

a range of primarily light hydrocarbon fuels. The products of both the direct and indirect processes are summarized later in Section 2.

For direct process liquids, considerable upgrading is required to produce stable fuels. Upgrading is minimized if fuels are used in stationary combustion such as for industrial boilers. If transportation fuels, such as gasoline, are desired then refining is required. This refining requires extensive hydrogenation and other steps to meet fuel specifications. The Fischer-Tropsch indirect process produces liquids that also require some upgrading, although to a much lesser degree. The Mobil Methanol-to-Gasoline technology does not require an additional refining step, nor does methanol which in some applications can be blended in small amounts with existing transportation fuels.

1.0 OVERVIEW OF ENVIRONMENTAL CONCERNS

Coal synfuels will produce many environmental problems, some of which are unavoidable while others can be avoided or at least minimized with appropriate designs and management practices. Some environmental problems are similar to those encountered with any large-scale industrial activity, especially those utilizing the nation's coal resources, while others will be relatively unique to coal liquefaction. Generally, problems will vary among regions and the types of coal liquefaction technologies employed. Table 1-1 summarizes major environmental issues associated with producing synthetic fuels from coal, according to the major steps in the

TABLE 1-1: SELECTED ENVIRONMENTAL ISSUES FOR COAL SYNFUELS

Production Stage	Land Use and Water Quality	Air Quality	Ecosystems	Safety and Health	Other
Mining	Short- and long-term land use changes, erosion, and uncertainty of reclamation in arid West Aquifer disturbance and pollution Nonpoint source water pollution (acid mine drainage--East; sedimentation--West)	Fugitive dust (especially in the West)	Disruption of wildlife habitat and changed productivity of the land Siltation of streams Habitat fragmentation from primary and secondary population growth	Mining accidents Occupational diseases in underground mining (e.g., black lung)	Increased water use for reclamation Coal transportation impacts on road traffic and noise
Liquefaction and Refining	Potential surface and groundwater pollution from holding ponds Wastewater discharges (East) Disposal of large amounts of solid wastes Local and-use changes Construction on flood plains	Emissions of "criteria pollutants" (i.e., NO _x , SO ₂ , particulates, etc.) Fugitive emission of carcinogenic substances Possible releases of trace elements Releases during "upset" conditions Possible localized odor problems	Air pollution damage to plants Contributions to acid rain Wildlife habitat fragmentation from population increases Contributions to the "greenhouse" effect	Occupational safety and health risks from accidents and toxic chemicals Carcinogens in direct process intermediates and fuel products	Water availability issues (especially in the West)
Product transport and end-use	Product spills from trains, pipelines, and storage	Changed automotive exhaust emissions (increase in some pollutants, decrease in others) Increased evaporative emissions from methanol fuels Toxic product vaporization	Acute and chronic damages from spills	Exposure to substances Uncertain effects of trace elements and hydrocarbons	Potential change in fuel economy Methanol corrosion and reduction of existing engine longevity

process--coal mining, liquefaction and refining, and the transport and end-use of the product.

1.1 MINING

The impacts from coal mining include:

- Disruption of aquifers, threatening nearby water wells;
- Water pollution caused by runoff from disturbed lands (particularly siltation and acid drainage);
- Losses in land productivity from soil alteration (especially in prime agricultural areas);
- Loss of wildlife habitat;
- Risks to worker health and safety; and
- Subsidence.

Coal liquefaction creates particular concern about mining impacts because of the very large coal requirements; for example, a **two** million barrel per day (bbl/day) coal synfuel industry would consume roughly 300 million tons of coal per year, an amount equal to 37 percent of the coal produced nationally in 1980. Some projections for coal production for the year 2000 have indicated a level of about 1,500 to 2,000 million tons per year (tpy) (U.S., Congress, OTA 1979). If the synfuel industry achieves a level of production of two million bbl/day, about 15 to 20 percent of U.S. coal mining would be dedicated to coal liquids. Based *on* projected coal mining patterns (i.e., projected regional distributions and surface vs. underground), over a 30-year period the surface area disturbed by mining at this rate would equal about 850 square miles (See Section 3.2). Figure 1-2 illustrates the regional variation

