2.1 EMISSIONS DURING "ROUTINE" OPERATING CONDITIONS

Air Emissions

Figure 1-3 given earlier shows the range, across five liquefaction processes (both direct and indirect) of emission levels of selected pollutants under normal operating conditions. The ranges in the data can be attributed to four factors:

- The different processes considered;
- Different sources for the data;
- Different assumptions about controls applied; and
- Calculations based on differing coal types (i.e., heat, ash, and sulfur content).

Despite these uncertainties, there do not appear to be major differences between the levels of "criteria" air pollutants emitted by the various processes under normal operating conditions. This conclusion reflects the fact that for all processes, the majority of gaseous emissions are produced in the auxiliary parts of the liquefaction system (i.e., coal handling, furnaces, boilers, acid gas treatment systems, etc.). These emission sources can all be handled by similar control techniques regardless of the process. The more important variables are coal type and the fuel used for auxiliary energy production (e.g., electric power production). In sum, it is not currently possible to distinguish among the technologies for these variables.

Water Effluents

For similar reasons there is also uncertainty about differences in wastewater pollution levels; in fact, the data on liquid effluent levels is subject to even greater uncertainty than for air emissions. In its preliminary analysis of wastewater treatment for indirect processes, EPA concluded that water pollution control has been "neglected" in synthetic fuel analyses, producing large data gaps and an immediate need for demonstration of the technical and economic viability of effluent controls (Inside EPA, 1980). Despite the uncertainties, important differences exist between direct and Lurgi indirect processes on the one hand and the remaining indirect processes on the other. These differences are due primarily to the fact that wastewater treatment for direct processes and the Lurgi indirect processes, unlike the others, require phenol separation and the handling of large quantities of complex organic compounds which are produced from the initial coal reactions. For these processes, estimated capital costs for wastewater treatment systems represents about 3 to 5 percent of total plant investment. In contrast, indirect processes based on Koppers-Totzek or Texaco gasification have expected capital costs for wastewater treatment of about two percent, or less, of total plant investment (U.S., EPA, Research Triangle Park 1981).

2.2 UPSET/ACCIDENT RISKS

In many cases of environmental analysis of synfuel plants, the pollution rates and subsequent impact analyses are based on levels that occur during "routine" or "normal" operating conditions. However, of equal environmental concern are the impacts caused by accidents or "upset" conditions.

When process upsets or emergencies occur, such as the blockage of a flow line, they will require the immediate venting of gases to relieve internal pressures and to prevent accidents. This venting will be done through a controlled combustor/flare system typically used in chemical and petrochemical plants. When this happens, normal pollution control systems are by-passed leading to higher emission rates of particulate, SO_2, unburned hydrocarbons, and other pollutants. To illustrate, Table 2-1 shows estimated SO_2 emission rates for the SRC II demonstration plant under upset conditions. A single occurrence of Case B would emit as much SO_2– in 2 hours as normally occurs during 4 to 10 days of operational Depending on how often they occur, such upsets could account for significant proportions of total emissions. And, the environmental impacts of such peak loadings could be greater than those occurring under normal conditions, although this question is seldom addressed in environmental studies. In the case of the SRC II demonstration plant, the flare stack will be about 235 feet high and in some events will emit a flame 100 feet wide and over 600 feet long.[2] Although the vent/flare system is designed to perform under these circumstances, if plants are located close to urban areas some psychological and aesthetic concerns may be raised.

Accidents and upsets affecting the wastewater treatment system can also occur; for example, surges of toxic compounds could kill

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[1] In some cases if incomplete combustion in the vent/flare system occurs, H_2S and hydrocarbons may also be released.

[2] The flare stack is only used when the rate of venting cannot be handled by the controlled combustor.

TABLE 2-1: ESTIMATED SO_2 EMISSIONS FROM THE FLARE IN THE SRC II DEMONSTRATION PLANT DURING UPSET CONDITIONS

Case	Event Description	Duration (hours)	SO_2 Emissions (tons)
A	One coal dissolver blown down from normal operating pressure to near atmospheric pressure in 45 minutes.	3/4	1
B	Two gasifiers vented at full load upstream of purification.	2	12.9
C	One load dissolver at full rate without purification.	4	5.6
D	Two gasifiers at full rate and pressure. Blocked in and blown down in 5 minutes, bypassing purification.	1/12	.03

Source: Adapted from U.S., DOE 1980, p. C-57.

the organisms in biological treatment systems. Unless adequate capacity exists in wastewater holding ponds, such events could lead to the direct discharge of toxic effluents into surface streams.

Since no commercial size liquefaction plants have operated in the United States, there are no data to measure the frequency of upsets.[1] However, based on comparisons between direct, indirect, and petroleum refining processes, inferences can be drawn on relative frequencies. The greater complexity of the direct processes vis-a-vis the indirect routes suggests that the former would

[1]Demonstration and pioneer commercial plants which involve scale-up risk, since their design is based on pilot plant information, can be expected to have more frequent upsets than future commercial plants whose design involves little or no scale-up risk.

encounter more frequent upsets. Similarly, direct process units, although similar to many refinery steps, would have greater frequency of upsets because of the high level of solids present in many of the streams.[1] Those solids may cause plugging and erosion which would not be encountered in refinery processing. There is a large economic incentive to minimize such upsets because reduced plant on-stream-time dramatically lowers the return on investment. Commercial plant constructors and operators would make use of all in-formation to maintain high on-stream-times.

