United States
Environmental Protection
Agency

Office of Exploratory
Research
Washington DC 20460

Research and Development

EPA-600/S9-82-010 August 1982

EPA

Project Summary

Mini-Assessment of Environmental Trends and Problems: Alternative Feedstocks

G. M. Burck, B. J. Riordan, K. C. Hoffman, and R. W. Meehan, II

This report discusses the potential for replacing oil and natural gas, the major organic chemical feedstocks, with alternative source materials and the consequent potential for environmental damage. Major emphasis is on five basic chemicals, and others are also considered in order to provide a more complete view of the chemical industry, particularly of those sectors where alternative feedstocks may have a significant impact. Using the Reference Materials System, current sources and uses of key chemicals are traced and a projection is made to the year 2000 under assumptions reflecting current market conditions. Three scenarios then define the upper limits for potential alternative feedstocks: (1) coal-based synthesis gas, (2) synfuel by-products, and (3) biomass. Residuals and socio-economic impacts are identified. Potential problems are ranked speculatively in terms of severity and then ranked in terms of likelihood. Several areas of further research are recommended. An extensive bibliography lists sources on the chemical industry and on fossil hydrocarbon and biomass derived feedstocks.

This Project Summary was developed by EPA's Office of Exploratory Research, Washington, DC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The principal concern of this report is the potential of alternative source materials for replacing oil and natural gas as feedstocks for basic organic chemicals and the consequent potential for environmental damage. The ultimate objective is to assist in the planning and development of the U.S. Environmental Protection Agency (EPA) research and development (R & D) programs. The scenarios employed are not meant to be forecasts; they are representations of credible upper limits on movements into alternative feedstocks and the specific events or circumstances that could lead to the scenario outcome.

The major emphasis is on five chemicals — benzene, ethylene, cyclohexane, ethylbenzene and styrene — selected by the EPA as representative of all basic organics. Synthesis gas and other large volume basic chemicals, plus major derivatives, are also considered in order to provide a more complete view of the chemical industry, particularly those sectors where alternative feedstocks may have a significant impact.

The Mini-Assessment approach employed here differs considerably from more conventional technological impact studies. In particular, as an attempt to guide anticipatory research, the Mini-

Assessment must include speculative information in addition to the definitive. It is necessary in such an assessment to resort to judgmental or subjective evaluation to address the "what if" type of question involved in preparing for future circumstances which may have potentially large impacts, but whose likelihood of occurring is highly uncertain. The Mini-Assessment is also aimed as much at detecting deficiencies in information as at applying existing information to particular problems.

Perhaps most important, the ultimate objective of this Mini-Assessment is not to direct EPA's attention to a particular future forecast but to "raise the consciousness" of the regulators with regard to the important effects of different futures and to point out the events that might move industry in alternative directions.

Technical Approach

The technical approach to the Mini-Assessment incorporates three discrete aspects:

- Derivation of alternative feedstock scenarios for the year 2000;
- Characterization of chemical flows from feedstocks to consumption (trajectories) for each scenario using the Reference Materials System framework; and
- Identification of differential environmental impacts associated with alternative feedstock scenarios.

In conjunction with a group of technical consultants and ORD's Office of Strategic Assessment and Special Studies (OSASS) staff, three scenarios involving use of alternative feedstocks in 2000 were established. The scenarios are characterized as:

Scenario A-1: Coal to Synthesis Gas to Chemicals

Scenario A-2: Coal to Synthetic Fuels with Chemical By-Products

Scenario A-3: Biomass to Chemicals.

The parameters of each scenario were established judgmentally. This approach provides a reasonable basis for the assessment of potential environmental problems that must be dealt with in a research and development program. Each scenario and its specific parameters is dependent upon a number of assumptions that are detailed in the text. The major overall assumptions are:

- Imports of chemical feedstocks remain small;
- Total chemical product demand grows at a 3.5 percent annual rate, slightly more than the GNP and similar to short-term industry expectations, but below rates prevailing during the fifties and sixties; and
- The composition of demand remains essentially invariant among the year 2000 scenarios; thus the scenario differences are driven by supply considerations rather than by demand.

