Synthetic Fuels Technology Overview

With Health and Environmental Impacts

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PREFACE

The purpose of this monograph is to provide background information on the important growing area of synthetic fuels for development and usage, especially their potential health and environmental impacts. The idea for this monograph grew out of work performed by E. J. Bentz & Associates, Inc., and sponsored by the U.S. Environmental Protection Agency (EPA) Office of Toxic Substances in support of its mission. Both authors express their gratitude to Mr. Joe Nash, the EPA project officer, for all his assistance and guidance through out the work effort, for his initiative in developing such study efforts, and for his encouragement to the authors to provide a wider circulation of their results to the general and increasingly interested public.

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ABSTRACT

With ever-increasing crude oil and natural gas prices, and with ever-growing possibilities of crude oil import supply reductions and disruptions, the need for alternate domestic fuel sources is growing. At present, oil imports represent about 44% of domestic petroleum usage, and a 90+ billion dollar foreign oil bill -- with subsequent erosion of jobs and domestic investment. In response to this vulnerable situation, the Federal Government has enacted an energy program, a significant part of which is the development of alternate domestic "synthetic" fuels. The recently enacted (June 30, 1980) National Energy Security Act -- and the resulting creation of a Synthetic Fuels Corporation (Energy Security Corporation) is a key example.

In order to achieve the goals of domestic alternate energy development, while preserving and maintaining recently achieved goals in environmental and health protection, it is necessary to review and assess potential impacts of alternate synthetic fuels strategies. Such early review can not only identify weaknesses and gaps in our current understanding (and data base) of the synthetic fuel technologies -- and their potential environmental and health impacts; but can also help to catalyze the development of cleaner and more efficient control technologies. This report attempts to provide a brief background on several of these key technologies, to help catalyze that development.

The report consists of two major sections:

I . The first section -- consisting of Chapters 2 and 3 -- describe the key synthetic fuel process technologies reviewed. They are: Lurgi Gasification of Coal; Fischer-Tropsch Liquefaction of Coal; Coal-Methanol; Donor Solvent Liquefaction of Coal; Tosco Surface Shale Retorting; Ethanol Production from Corn; and Coal-Methanol-Gasoline.

II. The second section -- Chapter 4 -- consists of a description, comparison, and review of key environmental, health, ecological, and socio-economic impacts associated with the above described synthetic fuel technologies. These assessments were made along the entire fuel cycle (production - movement - usage) rather than just for the production segment of the cycle. This was felt necessary for a complete assessment of their substitutability for current fuel technologies.

The second section -- and the report -- concludes with Section 4, which provides a comparison of impact indices associated with the technologies. Because much-needed statistical data is not available, relative indices were developed and used to denote comparative effects. As with any index, it has a very limited application, and care must be taken in using it. It is no substitute for site-specific, or process-specific data and analysis, and can only provide an "umbrella-type" comparison.

The use of control technologies and procedures can significantly reduce the impacts suggested by unconstrained indices. As actual impact data becomes available, it can replace the use of relative indices in comparative analysis.

The report also has provided, in its Appendices, useful source/background information for future study efforts.

As indicated in the report, and by the indices, the coal-gasification processes, and the indirect liquefaction processes (through gasification steps) are not only the closest to commercialization (Fischer-Tropsch indirect liquefaction using Lurgi gasification process is being commercially used in the SASOL process in South Africa today), but are also the least uncertain associated with their potential discharges. These processes will probably be the first to be commercialized on a large scale, and hence should receive immediate attention. Many of the other synthetic processes -- especially the direct liquefaction processes -- are still in the pilot, R&D stage, and hence pose more uncertainties associated with both commercial scale-up and usage. These uncertainties pose concern for potential adverse impacts. These processes also will require more time to come on-line. Oil-from-shale, particularly from the West (Colorado, Montana, and Wyoming) appears to be a promising replacement for imported crude, although water availability (in the arid

West); environment, and health concerns of the retorted product; and large-scale community disruption associated with potential development pose serious concerns. Ethanol-from-corn via fermentation distillation technology is a well established technology. The ethanol so produced serves as a motor fuel extender (gasohol) and octane enhancer for unleaded gasoline fuels. Second-generation ethanol technologies -- such as cellulosic waste conversion -- will enable the use of a broader (and larger) base of feedstocks -- many of which are nuisance products (crop and forest residues, municipal wastes). This will significantly reduce potential conflicts in limited resource supply, and potential food/feed competition.

As indicated in Table 7, there are different types of health, environmental, and socio-economic impacts along the different segments of the fuel cycle (from raw material extraction to end-usage). Although dependent on the particular technology process employed, key new potential health impacts are strongly associated with feedstock extraction and transportation, as well as health impacts associated with the release of combustion products from the conversion and end-use products. Key potential environmental and ecological impacts are associated with conversion discharges (air, water, solid waste) as well as potential global impacts due to CO_2 emission buildup (although this is subject of much uncertainty). Local land erosion, acidic mine drainage, subsidence, and water usage (in water-scarce areas) are among potential ecological concerns. Socio-economic impacts include many secondary, yet real concerns -- associated with transient large-scale growth in mainly rural areas having little infrastructure support -- such as congestion and community disruption.