2.3 ENVIRONMENTAL HEALTH RISKS

Direct liquefaction processes, and to a lesser extent indirect processes based on Lurgi gasification, create significantly greater environmental health risks than other coal liquefaction processes. This stems from the complex organic compounds which are contained in the intermediate streams and high boiling point end-products of some of the liquefaction processes. In contrast, with indirect processes using entrained or fluidized bed gasifiers (such as Texaco, Koppers-Totzek, or Winkler) all the complex organic molecules are destroyed and converted to gas consisting primarily of hydrogen, carbon monoxide, carbon dioxides, water, and methane. Purified hydrogen/carbon monoxide mixtures are then catalytically converted to methanol, gasoline, or Fischer-Tropsch liquids, which

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[1]Some indication of the frequency of accidents in refineries can be obtained from reported fire losses. According to data reported by the American Petroleum Institute covering the 1975-79 time period, there were between 1.15 to 1.42 fires (with losses exceeding $1,000) per refinery per year (API, 1977-80).

have health risks similar to currently used liquid fuels: toxicity upon ingestion or inhalation, and some risk of cancer upon repeated contact, ingestion, or inhalation.[1]

On the other hand, indirect processes using Lurgi gasifiers produce a wider range of organic compounds including some heavy oil and tars that contain polynuclear aromatic hydrocarbons and amines that have been associated with carcinogenic and mutagenic activity. The compounds are present in product streams from the gasifier and enter into wastewater streams during gas purification. Direct processes produce much greater amounts of these polynuclear aromatic hydrocarbons and amines. These compounds are contained almost entirely in the heavy products end (above 650°F), including intermediate streams, waste streams, and end-products. Occupational and public health risks from exposure are created because these compounds can enter the environment in several ways:

- Fugitive hydrocarbon emissions (i.e., leaks from valves, flanges, etc.);
- Releases during plant accidents;
- Releases in wastewater;
- Direct contact with direct process end-products; and
- Combustion products from using direct process liquids.

Even if developers of synfuels are aware of these problems, and taking particular care to protect workers, the degree of risks are

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[1]Cancer risk from compounds in gasoline and Fischer-Tropsch liquids as compared to direct process liquids are substantially lower (see Background Report and further discussion in this section). However, the range of the common compounds in gasoline, such as benzene, are implicated in elevated cancer rates (see Kingsbury et al. 1979).

highly uncertain at the present time. The principal issues are:

- What fractions pose the greatest health risks?
- What are the types and degrees of risk?
- What are the possible mitigating measures? and
- What differences occur among technologies?

In order to answer these questions, systematic laboratory testing of process streams, plant emissions and effluents, and end-products is needed. The outcome of a program of initial biological screening tests could be available during the next several years. However, long term clinical or epidemiological data is always likely to be inadequate to substantiate human health risk (see Section 4).

One of the greatest environmental health concerns is the release of these highly toxic substances through "fugitive hydrocarbon emissions" (i.e., emissions from leaks in valves, flanges, pump seals, process drains, etc.).[1] This is a particular concern for direct processes because of the polynuclear aromatic hydrocarbons and amines in many of the process streams. Studies of existing oil refineries have shown high levels of nonmethane hydrocarbon (NMHC)[2]

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[1]The concentration and fate of toxic and carcinogenic materials in these fugitive emissions is uncertain. According to several studies, only liquids boiling above 650°F showed carcinogenic activity (see Background Report). Just what fraction of such a stream leaking from a valve would vaporize into the air or drip onto the ground is uncertain. The possibility is that both air and surface water pollution could result.

[2]Nonmethane hydrocarbons is a very broad spectrum since it includes every hydrocarbon from ethene and ethylene on up to asphalts (i.e. , it is everything other than methane itself) . Therefore levels of NMHC has no direct relationship to concentrations of carcinogenic hydrocarbons. For example, leaks from propane storage would yield high NMHC values in the complete absence of carcenogenic or mutagenic compounds.

fugitive emissions implying that a potential for human exposure to these hydrocarbons exists. However, coal synfuel developers believe that such emissions can be substantially reduced through a "directed maintenance program." For example, for the SRC II demonstration plant it is estimated that 679 tpy of fugitive NMHC's will be emitted in an "unmitigated" case, but only 97 tpy with a "directed maintenance program." All developers contacted (represented by the six coal conversion technologies identified) are committed to such a program. However, what constitutes a directed maintenance program has not been rigorously specified, but generally it would require systematic monitoring for leaks and repairing those that exceed certain levels. To what extent such a program would reduce fugitive emissions and their associated risks is still unclear except that theoretically it would represent an improvement over conventional refinery practices.

2.4 PRODUCT AND CONVERSION EFFICIENCY DIFFERENCES

Differences in the products and in the conversion efficiency of various liquefaction processes can result in very different environmental impacts. For example, if two processes produce the same product but one has a higher conversion efficiency, then it will, on a per-unit-of-energy basis, cause fewer impacts associated with mining and liquefaction. Direct comparisons generally are not possible, however, because of uncertainties in the data (i.e., on energy conversion efficiency) and because of the wide range of products produced. Some processes produce all transportation fuel, such as the Mobil Methanol-to-Gasoline (MMG) process, whereas other processes produce more fuel oil suitable for stationary boilers. In addition, the MMG and methanol processes do not require any further refining step, whereas such refining is generally required with the direct processes to produce transportation fuels.

