed throughout the five-year development program.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $732,000
2. Per Year - FY 1977 $120,000
   FY 1978 $132,000
   FY 1979 $145,000
   FY 1980 $110,000
   FY 1981 $175,000

BER Balanced Program Plan

Program Unit

5.4.2 Methodology for determining the structure of construction and operating populace

Program Unit Objective: Develop methodologies for (1) inventorying local labor force in terms of skills needed, employment rates, etc., (2) forecasting number and characteristics of construction and operating work force in terms of commuting ranges and in-migration, and (3) estimating secondary employment and effects upon existing labor forces from employment shifts.

Scope: Techniques are needed for inventorying local labor forces and for determining fairly precisely sources of manpower necessary to ameliorate deficiencies. A general approach toward defining structural characteristics of the construction and operating force and support personnel would comprise an integral part of the overall methodology. Such characterizations would form a base for forecasting the magnitude and extent likely 2° and 3° development on both local and/or regional scales.

Milestones:

1. Develop/document socio-economic regional profile emphasizing employment and labor force characteristics and patterns.

2. Survey local businesses and industries to determine present employment market.

3. Investigate labor force characteristics of similar scale construction projects elsewhere.

4. Determine manpower needed by interrelating regional labor force characteristics with recognized manpower necessary in other similar size construction projects.

5. Utilize established predictive models to estimate secondary effects of construction.

6. Document methodology for final report.

Technology Development Time Frame: Each feasible technology should be examined in terms of the impacts on local labor forces. This work should begin with the development of demonstration plants and continue as needed.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $120,000

2. Per Year - FY 1977 $ 60,000

FY 1977	$ 60,000
FY 1978	$ 60,000
FY 1979	$ -0-
FY 1980	$ -0-
FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.4.3 Evaluation of existing political structure

Program Unit Objective: Assess and evaluate local and relevant limited state institutional structure in terms of (1) structural characteristics, (2) history of operation, (3) degree of "professionalization" of staff, (4) capability to respond to and manage growth and change, (5) policy development process. Select interfacing approach and develop structure needed to interface with existing institutional arrangements.

Scope: A multi-phase program will be necessary for interfacing site selection and development with possible local, state and federal governmental institutions and policies. The program would be designed to evaluate various possible working arrangements with local and other authorities, and would allow for selection of a best practicable approach according to a particular set of conditions. Public budget capabilities also will be assessed to determine if communities can be expected to meet public works demands.

Milestones:

1. Assess strength, viability and proliferation of local political units.

2. Contact appropriate officials and establish intercommunication network.

3. Evaluate existing arrangements, and recommend improvements.

4. Establish clearing house of information and goal assessment. Provide opportunity for ongoing information exchange and correction.

Technology Development Time Frame: This work should begin immediately in order to mitigate the institutional problems which will occur as the result of large economic events such as the placement of a large coal conversion facility in a community, region and state.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $258,000

2. Per Year - FY 1977 $ 60,000
FY 1978 $ 66,000
FY 1979 $ 66,000
FY 1980 $ 66,000
FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.4.4 Evaluating community service capabilities

Program Unit Objective: Develop methodologies for defining and estimating public and private service needs of construction and operating work forces. Compare needs estimates with institutional and budget capability as assessed in 5.4.3. Devise mitigating measures (payments, assistance, and structures to administer both) to internalize social-institutional-economic costs on local and state levels.

Scope: A methodology is needed for defining service needs of the construction and operating force, and superimposing these on extant facilities. An array of mitigating measures will be developed and examined for cost effectiveness and public acceptibility.

Milestones:

1. Identify present levels of public and private services.
2. Compare present level of services with present and proposed population estimate.
3. Utilize predictive models to determine needed services for proposed population increases.
4. Devise mitigation strategies to internalize social, institutional and economic costs.

Technology Development Time Frame: This work should begin once construction of a demonstration plant is begun.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1.	Total		$126,000
2.	Per Year -	FY 1977	$ -0-
		FY 1978	$ 66,000
		FY 1979	$ 60,000
		FY 1980	$ -0-
		FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.4.5 Social-cultural impacts assessment

Program Unit Objective: Devise an overall social-cultural impact assessment utilizing previous assessments (5.4.1 - 5.4.4) on labor force demographic arrangements. Determine public acceptance of coal conversion products. Define short and long term as well as mitigatable and unmitigatable effects. Balance the above in an acceptable social cost/benefit evaluation.

Scope: A comprehensive methodology for overall assessment of social impacts on local and regional populations is needed. Inputs to the assessment scheme would be drawn from the combined results of technology assessments, products to be produced, and evaluations of extant social structure. Short- and long-term effects must be considered and ultimately an acceptable social cost and benefit balancing routine realized. This task would additionally draw on the other social and demographic effects sectors in providing an overall assessment of the impacts on social, demographic, economic, and political changes. An important part of the social impact assessment will be the determination of the public acceptance of coal conversion derived products.

Milestones:

1. Identify critical social-cultural impacts in the siting of coal conversion facilities to include considerations of labor force, demographics, taxes and institutional arrangements.

2. Develop a set of standardized measurement techniques applicable to the determination of social impact from the siting of coal conversion facilities.

3. Design a comprehensive methodology which would incorporate the various social cultural considerations into an overall assessment scheme.

4. Examine the assessment scheme in terms of its ability to handle near field and far field as well as short and long term effects.

5. Devise an acceptable social cost benefit routine which would incorporate considerations derived from the social cultural assessment methodology.

Technology Development Time Frame: Vital work for the siting feasibility studies and policy and public awareness work. Work should proceed immediately.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $337,000

2. Per Year -

FY 1977	$120,000
FY 1978	$132,000
FY 1979	$ 60,000
FY 1980	$ -0-
FY 1981	$ -0-

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Integrated Assessment

Problem Title: Regional, National and International Economic Impacts of Coal Conversion Facilities (II.5.5.0)

Objectives: Research is necessary to assess the regional multi-regional and national implications of coal conversion technologies using scenarios varying the number and type of energy production facilities and demands for products derived. Scales to be examined should be from sub-state area to international and should focus upon: market analysis of coal and coal products; economic demand analysis for siting; and fuel-cycle cost/benefit analysis to determine regional mixes of coal conversion facilities.

Priority: High

Program Unit Titles:

5.5.1 Assessment of major coal regions capacity to supply coal conversion facilities

5.5.2 Determination of optimal number and mixture of coal conversion facilities

BER Balanced Program Plan

Program Unit

5.5.1 Assessment of major coal regions capacity to supply coal conversion facilities

Program Unit Objective: The objective of this unit is to project coal market conditions in the absence and presence of conversion facilities to establish the degree of disruption associated with the additional facilities.

Scope: The ability of major coal regions to supply coal conversion facilities without disrupting existing coal market regions should be studied and a regional economic demand model developed which would assist in minimizing regional market impacts with the siting of one or more coal conversion facilities. Detailed analysis of existing and future coal markets should be constructed. Any new Federal or state legislative and tax programs should be factored into the analysis. Regional demand models should be developed.

Milestones:

1. Modify existing regional coal demand models, and project baseline coal demands.

2. Develop method for forecasting future supply potential of coal producing areas.

3. Combine supply and demand analysis to determine areas of potential excess supply.

4. Modify analysis as appropriate to consider the impact of institutional changes.

Technology Development Time Frame: This assessment is vital to all siting work and the ability to determine the number and size of plants which should be constructed.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $1,000,000

2. Per Year -

FY 1977	$	500,000
FY 1978	$	500,000
FY 1979	$	-0-
FY 1980	$	-0-
FY 1981	$	-0-

BER Balanced Program Plan

Program Unit

5.5.2 Determination of optimal number and mixture of coal conversion facilities

Program Unit Objective: The objective of this unit is to determine the site-specific characteristics of coal conversion technologies as reflected in costs, and within the constraint of projected demands determine an optimal deployment strategy.

Scope: Study should be conducted to determine the net energy input/output expenditure ratios for various coal conversion technologies using varying cost and benefit accruals and to determine the viability and appropriate mixture of number and type of coal conversion facilities. Raw material costs (extraction, reclamation, etc.), production costs, waste disposal costs, transportation costs, and product manufacture and marketing costs should be studied in detail to assess the relative economic benefits and costs of coal conversion operations in comparison to other energy production technologies. National energy scenarios should be constructed with varying constraints and objectives depending on types of products produced.

Milestones:

1. Develop cost models that consider site-specific cost characteristics of alternative conversion technologies.

2. Develop transportation models that relate transport costs from facility to plant of final demand.

3. Develop schedule of optimal mixture of coal conversion facilities under alternative levels of demand.

4. Contrast schedule developed in 3. with alternative supply scenarios to determine optimal number of plants.

Technology Development Time Frame: This work is related to the program plans noted in section 5.7.0. Work should begin immediately.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $630,000

2. Per Year -

Per Year -	FY 1977	$200,000
	FY 1978	$250,000
	FY 1979	$ 60,000
	FY 1980	$ 60,000
	FY 1981	$ 60,000

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Integrated Assessment

Problem Title: Local Economic Impacts Associated with Siting of Coal Conversion Facilities (II.5.6.0)

Objectives: Research should focus upon economic constraints likely to exist within most communities to respond to the needs of coal conversion facilities. Local impacts will be measurable in changes in tax rates and the demand and expenditure of local revenues. Income streams should be calculated to determine money flow which likely to ensue once coal conversion facilities are constructed. Multiple effects should be calculated. Some of the specific studies which should be conducted are: case study and model construction of local income flows; cost/benefit analysis of siting for direct and long-term impacts; development of an assessment model of tax structure impacts; and development and operationalization of capital investment model.

Priority: High

Program Unit Titles:

5.6.1 Identification and quantification of local economic structures and multiple effects

5.6.2 Local costs and benefits associated with siting coal conversion facilities

5.6.3 Impacts on local tax structures of siting coal conversion facilities

5.6.4 Study of capital investments associated with coal conversion facilities and local impacts

BER Balanced Program Plan

Program Unit

5.6.1 Identification and quantification of local economic structures and multiple effects

Program Unit Objective: The objective of this unit is to determine if different coal conversion technologies produce different local economic effects and the characteristics of local communities that enhance and/or diminish these effects.

Scope: Identify and quantify sources of income flow to local economies. Multiple effects should be calculated on the basis of the basic/non-basic income ratios for various coal conversion operations. These analyses should be undertaken for pilot plants as well as proposed commercial plants. Case studies of local economic impacts resulting from the siting of technological facilities economically similar to coal conversion facilities will be conducted to characterize and quantify probable changes in local economic structure which resulted from proposed coal conversion facilities. Existing economic theory will be utilized where applicable. Models will then be developed to simulate and predict the changes in local economic structure resulting from the siting of various types and sizes of coal conversion facilities.

Milestones:

1. Identify specific sources of expenditure of alternative conversion facilities.

2. Identify specific characteristics of localities that determine local expenditure flows.

3. Construct general economics model for measuring economic impacts.

4. Conduct case studies to gather data for implementing economic model.

Technology Development Time Frame: This work should be coupled with the regional impact assessments of possible multiplier effects previously noted. Work should begin simultaneously with the construction of demonstration plants and commercial plants.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1.	Total		$192,000
2.	Per Year -	FY 1977	$ 60,000
		FY 1978	$ 66,000
		FY 1979	$ 66,000
		FY 1980	$ -0-
		FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.6.2 Local costs and benefits associated with siting coal conversion facilities

Program Unit Objective: The objective of this unit is to determine the timepath of local benefits and costs associated with coal conversion facilities sitings.

Scope: Identify and quantify the immediate and long-range (beyond initial construction) impacts in terms of costs and benefits which either accrue to local communities. Cost/benefit ratios will be calculated for immediate and long-term effects such as increases in populations, increased tax revenue, increased demand for public facilities, and increased demand for commercial and personal services over short terms and long terms.

Milestones:

1. Modify model developed in 5.6.1 to operate annually.
2. Modify model developed in 5.6.1 to include participation rates and activity rates for appropriate population, tax rate/public service variables.
3. Operate model for case studies corresponding to 5.6.1.

Technology Development Time Frame: Costs/benefit analyses will be necessary for impact statements in each location event. Methodologies should be developed before needed. Work should begin immediately.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1. Total $132,000
2. Per Year - FY 1977 $ 66,000
   FY 1978 $ 66,000
   FY 1979 $ -0-
   FY 1980 $ -0-
   FY 1981 $ -0-

BER Balanced Program Plan

Program Unit

5.6.3 Impacts on local tax structures of siting coal conversion facilities

Program Unit Objective: The objective of this research is to provide an in-depth examination of public service costs and tax base changes that will be associated with coal conversion facilities under alternative siting conditions.

Scope: This research should assess the capacity of local tax systems to absorb and pay for services which must be provided to coal conversion facilities. This should include an analysis of the amount of taxes which should be assessed to pay for commodity services to the facility and the construction and operating employment. This analysis should be coordinated with monitoring of community costs of proposed pilot plants and the development of a tax impact assessment model based upon various sizes and types of coal conversion facilities.

Milestones:

1. Based on the economic information provided through 5.6.1, generate tax base charges that will be associated with alternative conversion facilities.

2. Integrate tax base findings with model developed in 5.6.2.

3. Based on participation rates associated with 5.6.2, develop public service costs associated directly and indirectly with alternative conversion facilities.

4. Integrate public service cost findings with model developed in 5.6.2.

Technology Development Time Frame: Local tax impact studies should begin with demonstration plants and generalized impact models developed before full-scale plants are sited.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$226,000
2. Per Year -	FY 1977	$100,000
	FY 1978	$ 66,000
	FY 1979	$ 60,000
	FY 1980	$ -0-
	FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.6.4 Study of capital investments associated with coal conversion facilities and local impacts

Program Unit Objective: The purpose of this objective is to construct a theoretical model, based on existing regional trade theory, that can be used to analyze facility investment decisions.

Scope: The proper local/external investment ratio should be determined which will best benefit local economies in terms of money circulation in local economies and flow of money outside of community. Monitoring of proposed pilot plants and similar energy production industries should be undertaken with these results factored into a theoretical model designed to optimize the capital investment benefits for local communities.

Milestones:

1. Construct regional investment/local investment model.

2. Gather data from plans for proposed pilot plants and similar facilities.

3. Analyze data through theoretical model.

Technology Development Time Frame: Investigation of local and regional investment economies where potential sites are located must be undertaken before development. Work should begin immediately.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$220,000
2. Per Year -	FY 1977	$100,000
	FY 1978	$ 60,000
	FY 1979	$ 60,000
	FY 1980	$ -0-
	FY 1981	$ -0-

BER Balanced Program Plan

Problem Definition

Technology: Coal Conversion

King-Muir Category: Integrated Assessment

Problem Title: Siting Coal Conversion Facilities (II.5.7.0)

Objectives: A regional assessment of social, economic, and ecologic factors in the siting of advanced coal conversion facilities including coal liquefaction, gasification, and fluidized - bed combustion will be prepared. The objectives will be to: evaluate their regional feasibility; preselect candidate siting areas; and develop information and generic methods of analysis applicable to the preparation and evaluation of environmental impact reports. Three capabilities will contribute to the development of scenarios of future energy production to the year 2020.

Priority: High

Program Unit Titles:

5.7.1 Siting criteria for coal conversion facilities

5.7.2 Multi-scale geographic base file for siting analysis

5.7.3 Siting variables at the regional scale (county-level data)

5.7.4 Screening for candidate siting areas

5.7.5 Siting at the local scale within candidate siting areas

5.7.6 Fine screening for candidate areas within candidate counties

5.7.7 Comparison of the number and capacity of suitable sites for coal conversion

BER Balanced Program Plan

Program Unit

5.7.1 Siting criteria for coal conversion facilities

Program Unit Objective: Identification and analysis of siting criteria for coal conversion facilities.

Scope: Engineers, planners, and environmentalist with experience in coal conversion technology and associated impacts will be utilized in structured policy analysis sessions (nominal group process) to determine specific data requirements and screening criteria. Output from these sessions will be utilized to structure siting criteria for site screening and selection analysis.

Technology Development Time Frame: These workshops to identify and specify the technology siting needs and constraints should begin immediately and continue annually as the new technology is added.

Milestones:

1. Hold workshops to determine siting criteria.
2. Catalog specific siting criteria for each type of facility in computer accessible form.
3. Update criteria as new information becomes available.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $150,000
2. Per Year - FY 1977 $ 50,000
   FY 1978 $ 25,000
   FY 1979 $ 25,000
   FY 1980 $ 25,000
   FY 1981 $ 25,000

BER Balanced Program Plan

Program Unit

5.7.2 Multi-scale geographic base file for siting analysis

Program Unit Objective: Development of a multi-scale geographic base file for the U. S.