There is a strong need for alternate domestic fuels, such as the ones we have discussed. With the introduction of appropriate control technologies, new, clean and efficient process modifications, careful siting considerations, and scheduled occupational work procedures, these potential adverse impacts can be significantly minimized. In order for this to be accomplished, however, data must be developed, in sufficient detail, to assist in making reasoned judgements and sound policy.

(I) INTRODUCTION

(A) Background on Synfuel(s)

(1) Need for domestic development of alternate fuels

With ever-increasing crude oil and natural gas prices, and with ever-growing possibilities of crude oil import supply reductions and disruptions, the need for alternate domestic fuel sources is growing. Although this is true for all end-use sectors, it is particularly true for the liquid fuel areas -- such as transportation, where the rolling stock infrastructure is captive, and fuel switching opportunities are minimal within the next twenty years (1). Although conservation gains have contributed (and will probably continue to contribute) to reductions in overall demand (and especially liquid fuel demand) from historic rates, the need for additional domestic fuels to meet domestic needs at reasonable and competitive prices will continue (2, 3, 4). Over the past 35 years, the ratio of U.S. oil reserves to total consumption has declined (3, 5). This decline is projected to continue, even though increased oil exploration, and secondary and tertiary oil recovery schemes, will help abate the decline. Oil imports represent about 44% of domestic petroleum usage (6), and if trended-out would reach a peak of about 57% of our petroleum usage around 1985 (7), or could be 7 million barrels per day in 2000 -- even with U.S. synthetic production at about 4 million barrels per day (8). Hence, the need for an aggressive, yet environmentally conscious synthetic fuels program.

The impacts (9) due to the importation of crude oil and refined products is staggering, in brief:

(a) direct costs: In the U.S., from a modest plateau of 1-2 billion/year (1958-68), to 25 billion in the embargo period (1973-74), heading for over 90 billion in 1980. This large capital drain not only erodes domestic investment opportunities, but fuels subsequent unemployment, and inflation.

(b) indirect costs: Energy has had a leading role in inflationary spirals. In 1979, domestic prices for energy, housing, food, and medical care rose at a 17.6% annual rate (3rd qtr. 1979), while CPI rose at a 6.6% annual rate. Energy prices led, with a 50.1% annual rate, while food supply (domestic sources) rose only at a 4.2% annual rate.

Similarly, spiralling crude prices have placed enormous stress on world trade balances -- creating serious world capital imbalance. As oil prices rise faster than global inflation, global debt refinancing becomes increasingly difficult.

Finally, supply vulnerability has placed a heavy toll on national security and independence.

(2) The Potential Role for Synfuels

Domestically produced synthetic fuels (from fossil fuels and biomass), as well as conservation and expanded use of coal in direct combustion utility boilers, will all play a growing role in the next critical twenty years. Synthetics -- mainly derived from coal and oil shale -- will provide as much as 12% of all fuel consumed in the U.S. (10), and as much as 20% of the crude oil available to refineries (11). Although virtually all resources will contribute to domestic alternate fuel development (including solar, geothermal, unconventional oil, and gas supplies), coal and oil shale will experience dramatic growth in the next two to three decades. This growth is especially crucial for the liquid fuel market, where changing product slates, intersectoral fuel competition, and potential refinery bottlenecks can constrain future supply certainty (12).

Whereas shale oil will provide -- after necessary conversion, upgrading, and refining -- a refinery product slate of liquids, gases, and solids, coal will experience an even more diverse market than its traditional one of direct combustion utility power generation. Table 1 illustrates the growing diversity of end uses forecast for U.S. coal (including the growing reliance on coal for utility power).

Table 1
End Use of Coal -- Scenario III
(reference 7)
(Quadrillion Btu Per Year)

Destination	1975	1980	1985	1990	1995	2000
Electric Power Generation	8.141	12.317	14.883	17.153	18.718	19.558
Synthetic Liquids	--	--	.005	.013	2.477	9.671
Synthetic Gases	--	--	--	.133	0.833	3.155
Miscellaneous Synthetics	--	--	--	.024	0.153	.325
Feedstocks	0.190	0.345	0.563	1.048	1.601	2.189
Metallurgical Coal	2.221	2.833	3.404	3.987	4.570	5.167
Coal Exports	1.800	2.057	2.334	2.707	3.103	3.507
Industrial Fuel	2.25	3.338	4.695	6.187	7.722	9.294
Total	14.602	20.890	25.884	31.252	39.177	52.866

By the year 2,010, coal and fuels derived from coal and biomass are expected to supply up to 40% of all U.S. energy demands, versus 10% and 9% for oil and natural gas (13). Similar assessment of world energy trends indicates that by the year 2,030, coal biomass, and their derivatives are expected to supply almost 30% of the energy demanded, versus 37% from oil and natural gas combined (14).