Figure 2-3 summarizes the product distribution from the six kinds of coal liquefaction processes. The proportion of each type of product can be varied somewhat; the proportions shown are those currently planned for demonstration and commercial plants (Rogers and Hill 1979). As shown in Figure 2-3, the indirect processes produce a much higher proportion of transportation fuels than the direct processes, which produce primarily heavy fuel oils. The direct processes can be adjusted to produce a higher fraction of transportation fuels; for example, the EDS process could be modified to shift the proportion of fuel oil from about 52 to 33 percent, with an attendant increase in naphtha and lighter fuels (Epperly, Plumlee and Wade 1980), but with a decrease in total throughput and thermal efficiency (see Figure 2-4).

In order to compare processes, Figure 2-5 gives three different bases[1] for comparing the "efficiency" of the six processes being

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[1]No single measure of energy efficiency is adequate; these three measures were chosen to illuminate the range of important considerations . However, even these three measures are inadequate in that they do not explicitly take into account (a) the differences in engine efficiency that different fuels might yield; for example, differences in miles per million Btu's between gasoline and methanol; and (b) energy requirements for additional refining (if any -- see Section 2.5). In addition, efficiency calculations do not reflect the differences in fuel quality that two different processes might produce (e.g., middle distillates from Fischer-Tropsch are more suitable for producing diesel and jet fuels than similar fractions from direct processes).

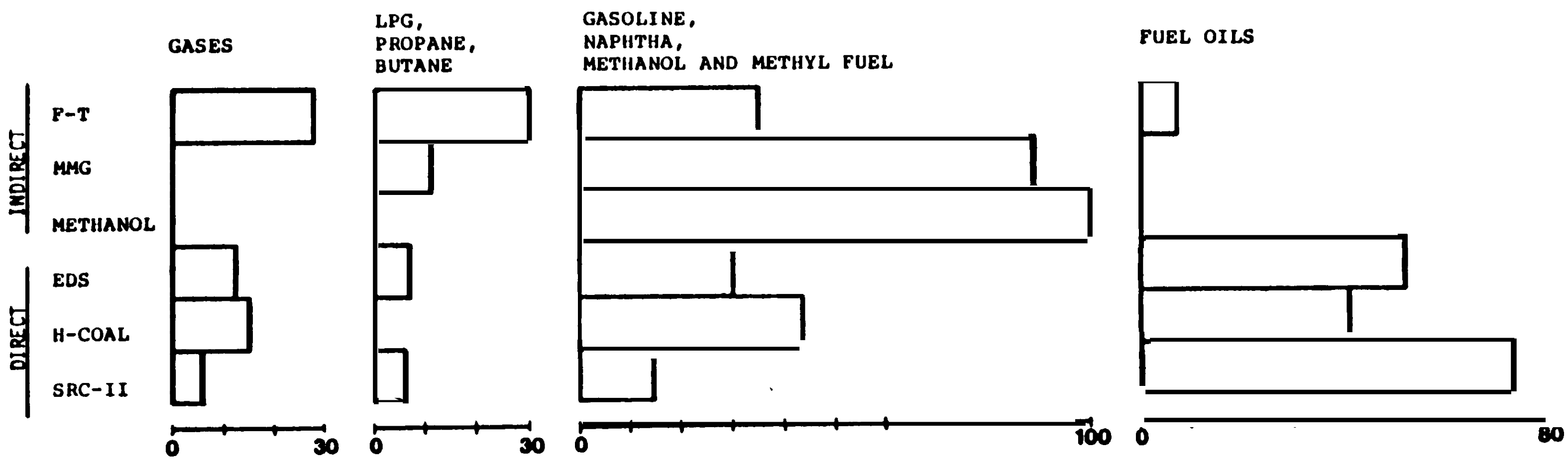


Figure 2-3: Comparison of product outputs. (product shares in percent on a Btu basis)