Scope: The geographic information problems of collection, storage, retrieval, and analysis of spatial data will be examined. Specific recommendations will be made regarding the optional cell sizes for data collection and the proper level of analysis for each data variable. Data input will be determined on the basis of the criteria provided by technology experts.

Milestones:

1. Determine types of data required for evaluating facility sites (Unit 5.7.1), including spatial resolution, temporal patterns, and units of measure.

Technology Development Time Frame: Geographic information systems are currently being developed to handle coal combustion and nuclear technologies. These capabilities should be augmented to handle coal conversion site screening needs.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$200,000
2.	Per Year -	FY 1977	$100,000
		FY 1978	$ 50,000
		FY 1979	$ 50,000
		FY 1980	$ -0-
		FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.7.3 Siting variables at the regional scale (county-level data)

Program Unit Objective: Data collection of key siting variables at the regional scale (county-level data).

Scope: Data items ranking high in the siting criteria (determined in Unit 5.7.1) will be collected for the U. S. at the county level. Extant data sources will be utilized where possible, but some data collection and compilation will be necessary.

Milestones:

1. Collect, edit, and enter selected data (Unit 5.7.1 and 5.7.2) into data base developed in Unit 5.1.5.

Technology Development Time Frame: Data collection for other energy technologies is currently underway. These data compilation tasks should be augmented in financial support to handle coal conversion siting needs.

Program Unit Priority: High

Estimated Program Unit Cost:

1.	Total		$100,000
2.	Per Year -	FY 1977	$ 50,000
		FY 1978	$ 50,000
		FY 1979	$ -0-
		FY 1980	$ -0-
		FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.7.4 Screening for candidate siting areas

Program Unit Objective: Coarse screening for candidate siting areas based on county-level data.

Scope: Siting criteria (determined in Unit 5.7.1) will be expressed quantitatively to indicate the importance of each factor in the geographic base file (Unit 5.1.5) relative to all other factors and to measure the compatibility of coal conversion facilities with each range of a variable. A suitability score will be calculated for each county for accepting a specific type of coal conversion facility.

Milestones:

1. Calculate suitability scores for siting specific types of facilities.

2. Identify counties that have major constraints which would preclude siting any facilities.

Technology Development Time Frame: A siting model capable of handling coal conversion facilities is currently being developed at ORNL. This model will have to be modified to handle coal conversion facilities with differing criteria and data input.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$75,000
2. Per Year -	FY 1977	$50,000
	FY 1978	$25,000
	FY 1979	$-0-
	FY 1980	$-0-
	FY 1981	$-0-

BER Balanced Program Plan

Program Unit

5.7.5 Siting at the local scale within candidate siting areas

Program Unit Objective: Data collection of key siting variables at the local scale within candidate counties.

Scope: Additional data items ranking high in the siting criterial (determined in Unit 5.7.1) will be collected for local areas within the counties scoring highest in the coarse screening of Unit 5.7.4. These data will represent spatial units (cells) of the size recommended in Unit 5.7.2.

Milestones:

1. Collect data within candidate counties for selecting sites within a county.

Technology Development Time Frame: This detailed assessment of suitable sites for many coal conversion facilities should begin in FY77 and continue as long as necessary. Such assessments will reduce the need for many comprehensive environmental impact statement preparations.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total $300,000

2. Per Year -

FY 1977	$ 75,000
FY 1978	$150,000
FY 1979	$ 75,000
FY 1980	$ -0-
FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.7.6 Fine screening for candidate areas within candidate counties

Program Unit Objective: Fine screening for candidate areas based on cellular data within candidate counties.

Scope: Siting criteria (determined in Unit 5.7.1) will be expressed quantitatively to indicate the importance of each variable in the geographic base file (Unit 5.7.5) relative to all other variables and to measure the compatibility of coal conversion facilities with each range of a variable. A suitability score will be calculated for each cell.

Milestones:

1. Calculate suitability scores for cells within candidate counties for siting energy facilities.

Technology Development Time Frame: Fine screening should begin in FY77 or when specific number of sites are chosen.

Program Unit Priority: Medium

Estimated Program Unit Cost:

1.	Total		$150,000
2.	Per Year -	FY 1977	$100,000
		FY 1978	$ 50,000
		FY 1979	$ -0-
		FY 1980	$ -0-
		FY 1981	$ -0-

BER Balanced Program Plan

Program Unit

5.7.7 Comparison of the number and capacity of suitable sites for coal conversion

Program Unit Objective: A comparison of the number and capacity of suitable sites for coal conversion facilities with the requirements projected in national screening of energy production to the year 2020.

Scope: Previous scenarios of future energy demand have been used to aggregate national or regional data to project production requirements to the year 2020. The objective of this research is to compare the projected requirements with the number of suitable sites available.

Milestones:

1. Compare projected energy requirements against potential production based on allocating energy facilities to suitable sites.

2. Optimize allocation of energy facilities based on suitability of sites and energy needs.

Technology Development Time Frame: This task cannot begin until potential sites for facilities are selected. It should begin as soon as possible, however, because of suspected impacts of coal conversion facilities on water availability and quality.

Program Unit Priority: High

Estimated Program Unit Cost:

1. Total		$100,000
2. Per Year -	FY 1977	$ 50,000
	FY 1978	$ 50,000
	FY 1979	$ -0-
	FY 1980	$ -0-
	FY 1981	$ -0-

III. RESEARCH REQUIREMENTS (MATRIX DISPLAYS AND SUMMARY 5-YEAR BUDGET)

INTRODUCTION

The purpose of this section is to outline a framework for biomedical and environmental research related to coal conversion technologies. This section is divided into three parts. The first deals with research necessary at specific sites for model demonstration and commercial plants. The second part concerns that research applicable to all alternative processes; the research differs from that in the first part in that (a) it can be performed at research facilities other than the plant site and (b) the importance of a Program Unit will vary with different aspects of the fuel cycle. The final part of this section contains cost summaries by King-Muir categories and Program Units for the first five years of the balanced program.

III.1 SITE-SPECIFIC RESEARCH FOR MODEL DEMONSTRATION AND COMMERCIAL PLANTS

Table III.1-1 contains a matrix display of the Problem and Program Units for each King-Muir category, with specific planned demonstration or commercial plants. Model plants include: (1) three gasification units [Lurgi, WESCO, Four Corners, New Mexico, planned 1978 operation (high Btu); Lurgi coupled with power plant, EPRI and Commonwealth Edison, Powerton, Illinois, planned 1978 operation (low Btu); and in-situ, LERC, Laramie, Wyoming, projected 1985 commercial (low Btu)]; (2) two liquefaction units [H-Coal, Hydrocarbon Research Inc., Catlettsburg, Kentucky, planned 1977 operation; Coalcon, Union Carbide, New Athens, Illinois, planned 1979 operation (liquid and high Btu)]; and (3) research and development facilities (i.e., PERC, LERC, ORNL).

The research suggested for these model plants includes both preoperational (two years) and operational (two to three years) environmental studies (Problem 3.7) clinical and epidemiological health surveys [Program Units 2.3.4, 2.4(1-4) and 2.5(1-3)] and related CMM research. In addition to the model plants, the health-related research (i.e., Problems 2.3, 2.4, and 2.5) and the CCM research should also be conducted at research facilities involved in development of coal conversion technology (i.e., PERC, ORNL). The costs for this have not been included in the budgets.

III.2 GENERAL RESEARCH PLAN

The goal of biomedical and environmental research in coal conversion is to evaluate processes and materials to determine potential biomedical/ environmental problems and to feed such information to design engineers

CHARACTERIZATION, MEASUREMENTS, AND MONITORING

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Model Demonstration or Commercial Plant

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Lurgi (WESCO '78)					Lurgi + Power Plant (CON ED '78)					H-Coal (Hydrocarbon Res., Inc. '78)					Carbon./Hydro-carbon. (UCC & Gen. Tire '79)					In-situ Gasification					Research Facilities				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
1.1.0 Sampling																														
1.1.1 Production of Material	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.1.2 Devices	B	C	C	B	B	B	B	C	B	B	B	B	C	B	B	B	B	C	B	B	A	A	C	B	A	B	B	C	A	B
1.1.3 Stability	B	C	C	A	B	B	B	C	A	B																				
1.1.4 Preservation	B	C	C	A	B	B	B	C	A	B	B	B	C	A	B	B	B	C	A	B	B	C	C	A	A	C	B	C	A	B
1.2.0 Methodology R/D																														
1.2.1 Inventory	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	C	C	C	B	C
1.2.2 Separations	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.2.3 Screening	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.2.4 Specifics	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.2.5 Classes	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.2.6 In-Situ Methods	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	B	C
1.2.7 Exposure Support	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B
1.3.0 Characterization																														
1.3.1 Quality Assurance	B	B	C	B	B	B	B	C	B	B	B	B	C	B	B	B	B	C	B	B	B	B	C	B	B	C	C	C	B	B
1.3.2 Process Streams	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.3.3 Airborne	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.3.4 Aqueous	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	B	A	A	B	A	A
1.3.5 Solids	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A
1.4.0 Instruments																														
1.4.1 Inventory	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B	B	B	B	A	B
1.4.2 Occupational	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A
1.4.3 Environmental	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	B	B	B	A	B	A	A	B	A	A
1.4.4 R/D Types	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B

HEALTH EFFECTS

COAL CONVERSION

Process: Model Demonstration or Commercial Plant

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Lurgi (WESCO '78)					Lurgi + Power Plant (CON ED '78)					H-Coal (Hydrocarbon Res., Inc. '78)					Carbon./Hydro-carbon. (UCC & Gen. Tire '79)					In-situ Gasification					Research Facilities				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
2.1.0 Toxic Materials																														
2.1.1 Information Review																														
2.1.2 Potential Health Effects																														
2.1.3 Methodology																														
2.2.0 Dose-Effect Relationships																														
2.2.1 Chemical and Bio-chemical Methods																														
2.2.2 Acute and Chronic																														
2.2.3 Biological Indi-cators																														
2.3.0 Methodology																														
2.3.1 Indicators of Sub-clinical Effects	A					A					A					A					A					A				
2.3.2 Utility of Methods	A					A					A					A					A					A				
2.3.3 Clinical Parameters	A					A					A					A					A					A				
2.3.4 Epidemiological Studies	A	A	C	A	B	A	A	C	A	B	A	A	C	A	B	A	A	C	A	B	A	A	C	A	B	A	A	C	A	B
2.4.0 Industrial Hygiene & Safety																														
2.4.1 Monitoring Techniques	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A
2.4.2 Skin & Equipment Surface Contam.	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Model Demonstration or Commercial Plant

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Lurgi (WESCO '78)					Lurgi + Power Plant (CON ED '78)					H-Coal (Hydrocarbon Res., Inc. '78)					Carbon./Hydro-carbon. (UCC & Gen. Tire '79)					*In-situ* Gasification					Research Facilities				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
2.4.3 Protective Devices	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A	A	A	C	A	A
2.4.4 Emergency Procedures	A	B	C	B	B	A	B	C	B	B	A	B	C	B	B	A	B	C	B	B	A	B	C	B	B	A	B	C	B	B
2.5.0 Clinical Studies Methodology																														
2.5.1 Exposed Populations	C	B	C	B	C	C	B	C	B	C	C	B	C	B	C	C	B	C	B	C	C	B	C	B	C	C	C	C	C	C
2.5.2 Epidemiological Procedures	C	B	C	B	C	C	B	C	B	C	C	B	C	B	C	C	B	C	B	C	C	B	C	B	C	C	C	C	C	C
2.5.3 Accident Concepts	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
2.6.0 Knowledge of Deleterious Effects																														
2.6.1 Design of Testing Procedures																														
2.6.2 Remedial and Protective Procedures																														
2.6.3 Extrapolation from Lab Tests																														

ENVIRONMENTAL EFFECTS AND TRANSPORT

COAL CONVERSION

Process: Model Demonstration or Commercial Plant

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. *Information need*
4. Urgency

King-Muir Category	Lurgi (WESCO '78)					Lurgi + Power Plant (CON ED '78)					H-Coal (Hydrocarbon Res., Inc. '78)					Carbon./Hydro-carbon. (UCC & Gen. Tire '79)					In-situ Gasification					Research Facilities				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
3.1.0 Acute Effects																														
3.1.1 Aquatic																														
3.1.2 Terrestrial																														
3.2.0 Chronic Effects																														
3.2.1 Several generations																														
3.2.2 Long-Term Studies																														
3.2.3 Background Environmental Factors																														
3.3.0 Microcosm Studies																														
3.3.1 Direct Effects																														
3.3.2 Indirect Effects																														
3.4.0 Effects Model Development																														
3.4.1 Population																														
3.4.2 Ecosystem																														
3.4.3 Verification																														
3.5.0 Routes, transformations, sinks																														
3.5.1 Terrestrial																														
3.5.2 Soils																														
3.5.3 Aquatic																														
3.5.4 Sediments																														

ENVIRONMENTAL EFFECTS AND TRANSPORT (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Model Demonstration or Commercial Plant

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Lurgi (WESCO '78)					Lurgi + Power Plant (CON ED '78)					H-Coal (Hydrocarbon Res., Inc. '78)					Carbon./Hydro-carbon. (UCC & Gen. Tire '79)					In-situ Gasification					Research Facilities				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
3.6.0 Modelling																														
3.6.1 Biotransformation																														
3.6.2 Soils, sediments																														
3.7.0 Operational Studies																														
3.7.1 Preoperational and Operational Studies	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	B	A	B	A	A					

PHYSICAL AND CHEMICAL PROCESSES AND EFFECTS

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Model Demonstration or Commercial Plant

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Lurgi (WESCO '78)					Lurgi + Power Plant (CON ED '78)					H-Coal (Hydrocarbon Res., Inc. '78)					Carbon./Hydrocarbon. (UCC & Gen. Tire '79)					In-situ Gasification					Research Facilities				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
4.1.0 Physical Transport																														
4.1.1 Atmospheric																														
4.1.2 Dispersion/distribution																														

and waste management personnel to ensure development of technologies most amenable to man and his environment. Two basic "populations" of humans are addressed.

Research for ensuring safety of industrial workers is most easily implemented and of more immediate concern (because industrial and research workers are currently in contact with these materials) than that research necessary to evaluate potential effects on the general public and the environment. Such research can be executed most rapidly because information on environmental transport and transformation is not necessary. Initially, acute effects studies must be conducted to determine carcinogenic and toxic potential of process, products, and effluent materials. These tests should be concerned with determining the concentration of materials necessary to produce specific health effects as well as the effect produced by expected ambient concentrations. Modes of delivery should be determined by potential modes of human contact (i.e., gaseous effluents by inhalation and skin contact). Since material mobility and transformation need be of little concern (time frame and spatial transport negate these), initial toxicological screening can be done on a hierarchial tier (composite materials, fractions, specific compounds). Information on the potential hazards of composite materials process streams and effluents needs to be made available to design engineers so that hazardous emissions to the work environment can be minimized. The information on composite materials will be of further use in that it will aid in determining where initial work on fractions and specific compounds should proceed. Such research should include rapid screening tests because the need for information to protect the industrial worker is immediate. Concomitant with this research, a critical review of the literature should be conducted which includes investigation of similarities and differences in coal conversion materials and petroleum materials and, consequently, the use of clinical and epidemiological data from this source.

Rapid screening tests (acute toxicity) of composite materials in aquatic and terrestrial environments should be conducted. The purpose of these relatively rapid screening tests are twofold. First, and foremost, they will allow early installation of engineering changes necessary to maintain environmental integrity in response to emissions from coal conversion technology. Secondly, such screening tests will aid in selecting those fractions and specific compounds which need to be investigated in more detailed, time consuming, and expensive research.