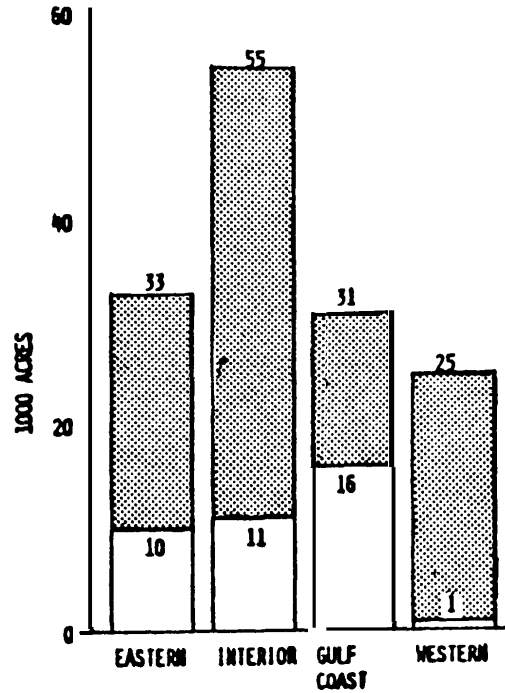


Figure 1-2: Surface area requirements for coal strip-mining over a 30-year lifetime for a 50,000 bbl/day plant.

by showing the coal land requirements over 30 years for a 50,000 bbl/day plant located in four different coal regions. As indicated, the variation can be large, ranging from 1,000 acres in certain western coal fields to 55,000 acres in the least productive Interior region coal fields. These differences are due to a variety of factors, but are a function of variations in the coal seam thickness and energy content of the coals.

1.2 COAL LIQUEFACTION AND REFINING

Table 1-1 also indicates the range of potential environmental impacts created by the coal liquefaction plant itself. Although

important technological differences exist among the various coal liquefaction processes (Section 2), there are also many similarities from an environmental standpoint. All plants are designed to transform a solid fuel, high in polluting compounds and mineral matter, into liquid fuels containing low levels of sulfur, nitrogen, trace elements, and other pollutants. In these processes, large volumes of gaseous, liquid, and solid process streams must be continuously and reliably handled and separated into end-products and waste streams. These waste streams, which can be air pollutants, water effluents, or solid wastes, must be treated to meet current laws and regulations that protect environmental values and should be treated to control discharges unique to this technology that are currently unregulated. In addition to these waste streams, other environmental concerns include potential ecosystem disruptions from population increases associated with building and operating the plants, the water requirements for cooling and other process needs, occupational safety and health risks, and possible increased hazards from using the synthetic fuels.

Air

Figure 1-3 shows the range of expected emission levels for selected "criteria pollutants" for liquefaction plants producing 50,000 bbl/day. As a point of comparison, a new coal-power plant meeting existing air emissions standards and capable of utilizing the same rate of coal as a 50,000 bbl/day liquefaction facility (which would have a capacity of about 1,700 to 2,600 megawatts) would produce roughly five to thirty times as much NO_x and

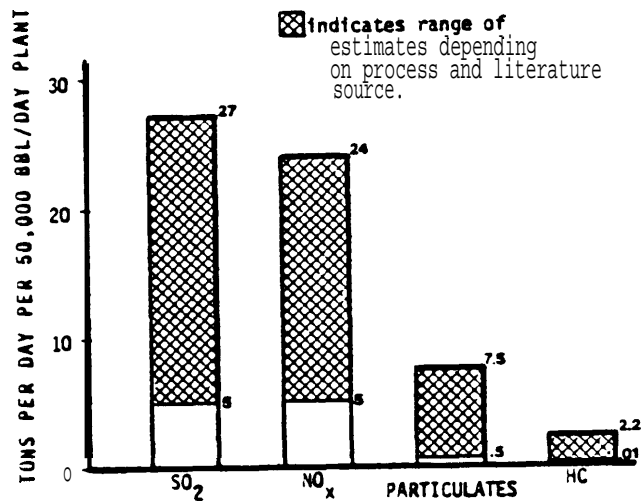


Figure 1-3: Range of air pollution emission levels.

SO₂, and one to twenty times as much particulates.¹ Therefore, while the emissions of criteria pollutants from coal synfuel plants are certainly not insignificant, they are generally much less than what could be expected from a large coal-fired power plant. The size of a coal-fired power plant (with emission rates equal to those described in the preceding footnote) which would give equivalent levels of emissions is shown in Figure 1-4. On the basis of plant size shown in the figure, the coal liquefaction plants are

¹Power plant and liquefaction facility size and emission rates are based on continuous operating conditions. Assumed liquefaction thermal efficiencies range between 45 and 69 percent (see sections 2.4 and 2.5), and power plant efficiency is 35 percent. The standards assumed for the coal-fired power plant (i.e., New Source Performance Standards) are: 0.03, 0.6, and 0.7 pounds per million Btu's of coal burned for particulate, SO₂, and NO_x, respectively. Emission standards are more complex than this, but these emission rates can be considered as "typical" values.