Source: Derived from Rogers and Hill 1979

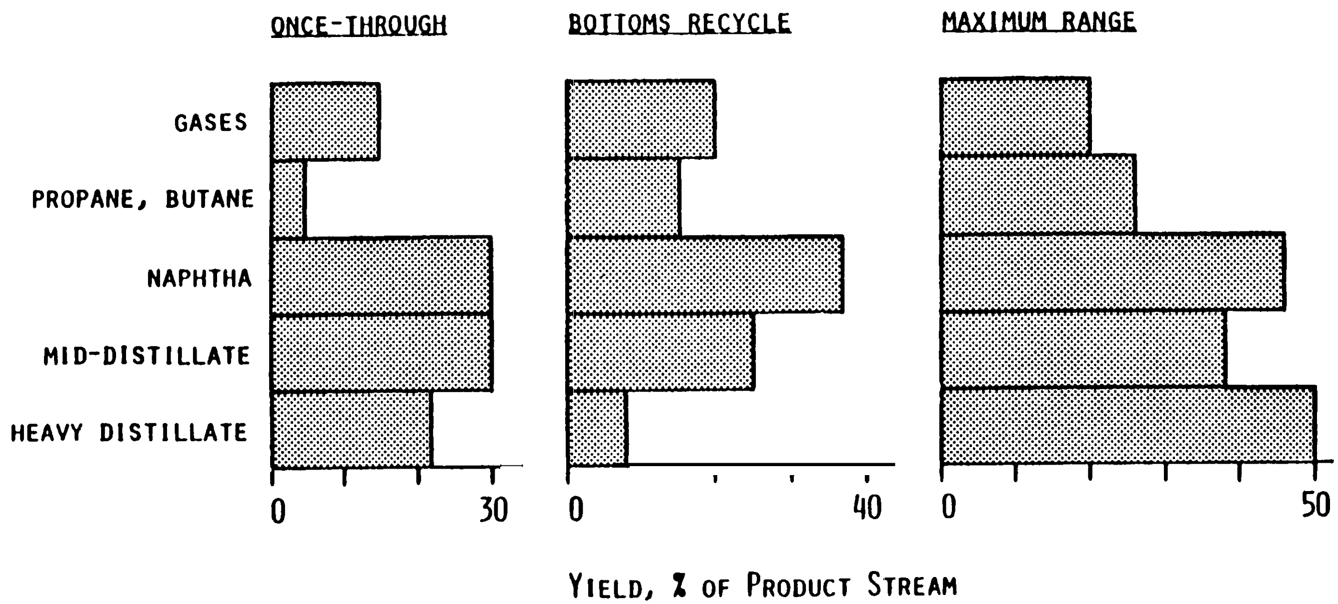
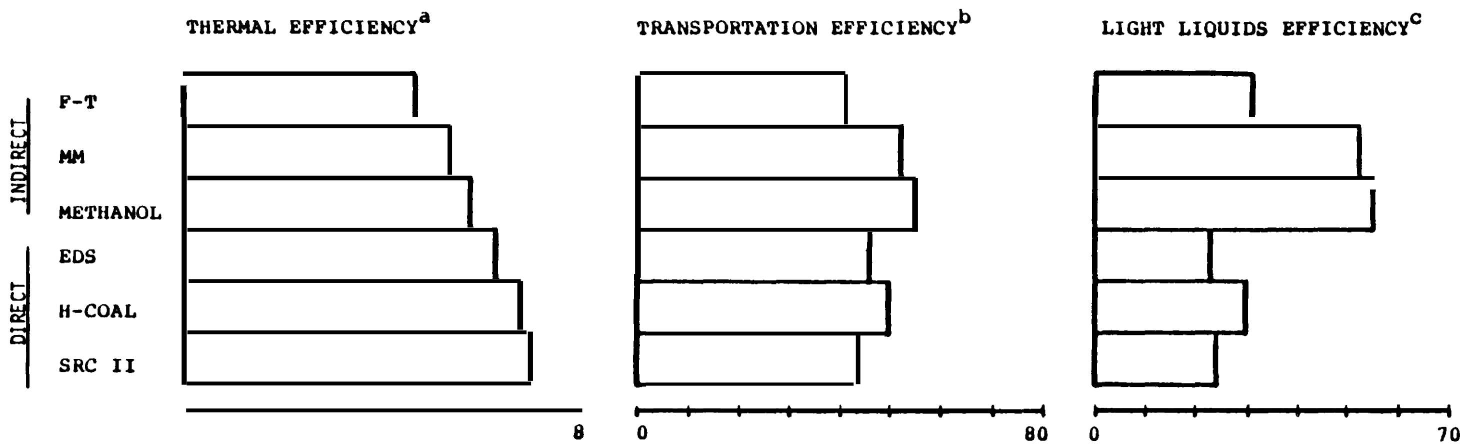


Figure 2-4: Range of Product Outputs from the Exxon Donor Solvent Process

Source: Adapted from Epperly, Plumlee and Wade 1980.



[a]Total hydrocarbon energy/total plant input with steam and electricity produced onsite.

[b]As in a, with total HC input corrected to indicate costs for upgrading to transportation fuel (gasoline grade) from the heavier fuel fractions.

[c]As in a, but include only hydrocarbons for transportation: propane,butane,LPG,me ,naphtha, and No.2 oil.

Figure 2-5: Comparison of Conversion Efficiencies considered. The first bar graph shows overall percent thermal energy efficiency (i.e., total Btu's output divided by Btu's of energy input). This comparison shows that the direct processes are substantially more efficient, ranging from the 69 percent SRC II process to the *46* percent Fischer-Tropsch indirect process. Accordingly, it would require 50 percent more coal, with all its attendant environmental and human health and safety impacts, **to use** Fischer-Tropsch process instead of the SRC II process for an equivalent Btu value of output.

At the other extreme, the "light liquids efficiency" is an index that only measures the thermal efficiency for producing fuels that can be directly used for transportation purposes with little or no upgrading. This includes the propane, butane, LPG, naphtha, and No. 2 fuel oil fractions. In this case methanol and methanol-to-gasoline have the highest efficiency, and the EDS and SRC II processes compare unfavorably. On this basis these latter processes would require two to four times the plant capacity to produce an equivalent amount of fuel that could be easily used by the transportation sector.

A third means for directly comparing these various processes is "transportation efficiency" represented by the middle bar graph of Figure 2-5. This "transportation efficiency" index is based on the Btu output of liquids, weighted against a value scale based on the economic cost of transforming that liquid to a high grade transportation fuel. For example, unleaded premium gasoline is weighted 1.0, the more efficient fuels of butane and propane are weighted

1.08 and 1.07 respectively (see Background Report, and Rogers and Hill 1979). Fuel oil is penalized, with a weighting of 0.56. Although the weights are based on economic costs and prices, they provide an approximation of transportation energy value of the product mixes at the liquefaction stage. When compared to thermal efficiency, the transportation efficiencies are lower across the board, reflecting the relative energy cost of upgrading coal liquids to transportation fuels. Methanol and methanol-to-gasoline processes have the highest "transportation efficiency," (54.6 percent and 52.2 percent, respectively), while Fischer-Tropsch and SRC II have the lowest (41.5 and 44.2 percent, respectively).[1]

2.5 UPGRADING AND REFINING

Comparison among the coal liquefaction processes should take into account the demand for the various products, and the feasibility and efficiency of refining and upgrading to meet market needs. From an environmental perspective, important factors include:

- How efficient will be the refining process to produce transportation fuels;
- Will grass roots refining capacity be needed; and
- What types of refinery impacts may occur.