While research related to the health of coal conversion workers is of most immediate need it is not the most significant long-term problem affecting the general human population or affecting the ultimate acceptability of coal conversion technologies. That biomedical and environmental research which ultimately will play a decisive role in the future of coal conversion centers on the effects of chronic exposures to large (perhaps all) segments of the population and general environment resulting from product use or process and effluent exposures (i.e., inhalation, drinking of contaminated water, etc.). Biomedical and environmental research to evaluate these risks is, by its very nature, time consuming

CHARACTERIZATION, MEASUREMENTS, AND MONITORING

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
1.1.0 Sampling																									
1.1.1 Production of Material	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.1.2 Devices	C	B	C	B	C	B	B	C	A	B	A	A	A	A	A	B	B	C	B	B	B	B	B	B	B
1.1.3 Stability	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	C	C	C	B	C
1.1.4 Preservation	C	C	C	B	C	B	B	A	B	B	A	B	A	A	A	C	C	B	A	C	C	C	C	B	C
1.2.0 Methodology R/D																									
1.2.1 Inventory	B	B	B	A	B	B	A	B	A	A	B	B	B	A	A	B	B	B	A	B	B	B	B	A	A
1.2.2 Separations	B	B	B	B	B	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A
1.2.3 Screening	B	B	C	C	B	A	A	A	A	B	A	A	B	A	A	A	A	B	A	A	B	B	A	B	B
1.2.4 Specifics	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	B	B	B	B	B	A	B	B	A	A
1.2.5 Classes	B	A	A	A	B	A	B	A	A	A	A	A	B	A	A	B	B	B	A	B	B	B	B	B	B
1.2.6 In-Situ Methods	C	C	C	C	C	A	B	A	A	B	A	A	B	A	A	C	C	C	B	C	C	C	C	C	C
1.2.7 Exposure Support	C	C	C	C	C	B	B	B	B	B	B	B	B	A	B	C	C	C	C	C	C	C	C	C	C
1.3.0 Characterization																									
1.3.1 Quality Assurance	C	C	C	C	B	B	B	B	C	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C
1.3.2 Process Streams						A	A	B	A	B											B	B	B	B	B
1.3.3 Airborne											A	A	A	A	A						C	C	C	C	C
1.3.4 Aqueous											A	A	A	A	A						C	C	C	C	C
1.3.5 Solids	A	A	B	A	A						A	A	A	A	A						B	B	B	A	B
1.4.0 Instruments																									
1.4.1 Inventory	B	B	B	A	B	A	A	A	A	B	A	A	B	A	A	C	C	C	B	C	B	B	B	A	B
1.4.2 Occupational	B	C	C	A	B	A	A	A	A	A						B	A	B	B	C	A	A	A	A	A
1.4.3 Environmental	B	B	B	B	B						A	A	A	A	B	B	B	A	B	B	A	A	A	A	A
1.4.4 R/D Types	C	C	C	C	C	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C

HEALTH EFFECTS

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
2.1.0 Toxic Materials																									
2.1.1 Information Review	A	A	B	A	A	A	A	B	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A
2.1.2 Potential Health Effects	A	A	B	A	A	A	A	B	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A
2.1.3 Methodology	A	A	B	A	B	A	A	B	A	B	A	B	A	A	B	A	B	A	A	B	A	B	A	A	B
2.2.0 Dose-Effect Relationships																									
2.2.1 Chemical and Biochemical Methods	A	A	B	A	A	A	A	B	A	A	B	B	A	A	B	C	C	B	B	C	B	B	A	A	B
2.2.2 Acute and Chronic	A	A	B	A	A	A	A	B	A	A	B	B	A	A	B	C	C	B	B	C	B	B	A	A	B
2.2.3 Biological Indicators	A	A	B	A	B	A	A	B	A	B	B	B	A	A	B	C	C	B	B	C	B	B	A	A	B
2.3.0 Methodology																									
2.3.1 Indicators of Subclinical Effects	B	A	B	A	B	A	A	B	A	B	C	C	B	A	C	C	C	B	B	C	B	C	B	B	B
2.3.2 Utility of Methods	B	A	B	A	B	A	A	B	A	A	C	C	B	A	C	C	C	B	B	C	B	C	B	B	B
2.3.3 Clinical Parameters	B	A	B	A	B	A	A	B	A	B	C	C	B	A	C	C	C	B	B	C	B	C	B	B	B
2.3.4 Epidemiological Studies	B	A	B	A	B	A	A	B	A	B	C	C	B	A	C	C	C	B	B	B	B	C	B	B	B

HEALTH EFFECTS (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
2.4.0 Industrial Hygiene & Safety																									
2.4.1 Monitoring Techniques																									
2.4.2 Skin & Equipment Surface Contam.																									
2.4.3 Protective Devices																									
2.4.4 Emergency Procedures																									
2.5.0 Clinical Studies Methodology																									
2.5.1 Exposed Populations																									
2.5.2 Epidemiological Procedures																									
2.5.3 Accident Concepts																									
2.6.0 Knowledge of Deleterious Effects																									
2.6.1 Design of Testing Procedures	B	A	B	A	B	B	A	B	A	B	B	B	A	A	B	B	C	A	A	B	B	B	A	A	B
2.6.2 Remedial and Protective Procedures	B	A	B	A	B	B	A	B	A	B	B	B	A	A	B	B	C	A	A	B	B	B	A	A	B
2.6.3 Extrapolation from Lab Tests	B	A	B	A	B	B	A	B	A	B	B	B	A	A	B	B	C	A	A	B	B	B	A	A	B

ENVIRONMENTAL EFFECTS AND TRANSPORT

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					High BTU Only Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
3.1.0 Acute Effects																									
3.1.1 Aquatic	C	C	C	B	C	A	A	B	A	A	B	A	B	B	B	C	C	C	C	C	A	A	A	A	A
3.1.2 Terrestrial	C	C	C	B	C	A	A	B	A	A	B	B	B	B	C	C	C	C	C	C	A	A	A	A	A
3.2.0 Chronic Effects																									
3.2.1 Several generations	C	C	C	B	C	A	A	B	A	A	B	A	B	B	B	C	C	C	C	C	B	A	A	A	A
3.2.2 Long-Term Studies	C	C	C	B	C	A	A	B	A	A	B	A	B	B	B	C	C	C	C	C	B	A	A	A	A
3.2.3 Background Environmental Factors	C	C	C	B	C	B	C	C	C	C	B	C	C	C	C	C	C	C	C	C	B	C	C	C	C
3.3.0 Microcosm Studies																									
3.3.1 Direct Effects	C	C	C	C	C	A	A	A	A	B	B	A	A	A	B	C	B	B	B	C	B	A	A	A	B
3.3.2 Indirect Effects	C	C	C	C	C	A	A	A	A	C	B	A	A	A	B	C	C	C	C	C	B	A	A	A	B
3.4.0 Effects Model Development																									
3.4.1 Population	C	C	C	C	C	B	A	A	A	A	C	B	B	B	B	C	C	C	C	C	B	B	B	B	B
3.4.2 Ecosystem	C	C	C	C	C	B	A	A	A	B	C	B	B	B	B	C	C	C	C	C	B	B	B	B	B
3.4.3 Verification	C	C	C	C	C	B	A	A	A	B	C	B	B	B	B	C	C	C	C	C	C	B	B	B	B
3.5.0 Routes, transformation, sinks																									
3.5.1 Terrestrial						A	B	B	B	A	A	B	B	B	A										
3.5.2 Soils						A	B	B	B	A	A	B	B	B	A										
3.5.3 Aquatic						B	C	C	B	A	B	C	C	B	A										
3.5.4 Sediments						B	C	C	B	A	B	C	C	B	A										

ENVIRONMENTAL EFFECTS AND TRANSPORT (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					High BTU Only Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
3.6.0 Modelling																									
3.6.1 Biotransformation						B	B	A	B	B															
3.6.2 Soils, sediments						B	B	A	B	B	C	C	B	B	B										
3.7.0 Operational Studies																									
3.7.1 Preoperational and Operational Studies																									

PHYSICAL AND CHEMICAL PROCESSES AND EFFECTS

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
4.1.0 Physical Transport																									
4.1.1 Atmospheric						A	A	A	A	A	A	A	A	A	A						C	C	B	C	B
4.1.2 Dispersion/distribution						B	B	A	B	B	B	B	B	B	B						C	C	B	C	B

INTEGRATED ASSESSMENT

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.1.0 Data Management																									
5.1.1 Coordination and Management System	B	B	A	A	B	A	A	A	B	B	B	A	A	B	B	B	A	B	B	B	B	B	B	B	B
5.1.2 Data Acquisition	B	B	B	B	B	A	A	A	A	A	B	B	C	B	B	B	B	B	B	B	B	C	A	B	C
5.1.3 Computing Facilities	B	C	C	C	C	A	A	A	A	A	B	B	B	B	B	B	C	C	C	C	B	C	C	C	C
5.1.4 Environmental Information	B	C	C	A	C	A	A	A	A	A	B	A	A	A	A	B	C	C	A	C	B	B	B	B	B
5.1.5 National Geoecology Data	B	C	C	C	C	A	B	A	B	C	B	A	B	A	B	B	C	C	A	C	B	C	C	C	C
5.1.6 Source Terms and Effects	B	C	C	C	C	A	A	A	A	A	B	C	C	C	C	B	C	C	C	C	B	A	A	A	A
5.1.7 Data Processing	B	A	A	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A
5.1.8 Synthesis and Policy Analysis	B	A	A	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A
5.2.0 On-Site Impacts																									
5.2.1 Land Area Needs	B	B	C	A	C	A	A	A	A	A	A	A	A	A	A	B	C	C	B	C	C	C	C	C	C
5.2.2 Topography	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	C	B	C	C	C	C	C	C
5.2.3 Competing Land-Use Requirements	B	B	A	A	B	A	A	A	A	A	A	A	A	A	A	B	C	C	A	C	C	C	C	C	C
5.2.4 Impacts on Existing Land-Use	B	B	C	A	B	A	A	B	A	A	A	A	B	A	A	B	C	C	A	C	C	C	C	C	C
5.2.5 Accessibility	B	A	C	A	A	A	A	B	A	A	A	A	B	A	A	B	A	B	A	A	C	C	C	C	C
5.2.6 Total On-Site Demands	B	A	C	A	A	A	A	A	A	A	A	A	A	A	A	B	C	C	B	C	C	C	C	C	C
5.2.7 Institutional Constraints	B	A	A	B	A	A	A	A	B	A	A	A	A	B	A	B	C	C	A	C	C	C	C	C	C
5.2.8 Coal Resource Locations	B	A	B	A	B	A	A	A	A	A	A	B	B	A	B	B	B	B	A	C	C	C	C	C	C

INTEGRATED ASSESSMENT (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
5.3.0 Off-Site Impacts																									
5.3.1 Land-Use Demands	B	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	C	B	B	C
5.3.2 Land Area Needs	B	B	B	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B	B	C
5.3.3 Population Trends	B	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	C	B	B	C
5.3.4 Impacts of Increased Population	B	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	B	C	C	B	C
5.3.5 Population Land-Use Impacts	B	B	A	A	B	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B	A	B
5.3.6 Community Water	B	A	A	A	A	A	B	B	B	B	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A
5.3.7 Waste Handling	B	A	A	A	A	A	B	B	B	B	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B
5.3.8 Direct and Secondary Impacts	B	C	C	C	C	A	A	A	A	A	A	B	B	B	B	B	C	C	C	C	B	A	A	A	A
5.3.9 Accessibility	B	B	B	B	B	A	B	B	B	B	A	B	B	B	B	B	A	A	A	A	B	B	B	B	B
5.4.0 Social Effects																									
5.4.1 Public Information Programs	C	B	B	B	B	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	A	A	A	A	A
5.4.2 Methodology	C	B	B	B	A	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A
5.4.3 Existing Political Structures	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	A	A	A	A	A
5.4.4 Community Services	C	C	C	C	C	A	A	A	A	A	A	C	C	C	C	B	C	C	C	C	A	B	B	B	B
5.4.5 Impacts	C	C	C	C	C	A	A	A	A	A	A	C	C	C	C	B	C	C	C	C	A	A	A	A	A
5.5.0 Economic Effects																									
5.5.1 Major Coal Regions	A	B	B	B	B	A	A	A	A	A	B	A	A	A	A	B	B	B	B	B	A	A	A	A	A
5.5.2 Optimal Facilities	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	B	B	B	B	B	A	A	A	A	A

INTEGRATED ASSESSMENT (continued)

COAL CONVERSION

Process: Gasification (Surface, Lurgi)

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.6.0 Local Economy																									
5.6.1 Local Economic Structure	A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	A	C	C	C	C	B	B	B	B	B
5.6.2 Cost/Benefit Analysis	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B
5.6.3 Local Tax Structures	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C
5.6.4 Capital Investments	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B

CHARACTERIZATION, MEASUREMENTS, AND MONITORING

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Process: Liquefaction (H Coal, Carbonization/ Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
1.1.0 Sampling																									
1.1.1 Production of Material	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.1.2 Devices	A	A	B	A	A	B	B	C	B	B	B	B	B	B	B	B	B	B	A	B	B	B	B	B	B
1.1.3 Stability	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	C	C	C	B	C
1.1.4 Preservation	A	A	B	A	A	B	B	A	B	B	A	B	A	A	A	C	C	B	A	C	C	C	C	B	C
1.2.0 Methodology R/D																									
1.2.1 Inventory	A	A	B	A	A	B	A	B	A	B	B	B	B	A	A	B	B	B	A	B	B	B	B	A	A
1.2.2 Separations	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A
1.2.3 Screening	A	A	B	A	A	A	A	A	A	B	A	A	B	A	A	A	A	B	A	A	B	B	A	B	B
1.2.4 Specifics	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A	A	A	A	A	B	B	A	A
1.2.5 Classes	A	A	B	A	A	A	B	A	A	A	A	A	B	A	A	A	A	A	A	A	B	B	B	B	B
1.2.6 In-Situ Methods	C	C	C	C	C	B	B	B	B	B	A	A	B	A	A	C	C	C	B	C	B	B	B	A	B
1.2.7 Exposure Support	C	C	C	C	C	B	B	B	B	B	B	B	B	A	B	C	C	C	C	C	A	A	A	A	A
1.3.0 Characterization																									
1.3.1 Quality Assurance	B	B	B	A	B	B	A	B	C	C	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C
1.3.2 Process Streams						A	A	B	A	B											B	B	B	B	B
1.3.3 Airborne											A	A	A	A	A						C	C	C	C	C
1.3.4 Aqueous	A	B	B	A	A						A	A	A	A	A						C	C	C	C	C
1.3.5 Solids	A	A	B	A	A						A	A	A	A	A						B	B	B	A	B
1.4.0 Instruments																									
1.4.1 Inventory	B	B	B	A	B	A	A	A	A	B	A	A	B	A	A	C	C	C	B	C	B	B	B	A	B
1.4.2 Occupational	A	A	A	A	A	A	A	A	A	A						B	A	B	B	C	A	A	A	A	A
1.4.3 Environmental	B	B	B	B	B						A	A	A	A	B	B	B	A	B	B	A	A	A	A	A
1.4.4 R/D Types	C	C	C	C	C	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C

HEALTH EFFECTS

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Process: Liquefaction (H Coal, Carbonization/ Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
2.1.0 Toxic Materials																									
2.1.1 Information Review	B	B	C	A	B	A	A	A	A	A	B	B	A	A	B	A	B	A	A	A	A	A	A	A	A
2.1.2 Potential Health Effects	B	B	C	A	B	A	A	A	A	A	B	B	A	A	B	A	B	A	A	A	A	A	A	A	A
2.1.3 Methodology	B	C	C	C	C	A	A	A	A	A	B	B	A	A	B	A	B	A	A	A	A	A	A	A	A
2.2.0 Dose-Effect Relationships																									
2.2.1 Chemical and Biochemical Methods	A	A	B	A	B	A	A	A	A	A	A	B	A	A	B	A	B	A	A	B	A	A	A	A	B
2.2.2 Acute and Chronic	A	A	B	A	B	A	A	A	A	A	A	B	A	A	B	A	B	A	A	B	A	A	A	A	B
2.2.3 Biological Indicators	A	B	B	B	A	A	A	A	A	A	A	B	A	A	B	A	B	A	A	B	A	A	A	A	B
2.3.0 Methodology																									
2.3.1 Indicators of Subclinical Effects	B	A	B	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	A	A	A	A	B
2.3.2 Utility of Methods	B	A	B	A	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	A	A	A	A	B
2.3.3 Clinical Parameters	B	B	B	B	B	A	A	B	A	B	B	B	A	A	B	B	B	A	A	B	A	A	A	A	B
2.3.4 Epidemiological Studies	B	C	C	C	C	A	A	B	A	B	B	B	A	A	B	B	B	A	B	B	A	A	A	A	B

HEALTH EFFECTS (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Liquefaction (H Coal, Carbonization/
Process: Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
2.4.0 Industrial Hygiene & Safety																									
2.4.1 Monitoring Techniques																									
2.4.2 Skin & Equipment Surface Contam.																									
2.4.3 Protective Devices																									
2.4.4 Emergency Procedures																									
2.5.0 Clinical Studies Methodology																									
2.5.1 Exposed Populations																									
2.5.2 Epidemiological Procedures																									
2.5.3 Accident Concepts																									
2.6.0 Knowledge of Deleterious Effects																									
2.6.1 Design of Testing Procedures	A	A	B	A	A	A	A	B	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A
2.6.2 Remedial and Protective Procedures	A	A	B	A	A	A	A	B	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A
2.6.3 Extrapolation from Lab Tests	A	A	B	A	A	A	A	B	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A