Table 1 summarizes the key characteristics of each scenario plus those of the year 2000 baseline. In A-2, synfuel by-products provide about 70 percent of the feedstocks for a chemical industry twice its current size of 40 million metric tons. In A-1, synthesis gas provides 40 percent of the feedstock demand (the total feedstock demand is 20 percent greater than that of A-2 due to the demand for methanol fuel). In A-3, biomass provides 60 percent of the demand which includes a 25 percent increment for ethanol fuel.

Building on the general descriptions of the scenarios, complete chemical pathways involving the five key chemicals, in addition to others, were derived for each alternative feedstock scenario, a year 2000 baseline case (R-2000), and for the past year (R-1980). The methodological framework employed for this purpose was the Reference Materials System (RMS), a network description of the flow of material resources, linking alternative resources and feedstocks to specific markets through processing and conversion pathways. Detailed RMS chemical networks were developed for the 1980 and 2000 baselines and for each alternative scenario, not as market forecasts but to show where major changes might occur in these limiting cases.

Where possible, environmental effects are calculated in detail, working from the RMS chemical networks. Residual coefficients are derived for each process in each trajectory involving the specified chemicals, and residual volumes are summed for each scenario. Where detailed information is not available, potential impacts are estimated and critical information gaps are identified. To the extent possible, residuals plus the other, less quantifiable, impacts are associated with EPA geographical regions and assessed in relation to comparable data developed in *Environmental Outlook, 1980*, (EPA-600/8-80-003) an EPA compilation of projections to the year 2000.

Severity/Likelihood Assessment

Given the speculative nature of the Mini-Assessment, environmental consequences must be evaluated in terms of the likelihood of occurrence as well as in terms of the potential severity of impact. Table 2 lists in declining order of severity the ten most prominent environmental effects identified in the study.

Two judgments greatly affect this assessment. First, since chemical feedstocks are simply by-products of synfuels generation, the environmental impacts associated with synfuel development are not allocated to chemicals at all. That is, fuel must bear the full cost burden, since without fuel uses there would be no synfuel plants to make chemical feedstocks.

Second, the size of the biomass market envisioned in Scenario A-3, in conjunction with an expanded pulp and paper industry, could warrant the establishment of intensively cultivated tree farms (silviculture facilities). Professional opinion is divided on this point. It is not clear what scale of biomass production would trigger intensive silvicultural methods as opposed to a refinement of current, less intensive methods, combined with fuller utilization of growth not currently suitable for paper manufacture.

Combined severity/likelihood ratings reflect the assessment that syngas development is quite likely; synthetic fuels less so; and biomass development relatively unlikely. Although Scenario A-3 (Biomass) dominates the top of the severity list, when likelihood factors are also considered, only nutrient and pesticide runoff retains its relative importance. Two other problems appear to be unambiguously more important: socioeconomic impacts (Region VIII) and total dissolved solids (Region III).

Regionally, the three scenarios shift chemical processing capacity from EPA Region VI to the Southeast where it is currently concentrated, toward Region III in the case of Scenarios A-1 and A-2, and toward Region VI to the Southeast in the case of Scenario A-3.

Overall, the greatest inducement toward the synthesis gas scenario is seen to be a significant increase in the price of oil and gas with respect to coal. Several other events would have important effects — a Federal methanol

Table 1. *Key Characteristics of Alternative Futures*

	R-2000 (Baseline)	A-1 (Syngas)	A-2 (Synfuels)	A-3 (Biomass)
Principal Feedstocks	Petroleum Natural Gas	Coal (40%) Petroleum Natural Gas	Synfuel by-products (70%) Petroleum	Biomass (60%) Petroleum Natural Gas
Relation of Growth to Energy Industry	Dependent	Independent	Dependent	Partly Dependent
Initiating Sector	Private	Private	Public	Mixed
Public Awareness	Moderate	Low	Very Low	High — Ethanol Fuel Low — Other
Location	Concentrated	Multi-center	Concentrated	Dispersed
Timing		1990	1990s	2000s
Likelihood	High	High	Moderate to none	Moderate — Ethanol Fuel Low — Other
Key to Technical Development		Catalysts for New Uses	Location; Control of Feed-Rate	Lignin Conversion, Avoiding Distillation, Bioconversion, Process Integration
Greatest Chemical Impact		Ethylene	C_1-C_4	Aromatics