The two classes of coal liquefaction processes have different refining needs. The MMG process produces a product directly usable

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[1]This comparison does not consider the superior quality of diesel fuel from the Fischer-Tropsch process compared to similar fractions from direct processes. Thus, Fischer-Tropsch may not be distinguishable from other processes in about the 45 percent transportation efficiency range.

as transportation fuel. The Methanol process can be considered to manufacture a blending stock for transportation fuels used in conventional engines, a feedstock for the MMG process, or pure ethanol to be used directly in appropriately modified engines. For these technologies, the conversion efficiencies described in the previous section represent the efficiencies for final products. For the Fischer-Tropsch process, a low octane gasoline (unsuitable for motor fuel unless upgraded) is a major product along with other transportation fuels such as diesel fuel. As indicated previously, some fuel oils are produced by the Fischer-Tropsch process which would require cracking and reforming to make transportation fuels.

The direct coal liquefaction processes produce light, middle, and heavy distillate fractions, with proportions varying depending on the specific process type and the amount of "recycle" or the residence time liquids spend in reactor vessels. The light distillate or naphtha fractions of direct processes make good gasoline blending stock after reforming. The EDS and H-coal processes can produce up to two-thirds naphtha and one-third fuel oil to maximize liquids with transportation value. The SRC II process, as indicated earlier, produces a greater amount of heavy products, although its product slate is also variable. In all cases, however, significant refining of the range of liquids is required to produce high proportions of transportation fuels. Because of the extensive refining requirements, including large hydrogen requirements, refining to transportation fuels is an energy intensive process. Table 2-2 indicates the efficiency of refining SRC-II liquids to

TABLE 2-2: EFFICIENCY OF REFINING SRC-II LIQUIDS[a]

Refinery Characteristics	Total Input Btu Requirement[b] (10^6 Btu/day)	Product Output[c] (10^6 Btu day) Gasoline	Jet Fuel	Efficiency
High severity hydrotreating	356,483	75,260	204,060	78.4
Intermediate severity hydrotreating	347,697	89,967	88,243	80.0
High severity hydrotreating and fluid catalytic cracking	352,423	265,000	--	75.2
Intermediate severity hydrotreating and single stage hydrocracking	335,524	265,000	--	79.0

[a]Refinery characteristics and data from Frumkin and Sullivan 1980.

[b]Includes a composite of SRC II syncrude, boiler fuel and electricity. SRC syncrude = 5.76 x 10^6 Btu/bbl; boiler fuel = 6.2 x 10^6 Btu/bbl; electricity = 10.5 x 10^6 Btu/MW. See Background Report.

[c]Gasoline = 5.3 x 10^6 Btu/bbl; jet fuel = 5.7 x 10^6 Btu/bbl.

gasoline and jet fuel. The low efficiency range, from about 75 to 80 percent, reflects the extensive cracking and hydrogenation requirements to upgrade these liquids.

The energy efficiency of refining improves as additional fuel oil remains in the product output (Frumkin and Sullivan 1980). Based on discussions with staff of direct process developers, they expect to utilize naphtha fractions as a gasoline blending stock and use heavier fractions to back out petroleum as a boiler fuel (Gulf Mineral Resources Co. 1980; Exxon Research and Development Corp. 1980; and Hydrocarbon Research Corp. 1980). In addition, environmental impact statement documentation for SRC II and SRC I facilities indicates that middle and heavy fractions will be used for boiler fuels (U.S., DOE 1981a, 1981b).

For these reasons, over the short term, environmental disturbances from additional refinery requirements for both direct and indirect coal liquids appear to be minimal. However, over the longer term if demand for transportation fuels cannot be met by petroleum liquids, refining direct process liquids to transportation fuels may be more favorable (Chevron Research 1981). Under these circumstances the most efficient refining operations for direct liquids would be from new grass roots refineries (Frumkin and Sullivan 1980) and refining coal liquids may be a significant environmental issue. Many of the issues are closely related to those for the liquefaction process itself, such as concerns about air and water quality, siting, and health considerations. The liquefaction processes can be ranked generally on the basis of additional refining requirements to meet transportation demand as follows (from major requirement to no requirement): (1) SRC II; (2) H-coal and EDS; (3) Fischer-Tropsch; and (4) Methanol and MMG.

3.0 WHAT ARE THE IMPORTANT LOCATIONAL FACTORS AFFECTING ENVIRONMENTAL IMPACTS?

The different regions of the country vary greatly in the type of coal resources and in the physiographic and social setting of these resources. These differences can affect both the type and size of commercial synfuels development and affect a range of air, water, land use, and ecological impacts. Within regions, small variations in location can influence both actual and perceived environmental impacts thus, local conditions are important to siting choices for individual plants. In addition, a range of institutional and economic factors affect siting choices and can result in site selections that conflict with environmental values. This section addresses three locational topics:

- Coal characteristics affecting regional location;
- Regional differences in environmental impacts; and
- Local differences in impacts within a region.