ENVIRONMENTAL EFFECTS AND TRANSPORT

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Liquefaction (H Coal, Carbonization/
Process: Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
3.1.0 Acute Effects																									
3.1.1 Aquatic	B	C	C	A	C	A	A	A	A	A	B	B	A	A	B	B	A	B	A	B	A	A	A	A	A
3.1.2 Terrestrial	B	C	C	A	C	A	A	A	A	A	B	B	A	A	B	B	A	B	A	B	A	A	A	A	A
3.2.0 Chronic Effects																									
3.2.1 Several generations	B	C	C	A	C		A	A	A	A	B	B	A	B	B	C	B	B	B	B	A	A	A	A	A
3.2.2 Long-Term Studies	C	C	C	A	C		A	A	A	A	B	B	A	B	B	C	B	B	B	B	A	A	A	A	A
3.2.3 Background Environ-mental Factors	C	C	C	A	C		A	B	A	B	C	A	B	A	B	C	C	C	C	C	B	B	B	A	B
3.3.0 Microcosm Studies																									
3.3.1 Direct Effects	C	C	C	B	C		A	A	A	B	B	B	B	B	B	B	B	B	B	C	A	A	A	A	B
3.3.2 Indirect Effects	C	C	C	B	C		A	A	A	B	B	B	B	B	B	C	C	C	C	C	A	A	A	A	B
3.4.0 Effects Model Development																									
3.4.1 Population	C	C	C	B	C	B	B	B	A	B	B	B	B	B	C	C	C	C	B	C	B	B	A	A	B
3.4.2 Ecosystem	C	C	C	B	C	B	B	B	A	B	B	B	B	B	C	C	C	B	B	C	B	B	A	A	B
3.4.3 Verification	C	C	C	B	C	C	A	A	A	B	C	B	B	B	C	C	C	B	B	C	C	C	C	C	C
3.5.0 Routes, transforma-tions, sinks																									
3.5.1 Terrestrial						A	A	B	B	A	A	A	B	B	A						A	B	A	A	A
3.5.2 Soils						A	A	B	B	A	A	A	B	B	A	C	B	C	B	C	A	B	A	A	A
3.5.3 Aquatic						A	A	B	A	A	A	A	B	A	A	B	B	A	B	B	B	C	B	A	A
3.5.4 Sediments						A	A	B	A	A	A	A	B	A	A						B	C	B	A	A

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ENVIRONMENTAL EFFECTS AND TRANSPORT (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Liquefaction (H Coal, Carbonization/
Process: Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
3.6.0 Modelling																									
3.6.1 Biotransformation						B	A	B	B	B	B	A	B	B	B	C	C	B	B	C	B	B	A	B	A
3.6.2 Soils, sediments						B	A	B	B	B	B	A	B	B	B						B	B	A	B	B
3.7.0 Operational Studies																									
3.7.1 Preoperational and Operational Studies																									

PHYSICAL AND CHEMICAL PROCESSES AND EFFECTS

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Liquefaction (H Coal, Carbonization/ Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
4.1.0 Physical Transport																									
4.1.1 Atmospheric						A	A	B	B	A	A	A	B	B	A						A	A	A	A	A
4.1.2 Dispersion/distribution						B	A	B	B	B	B	A	B	B	B						A	A	A	B	A

INTEGRATED ASSESSMENT

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Process: Liquefaction (H Coal, Carbonization/ Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.1.0 Data Management																									
5.1.1 Coordination and Management System	B	B	A	A	B	A	A	A	B	B	B	A	A	B	B	B	A	B	B	B	B	B	B	B	B
5.1.2 Data Acquisition	B	B	B	B	B	A	A	A	A	A	B	B	C	B	B	B	B	B	B	B	B	C	A	B	C
5.1.3 Computing Facilities	B	C	C	C	C	A	A	A	A	A	B	B	B	B	B	B	C	C	C	C	B	C	C	C	C
5.1.4 Environmental Information	B	C	C	A	C	A	A	A	A	A	B	A	A	A	A	B	C	C	A	C	B	B	B	B	B
5.1.5 National Geoecology Data	B	C	C	C	C	A	B	A	B	C	B	A	B	A	B	B	C	C	A	C	B	C	C	C	C
5.1.6 Source Terms and Effects	B	C	C	C	C	A	A	A	A	A	B	C	C	C	C	B	C	C	C	C	B	A	A	A	A
5.1.7 Data Processing	B	A	A	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A
5.1.8 Synthesis and Policy Analysis	B	A	A	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	A	A
5.2.0 On-Site Impacts																									
5.2.1 Land Area Needs	B	B	C	A	C	A	A	A	A	A	A	A	A	A	A	B	C	C	B	C	C	C	C	C	C
5.2.2 Topography	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	C	B	C	C	C	C	C	C
5.2.3 Competing Land-Use Requirements	B	B	A	A	B	A	A	A	A	A	A	A	A	A	A	B	C	C	A	C	C	C	C	C	C
5.2.4 Impacts on Existing Land-Use	B	B	C	A	B	A	A	B	A	A	A	A	B	A	A	B	C	C	A	C	C	C	C	C	C
5.2.5 Accessibility	B	A	C	A	A	A	A	B	A	A	A	A	B	A	A	B	A	B	A	A	C	C	C	C	C
5.2.6 Total On-Site Demands	B	A	C	A	A	A	A	A	A	A	A	A	A	A	A	B	C	C	B	C	C	C	C	C	C
5.2.7 Institutional Constraints	B	A	A	B	A	A	A	A	B	A	A	A	A	B	A	B	C	C	A	C	C	C	C	C	C
5.2.8 Coal Resource Locations	B	A	B	A	B	A	A	A	A	A	A	B	B	A	B	B	B	B	A	C	C	C	C	C	C

INTEGRATED ASSESSMENT (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Process: Liquefaction (H Coal, Carbonization/ Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.3.0 Off-Site Impacts																									
5.3.1 Land-Use Demands	B	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	C	B	B	C
5.3.2 Land Area Needs	B	B	B	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B	B	C
5.3.3 Population Trends	B	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	C	B	B	C
5.3.4 Impacts of Increased Population	B	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	B	C	C	B	C
5.3.5 Population Land-Use Impacts	B	B	A	A	B	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B	A	B
5.3.6 Community Water	B	A	A	A	A	A	B	B	B	B	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A
5.3.7 Waste Handling	B	A	A	A	A	A	B	B	B	B	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B
5.3.8 Direct and Secondary Impacts	B	C	C	C	C	A	A	A	A	A	A	B	B	B	B	B	C	C	C	C	B	A	A	A	A
5.3.9 Accessibility	B	B	B	B	B	A	B	B	B	B	A	B	B	B	B	B	A	A	A	A	B	B	B	B	B
5.4.0 Social Effects																									
5.4.1 Public Information Programs	C	B	B	B	B	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	A	A	A	A	A
5.4.2 Methodology	C	B	B	B	B	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A
5.4.3 Existing Political Structures	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	A	A	A	A	A
5.4.4 Community Services	C	C	C	C	C	A	A	A	A	A	A	C	C	C	C	B	C	C	C	C	A	B	B	B	B
5.4.5 Impacts	C	C	C	C	C	A	A	A	A	A	A	C	C	C	C	B	C	C	C	C	A	A	A	A	A
5.5.0 Economic Effects																									
5.5.1 Major Coal Regions	A	B	B	B	B	A	A	A	A	A	B	A	A	A	A	B	B	B	B	B	A	A	A	A	A
5.5.2 Optimal Facilities	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	B	B	B	B	B	A	A	A	A	A

INTEGRATED ASSESSMENT (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION
Liquefaction (H Coal, Carbonization/
Process: Hydrocarbonization, Solvent Refined Coal)

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.6.0 Local Economy																									
5.6.1 Local Economic Structures	A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	A	C	C	C	C	B	B	B	B	B
5.6.2 Cost/Benefit Analysis	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B
5.6.3 Local Tax Structures	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C
5.6.4 Capital Investments	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B	B

CHARACTERIZATION, MEASUREMENTS, AND MONITORING

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification - In Situ

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
1.1.0 Sampling																									
1.1.1 Production of Material	A	A	A	A	A	A	A	A	A	A						A	A	A	A	A	A	A	A	A	A
1.1.2 Devices	C	B	C	B	C	B					B	B	B	B	A	B	B	C	B	B	B	B	B	B	B
1.1.3 Stability	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	C	C	C	B	C
1.1.4 Preservation	C	C	C	B	C	B	B	A	B	B	A	B	A	A	A	C	C	B	A	C	C	C	C	B	C
1.2.0 Methodology R/D																									
1.2.1 Inventory	B	B	B	A	B	B	A	B	A	A	B	B	B	A	A	B	B	B	A	B	B	B	B	A	A
1.2.2 Separations	B	B	B	B	B	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A
1.2.3 Screening	B	B	C	C	B	A	A	A	A	B	A	A	B	A	A	A	A	B	A	A	B	B	A	B	B
1.2.4 Specifics	A	A	B	A	A	A	A	B	A	A	A	A	B	A	A	B	B	B	B	B	A	B	B	A	A
1.2.5 Classes	B	A	B	A	B	A	B	A	A	A	A	A	B	A	A	B	B	B	A	B	B	B	B	B	B
1.2.6 In-Situ Methods	C	C	C	C	C	B	B	B	B	B	A	A	B	A	A	C	C	C	B	C	C	C	C	C	C
1.2.7 Exposure Support	C	C	C	C	C	B	B	B	B	B	B	B	B	A	B	C	C	C	C	C	C	C	C	C	C
1.3.0 Characterization																									
1.3.1 Quality Assurance	C	C	C	C	B	B	A	B	B	C	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C
1.3.2 Process Streams						A	A	B	A	B											B	B	B	B	B
1.3.3 Airborne											A	A	A	A	A						C	C	C	C	C
1.3.4 Aqueous											A	A	A	A	A						C	C	C	C	C
1.3.5 Solids	A	A	B	A	A						A	A	A	A	A						B	B	B	A	B
1.4.0 Instruments																									
1.4.1 Inventory	C	C	C	A	C	A	A	A	A	B	A	A	B	A	A	C	C	C	B	C	B	B	B	A	B
1.4.2 Occupational	B	C	C	A	B	A	A	A	A	A						B	A	B	B	C	A	A	A	A	A
1.4.3 Environmental	C	C	C	C	C						A	A	A	A	B	B	B	A	B	B	A	A	A	A	A
1.4.4 R/D Types	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	B	C

HEALTH EFFECTS

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification - In Situ

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
2.1.0 Toxic Materials																									
2.1.1 Information Review	A	A	B	A	A	A	A	B	A	A	B	B	A	A	A	B	B	B	A	B	B	B	A	A	B
2.1.2 Potential Health Effects	A	A	B	A	A	A	A	B	A	A	B	B	A	A	A	B	B	B	A	B	B	B	A	A	B
2.1.3 Methodology	A	A	B	A	B	A	A	B	A	B	B	B	A	A	B	B	B	B	A	C	B	B	A	A	B
2.2.0 Dose-Effect Relationships																									
2.2.1 Chemical and Bio-chemical Methods	A	A	B	A	A	A	A	B	A	A	B	B	A	A	B	C	C	B	B	C	B	B	A	A	B
2.2.2 Acute and Chronic	A	A	B	A	A	A	A	B	A	A	B	B	A	A	B	C	C	B	B	C	B	B	A	A	B
2.2.3 Biological Indi-cators	A	A	B	B	B	A	A	B	A	B	B	B	A	A	B	C	C	B	B	C	B	B	A	B	B
2.3.0 Methodology																									
2.3.1 Indicators of Sub-clinical Effects																									
2.3.2 Utility of Methods																									
2.3.3 Clinical Parameters																									
2.3.4 Epidemiological Studies																									

HEALTH EFFECTS (continued)

COAL CONVERSION

Process: Gasification - In Situ

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
2.4.0 Industrial Hygiene & Safety																									
2.4.1 Monitoring Techniques																									
2.4.2 Skin & Equipment Surface Contam.																									
2.4.3 Protective Devices																									
2.4.4 Emergency Procedures																									
2.5.0 Clinical Studies Methodology																									
2.5.1 Exposed Populations	C	C	B	B	C	C	C	B	B	C	B	C	A	A	B	B	C	A	A	B	B	C	A	A	B
2.5.2 Epidemiological Procedures	C	C	B	B	C	C	C	B	B	C	B	C	A	A	B	B	C	A	A	B	B	C	A	A	B
2.5.3 Accident Concepts	C	C	B	B	C	C	C	B	B	C	B	C	A	A	B	B	C	A	A	B	B	C	A	A	B
2.6.0 Knowledge of Deleterious Effects																									
2.6.1 Design of Testing Procedures	B	A	B	A	B	B	A	B	A	B	B	B	A	A	B	B	C	A	A	B	B	B	A	A	B
2.6.2 Remedial and Protective Procedures	B	A	B	A	B	B	A	B	A	B	B	B	A	A	B	B	C	A	A	B	B	B	A	A	B
2.6.3 Extrapolation from Lab Tests	B	A	B	A	B	B	A	B	A	B	B	B	A	A	B	B	C	A	A	B	B	B	A	A	B

ENVIRONMENTAL EFFECTS AND TRANSPORT

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification - In Situ

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
3.1.0 Acute Effects																									
3.1.1 Aquatic	C	C	C	C	C	A	A	B	A	B	A	A	B	A	C						A	A	B	A	B
3.1.2 Terrestrial	C	C	C	C	C	A	A	B	A	B	A	A	B	A	C						A	A	B	A	B
3.2.0 Chronic Effects																									
3.2.1 Several generations	C	C	C	C	C	A	A	B	A	B	A	A	B	A	C						A	A	B	A	B
3.2.2 Long-Term Studies	C	C	C	C	C	A	A	B	A	B	A	A	B	A	C						A	A	B	A	B
3.2.3 Background Environmental Factors	C	C	C	C	C	A	B	B	B	C	B	B	B	B	C						A	B	B	B	C
3.3.0 Microcosm Studies																									
3.3.1 Direct Effects	C	C	C	C	C	A	A	B	A	B	B	A	B	A	C						A	A	B	A	B
3.3.2 Indirect Effects	C	C	C	C	C	A	A	B	A	B	B	A	B	A	C						A	A	B	A	B
3.4.0 Effects Model Development																									
3.4.1 Population	C	C	C	C	C	A	A	B	A	C	B	A	B	A	C						A	A	B	A	C
3.4.2 Ecosystem	C	C	C	C	C	A	A	B	A	C	B	A	B	A	C						A	A	B	A	C
3.4.3 Verification	C	C	C	C	C	B	A	B	A	C	C	A	B	A	C						B	A	B	A	C
3.5.0 Routes, Transformations, sinks																									
3.5.1 Terrestrial						B	B	B	B	B	C	C	C	B	B						B	B	B	B	C
3.5.2 Soils						C	C	C	B	B	C	C	C	B	C						B	B	B	B	C
3.5.3 Aquatic						A	A	A	B	A	B	B	A	B	B						C	C	B	B	C
3.5.4 Sediments																					C	C	B	B	C

ENVIRONMENTAL EFFECTS AND TRANSPORT (continued)

COAL CONVERSION

Process: Gasification - In Situ

Importance
A - High
B - Medium
C - Low

Areas for Priorities:
1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4	Problem	1	2	3	4
3.6.0 Modelling																									
3.6.1 Biotransformation																					B	B	B	B	C
3.6.2 Soils, Sediments						C	C	C	B	C											B	B	B	B	C
3.7.0 Operational Studies																									
3.7.1 Preoperational and Operational Studies																									

PHYSICAL AND CHEMICAL PROCESSES AND EFFECTS

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification - In Situ

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
4.1.0 Physical Transport																									
4.1.1 Atmospheric						B	B	B	B	B	C	C	C	B	B						B	B	B	B	B
4.1.2 Dispersion/distribution						A	A	A	A	A											B	B	B	B	C