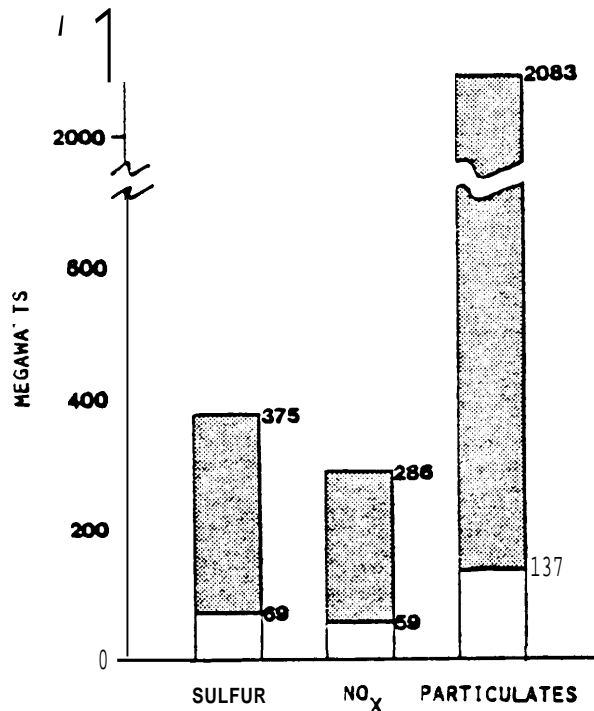


Figure 1-4: Size ranges of coal-fired power plants with emissions equal to 50,000 bbl/day synfuel plants.

equivalent to relatively small power plant units, except for particulates. Air dispersion modeling calculations have, in fact, shown that coal liquefaction facilities should be able to meet even the relatively stringent Prevention of Significant Deterioration (PSD) Class II standards for ambient air quality during "normal" operations in all locations studied.¹ However, it should be emphasized that this general finding is based on emission rates during "normal" operations only; during "upsets" or emergencies the

locations **where** dispersion modeling has been performed include western, interior, and eastern states (see Background Report). However, if multiple industrial pollution sources desire to locate in an airshed, PSD Class II increments could pose a constraint.

PSD Class II standards do not apply, but emission rates could be considerably higher for relatively brief periods.

Another potential problem is odor, which can be quite important on a localized basis. Odor episodes outside plant boundaries are well documented from petroleum refineries (NAS, 1979). Complaints by residents living near refineries include description of repeated annoyance, and frequent or occasional dizziness, nausea, vomiting, eye irritation, burning and irritation of the nose, and other symptoms (MITRE, 1981). At the present time, information is not available to indicate whether odor problems from coal liquefaction facilities may be better or worse than refineries. Like petroleum refineries, hydrogen sulfide is likely to be one of the major malodorous emissions (MITRE, 1981) because of its relative abundance in process streams. The lowest detection thresholds are for chemicals such as chlorophenols and mercaptans. Emission sources of many of the malodorous chemicals include fugitive emissions from valve fittings and pumps, venting or flaring, waste treatment ponds, and storage ponds. Data on levels of emissions from coal liquefaction facilities for specific malodorous compounds are not available.

Trace Organic Compounds

Trace emissions of carcinogenic compounds formed in the liquefaction process are probably of more concern than criteria pollutants. Some coal liquefaction processes (primarily those of the "direct" type) produce a wide range of organic compounds including polynuclear aromatic hydrocarbons and polynuclear aromatic amines

known to be carcinogenic. The concern is that workers and the general public could be exposed to these substances through trace levels in pollution streams, through accidental releases to the air and water, and through direct contact with end-products which might contain these compounds. At the present time, the degree of risk is highly uncertain due to:

- Lack of information on the precise nature of the chemical compounds produced;
- Uncertainty about the ability to control releases;
- Potential for multiple exposure paths for the populace;
- Inadequate scientific understanding of the long term human health effects from low-level but chronic exposures; and
- Potential for detoxifying the end products.