Increasingly over time, there will be many key end-use markets -- residential-commercial, industrial, transportation -- that will depend on synthetic and other alternate fuels. In order for these alternate fuels to be developed, and commercialized in environmentally acceptable ways, there are many requirements -- economic and other -- that must be met.

Figure 1 lists the key factors that will affect the development of the syntehtic fuels industry. Key among those concerns are:

- o long lead times
- o large capital expenditures
- o key resource requirements (such as water)
- o resolution of key environmental and health concerns.

In the following report, we will identify and discuss several of the most critical health and environmental concerns, as they affect synfuel development.

FIGURE 1: SYNTHETIC FUELS INDUSTRY

Driving Forces

- Depletion and cost escalation of conventional domestic energy supplies.
- Shortages of environmentally acceptable fuels.
- Constraints imposed on alternate energy systems.
- The presence of existing fuel distribution systems.
- A seemingly chronic negative imbalance in foreign trade and payments schedules.
- National security.
- Governmental incentives.

Constraining Forces

- Technological and economic factors.
- Product costs/markets (interfuel competition).
- Status of technology and technological risk.
- Financial risk.
- Capital availability.
- Environmental and social factors:
  - Air Quality
  - Water Quality
  - Land Reclamation
  - Social dislocation
- Availability of resources:
  - Energy resources
  - Water resources
  - Land/Site availability
  - Skilled work force
- National, state, and local policies.

Courtesy: National Academy of Sciences, Transportation Research Board; "Transportation of Energy Materials"; Synthetic Fuels, pg. 26, Dr. E.J. Bentz, Jr, April 1980

(B) Objectives and Methodology

The objective of this report is to provide a brief overview of the major potential health, environmental and socio-economic implications of the key synthetic fuel energy systems.

The assessment is based on the following steps:

(a) Identification and review of the key energy processes, their characteristics, resource requirements, emissions, effluents and solid wastes.

(b) Description of the major potential impacts.

(c) Development of indexes that indicate the relative size of the major impacts.

(d) A comparison and summary of the major impacts.

Table 2 is a summary of the major synthetic fuel processes selected for evaluation, and an outline of the energy systems involved.

TABLE 2. ENERGY SYNTHETIC FUEL PROCESSES SELECTED FOR EVALUATION

Name of Process	Feedstock	Production or Extraction	Local Transport	Local Pretreatment	Transport to Conversion Plant	Conversion to Fuel	Distribution to End Users	End Use
Lurgi Gasification of coal	Coal	Strip Mining Underground Mining	Conveyor Truck Rail	Breaking and Sizing Steam Coal Cleaning	Rail Barge Truck	Lurgi High Btu Gasification	Pipeline	Residential, Commercial,[b] Industrial[b]
Fischer-Tropsch Liquefaction of Coal	Coal	Strip Mining Underground Mining	Conveyor Truck Rail	Breaking and Sizing Steam Coal Cleaning	Rail Barge Truck	Indirect Liquefaction from Synthetic Gas	Pipeline Truck[a] Rail[a]	Residential, Commercial,[c] Industrial[c]
Coal-Methanol	Coal	Strip Mining Underground Mining	Conveyor Truck Rail	Breaking and Sizing Steam Coal Cleaning	Rail Barge Truck	Indirect Liquefaction from Synthetic Gas	Pipeline Truck[a] Rail[a]	Residential, Commercial,[d] Industrial[d]
Donor Solvent Liquefaction of Coal	Coal	Strip Mining Underground Mining	Conveyor Truck Rail	Breaking and Sizing Steam Coal Cleaning	Rail Barge Truck	Direct Liquefaction from Coal	Pipeline Truck[a] Rail[a]	Residential, Commercial,[c] Industrial[c]
Tosco Surface Shale Retorting	Oil-shale	Strip Mining Underground Mining	Conveyor	Breaking and Sizing	Conveyor Rail	Tosco Retorting of Shale Oil	Pipeline Truck[a] Rail[a]	Residential, Commercial,[c] Industrial[c]
Ethanol Production from Corn	Corn	Cultivation of Crops	Tractor Truck Rail	Not Applicable	Truck Rail	Fermentation to Alcohol	Pipeline Truck[a]	Residential, Commercial,[c] Industrial[c]
Coal-Methanol-Gasoline	Coal	Strip Mining Underground Mining	Conveyor Truck Rail	Breaking and Sizing Steam Coal Cleaning	Rail Barge Truck	Indirect Liquefaction of Synthetic Gas to Methanol and conversion of Methanol to Gasoline	Pipeline Truck[a] Rail[a]	Residential, Commercial,[c] Industrial[c]