3.1 COAL CHARACTERISTICS

Several critical characteristics of coal affect where coal liquefaction plants may be deployed, including the size of coal deposits, the composition of coals, and the combustion characteristics. In addition, of course, a range of other environmental resources is required, including adequate land and water resources and a suitable workforce. Where coal liquefaction plants may be deployed and what coal resources may be developed are major concerns because they determine what regions and environments will be impacted by coal liquefaction. This section addresses how coal resources affect the choice and location of coal liquefaction technologies, while the following sections address environmental effects dependent on locational factors.

Liquefaction plants are most likely to be located in proximity to coal deposits (indicated in Figure 3-l). This is because transportation costs for shipping the coal would be substantially greater than the cost of transporting the volumes of liquid products that would be produced from that coal. However, shipping coal long distances (e.g., greater than 300 miles) is possible and would be dependent on the choice of transportation modes available and many siting factors. For example, construction costs for coal liquefaction plants in the Gulf Coast Province are substantially less than in the Northern Great Plains or Interior Provinces (Fluor 1979), reducing capital outlays in Gulf Coast locations. Because of the complexity of factors involved in siting facilities, it is not possible to determine the most favorable coal liquefaction facility location based on a single criterion, such as proximity to coal deposits.

Coal liquefaction processes vary in their suitability to certain coal types. Eastern and Interior bituminous coals are generally more suitable for direct liquefaction processes than western subbituminous coals and lignite. This difference in suitability is

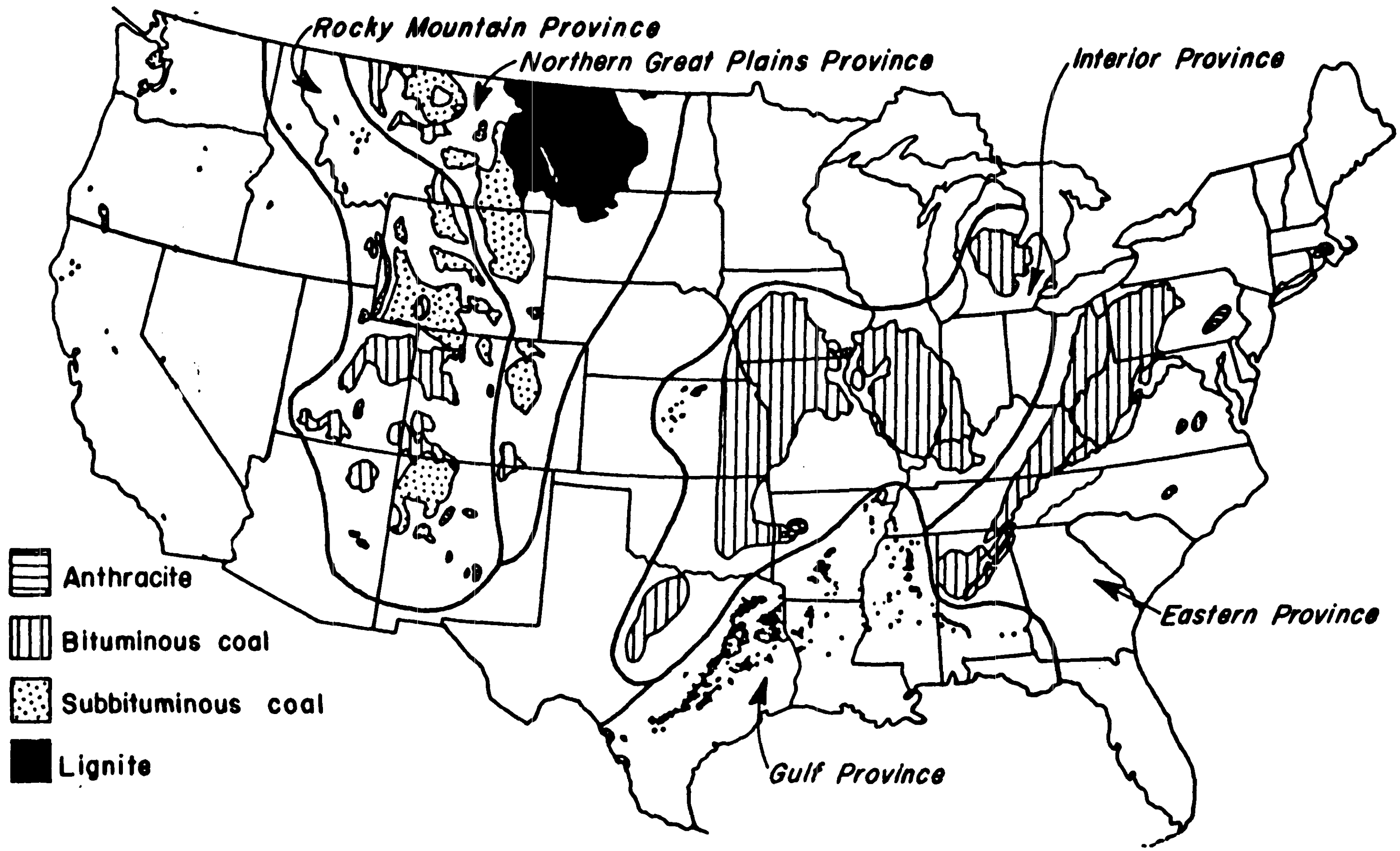

Figure 3-1: Distribution of coal resources in the coterminous 48 states.