These uncertainties are primarily related to the absence of commercial plant experience and the limited environmental health testing of intermediate and end products.

Because of these human health concerns, detoxification or segregation of these streams with on-site use and disposal or special transportation methods may emerge as an essential prerequisite to a direct process liquefaction industry. For example, operation of plants to maximize the naphtha fractions (gasoline blending stocks) could eliminate the export of hazardous heavy fractions since these would be used on-site for hydrogen and/or power production (see also, sections 2.4 and 2.5).

Water

Coal liquefaction plants will also produce a number of wastewater streams which contain many pollutants known to cause health

and environmental problems. For example, process wastewaters will contain phenol, ammonia, polynuclear aromatic hydrocarbons, chlorides, sulfates, cyanides, and a variety of trace elements such as arsenic, cadmium, and mercury. Existing industrial wastewater treatment technologies are expected to be able to control most of these effluents. However, three factors contribute to the potential for water pollution. First, there is the possibility for incidents that will cause the wastewater treatment systems to not meet design specifications. For example, violations of discharge permit standards apparently occur in the range of between about one and six times per year for a refinery (U.S., EPA, Research Triangle Park 1981).¹ Second, it is still not certain that planned wastewater treatment technologies can continuously control the trace elements and toxic organic compounds or the potential interactions among the various pollutants associated with coal liquefaction processes. Finally, designers are planning on "zero discharge" in the West through the use of evaporative holding ponds, but in the East, plans now call for continuous or intermittent discharge of

¹**Violations** are recorded primarily for discharges of **total suspended solids**, biochemical oxygen demand (**BOD**) or pH, not for trace elements, **organics**, or phenols (U.S., EPA, Research Triangle Park 1981). Refineries operated by major oil companies generally have fewer violations than small independent refineries. In addition, because refineries now employ Best Practicable Control Technology Currently Available, problems with compliance with discharge permit standards have been significantly reduced during the past several years (U.S., EPA, Research Triangle Park 1981). Well managed treatment plants rarely have problems with compliance (Franzen 1981), while poorly managed facilities have recurrent violations (U.S., EPA, NEIC 1981) .

pollutants.¹ Options that avoid direct discharge have been reviewed for pioneer plants including deep well injection, surface impoundment, brine concentration, water reuse, evaporation, and incineration of residues. However, even where plans call for low or zero discharge rates to surface streams, there are risks due to windblown drift, seepage, spills, or flooding of holding ponds.

Solid Wastes

The disposal of solid wastes also represents an important issue, both in terms of its long-term land-use effects and in terms of the possibility of toxic materials being leached from the disposal site. Despite a wide variation in the composition of these solid wastes, they are basically of two types:

- Large volumes of ash wastes that were originally part of the coal; and
- Elements separated from ash and coal, wastewater treatment sludges, other added materials (such as catalysts) and partial combustion products.

The magnitude of the wastes (largely ash) is great--a 50,000 bbl/day plant over 30 years would produce enough ash to require one square mile of land with waste piled 50 feet high. One of the major issues has to do with whether these wastes (or some portions thereof) should be declared "hazardous" under the 1976 Resource Conservation and Recovery Act and, thus, be subject to very

¹In Eastern locations discharge volumes may represent up to one-fourth of water withdrawn for process or cooling purposes. For example, average discharge for the 6,000 tons per day (tpd) coal capacity SRC-II pilot plant is expected to be 1,238 gallons per minute, and withdrawals are to be 4,826 gallons per minute.

stringent disposal requirements. If this were to occur, it could have serious economic consequences for a synfuels industry.

Other Impacts

A range of other environmental problems in addition to those related directly to gaseous, liquid, and solid wastes is important.

For example:

- . The extremely large plant size--requiring approximately 2,000 acres for a 50,000 bbl/day facility--creates aesthetic and land-use impacts;
- Large shipments of coal to plants located away from mines--for a 50,000 bbl/day plant, roughly 20,000 tons per day, or 200 train cars carrying 100 tons each--create noise, dust, and disruptions to local road traffic; and
- The consumption of water for plant operations--anywhere from 3,400 to 5,900 acre-feet per year (AFY) for a 50,000 bbl/day facility, depending on the design--although only a small fraction of existing supplies in most areas, raises concerns over the appropriate use of an increasingly scarce resource, especially in the arid West.