INTEGRATED ASSESSMENT

COAL CONVERSION

Process: Gasification - In Situ

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.1.0 Data Management																									
5.1.1 Coordination and Management System	B	A	A	A	A	A	A	A	A	A	C	B	B	B	B	A	A	A	A	A	A	A	A	A	A
5.1.2 Data Acquisition	B	A	A	A	A	A	A	A	A	A	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A
5.1.3 Computing Facilities	B	A	B	A	B	A	A	B	B	A	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A
5.1.4 Environmental Information	B	B	B	B	B	A	A	A	A	A	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A
5.1.5 National Geoecology Data	B	B	B	B	B	A	A	A	A	A	C	C	C	C	C	A	B	B	B	B	A	B	B	B	B
5.1.6 Source Terms and Effects	B	B	B	B	A	A	A	A	A	A	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A
5.1.7 Data Processing	B	C	C	C	C	A	A	B	C	A	C	C	C	C	C	A	B	A	A	B	A	B	A	A	B
5.1.8 Synthesis and Policy Analysis	B	C	C	C	C	A	A	A	A	A	C	C	C	C	C	A	A	A	B	B	A	A	A	B	B
5.2.0 On-Site Impacts																									
5.2.1 Land Area Needs	A	B	B	A	B	A	B	B	B	B	B	C	C	C	C	B	C	B	B	B	C	C	C	C	C
5.2.2 Topography	A	A	A	B	B	A	B	B	B	B	B	C	C	C	C	B	C	B	B	B	C	A	A	B	A
5.2.3 Competing Land-Use Requirements	A	A	A	A	A	A	B	A	B	A	B	C	C	C	C	B	C	B	B	B	C	B	B	B	A
5.2.4 Impacts on Existing Land-Use	A	B	B	A	B	A	A	A	A	A	B	C	C	C	C	B	B	B	B	B	C	C	A	B	B
5.2.5 Accessibility	A	B	B	A	A	A	A	A	B	A	B	C	C	C	C	B	B	B	B	A	C	B	A	B	B
5.2.6 Total On-Site Demands	A	A	A	A	A	A	A	A	A	A	B	C	C	C	C	B	C	C	C	C	C	C	C	C	C
5.2.7 Institutional Constraints	A	B	B	B	B	A	B	B	B	B	B	C	C	C	C	B	A	A	A	A	C	A	A	A	A
5.2.8 Coal Resource Locations	A	A	A	A	A	A	B	B	B	B	B	C	C	C	C	B	A	B	B	B	C	A	A	A	A

INTEGRATED ASSESSMENT (continued)

COAL CONVERSION

Process: Gasification - In Situ

Importance

A - High
B - Medium
C - Low

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.3.0 Off-Site Impacts																									
5.3.1 Land-Use Demands	B	B	A	B	A	A	B	A	B	A	C	C	C	C	C	C	C	A	B	B	B	C	A	C	C
5.3.2 Land Area Needs	B	A	A	A	A	A	B	B	B	B	C	A	A	A	A	C	C	C	C	C	B	C	A	C	C
5.3.3 Population Trends	B	B	A	B	A	A	B	A	B	A	C	C	C	C	C	C	C	C	C	C	B	C	A	C	C
5.3.4 Impacts of Increased Population	B	C	C	C	C	A	C	C	C	C	C	B	B	B	B	C	C	C	C	C	B	C	A	C	C
5.3.5 Population Land-Use Impacts	B	B	B	B	B	A	A	A	A	A	C	A	A	B	B	C	C	C	C	C	B	C	A	C	C
5.3.6 Community Water	B	C	C	C	C	A	B	A	B	A	C	C	C	C	C	C	C	C	C	C	B	C	A	C	C
5.3.7 Waste Handling	B	C	C	C	C	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	B	A	A	A	A
5.3.8 Direct and Secondary Impacts	B	C	A	B	B	A	A	A	A	A	C	C	C	C	C	C	A	A	A	A	B	A	A	A	A
5.3.9 Accessibility	B	B	A	B	A	A	B	A	B	A	C	C	C	C	C	C	A	A	A	A	B	A	A	A	A
5.4.0 Social Effects																									
5.4.1 Public Information Programs	C	C	C	C	C	A	A	A	B	A	C	C	C	C	C	B	A	B	B	A	B	C	B	B	C
5.4.2 Methodology	C	C	C	C	C	A	B	B	B	A	C	C	C	C	C	B	C	C	C	C	B	C	B	B	C
5.4.3 Existing Political Structures	C	C	C	C	C	A	B	B	B	A	C	C	C	C	C	B	A	A	B	A	B	C	B	B	C
5.4.4 Community Services	C	C	C	C	C	A	B	C	C	B	C	C	C	C	C	B	C	C	C	C	B	C	B	B	C
5.4.5 Impacts	C	C	C	C	C	A	A	A	A	A	C	C	C	C	C	B	C	C	C	C	B	C	B	B	C
5.5.0 Economic Effects																									
5.5.1 Major Coal Regions	A	A	A	A	A	B	B	A	B	A	C	C	C	C	C	B	B	B	B	B	A	B	A	B	A
5.5.2 Optimal Facilities	A	A	A	A	A	B	B	A	B	B	C	C	C	C	C	B	B	B	B	B	A	B	A	B	A

INTEGRATED ASSESSMENT (continued)

Importance

A - High
B - Medium
C - Low

COAL CONVERSION

Process: Gasification - In Situ

Areas for Priorities:

1. Severity
2. Extent
3. Information need
4. Urgency

King-Muir Category	Fuel Pretreatment					Conversion Process					Waste Management					Product Storage/ Transportation					Commercial Utilization				
	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4	Prob-lem	1	2	3	4
5.6.0 Local Economy																									
5.6.1 Local Economic Structures	B	B	B	B	B	B	A	A	B	A	C	C	C	C	C	A	C	C	C	C	A	B	A	A	B
5.6.2 Cost/Benefit Analysis	B	B	B	C	B	B	A	A	B	A	C	C	C	C	C	A	B	B	B	B	A	A	A	A	A
5.6.3 Local Tax Structures	B	A	A	B	A	B	A	A	B	A	C	C	C	C	C	A	A	A	A	A	A	C	C	C	C
5.6.4 Capital Investments	B	A	A	A	A	B	A	A	A	A	C	C	C	C	C	A	A	A	A	B	A	C	C	C	C

and costly; this research requires a long lead-time and cannot be forced easily into the short-term time constraints necessary for quick technology development. Such research will follow some of the classical pathways initiated in evaluating potential radiation effects. It is more complex than nuclear research, however, in that analytical capabilities are more difficult and biological transformation products exist.

Research in this area will include evaluating chronic effects of low-level exposures with respect for man to carcinogenesis, mutagenesis, and teratogenesis. Investigations of cocarcinogenesis are also necessary. In certain areas it will be necessary to develop tests having sufficiently sensitive endpoints. Environmental research will center on two major areas: (1) investigations of potential effects of low-level releases, and (2) studies of the availability of coal conversion materials to man. In the latter case, this includes transformation production, cycling, bioaccumulation, and ecological effects.

As has been mentioned previously it is neither economically or scientifically feasible or appropriate to evaluate every compound arising from every alternative conversion process. Some research must be directed at developing information on classes or groups of materials (i.e., PAH compounds) and illucidating mechanisms of environmental and biological perturbations.

III.3 SUMMARY AND CONCLUSION

The research proposed in the previous pages summarizes that biomedical and environmental research necessary to (1) ensure the safety of the coal conversion worker and (2) to enable the development of coal conversion technologies having minimum impact on man and his environment.

Several factors have not been explicitly stated in the research plans but deserve mention and investigation. Because of the potential instability of organic components in test materials and the embryonic state of analytical capabilities for organics, some form of quality assurance and system of sample storage is necessary. A central analytical facility which can receive materials from various pilot, demonstration, and commercial plants needs to be established. This central facility would not be intended to preclude chemical identifications at the various developmental engineering facilities (CMM work which should be conducted), but would (a) receive reference materials from process, product, and effluent streams of all developmental conversion units, (b) store such materials, (c) provide composite materials and fractions for screening toxicity tests (both biological and environmental), (d) provide information on suitable measurement methodologies, and (e) coordinate interlaboratory comparisons on material composition.

(1) Biomedical and environmental research related to coal conversion technologies must be closely linked with analytical capabilities for qualitative and quantitative determinations (not necessary for toxicity screening research).

(2) Biomedical and environmental research investigating coal conversion technologies must possess the analytical capabilities necessary to follow specific compounds through the abiotic and biotic systems, identify transformation products, and quantify low levels of specific materials. Such research is best performed at large multidisciplinary research facilities.

(3) It would be inefficient to establish biological and environmental screening procedures at each conversion development facility. A centralized laboratory should be established to receive materials from the various developmental units and this laboratory equipped to perform acute toxicity screening test. This operation would best be done in conjunction with the central analytical facility.

(4) The potential differences in materials arising from coal conversion as a result of different processes or coal used increases the complexity of necessary biomedical and environmental research. An engineering unit which would be of immeasurable value to such a BER Program is one which possesses great flexibility in mode of operation. Such a process development unit could be modified to run at different temperature regimes in each of the three major liquefaction processes and would be capable of using various types of coal. This unit would be valuable for CMM research aimed at understanding kinetics and products of coal conversion and for producing materials for screening toxicity tests. In the latter case, the biomedical and environmental screening research would provide early information regarding conversion alternatives most amenable to the environment and man.

Such a unit is engineeringly possible. Initially a bench scale unit would be sufficient (although it would possess certain limitations) followed by a larger Process Development Unit. Such a facility should be coupled with the central analytical and screening facilities for maximum value.

Finally, coal conversion is most certainly an initial alternative for attaining "Project Independence." For DBER it provides the potential for aiding in the development of a technology rather than in an <u>a posteriori</u> evaluation which requires an adaptation of commercial technology.

III.4 FIVE-YEAR BUDGET SUMMARIES - KING-MUIR CATEGORIES

OVERALL

	King-Muir Category	Thousands of Dollars 1977	1978	1979	1980	1981	Total
II.1.1	Characterization, Measurements, and Monitoring	3,470	4,570	4,565	4,295	3,585	20,485
II.2.1	Health Effects	13,450	19,300	22,290	24,715	27,235	106,990
II.3.1	Environmental Effects and Transport	4,710	6,470	9,860	9,420	9,440	39,900
II.4.1	Physical and Chemical Processes and Effects	300	480	560	560	560	2,460
II.5.1	Integrated Assessment	5,931	5,414	3,627	2,161	1,880	19,013
YEARLY TOTAL		27,861	36,234	40,902	41,151	42,700	188,848

II.1.1 CHARACTERIZATION, MEASUREMENTS, AND MONITORING

Problem	Program	Thousands of Dollars 1977	1978	1979	1980	1981	Total
II.1.1.0							
	1.1.1	800	800	500	500	300	2,900
	1.1.2	60	200	225	225	225	935
	1.1.3	60	90	90	90	60	390
	1.1.4	30	90	90	90	60	360
	Total	950	1,180	905	905	705	4,645
II.1.2.0							
	1.2.1	60	60	30	30	30	210
	1.2.2	480	480	240	240	240	1,680
	1.2.3	360	360	360	180	180	1,440
	1.2.4	240	240	180	180	180	1,020
	1.2.5	180	180	180	180	180	900
	1.2.6	60	120	180	180	180	720
	1.2.7	60	120	120	120	90	510
	Total	1,440	1,560	1,290	1,110	1,080	6,480
II.1.3.0							
	1.3.1	60	120	120	120	60	480
	1.3.2	240	240	240	240	120	1,080
	1.3.3	240	240	240	240	120	1,080
	1.3.4	240	240	240	240	120	1,080
	1.3.5	180	180	180	90	90	720
	Total	960	1,020	1,020	930	510	4,440
II.1.4.0							
	1.4.1	120	120	60	60	30	390
	1.4.2	-0-	300	600	600	600	2,100
	1.4.3	-0-	300	600	600	600	2,100
	1.4.4	-0-	90	90	90	60	330
	Total	120	810	1,350	1,350	1,290	4,920
GRAND TOTAL		3,470	4,570	4,565	4,295	3,585	20,485

II.2.1 HEALTH EFFECTS

Problem	Program	Thousands of Dollars					
		1977	1978	1979	1980	1981	Total
II.2.1.0							
	2.1.1	1,000	800	850	900	1,000	4,550
	2.1.2	1,000	2,000	2,200	2,400	2,600	10,200
	2.1.3	600	800	850	950	1,000	4,200
	Total	2,600	3,600	3,900	4,250	4,600	18,950
II.2.2.0							
	2.2.1	2,000	3,000	3,500	3,800	4,100	16,400
	2.2.2	3,000	5,000	5,500	6,000	6,500	26,000
	2.2.3	600	700	760	820	880	3,760
	Total	5,600	8,700	9,760	10,620	11,480	46,160
II.2.3.0							
	2.3.1	500	600	650	700	750	3,200
	2.3.2	400	450	500	550	600	2,500
	2.3.3	400	450	500	550	600	2,500
	2.3.4	400	500	600	800	1,000	3,300
	Total	1,700	2,000	2,250	2,600	2,950	11,500
II.2.4.0							
	2.4.1	300	400	500	600	700	2,500
	2.4.2	50	100	150	175	200	675
	2.4.3	200	250	300	325	350	1,425
	2.4.4	50	100	110	120	130	510
	Total	600	850	1,060	1,220	1,380	5,110
II.2.5.0							
	2.5.1	300	350	375	400	600	2,025
	2.5.2	100	150	170	325	400	1,145
	2.5.3	50	50	75	100	125	400
	Total	450	550	620	825	1,125	3,570
II.2.6.0							
	2.6.1	1,000	1,500	2,000	2,200	2,400	9,100
	2.6.2	1,000	1,500	2,000	2,200	2,400	9,100
	2.6.3	500	600	700	800	900	3,500
	Total	2,500	3,600	4,700	5,200	5,700	21,700
GRAND TOTAL		13,450	19,300	22,290	24,715	27,235	106,990

II.3.1 ENVIRONMENTAL EFFECTS AND TRANSPORT

Problem	Program	Thousands of Dollars					
		1977	1978	1979	1980	1981	Total
II.3.1.0							
	3.1.1	625	500	500	500	500	2,625
	3.1.2	625	500	500	500	500	2,625
	Total	1,250	1,000	1,000	1,000	1,000	5,250
II.3.2.0							
	3.2.1	600	1,200	1,200	1,200	1,200	5,400
	3.2.2	-0-	-0-	900	1,440	1,440	3,780
	Total	600	1,200	2,100	1,640	1,640	7,180
II.3.3.0							
	3.3.1	-0-	-0-	300[a]	300[a]	300[a]	900[a]
	3.3.2	-0-	-0-	300[b]	300[b]	300[b]	900[b]
	3.3.3	-0-	-0-	500[c]	500[c]	500[c]	1,500[c]
	Total	-0-	-0-	1,100	1,100	1,100	3,300
II.3.4.0							
	3.4.1	-0-	360	360	360	360	1,440
	3.4.2	-0-	-0-	600	600	600	1,800
	Total	-0-	360	960	960	960	3,240
II.3.5.0							
	3.5.1	-0-	240	480	480	480	1,680
	3.5.2	150	280	340	280	280	1,330
	3.5.3	150	150	300	300	300	1,200
	3.5.4	-0-	120	240	240	240	840
	Total	300	790	1,360	1,300	1,300	5,050
II.3.6.0							
	3.6.1	-0-	-0-	100	180	200	480
	3.6.2	60	120	240	240	240	900
	Total	60	120	340	420	440	1,380
II.3.7.0							
	3.7.1	2,500[d]	3,000[d]	3,000[d]	3,000[d]	3,000[d]	14,500[d]
GRAND TOTAL		4,710	6,470	9,860	9,420	9,440	39,900

[a]Based on three representative species.

[b]Based on three representative ecosystems.

[c]Based on five models.

[d]Based on five representative facilities.