Source: Univ. of Okla., S&PP 1975.

generally due to the higher liquids yield from bituminous coals (Epperly, Plumlee and Wade 1980; Fluor 1979). The yield differences for direct liquefaction processes are due to the additional hydrogenation requirements needed for coals with high oxygen content, characteristic of western coals and lignite (Simbeck, Dickenson and Moll 1980). This hydrogenation requirement is represented by the hydrogen distance in Figure 3-2. The higher capital and operational cost for hydrogenation generally offsets the lower cost advantage of lower rank western coals and lignites (Simbeck, Dickenson and Moll 1980; Fluor, 1979). The SRC II process is not suitable for western coals because of their low pyritic iron content. This iron acts as an essential catalyst for the liquefaction reactions in the SRC II process. Currently, direct process plants have been proposed only for eastern locations.

The indirect processes can utilize a wide range of coals. Although, like direct processes, they have higher yields per ton of coal for higher rank coals, they do not directly hydrogenate coal and, thus, do not operate at such an economic disadvantage as the lower cost subbituminous coals and lignites. For these reasons indirect process plants have been proposed for western as well as Interior and Eastern province locations. In addition, some studies indicate that indirect processes may be more favorable in western locations due to the lower coal costs (Simbeck, Dickenson and Moll 1980).

The caking or agglomerating properties of coal at high temperature restrict some gasifier and reactor applications. However,

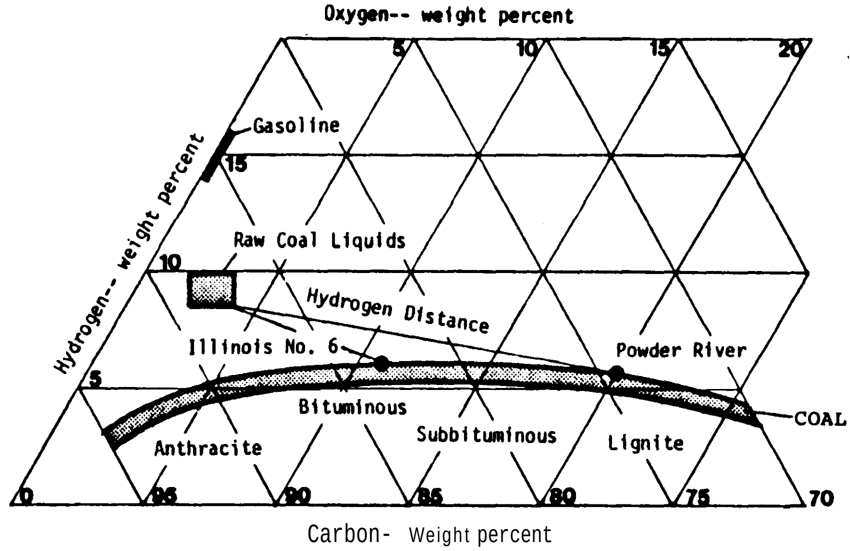

Figure 3-2: Direct coal liquefaction favors bituminous coals due to hydrogen requirements for oxygen.

Source: Adapted from Simbeck, Dickenson and Moll 1980.

recently even Lurgi gasifiers which were susceptible to clogging have been designed to accept caking coals.

In summary, direct processes are more likely to be deployed in Interior and Eastern coal regions than in Rocky Mountain, Northern Great Plains, or Gulf Coast coal provinces. Indirect processes have greater flexibility for utilizing different coals, potentially can be sited in a wide range of U.S. locations, and are perhaps favored in the West if coal costs remain lower there.

3.2 REGIONAL DIFFERENCES IN ENVIRONMENTAL IMPACTS

Table 3-1 presents key environmental factors affecting coal liquefaction impacts and describes how these impacts are affected by regional differences in these underlying factors. The thickness of coal seams, for example, results in more land disturbance in the

TABLE 3-1: REGIONAL CONDITIONS AFFECTING ENVIRONMENTAL IMPACTS

An EXISTING CONDITION	Determines an INTERMEDIATE EFFECT	Which partially determines an ENVIRONMENTAL IMPACT	REGIONAL IMPLICATIONS
Thickness of the coal seam	The amount of land disturbed	Ecological impacts	Minable coal seam thickness ranges from less than several feet in the Eastern Province to more than 50 feet in the Northern Great Plains. Ecological impacts that are caused by direct land disturbance due to surface mining include preemption of wildlife habitat, recreational areas, and agricultural lands. These will be more serious in the East than in the West.
Sulfur content of the coal	Sulfur emissions	Air quality and ecological impacts	Average sulfur content ranges from less than one percent in the Northern Great Plains and Rocky Mountain provinces to more than four percent in the Interior Province. However, the potential for increased SOx emissions in the East is partially offset by the ability to add emission controls to a synthetic fuel facility. Sulfur emissions affect ambient air concentrations of SOx and acid rain formation; acid rain, in turn, reduces species diversity and productivity in terrestrial and aquatic ecosystems. These problems are, therefore, potentially more serious in the East than in the West.
Ash content of the coal	Solid waste amounts	Ecological and water quality impacts	Ash content ranges from about seven percent in the Northern Great Plains Province to as much as fifteen percent in the Eastern Province. Thus, the amount of solid waste that requires disposal is greater in the Eastern Province than in the Northern Great Plains. The amount of land required for solid waste disposal increases with ash content as do the ecological impacts caused by that disturbance. To the extent that leaching from the solid waste disposal sites occurs, water quality is affected.
Rainfall	Reclamation potential, potential for flooding, potential for seepage. The need to discharge effluents	Ecological and water quality impacts	Rainfall ranges from over 50 inches per year in parts of the Eastern Province to less than seven inches per year in parts of the Rocky Mountain Province. High rainfall is beneficial in the sense that reclamation is made easier and soils are generally better. It can, however, also cause problems: floods increase the likelihood of a spill from a waste disposal site; seepage and leaching from waste disposal sites increase with precipitation; and evaporation rates are lower causing water effluents to accumulate if not discharged. Thus, the high rainfall in the East reduces land impacts but increases water quality impacts; the reverse is true in the West.
Wind and inversion frequency	Air dispersion potential	Air quality impacts	A combination of wind and temperature conditions generally determines the potential for dispersion of air pollutants. While it varies both seasonally and by location within a coal province, it is generally very good in the Northern Great Plains and Gulf Coast provinces; this ameliorates air quality problems there.
Terrain	The potential for plume impaction	Air quality impacts	Rough terrain occurs through the Eastern Province and in parts of the Rocky Mountain Province. Consequently, the probability of plume impaction from synfuel stacks on elevated terrain is greatly increased; such impaction greatly increases ground level concentrations of air pollutants.