The process of upgrading and refining the products of coal liquefaction (when required) could occur in on-site refining operations or at a separate refinery. Refineries processing coal liquids need a large capacity for hydrotreating and hydrocracking capability to break down and improve the quality of coal liquids. Many of the wastewater treatment and air quality problems described above for the liquefaction process will be similar for refineries. However, downstream refining problems are likely to be less critical than coal liquefaction steps due to the following features:

- Nearly all of the entrained solids have been eliminated from the product streams. This reduces air, water, and solid waste disposal requirements;

- The sulfur and nitrogen have been largely removed; and
- Most of the trace elements have been removed.

However, compared to existing refineries with crude oil feedstocks, refineries processing coal liquids face additional problems:

- The heavy liquids from coal are not compatible with the heavy ends of crude oil, and therefore would have to be refined in separate units;
- From direct coal liquefaction processes, some entrained particulate matter containing trace elements remains;
- Heavy coal liquids fractions will contain polynuclear aromatic hydrocarbons and polynuclear aromatic amines that need to be segregated and hydrotreated to reduce their toxicity;
- More severe hydrotreatment capacity is needed, and special wastewater treatment capacity and capability may be needed;
- Although much of the sulfur and nitrogen may be removed, levels may exceed those normally found in petroleum feedstocks (especially for nitrogen); and
- Coal liquids are unstable compared to petroleum feedstocks, requiring short distance transport and timely utilization of feedstocks (Conser, Garrett and Weiszmann 1979).

No data are available on the air, water, and solid waste discharges anticipated from a coal liquids refinery. This may mark a significant omission in the Department of Energy (DOE) and Environmental Protection Agency (EPA) programs for characterizing advanced fossil fuel programs. Coal liquids are being tested in existing refineries, but a large-scale coal liquids-refining operation would **most** likely require a grass roots refining facility, probably in close proximity to the coal liquefaction plant, in order to utilize the unstable coal liquefaction products (Conser, Garrett and Weiszmann 1979).

1.3 PRODUCT TRANSPORT AND END-USE

As with crude oil and existing transportation fuels, the transport of coal liquefaction intermediate and final products will be by pipe, rail, truck, and barge. Environmental impacts can result from spills, fires, and explosions. The nature of most transportation impacts from shipping coal liquids is similar to those for shipping crude oil, now a wide-spread activity. However, two differences stand out: the toxicity of intermediate products from direct processes is higher than for petroleum, which may result in a greater environmental risk and may require special clean-up precautions to avoid contamination of workers; and coal liquid feedstocks may plug or reduce pipeline performance. For these reasons, special precautions in shipping direct process intermediate products may be appropriate. For example, transportation systems may need to employ insulated pipe or heated containers (U.S., DOE 1981a).

Some coal liquefaction products will be shipped relatively short distances (less than 100 miles) to nearby refineries, while others will be shipped much longer distances by rail, truck, or pipeline. However, due to product instability and gum formation for direct process coal liquids, long distance pipeline shipment of some products may be restricted primarily to batch bulk shipments, such as tank-cars. For example, fuel oil fractions from the SRC II demonstration facility (**6,000** tpd of coal feed) are expected to be shipped by rail. Each month the demonstration plant would use about 12 unit trains, each containing 63,000 tons, for shipping the fuel oil. Based on extrapolation from spills of hazardous

commodities, a "reportable" spill¹ would be expected to occur every 1.3 to 2.8 months. Spills over bodies of water would be expected to occur once every 30 to 60 months (U.S., DOE 1981a). Based on volume of a product shipped, a commercial-scale plant would have about 5 times higher probability of spills than would the demonstration plant. Because the transport of products is essential to the coal liquefaction fuel cycle, measures to minimize frequent spills along transportation corridors should be considered an integral part of the safety and hygiene provisions for this technology.

The impacts from end-use of synthetic fuels, compared to those from conventional fuels, depend on the type and uses of fuels produced (ranging from heavy oils to be used in industrial and utility boilers to methanol to be used in automobiles) and the degree of refining used to upgrade the synfuel products. Table 1-2 summarizes the problems associated with the transportation uses of the various fuel forms as compared to petroleum derived liquids.

Differences in environmental effects from alternative fuels end-use are primarily a function of combustion products. However, concern over fuel handling and the effects on engines and their performance may also have secondary environmental consequences.