II.4.1 PHYSICAL AND CHEMICAL PROCESSES AND EFFECTS

		Thousands of Dollars					
Problem	Program	1977	1978	1979	1980	1981	Total
II.4.1.0							
	4.1.1	240	360	360	360	360	1,680
	4.1.2	60	120	200	200	200	780
	Total	300	480	560	560	560	2,460
GRAND TOTAL		300	480	560	560	560	2,460

II.5.1 INTEGRATED ASSESSMENT

Problem	Program	Thousands of Dollars 1977	1978	1979	1980	1981	Total
II.5.1.0							
	5.1.1	350	350	300	300	300	1,600
	5.1.2	200	250	200	200	200	1,050
	5.1.3	1,000	300	200	200	200	1,900
	5.1.4	300	200	150	150	150	950
	5.1.5	400	450	400	300	300	1,850
	5.1.6	100	100	100	-0-	-0-	300
	5.1.7	300	400	200	150	150	1,200
	5.1.8	500	500	300	300	200	1,800
	Total	3,150	2,650	1,850	1,600	1,500	10,750
II.5.2.0							
	5.2.1	50	50	-0-	-0-	-0-	100
	5.2.2	300	200	-0-	-0-	-0-	500
	5.2.3	60	60	60	-0-	-0-	180
	5.2.4	60	60	100	-0-	-0-	220
	5.2.5	100	100	60	-0-	-0-	260
	5.2.6	150	100	100	60	60	470
	5.2.7	200	100	100	-0-	-0-	400
	5.2.8	300	300	150	60	60	870
	Total	1,220	970	570	120	120	3,000
II.5.3.0							
	5.3.1	-0-	200	60	-0-	-0-	260
	5.3.2	60	60	60	60	-0-	240
	5.3.3	60	60	60	-0-	-0-	180
	5.3.4	-0-	-0-	60	60	-0-	120
	5.3.5	100	100	60	-0-	-0-	260
	5.3.6	80	80	60	-0-	-0-	220
	5.3.7	-0-	60	60	-0-	-0-	120
	5.3.8	100	60	60	60	-0-	280
	5.3.9	-0-	60	60	60	60	240
	Total	400	680	540	240	60	1,920
II.5.4.0							
	5.4.1	120	132	145	110	175	682
	5.4.2	60	60	-0-	-0-	-0-	120
	5.4.3	60	66	66	66	-0-	258
	5.4.4	-0-	66	60	-0-	-0-	126
	5.4.5	120	132	60	-0-	-0-	312
	Total	360	456	331	176	175	1,498
II.5.5.0							
	5.5.1	500	500	-0-	-0-	-0-	1,000
	5.5.2	200	250	60	60	60	630
	Total	700	750	60	60	60	1,630
II.5.6.0							
	5.6.1	60	66	66	-0-	-0-	192
	5.6.2	66	66	-0-	-0-	-0-	132
	5.6.3	100	66	60	-0-	-0-	226
	5.6.4	100	60	60	-0-	-0-	220
	Total	326	258	186	-0-	-0-	770
II.5.7.0							
	5.7.1	50	25	25	25	25	150
	5.7.2	100	50	50	-0-	-0-	200
	5.7.3	50	50	-0-	-0-	-0-	100
	5.7.4	50	25	-0-	-0-	-0-	75
	5.7.5	75	150	75	-0-	-0-	300
	5.7.6	100	50	-0-	-0-	-0-	150
	5.7.7	50	50	-0-	-0-	-0-	100
	Total	475	400	150	25	25	1,075
GRAND TOTAL		5,931	5,414	3,627	2,161	1,880	19,013

APPENDIX A

CHEMICAL COMPOSITION AND POTENTIAL HAZARDS OF COAL CONVERSION PRODUCTS, PROCESS, AND EFFLUENT STREAMS FOR SELECTED COAL CONVERSION PROCESSES

This section presents available information on process streams, including similarities and differences, for process alternatives.

Synthane Process

The Synthane process, developed by the Bureau of Mines, has progressed to the point where a 75-ton/day pilot plant for the conversion of bituminous and sub-bituminous coal and lignite into sulfur-free substitute natural gas (SNG) is under construction at Bruceton, Pa. Besides the principal product, synthetic natural gas, by-products tar, ammonia, and elemental sulfur are expected.

This product gas will have the following composition, expressed as vol. %: 2.1, N_2; 3.6, H_2; 0.1, CO; 3.7, CO_2; and 90.5, CH_4. No data are available on trace organic or inorganic components in the product gas.

Process streams are by far the most hazardous element in the gasification process. Besides the large quantities of H_2, CO, CO_2, CH_4, and C_2H_2 made in the gasifier, there are a number of trace components which are of interest. These are shown in Table A-1 which shows the sulfur compounds plus the BTX (benzene-toluene-xylene) components from several coal sources.

The major effluent problem is the contaminated condensate from the gasifier which includes water, water soluble organics and inorganics, tars, and dusts. Table I.2-1 compares the components in a coke-plant weak ammonia liquor with those in by-product water from Synthane gasification of char, lignite, and several coals. It is rather significant that such a wide range of components occur as the result of different coal sources. Fortunately, plant clean-up systems reduce these potentially hazardous components (e.g., crude phenols) to acceptable levels in product and waste streams. Bethlehem Steel Co. has reduced the phenol level of its coke-plant weak ammonia liquor to 100 ppb by biological oxidation and has reduced the thiocyanates by an average of 70 percent. The Synthane pilot plant will employ the same clean-up system. The by-product water will be used as recycled cooling water and, judging by the trace element analysis of condensate from coal gasification test, (See Table I.2-2), no problem should be encountered. Generally, excess water is discharged as blowdown to evaporation ponds, thereby bleeding off the water-soluble trace elements.

Table A-1. Components in gasifier gas (in ppm). [Source: A. J. Forney, W. P. Haynes, Stanley J. Gasior, Glenn E. Johnson and J. P. Strakey, Jr., "Analyses of Tars, Chars, Gases and Water Found in Effluents from the Synthane Process," Pittsburgh Energy Research Center, Tech. Prog. Report 76, January 1974.]

	Illinois No. 6 coal	Illinois char	Wyoming subbituminous coal	Western Kentucky coal	North Dakota lignite	Pittsburgh seam coal
H_2S	9,800	186	2,480	2,530	1,750	860
COS	150	2	32	119	65	11
Thiophene	31	0.4	10	5	13	42
Methyl thiophene	10	0.4	-	-	-	7
Dimethyl thiophene	10	0.5	-	-	11	6
Benzene	340	10	434	100	1,727	1,050
Toluene	94	3	59	22	167	185
C_8 aromatics	24	2	27	4	73	27
SO_2	10	1	6	2	10	10
CS_2	10	-	-	-	-	-
Methyl mercaptan	60	0.1	0.4	33	10	8

Of the several Synthane by-products, perhaps the most hazardous are the tars which are composed of several potential carcinogens as indicated in the mass spectrometric analyses of the benzene-soluble tar component from lignite and several coals, as shown earlier in Table I.2-6.

Hygas Process

Another source of high-Btu pipeline gas, the Hygas process, is characterized by hydrogasification. Here the coal, in a coal-derived oil slurry, is gasified in an atmosphere of hydrogen. In this mode of gasification, additional liquid products such as the aromatics, benzene, toluene, and xylene are produced and treated as valuable by-products. Hazardous components are removed from the mainstreams in the water scrubber following shift conversion where most of the HCN is hydrogenated to ammonia.

Koppers-Totzek Process

The Koppers-Totzek process is a commercially proven scheme to produce a gas having a heating value of about 300 Btu/ft^3. Utilizing western, Illinois, and eastern coals (See Ref. 1), a product gas composed primarily of carbon dioxide, carbon monoxide, and hydrogen with only trace amounts of methane can be expected (See Table A-2).

In contrast to the high-Btu gasification processes the only by-products are steam and sulfur. Because of the high gasification temperature, 3000-3500°F, phenols, pyridine, and organics are not formed and the quantities of other soluble contaminants are minimized. A bleed stream from the recirculated water system is continuously fed to the stripper where gaseous NH_3, CO_2, H_2S, and some cyanide are removed and sent to the Claus unit for incineration. Table A-3 (See Ref. 1) shows the composition of five water streams within the process.

Liquefaction - Carbonization/Hydrocarbonization

Liquefaction of coal can be accomplished by carbonization and hydrocarbonization in dry fluidized beds. Several domestic commercial processes use this basic technology. Of these, the Coalcon process (Coalcon Company, a subsidiary of Union Carbide Corporation and Chemical Construction Company) is projected to process 2600 tons/day of coal in 1979. The COED process (Char Oil Energy Development process developed by FMC Corp.) is in pilot plant stage (36 tons/day coal) and is not projected to be used commerically within 10 years or more. The Garrett Pyrolysis Process and U.S. Steel's Clean-Coke Process are similar methodologies. Of these processes most information concerning product, process streams, and effluent composition is available for the COED process. Consequently, data will be presented principally for the COED process with differences being indicated where appropriate.

Table A-2. Product gas analyses (in volume %). [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards under Contract Number G8-02-1358, March 1974.]

Gas component	Illinois coal	Eastern coal	Western coal
CO	61.05	57.23	61.01
CO_2	-	2.83	3.51
H_2	37.73	38.71	33.60
N_2	1.17	1.20	1.24
H_2S	0.02	0.026	0.025
COS	0.01	0.003	0.0027

Table A-3. Koppers coal gasification water analyses, Kutahya, Turkey. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards under Contract Number G8-02-1358, March, 1974.]

Sample location		I	II	III	IV	V
pH value		8.8	8.8	8.9	8.8	8.9
Conductivity	S	7.6	1.8	2.0	1.8	1.8
		0.001	0.01	0.01	0.01	0.01
CaO	mg/l	78	101	78	135	179
MgO	mg/l	97	161	194	145	113
Ma	mg/l	17.5	17.5	17.5	17.5	17.5
K	mg/l	5.6	8.8	10.0	8.0	8.0
Zn	mg/l	0.01	0.03	0.02	0.02	0.02
Fe	mg/l	0.05	0.22	1.95	0.20	0.64
NH_4	mg/l	0.32	157	184	137	122
NO_2	mg/l	0.02	0.13	4.47	0.24	4.37
NO_3	mg/l	58.2	3.32	13.7	24.7	22.9
PO_4 total	mg/l	1.89	0.81	1.21	0.81	2.70
Cl	mg/l	18	85	96	57	46
SO_4	mg/l	42	216	155	255	109
CN	mg/l	0.26	0.52	12.5	1.4	14.0
H_2S	mg/l	-----------------	-------	Not detected	-------	-----------------
$KMnO_4$ consumed	mg/l	8	9	400	11	145
COD	mgO_2/l	14	18	128	16	63
SiO_2	mg/l	14.8	16.0	14.8	19.8	42.6
Suspended solids	mg/l	14	4612	5084	3072	50
Hot residue, 800°C	mg/l	4	3918	4356	2690	46
Stripped residue	mg/l	568	812	940	706	724
Hot residue, 800°C	mg/l	268	550	588	526	512
Cu	mg/l	0.01	0.01	0.01	0.01	0.06

I Cooling water to slag quench tank.

II Water from slag quench tank.

III Wash water from gas cooler.

IV Total to clarifier.

V Water out of clarifier.

COED Process

In the COED process the temperature-staged pyrolysis is conducted in a series of fluidized-bed reactors. The product from this process consists of a low-Btu fuel gas which can be sold or it can be used to provide the hydrogen and power requirements of the COED process and a hydrogenated pyrolysis oil called syncrude (Table A-4). The syncrude product can be expected to contain an abundance of phenols since low-temperature carbonization favors their production and also, hydrotreating reduces the higher boiling tars to phenols. In essence, the mainstream contains many potential carcinogens from the pyrolysis stage to end products.

A third product, char, often requires desulfurization before it is suitable as a utility fuel. The level of sulfur remaining in the treated char is dependent upon the coal source. The char also provides the vehicle for removal of ash from the plant.

To reduce the load on the various waste-stream facilities, the coal dust and fines generated in the process, the filter cake from the filtration section, and the process wastewater are recycled to the fourth stage reactor. This destroys most of the organic contaminants.

The Chevron wastewater treatment facility constitutes the principal means of separating the by-product ammonia from the acid gases which yield another by-product, sulfur, in the Stretford sulfur recovery section. The treated wastewater, which serves as cooling water, contains several ppm of hydrocarbons.

Over 50 unknown constituents were detected and separated in a gas chromatographic analysis of a COED process stack gas sample. Thus identification of these components is of primary concern because they represent constituents which are ejected from the stack into the atmosphere.

Over 50 unknown constitutents were also detected in COED process pyrolysis gas. Characterization of the sulfur-containing components in this sample indicated H_2S was the major component, with thiophen, COS, and CH_3SSCH_3 minor constituents ranked in decreasing order of concentration (See Ref. 2). Because the pyrolysis gas represents a product gas for "consumer" use, the unknown constituents should be identified. Principal constituents of this product gas in volume percent are: H_2, 46.3%; CO, 22.1%; CO_2, trace; CH_4, 14.8%; C_2H_4, 0.7%; C_2H_6, 12.2%; C_3H_6, 1.9%; C_3H_8, 0.2%; C_4H_{10}, 1.8%; H_2S, trace (See Ref. 1).

Phenolic and acidic constituent analyses for nine sample sources are given in Table A-5. Sulfur and organosulfur component analyses are given in Table A-6 (Ref. 2). Sulfur components in stack gases may represent a control problem. The unknown sulfur components in the product oil should be characterized.

Table A-4. Composition of product syncrude and fuel gas from Utah A seam and Illinois No. 6 coals. [Source: Booz-Allen Applied Research, "Emissions from Processes Producing Clean Fuels," Report prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards under Contract Number G8-02-1358, March 1974.]

Coal source syncrude component	Utah A seam (wt. %)	Illinois No. 6 (wt. %)
C	85.8	87.80
H	11.8	9.94
O	2.0	1.22
N	0.32	0.82
S	0.02	0.22
Ash	-	-
Fuel gas component	(vol. %)	(vol. %)
H_2	49.30	46.3
H_2O	-	-
CO	22.67	22.1
CO_2	Trace	Trace
CH_4	21.06	14.8
C_2H_4	0.45	0.7
C_2H_6	2.71	12.2
C_3H_6	1.72	1.9
C_3H_8	1.13	0.2
C_4H_8	0.34	-
C_4H_{10}	0.40	1.8
C^+_5	0.22	-
O_2	-	-
N_2	-	-
NH_3	-	-
H_2S	-	Trace

Table A-5. Acidic compounds and pH values for COED samples. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Sample Source	pH (% solu)	Phenol (mg/g)	O-cresol (mg/g)	M + P cresol (mg/g)	Total phenol + cresols (mg/g)	Color phenol (mg/g)	Weak acid (meq/g)*	Very weak acid (meq/g)	Total weak acid (meq/g)
Unfiltered raw oil	7.12	20.94	6.45	5.83	33.23	18.84	0	0	0
Filter cake	7.35	1.54	0.99	0.38	6.15	7.10	0	0	0
Filtered raw oil	7.45	11.12	3.69	4.03	18.84	14.67	0	0	0
Syncrude	8.08	7.37	2.66	1.48	11.50	6.59	0	0	0
Produce Separator Liquor	7.65	1.65	0.37	0.98	3.0	2.06	0.070	0.047	0.117
Dryer-stage I liquor	5.45	-	-	-	-	0	0.004	0.003	0.007
Char	8.38	-	-	-	-	0	0	0	0
Dryer-stage 1 fines	5.60	0	0	0	0	0	0.014	0.031	0.045
Produce Separator fines	5.68	-	-	-	-	0	0	0	0

*meq/g - milliequivalent per gram

Table A-6. Sulfur compounds in pyrolysis and stack gas from COED process. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Compounds	Pyrolysis gas (ng/ml)	Stack gas (ng/ml)
COS	6.4	11.0
H_2S	68.0	12.8
Thiophen	16.0	0.9
$(CH_3S)_2$	0.8	-

Of interest for carcinogenic potential, polynuclear aromatic hydrocarbons (PAH) compounds were analyzed in several samples (Table A-7). It is significant that benzo (a) pyrene (BaP) was found in the aqueous effluents, thus representing evidence that excess effluent waters which are not recycled should be examined for such hazardous constituents. It is also significant that PAH compounds are present at relatively high concentrations in the syncrude oil.

Table A-8 indicates high concentration of organics in the aqueous effluents from several process streams.

Spark-source mass spectrometric determinations of metal concentrations in COED samples are given in Table A-9.

Coalcon Process

The proposed Coalcon plant is to have an output of 3900 bbl/day of oil and 22 x 10^6 ft^3/day of fuel gas. This process may have considerable potential for commercialization because it is adaptable to many types of coal, and provides for low-temperature carbonization and hydrogenation of finely divided coal in a fluidized state without benefit of a supporting oil. The yield of oil is attractive and its composition is heavy in phenols and aromatics.

Since the operation is proprietary, little information is available on process, product, and effluent streams. However, based on early published studies with a sub-bituminous Wyoming coal, we find the process keyed to produce char, tar, gas, hydrogen, and accompanying reaction water. Table A-10 shows the product yields and compositions under two sets of operating conditions. (See Ref. 3). Coalcon proposes to make oil and fuel gas their primary products; therefore, it may be assumed that sulfur, ammonia, phenols, and other chemical feedstocks will be considered as by-products.

U.S. Steel's Clean-Coke Process

The composition of U.S. Steel's Clean-Coke Process streams should not be much different from similar processes, nor would the waste streams, since conventional recovery processes are employed in most. Available analytical data are presented in Tables A-11 through A-14.

Garrett Pyrolysis Process

The Garrett Pyrolysis Process, another carbonization-hydrocarbonization mode of liquefaction, produces the highest tar yield of any so far known, 35% of m.a.f. coal. Since this process is characterized as a low-temperature carbonization system with very short reactor residence time, it is anticipated that the percent of phenols and other low boiling carcinogens will be greater than in the aforementioned two processes.