(continued)

TABLE 3-1: Continued

An EXISTING CONDITION	Determines an INTERMEDIATE EFFECT	Which partially determines an ENVIRONMENTAL IMPACT	ᴙEG ONAL MPL CAT ONS
Popu ation dens ty	Wilderness character	Ecological and human health impacts	The low population density of the Great Plains and Rocky Mountain coal provinces affects the ecological sensitivity of the area. Synthetic fuel development will cause an increase in population density in the West. This increase will fragment ecosystems, fragment wildlife habitat, alter the natural appearance of the West's vistas, and in general, change its open-space character. On the other hand, with lower population density, there are fewer risks of adverse human health effects from coal liquefaction pollution.
Existing agricultural lands	Changed land use	Agricultural impacts	Agriculture is sometimes in competit on with energy development for land; the Interior Coal Province s characterized by pr me agricultura land--some of the best in the U.S. While land reclamation following mining in that province is possible, reclamation to existing high fertility levels is questionable. Preemption of agricultural lands by coal mining is also an issue in the Northern Great Plains--not because the land is so fertile but because reclamation is in doubt and agriculture is a way of life there.
Existing ecosystems	Reductions or modifications to land and plants	Ecological impacts	Values associated with terrestrial ecosystems include uniqueness, vastness, wildlife habitats (including endangered species habitats), recreation, and productivity. The ecosystems in the West are valued very highly for their wilderness character, vastness, and high quality wildlife habitat; in the East they are valued more for their productivity.
Existing air quality		Air quality impacts	In general, air quality is worse in the Interior and Eastern provinces than in the Northern Great Plains or Rocky Mountain provinces; non-attainment with respect to one or more criteria pollutants is more of a problem in the East. The presence of poor a r quality and non-attainment will make synthetic fuel development difficult. In the Rocky Mountain Province, however, the presence of many Class I PSD areas will make synthetic fuel development difficult.
Existing water quality		Water quality impacts	Streams in the Interior and Eastern provinces are, in general, more polluted with organic and inorganic chemicals than those in the Northern Great Plains and Rocky Mountain provinces; this could make synthetic fuel develoment in the East more difficult in water quality limited streams, where additional discharges may be restricted.

East than in the West. The sulfur and ash content of coal also affects the extent of air and solid waste impacts. Meteorological conditions can intensify some air impacts especially in the East where ventilation rates are low and the frequency of inversions is higher. Population density and the composition and character of existing ecosystems are also important. Table 3-2 summarizes how regional sensitivity to impacts from synfuels can vary.

Five ecological issues associated with synthetic fuel development provide a broad framework for examining the regional variations in environmental impacts:

- Degradation of air quality;
- Degradation of water resources, including native stream and riparian ecosystems;
- Degradation of terrestrial ecosystems from mining;
- Degradation of terrestrial and aquatic ecosystems due to acid rain, especially in the East; and
- Degradation of the overall ecological character of some areas.

These problems are not unique to synthetic fuel development, but are generally associated with any intense industrial development. Ecological impacts such as reduction in wildlife populations and changes in plant communities result from the cumulative effects of many disturbances. Coal liquefaction is just one of many industrial and social developments that disturb ecosystems; and, together with increasing industrialization in resource rich areas of the nation, it will contribute to progressive changes in ecosystems.

TABLE 3-2: FACTORS CONTRIBUTING TO REGIONAL ENVIRONMENTAL SENSITIVITY TO SYNTHETIC FUEL DEVELOPMENT
(relativey sensitivity)

Province	Air Quality	Water Quality	Water Availability	Ecological	Population Impacts
Eastern	Complex terrain and poor ambient air quality; scenic vistas (high)	Widespread existing pollution sources (high)	High rainfall and streamflow (low)	Valued forest lands (moderate	Varied population density (moderate)
Interior	Poor ambient air quality (moderate)	Widespread existing pollution sources (high)	High rainfall and streamflow (low)	Varied land use (low)	Varied population density (low)
Gulf Coast	Locally poor air quality in some areas contributes to sensitivity; good ventilation (moderate)	Local existing pollution sources (moderate)	High rainfall and streamflow (low)	Varied land use (low)	Varied population density (low)
Rocky Mountain	Complex terrain and several Class I PSD areas; scenic vistas (high)	Limited flow; variable quality (high)	Limited rainfall and stream flow (high)	Valued recreation land (high)	Low population density (high)
Northern Great Plains	Good ventilation, good existing quality (low)	Moderate flow, variable quality (low)	Limited rainfall (moderate	Agriculture cropland (moderate	Low population density (moderate)