Emissions are primarily dependent on the quality of fuels and how they are utilized. Direct processes produce fuels which are generally high in aromatic compounds, sulfur, and nitrogen

¹A "reportable" spill is one for which losses in value or to property exceed \$2,900 (U.S., DOE 1981a).

TABLE I-2: SUMMARY OF TRANSPORTATION END USE PROBLEMS

Coal Derived Transportation Fuel	Combustion Characteristics	Emissions	Engine Effects	Sources
Gasoline from direct processes	Similar to gasoline Blending agent (can improve octane)	NO _x higher Trace elements higher		Epperly, Plumlee and Wade 1980; Simbeck, Dickenson and Moll 1980.
Diesel ^a fuel (from direct processes)	Aromatic fuels smoke Low cetane number (depends on hydro- treating)	Particulate much higher NO _x and hydro- carbons higher potentially (depends on hydrotreating)	Possibly reduced mileage with lower cetane numbers	Ghassemi and Iyer 1981.
Jet fuel (from direct processes)	Aromatic fuels smoke, incomplete combustion	Particulate and hydrocar- bons higher	Burnt combustors	Delaney and Lander 1980.
Gasoline (from in- direct processes)	Similar to gasoline	Similar to gasoline	Similar to gasoline	Kam 1980.
Methanol	Similar to gasoline when blended in small proportions Uncertain stability	Increased evaporative emissions but possible reduction in exhaust emis- sions (except aldehydes)	Corrosion	Kermode, Nicholson and Jones 1979; U.S., DOE 1978; Barr and Parker 1976.

^aPerformance of diesel fuels derived from direct process depends in part on the extent of hydrotreating. With severe hydrotreatment, a minimum cetane number of 40 can be achieved (Sullivan et al. 1980).

compared to indirect processes or to petroleum derived fuels.¹ Diesel and jet fuels must be low in aromatic content to avoid incomplete combustion and smoking. In contrast lightweight aromatic compounds are good gasoline feedstocks. For this reason the naphtha fractions of synthetic coal liquids provide a good blending stock and actually can improve the octane rating and performance of gasoline engines. With extensive refining, including severe hydro-treating and hydrocracking, fuels that meet diesel and jet specifications can also be made. Oxygen and nitrogen present in small amounts in direct process components also contribute to product instability. More studies are needed to completely evaluate the storage and long-term performance of liquid fuels derived from direct processes.

Indirect process liquids typically have no sulfur, nitrogen, or particulate. Gasoline from the Lurgi Sasol plant has a low octane rating, but can be upgraded to premium specifications. The Mobil Methanol-to-Gasoline process directly produces a premium grade gasoline. Methanol can be used as is or blended, and generally has lower emissions compared to gasoline, except for aldehydes. Aldehydes can contribute to the formation of photochemical oxidants. A major benefit of methanol is lower NO_x emissions resulting from lower flame temperatures.

¹**Most crude oils**, compared to direct process liquids, are lower in aromatic compounds. However, crude oils have a wide range of compositions in sulfur, nitrogen, and aromatic content. Many U.S. refineries are being modified to accept poorer quality crude oils.

However, the overall and long term performance of engines utilizing these alternative fuels is uncertain. Methanol is relatively corrosive and can reduce engine life. In addition, the instability of fuels and their tendency to form deposits and gums may reduce engine performance and contribute to exhaust emissions. The quality of fuels, however, is largely amenable to modification, so that one major variable affecting performance is the cost and efficiency of refining to provide a suitable grade of fuel. The efficiency of refining is discussed in Section 2.5 which compares the refined products in more detail.

One important issue concerning end-use and the entire synfuel cycle is the global CO₂ problem (i.e., the "greenhouse" effect) and the relative effects that a synfuel program could have. Figure 1-5 shows the contributions to CO₂ emission rates relative to crude oil (this includes CO₂ emissions at both the conversion/processing stages and the end-use stage) . As indicated, the production and use of coal synfuels will release approximately 1.7 times more CO₂ than crude oil over the entire fuel cycle. One major study concluded that because synfuels will represent a relatively small contribution to worldwide energy supplies, "CO₂ emissions do not appear to be a major environmental constraint in the development of a U.S. synthetic fuels program" (U.S., DOE, Asst. Sec. for Environment, Off. of Technology Impacts 1980, p. 5-32). However, if CO₂ is perceived to be a major environmental problem in the future, then even the relatively small CO₂ contribution from synfuel plants will need to be considered in the context of other contributing