Table A-7. Distribution of three polynuclear aromatic hydrocarbons in COED samples. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Sample type	Compounds[a]		
	BaP	BaA	Phen.
Product Separator Liquor (ppb)	8.0	-	-
Dryer Liquor (ppb)	9.3	-	-
Syncrude (ppm)	51	Trace	Trace
Unfiltered Raw Oil (ppm)	107	42	270
Filtered Raw Oil (ppm)	96	52	400

[a]BaP, benzo (a) pyrene; BaA benzo (a) anthracene; Phen, phenanthrene.

Table A-8. Dissolved organic carbon (DOC) results for aqueous samples from COED process. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Sample	Sampling condition*	DOC (μg/ml)
Product separator	Included	9,500
(2nd stage liquor)	Excluded	11,600
Dryer-scrubber	Included	148
(1st stage liquor)	Excluded	133

*Surface of sample was included or excluded during sampling procedure.

Table A-9. Trace element results (ppm) for the COED process.[a] [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge Tenn., Dec. 1975.]

Element	1	4	5	6	7	9	11	12	13	14
Al	5,000	5,000	10,000	2,000	90	70	4	4	100	30
As	3	3	7	2	2	0.7	0.01	3	2	1
B	200	200	200	100	4	10	3	0.5	3	20
Ba	5	1	10	1	1	3	<0.5	<0.05	2	0.1
Bi	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.3	<0.3	<0.3	<0.3
Br	<0.2	0.7	<0.2	0.1	<0.1	<0.3	<0.3	<0.3	<0.3	3
Ca	1,000	3,000	3,000	1,000	30	100	500	1	100	200
Cd	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Cl	20	100	20	20	3	1	10	10	30	10
Co	1	0.2	2	0.3	0.1	0.1	1	0.2	0.4	<0.1
Cr	5	2	2	2	0.7	1	1	0.5	5	2
Cs	<0.1	1	0.5	0.6	0.2	0.2	5	<0.5	<0.5	<0.2
Cu	3	2	10	2	0.3	0.3	5	1	1	0.4
F	4	2	10	2	1	2	<0.5	<0.1	3	0.2
Fe	10,000	7,000	10,000	15,000	400	500	300	50	3,000	20
Ga	1	0.5	2	0.2	0.2	0.1	<0.1	<0.5	0.3	<0.1
Ge	1	0.8	1	1	<0.7	<0.5	<0.5	<0.5	<0.5	<0.5
K	200	250	500	200	10	100	4	0.2	100	10
La	10	1	5	2	1	1	0.1	<0.1	5	0.1
Mg	80	200	500	500	20	20	80	<3	50	20
Mn	5	5	10	2	0.4	0.6	7	0.1	5	0.4
Mo	5	0.5	20	<0.5	0.7	<0.5	0.8	2	<0.5	5
Na	50	100	500	50	10	30	10	3	50	300
Nb	2	0.1	0.4	0.2	0.3	0.3	<0.1	0.5	<0.5	0.5
Nd	10	2	5	3	1	2	1	<0.5	3	0.5
Ni	30	30	50	7	4	10	100	1	50	10
P	20	10	70	10	3	5	0.2	0.7	20	2
Pb	3	1	10	1	1	2	0.1	0.5	2	<0.1
Pr	2	0.5	3	1	0.4	0.3	0.4	<0.5	1	0.1
Rb	1	0.5	2	0.3	0.2	0.2	0.02	0.5	0.5	<0.1
Sb	0.5	<0.2	0.1	<0.2	<0.1	<0.1	<0.1	<0.1	0.1	<0.2
Sc	3	1	1	1	0.4	0.5	<0.5	<0.5	1	<0.5
Se	0.3	≤0.1	0.4	0.1	≤0.1	<0.1	0.2	<0.5	1	2
Si	3,000	7,000	15,000	15,000	1,000	2,000	30	10	8,000	1,000
Sn	<0.3	<0.3	≤0.3	<0.3	<0.3	<0.1	<0.1	3	<0.5	0.8
Sr	10	5	30	10	10	4	0.3	<0.5	10	<0.5
Ta	≤1	≤1	≤1	≤1	≤0.5	≤0.5	≤1	≤1	≤1	≤3
Te	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Th	0.7	0.2	0.1	0.2	0.8	0.4	<0.1	<0.5	0.7	<0.1
Ti	200	50	100	50	20	20	<1	<1	70	<1
Tl	2	0.5	3	0.5	0.5	1	0.3	<0.5	0.3	<0.5
U	2	0.7	2	0.6	1	0.5	<0.1	<0.5	<0.6	<0.5
V	50	5	30	15	2	2	0.1	<0.5	5	0.1
W	3	<0.5	2	<0.5	0.4	0.4	<0.5	<0.5	<0.5	<0.5
Y	7	1	5	2	1	1	0.5	<0.3	3	<0.3
Zn	10	3	10	4	2	1	3	0.3	1	1
Zr	10	3	20	1	2	3	<0.5	<0.5	10	3

[a]Paradise Kentucky No. 9-Seam Coal, Feed, 1; raw pyrolysis oil, 4; filter cake, 5; filtrate, 6; syncrude oil, 7; 2nd stage liquor, 9; 1st stage liquor, 11; product char, 12; fines and oil, 13; 2nd stage cyclone fines, 14.

Table A-10. Composition of gas, tar and char (Coalcon process). [Source: C. W. Albright and H. G. Davis, Union Carbide Corporation. Pre-print of paper presented at ACS Division of Fuel Chars, Chicago, Illinois, September 1970, p. 99.]

Operating conditions		
Hydrocarbonization	Mild	Severe
Temperature, °C	560	567
Hydrogen partial pressure, psi	310	940
Residence time, min	8.2	10.2
Yields (wt. % m.a.f.[a] coal)		
Char	50.4	38.4
Tar	21.3	29.0
Water	13.2	19.0
Gas	16.0	16.2
Hydrogen	1.4	3.5
Unaccounted for	0.5	0.7
	100.0	100.0
Gas composition (vol. %, H_2 free)		
Component		
Methane	46.3	63.1
Ethane	9.1	13.7
Propylene	1.8	0.3
Propane	4.7	4.5
Butenes	1.1	0.6
n-Butane	0.4	0.5
i-Butane	0.7	0.4
C_5's	0.2	0.1
CO	28.2	14.1
CO_2	7.5	2.5
H_2S	0.2	0.2
Molecular weight	25.5	22.36
Wt. % hydrogen in gas	12.1	17.34
Tar composition		
Distillation (wt. % of tar)		
Fraction, from-to, °C.		
IBP-260°C.	37.0	44.5
260-340°C.	12.0	7.0
340°C.	51.0	48.5
Tar acids (wt. % m.a.f. coal)		
IBP-260°C.	5.1	7.6
260-340°C.	1.5	0.8
Yield of basic aromatics, (lb/ton m.a.f. coal)		
Benzene	0.1	0.4
Toluene	0.2	0.2
Naphthalene	0.3	0.6
Light oil (130-260°C.) tar acid distribution (wt. %)		
Phenol	34.5	33.4
o-Cresol	8.7	7.8
m,p-Cresol	27.2	24.5
Ethylphenols and xylenols	17.1	18.9
Higher phenols by difference	12.5	15.4
Phenol yield (wt. % m.a.f. coal)		
	1.8	2.2
Char composition		
C	90.1	93.0
H	3.9	3.8
N	1.2	1.3
S	1.0	0.6
O (by difference)	3.8	1.3

[a]m.a.f. - moisture-ash-free.

Table A-11. Composition of carbonization chemical oil* from U.S. Steel Clean-Coke Process: Tar acid fraction. [Source: U.S. Steel "Clean-Coke Project," U.S.S. Engineers and Consultants, Inc., Interium Report No. 1 to OCR for period March 1972 to April 1974.]

Component	Percent**
Phenol	12.5
o-Cresol	10.6
m,p-Cresol	23.6
2,6-Xylenol	1.9
o-Ethylphenol; 2,4- and 2,5-xylenol	13.2
2,3- and 3,5-Xylenol; m,p-ethylphenol	11.5
3,4-Xylenol	2.8
Unidentified	3.3
Unidentified	3.2
3-Ethyl-5-methylphenol	3.2
Unidentified	2.3
Unidentified (15 compounds)	11.8

*Chemical oil. The indicated components were derived from the tar acid fraction of the chemical oil from carbonization of oxidized Zeigler coal at 1365F, 80 psia and 30-min reaction time.

**By gas chromatography.

Table A-12. Composition of carbonization chemical oil* from U.S. Steel Clean-Coke Process: Tar base fraction. [Source: U.S. Steel "Clean-Coke Project," U.S.S. Engineers and Consultants, Inc., Interium Report No. 1 to OCR for period March 1972 to April 1974.]

Component	Percent**
Pyridine and α-picoline	10.2
2,6-Lutidine and unidentified	6.3
Unidentified (possibly 2-ethylpyridine)	2.3
Picolines and lutidines	20.0
Unidentified (possibly alkylpyridines)	10.3
Aniline	12.4
o,p-Toluidine	2.7
2,6-Xylidine	1.3
m-Toluidine	3.1
2,4-Xylidine	1.6
2,5-Xylidine	0.9
Quinoline and unidentified	7.7
Quinaldine	3.6
Isoquinoline and unidentified	8.5
Unidentified (possibly alkylquinolines)	9.1

*Chemical oil. The indicated components were derived from the tar acid fraction of the chemical oil from carbonization of oxidized Zeigler coal at 1365F, 80 psia and 30-min reaction time.

**By gas chromatography.

Table A-13. Composition of carbonization chemical oil* from U.S. Steel Clean-Coke Process: Tar neutral fraction. [Source: U.S. Steel "Clean-Coke Project," U.S.S. Engineers and Consultants, Inc., Interium Report No. 1 to OCR for period March 1972 to April 1974.]

Component	Percent**
Benzene	2.9
Unidentified	0.7
Toluene	4.7
Unidentified	0.8
m,p-Xylene	6.6
o-Xylene	4.3
m,p-Ethyltoluene	2.8
1,3,5-Trimethylbenzene and unidentified	4.2
1,2,4-Trimethylbenzene	7.9
1,2,3-Trimethylbenzene and unidentified	8.6
Indane	4.3
Possibly dimethylethylbenzenes	5.2
Indene and coumarone	9.8
Unidentified	1.5
Benzonitrile and methylcoumarones	7.5
Unidentified	2.3
Unidentified	2.5
Unidentified	3.1
Naphthalene	7.8
Unidentified	1.0
Unidentified	0.7
2-Methylnaphthalene	5.2
1-Methylnaphthalene	1.6
1- and 2- Ethylnaphthalene	1.1
Diphenyl	1.8
Unidentified	1.1

*Chemical oil. The indicated components were derived from the tar acid fraction of the chemical oil from carbonization of oxidized Zeigler coal at 1365F, 80 psia and 30-min reaction time.

**By gas chromatography.

Table A-14. Analysis of product water from the carbonization* of oxidized Zeigler coal by the U.S. Steel Clean-Coke Process. [Source: U.S. Steel "Clean-Coke Project," U.S.S. Engineers and Consultants, Inc., Interium Report No. 1 to OCR for period March 1972 to April 1974.]

Component	Parts per Million
CNS^-	1,171
CN^-	74
$SO_4^=$	2,050
$S^=$	562
NH_3	33,320
Phenol	3,200
o-Cresol	700
m,p-Cresol	1,500
Xylenols	500

*Carbonization conditions:

Charge = 2900 grams oxidized coal (3 consecutive runs)

Temperature = 1365 F

Pressure = 80 psia

Time = 30 min

Yield = 9.0% tar and 4.5% product water (based on coal)

Liquefaction - Catalytic Hydrogenation

One of the oldest technologies for the liquefaction of coal is the catalytic hydrogenation of a paste or slurry of finely divided coal in coal--derived oil. Those processes which appear to have the greater prospects for exploitation on a commercial level in the near term are H-Coal, Synthoil, and Exxon. The H-Coal process, developed jointly by Hydrocarbon Research, Inc. and the Office of Coal Research, represents the most highly developed process in the field of catalytic hydrogenation, utilizing a wide range of coals. A 600-ton/day coal plant is projected for construction at Catlettsburg, Ky. for the production of a light synthetic crude oil at a lower coal throughput or a liquid product wherein low sulfur fuel oil is maximized at the higher coal throughput. The Synthoil process is in the pilot plant stage and the design and construction of a 8-ton (coal)/day Process Development Unit (See Ref. 4) to operate with 4- to 6-in. I.D. reactors is in the advanced stages of planning to demonstrate the commercial aspects of the process. The Exxon hydrogen donor process is in the late bench-scale level of operation.

H-Coal Process

The H-Coal process is characterized by an ebullated bed of hydrogenation catalyst being contacted, under controlled conditions of temperature and pressure, by a slurry of pulverized coal and a coal-derived oil in a hydrogen atmosphere to produce hydrogenation gases and light crude distillate. The 600-ton/day pilot plant is being designed to function under two modes of operation: to produce (1) an all-distillate light synthetic crude oil or (2) a low-sulfur fuel oil with the recovery of the associated by-products - fuel gas, sulfur, ammonia, ammonium sulfate, and sulfuric acid. Under the synthetic crude oil mode of operation the distillate oil and hydrocarbon gases are separated from the reactor vapors. The liquid leaving the reactor is sent to vacuum distillation to recover the distillate from the unconverted coal, ash, and residuum. The principal compound of the vacuum bottoms, residuum, is thermally cracked to produce additional distillate and char. The combined distillates constitute the synthetic crude oil product. Low-sulfur fuel oil production is represented by the liquid produced in catalytic hydrogenation after being separated by filtration or hydrocyclone from the unconverted coal, ash, and residuum. The fuel oil is satisfactory for burning in a utility plant and the synthetic crude for refining for gasoline production. Table A-15 shows the distribution of fractions where the H-Coal plant is operated according to the two product modes with Illinois No. 6 seam coal (See Ref. 5).

The component yield for the hydrogenation section of a H-Coal Process plant with a 7830-ton/day dry coal capacity is illustrated in Table A-16. (See Ref. 6). Tables A-17 and A-18 show the shift in distribution of components in the hydrogenation products from two coal sources processed early in H-Coal process development (See Ref. 7).

Table A-15. Coal hydrogenation results (wt. % of m.a.f.* Illinois coal). [Source: H. H. Stokler, HRI, "H-Coal Pilot Plant Program." Presented at the 67th Annual Meeting of AICHE, Washington, D. C., December 1974.]

Desired product	Synthetic crude	Low-sulfur fuel oil
Normalized product distribution		
C_1-C_3 hydrocarbons	10.7	5.4
C_4-400°F distillate	17.2	12.1
400-650°F distillate	28.2	19.3
650-975°F distillate	18.6	17.3
975°F+ residual oil	10.0	29.5
Unreacted ash-free coal	5.2	6.8
H_2O, NH_3, H_2S, CO, CO_2	15.0	12.8
Total (100.0 + H_2 reacted)	104.9	103.2
Conversion, %	94.8	93.2
Hydrogen consumption, scf/ton	18,600	12,200

*m.a.f. - moisture-ash-free.

Table A-16. Yield balance for coal hydrogenation (H-Coal). [Source: "Evaluation of Project H-Coal," American Oil Co. Report to OCR for April-August 1967, PB 177068.]

Material	lb/hr	Wt. (% of dried coal)
<u>Input</u>		
Dried coal	718,000	
<u>Output</u>		
H_2O	66,056	9.2
H_2S	15,796	2.2
NH_3	7,180	1.0
C_1	20,822	2.8
C_2	20,823	2.8
C_3	22,977	3.2
C_4	22,256	3.1
C_5-180°F	14,870	2.1
180-375°F	77,400	10.8
375-675°F	177,649	16.4
675-975°F	80,416	11.1
975+°F	78,262	10.9
Char	68,210	9.5
Ash	83,288	11.6

Table A-17. Composition of fractionated products from Illinois No. 6 coal. [Source: Project H-Coal Report on Process Development, February 1965 through September 1967, Office of Coal Research, R & D Report No. 26.]