Table 2. *Ten Prominent Environmental Concerns (listed in relative order of severity)*

Problem	Region Likely Affected	Scenario
1. Nutrient and pesticide runoff	IV (Southeast)	A-3
2. BOD discharges	IV	A-3
3. Socioeconomic impacts	VIII (Mountain)	A-2
4. Socioeconomic impacts	IV	A-3
5. Hydrocarbon emissions	VIII	A-1
6. NO_x emissions	VIII	A-1
7. Total dissolved solids discharge	III (Middle Atlantic)	A-1
8. Land subsidence	III, IV and V (Great Lakes)	A-1
9. Acid drainage	III	A-1
10. Disturbance of wildlife habitats	IV	A-3

program, successful scale-up of coal-to-chemicals technologies, and more permissive regulation of coal mining and leasing of coal properties — but lower overall impacts.

In the case of the biomass scenario, price is again seen as a major initiating factor. A more important initiating factor, however, concerns the state of ethanol production technology. A breakthrough in fermentation technology could intensify private sector investment and/or government commitment to ethanol development and stimulate research and development in the area of lignin technology. Ethanol production would necessarily produce large amounts of by-product lignin, which even if unutilized could present significant environmental problems.

In summary, while coal gasification is primarily driven by economic forces, wood chemicals would be affected by both economic and technological developments.

Information Deficiencies

One of the objectives of a Mini-Assessment is to point out pertinent areas in which information deficiencies occur. Ten of the most important areas are shown in Table 3. It is not at all surprising that the wood-to-chemicals scenario dominates the list. This is clearly the area about which the least is known, from the basic chemistry through to socio-economic impacts.

The one item that carries through the three scenarios relates to the geographical and economic factors that affect choice of location for chemical processing and related activities. Since it is clear that the environmental impacts of alternative chemical feedstocks will be almost entirely regional and local in nature, it is extremely important to have better information on the potential locational patterns for each scenario. The regional assignments developed for this study are crude and should be considered illustrative rather than definitive.

★ U.S. GOVERNMENT PRINTING OFFICE: 1982-559-017/0774

A number of specific research recommendations relating to the information deficiencies identified may be drawn. The most important are:

- Assess the geographical/economic impacts of any industrial migration, and particularly of chemical process industries, to regions with low population;
- Provide for monitoring of new chemical and energy plants to determine what trace elements and toxic substances may be emitted on the industrial scale and what are their ecological pathways;
- Encourage silviculture research programs to establish pesticide requirements, runoff effects and the ecological impacts of growing, harvesting and using the biomass; and
- Follow the research in lignin chemistry and processing technology which will be prompted by the ethanol program and encourage attention to the environmental impacts.

Table 3. *Ten Important Areas of Information Deficiency*

Scenario A-1
1. *Geographical/economic factors affecting syngas locational decisions*
2. *Generation of trace elements and toxic substances in effluents*

Scenario A-2
3. *Geographical/economic factors affecting by-product chemical locational decisions*

Scenario A-3
4. *Pesticide needs of silviculture*
5. *Geographical/economic factors affecting biomass chemical locational decisions*
6. *Lignin chemistry and processing technology*
7. *Design factors for representative wood plantation/chemical processing plant*
8. *Competitive economics vis-a-vis other chemical feedstocks*
9. *Ecological effects of silviculture*
10. *Technological aspects of controlling silviculture runoff*

G. M. Burck, B. J. Riordan, K. C. Hoffman, and R. W. Meehan, II are with MATHTECH, Inc., Arlington, VA 22209.
David Bennett *is the EPA Project Officer (see below).*
The complete report, entitled "Mini-Assessment of Environmental Trends and Problems: Alternative Feedstocks," (Order No. PB 82-227 810; Cost: $19.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Office of Exploratory Research
Office of Research and Development
U.S. Environmental Protection Agency
Washington, DC 20460

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300