Component	Wt %	Component	Wt %
Composition of C_4 - 400°F fraction			
Saturated compounds		Alkyl benzenes	
nC_4	0.10	C_6	0.89
iC_5	0.20	C_7	3.77
nC_5	0.69	C_8	4.76
C_6	2.48	C_9	4.16
C_7	2.87	C_{10}	2.58
C_8	2.08	C_{11}	1.29
C_9	1.59	C_{12}	0.10
C_{10}	1.19		17.55
C_{11}	0.69		
C_{12}	0.10		
	11.99		
Saturated naphthenes		Other compounds	
Monocycloparaffins	42.64	Indans	6.44
Dicycolparaffins	8.50	Naphthalenes	0.59
Tricycloparaffins	0.19	Phenols (mol. wt)	
	51.33	108	0.13
		122	0.56
Unsaturated naphthenes		136	0.19
		150	0.02
Monocycloparaffins	5.32		7.93
Dicycloparaffins	4.98		
Tricycloparaffins	0.90	Total =	100.00
Composition of 400-650°F fraction			
Saturated compounds		Aromatic compounds	
n- paraffins	4.8	Alkyl benzenes	12.6
i-paraffins	1.7	Indans & Tetralins	30.8
Monocycloparaffins	14.0	Indenes	5.7
Dicycloparaffins	7.9	Naphthalene	0.2
Tricycloparaffins	2.6	Naphthalenes	3.5
	31.0	Acenaphthenes (C_nH_{2n-14})	4.0
Unsaturated nonaromatic		Acenaphthenes (C_nH_{2n-16})	2.2
Monocycloparaffins	4.3	Tricyclics (C_nH_{2n-18})	0.4
	4.3		59.4
		Other compounds	
		Phenols (mol. wt)	
		108	0.04
		122	0.52
		136	0.98
		150	0.38
		164	0.07
		178	0.01
		Other non-hydrocarbons	3.10
			5.10
		Total =	100.00
Composition of 650-919°F fraction			
Saturated compounds			
Paraffins	1.4	Paraffins	0.0
Monocycloparaffins	3.1	Monocycloparaffins	0.5
Bicycloparaffins	0.6	Bicycloparaffins	0.3
Tricycloparaffins	0.7	Tricycloparaffins	0.2
Tetracycloparaffins	0.4	Tetracycloparaffins	0.2
Pentacycloparaffins	0.2	Pentacycloparaffins	0.1
Hexacycloparaffins	0.1	Hexacycloparaffins	0.1
Phenyls	0.3	Phenyls	0.2
	6.8	Total	1.6
Alkyl benzenes	3.0		
Indans &/or tetralins	0.5		
Other aromatics*	72.8		
Phenolic compounds	1.5		
Other non-hydrocarbons	13.8		
	91.6		
Total =	100.0		

*An approximate breakdown of aromatic-type compounds is given below:

Component type	Millimoles/100 grams
Napthalenes	93.4
Phenanthrenes	91.1
Chrysenes	21.9
1-2 ben-anthracenes 3-4 benzphenanthrenes	14.6
Pyrenes	15.4
5-ringed compounds	5.1

Table A-18. Composition of fractionated products from Wyoming subbituminous coal. [Source: Project H-Coal Report on Process Development, February 1965 through September 1967, Office of Coal Research, R & D Report No. 26.]

Composition of C_4 - 400°F fraction

Component	Wt %	Component	Wt %
Saturated paraffins		*Unsaturated naphthenes*	
C_4	0.20	Monocycloparaffins	7.71
iC_4	0.20	Dicycloparaffins	7.28
nC_5	0.88	Tricycloparaffins	1.67
C_6	2.54		16.66
C_7	2.85		
C_8	3.07	*Alkyl benzenes*	
C_9	2.48		
C_{10}	1.60	C_6	1.38
C_{11}	0.82	C_7	3.05
C_{12}	0.06	C_8	3.83
	14.70	C_9	3.34
		C_{10}	1.86
Olefins, diolefins, etc.		C_{11}	0.69
C_6	0.02		14.13
C_8	0.57		
C_9	3.12	*Other compounds*	
C_{10}	0.37	Indans	5.11
C_{11}	0.16	Naphthalenes	0.79
	4.24	Phenols (mol. wt)	
		108	0.41
Saturated naphthenes		122	0.91
		136	0.36
Monocycloparaffins	36.82	150	0.03
Dicycloparaffins	6.09		7.61
	42.91	Total =	100.3

Composition of 400-650°F fraction

Component	Wt %	Component	Wt %
Saturated compounds		*Aromatic compounds*	
n-paraffins	8.8	Alkyl benezenes	6.7
i-paraffins	2.1	Indans & tetralins	23.2
Monocycloparaffins	7.5	Indenes	8.7
Dicycolparaffins	2.7	Naphthalenes	12.3
Tricycloparaffins	1.1	Acenaphthenes (C_nH_{2n-14})	12.7
	22.2		
		Acenaphthylenes (C_nH_{2n-16})	1.7
Unsaturated nonaromatic			
Paraffins	1.4	Tricyclics (C_nH_{2n-18})	0.5
Monocycloparaffins	1.9		65.8
Dicycloparaffins	0.8		
Tricycloparaffins	0.4	*Other compounds*	
	4.5	Phenols (mol. wt)	
		108	0.4
		122	0.4
		136	1.5
		150	0.7
		Other non-hydrocarbons	0.2
			7.5
		Total =	100.0

Composition of 650-900°F distillate

Component	Wt %	Component	Wt %
Saturated compounds		*Unsaturated nonaromatic*	
Paraffins	7.2	Paraffins	0.6
Monocycloparaffins	1.4	Monocycloparaffins	0.7
Dicycloparaffins	0.4	Dicycloparaffins	0.1
Tricycloparaffins	0.6	Tricycloparaffins	0.0
Tetracycloparaffins	0.5	Tetracycloparaffins	0.0
Pentacycloparaffins	0.3	Pentacycloparaffins	0.0
Hexacycloparaffins	0.3	Hexacycloparaffins	0.1
			1.5
Other compounds			
Alkyl benzenes	0.2		
Other aromatics*	74.0		
Phenolic compounds	0.6		
Other non-hydrocarbons	12.6		
	87.4		
Total =	100.0		

*An approximate breakdown of aromatic-type compounds is given below:

Component type	Millimoles/100 grams
Napthalenes	91.7
Phenanthrenes	116.7
Chrysenes	26.1
1-2 benzanthracenes 3-4 benzphenanthrenes	15.2
Pyrenes	19.2
5-ringed compounds	5.1

It is reasonable to assume that if component distribution is sensitive to coal sources, then it may also be sensitive to changes in operating procedures. The greatest potential for carcinogenicity in this process would be expected from some of the materials contained in the 340 to 490°C fraction. Specifically, the portion of this fraction identified as aromatics and aromatic-type compounds, for example, phenanthrenes, chrysenes, 1,2- benzanthracenes, 3,4- phenanthrene, pyrenes, and five-ringed compounds could be hazardous. The nonhydrocarbon fraction and the phenolics should be considered as possible carcinogenic or co-carcinogenic (See Ref. 8).

The total products of hydrogenation, the higher-boiling distillates, the filtered or centrifuged oils, the char, the residues, and the recycled solvent oil are all potentially hazardous materials (See Ref. 9). Also the complex nature of these products calls for consideration of potential carcinogenic and co-carcinogenic hazards involving the associated paraffins (solvents), phenols, and high-molecular-weight aromatics.

No information is available on the composition of stack gases and wastewater effluents. However, it is expected that they, like those associated with coal gasification, are dependent upon the efficiency of the conventional clean-up subsystems. The wastewater probably contains traces of phenol, cyanide, hydrocarbons, and soluble inorganics.

Synthoil Process (See Ref. 4)

The Synthoil process was developed to liquify and desulfurize low-quality, high-sulfur coals in a single step, by catalytic hydrotreatment in a highly turbulent co-current upflow, packed-bed reactor to produce nonpolluting utility fuel oil. A slurry of powdered coal in a portion of the product oil are combined with a mixture of recycle and fresh hydrogen and introduced into the reactor packed with pellets of catalyst. The total reactor product stream is separated into its respective components, gases, liquids, and unreacted solids by means of a gas disengager and a centrifuge. The liquid is divided into recycle, quench, and product oil. The separated solids are pyrolized to yield additional product oil and a residue which is used to produce process hydrogen.

Ammonia and hydrogen sulfide, removed in purification of gasifier gases, can be used for the production of $(NH_4)_2SO_4$ while C_1-C_5 hydrocarbons can be sold to natural gas distributors.

Experimental work with Western Kentucky coal in reactors operating at temperatures of about 450°C and pressures of 2000 to 4000 psi yields a fuel oil and residue whose compositions are shown in Table A-19. A. G. Sharkey, Jr. et al. (Ref. 10), report data given in Table A-20 and A-21, obtained by mass spectrometric analysis of Synthoil products including heavy oil and asphaltene fractions, showing that they contain many hazardous hydrocarbons as well as organic sulfur compounds. Shults, W. D. et. (Ref. 2), have likewise shown in recent unpublished analysis results of Synthoil product oil, Tables A-22 to A-25, that it contains many suspected carcinogens.

Table A-19. Analysis of oil products and residues from hydrodesulfurization experiments at 450°C. [Source: Paul M. Yavorsky, U.S. Bureau of Mines, "The Synthoil Process," presented at the 67th Annual Meeting of AICHE, Washington, D. C., December 1974, No. 350.]

	Analysis (wt. %)	
	4.6 percent sulfur coal processed at 4000 psig	3.0 percent sulfur coal processed at 2000 psig
Solvent analysis		
Product oil		
Oil	79.5	62.7
Asphaltene	17.4	24.4
Organic benzene insolubles	2.1	11.6
Ash	1.0	1.3
Residue		
Organic benzene insolubles	-	33.1
Ash	-	27.7
Asphaltene	-	9.0
Oil	-	30.2
Sulfur	-	2.10
Elemental analysis (ash free)		
Product oil		
Carbon	89.9	89.6
Hydrogen	9.2	7.6
Nitrogen	0.6	0.9
Sulfur	0.19	0.31
Oxygen (by difference)	-	1.6

Table A-20. Major structural types in heavy oil and asphaltene fractions from Synthoil product. [Source: A. G. Sharkey, Jr., et al., "Mass Spectrometric Analysis of Coal-Derived Fuels," U.S. Bureau of Mines (in press).]

Structural types[a]	Heavy Oil	Asphaltene
	Percent of Total Ionization	
Alkylbenzenes	11	9
Indenes	7	4
Indans	9	2
Naphthalenes	6	2
Acenaphthylenes	12	8
Biphenyls	21	11
Anthracenes; phenanthrenes	6	4
Phenylnaphthalenes	5	6
4-rings, peri-condensed	5	11
4-rings, cata-condensed	3	9
5-rings, peri-condensed	4	15
5-rings, cata-condensed	1	5
6-rings, peri-condensed	1	10
Phenols	9	4

[a]Including alkyl derivatives.

Table A-21. Organic sulfur compounds in the products of coal hydrogenation. [Source: A. G. Sharkey, Jr., et al., "Mass Spectrometric Analysis of Coal-Dervied Fuels," U.S. Bureau of Mines (in press).]

	mol. wt	Molecular formula	Identification[a]
Light oil	134	C_8H_6S	Benzothiophene
	148	C_9H_8S	Methylbenzothiophene
	162	$C_{10}H_{10}S$	Dimethylbenzothiophene
Heavy Oil	98	C_5H_6S	Methylthiophene
	138	$C_8H_{10}S$	Tetrahydrobenzothiophene
	174	$C_{11}H_{10}S$	Benzylthiophene
	184	$C_{12}H_8S$	Dibenzothiophene
	198	$C_{13}H_{10}S$	Methyldibenzothiophene
	208	$C_{14}H_8S$	Benzo [def] dibenzothiophene
	234	$C_{16}H_{10}S$	Naththobenzothiophene
	248	$C_{17}H_{12}S$	Methylnaphthobenzothiophene
	284	$C_{20}H_{12}S$	Dinaphthothiophene

[a]Based upon molecular formula determined by high-resolution mass spectrometry. Other isomeric forms possible in some instances.

Table A-22. Acidic compounds in Synthoil oil. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Component	Result
Weak acids	0 meq/g[a]
Very weak acids	1.10 meq/g
Phenol	4.90 mg/g
o-Cresol	2.36 mg/g
m-Cresol	5.48 mg/g
p-Cresol	2.96 mg/g

[a]meq/g - milliequivalent per gram.

Table A-23. N-Compounds in Synthoil oil. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Compound	Result
Indole	210 ppm
Skatole	128 ppm

Table A-24. Sulfur compounds in Synthoil oil. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/ETAC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Sample or subfraction	Number of sulfur compounds observed in GLC[a] profile
Synthoil oil	> 40
Neutral PAH fraction	> 20
3-membered rings PAH[b] subfraction	> 20
4-membered rings PAH subfraction	none
5-membered rings PAH subfraction	none

[a]GLC - gas-liquid chromatographic.

[b]PAH - polynuclear aromatic hydrocarbons.

Table A-25. PAH compounds in Synthoil oil. [Source: W. D. Shults et al., "Preliminary Results: Chemical and Biological Examination of Coal-Derived Material," ORNL/NSF/EATC-18, Oak Ridge National Laboratory, Oak Ridge, Tenn., Dec. 1975.]

Compound	Result (ppm)
phenanthrene	413
benzo(a)anthracene	18
benzo(a)pyrene	41

The sources of pollution from a coal liquefaction process utilizing catalytic hydrogenation, and in general any liquefaction process, are the gaseous and liquid effluents, solid wastes, and trace metals in the product oil. The primary end source of polluting gaseous effluents is the stack gas which is discharged to the atmosphere. The stack gas represents the combined gaseous effluents from the cleanup of acid gases and sour water which originated in the pyrolysis of coal and char and the catalytic liquefaction of coal. Prior to cleanup, the effluents consist of H_2, CH_4, C_2H_6, H_2S, NH_3, H_2O vapor, and other N- and S- containing compounds. Unfortunately, accurate analytical data on many of the polluting gaseous effluents are not available (See Ref. 10). The liquid effluents are the scrub-water and scrub-oil from the recycle gas purification system and from the make-up H_2 generation section. No analytical data are available on these effluents; however, data for those associated with gasification may be applicable.

Exxon Process (See Ref. 11)

Exxon is currently operating a one ton/day coal liquefaction pilot plant at Baytown, Texas, with the design of a 250-ton/day plant for the same site one-half complete. The construction of the larger unit is scheduled for completion in 1978.

In the Exxon process, cobalt molybdate catalyzes the hydrogenation of the finely divided coal suspended in and dissolved by a coal-derived hydrogen transfer solvent. Except for lower consumption of catalyst (claimed by the developers), the Exxon process is very similar to the H-Coal process.

The products, by-products, process streams, and waste effluents can be expected to be essentially of the same composition as those of the H-Coal and Synthoil processes.

Liquefaction - Hydrogenation (Solvation)

The depolymerization of coal using solvents such as tetralin, decalin, aromatics, and coal-derived oils has been under investigation for over 50 years. In bench-scale and pilot plant investigations, the solubilization of coal with solvents has been coupled with hydrogenation without benefit of added catalysts. The catalytic effect of the inorganics present in the raw coal has been studied and it is not to be discounted.

Solvent Refined Coal (SRC)

The Solvent Refined Coal (SRC) process is essentially a mild hydrogenation process that produces a low-ash, low-sulfur, high-heating-value liquid or solid fuel from coal. In the SRC process, a highly aromatic solvent, a by-product of the process, dissolves coal at 454°C and 1,000 psi in the presence of a hydrogen-rich fuel gas. Ash and unreacted carbon are filtered from the resulting liquid before it is flashed to remove solvent and light oil fractions containing sulfur. The remaining liquid is solidified by cooling, yielding the low-sulfur product fuel (Syn-coal). The byproducts from the process for which there is a market are elemental sulfur, phenols, cresylic acid, light oil, and ammonia (See Ref. 1).

Since the Syn-Coal product contains many of the higher boiling distillates, it should receive the same regard as the H-Coal and Synthoil products. At this time no detailed analysis is available on the SRC product.

The largest volume of waste solids from the plant is the mixture of coal ash and filter material from the fluidized bed boilers containing a minimum amount of carbon and a low concentration of sulfur. These solids along with the solid residue from the wastewater treatment section are disposed of in the mine. This material is relatively inert and should pose no problem of leaching and oxidation; however, no known studies have been made in this area.

The phenols and cresylic acids present in process water are recovered by the Phenosolvan process and a combination of distillation and extraction, respectively. Cresylic acid in the wastewater is reduced to about 100 ppm. Process water, containing residual phenol and cresylic acids, is filtered through activated carbon.

The gaseous effluents will contain less than one percent of the sulfur entering the plant and also some unidentified components.

In solvent-refining operations, precautions should be taken to avoid contact with the light oil (naphthene) stream, the filter cake, the flashed recycle solvent, and finally, the liquid coal. No analytical data are available on any of those streams.

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