DISCLAIMER

This report has been reviewed by the Office of Energy, Minerals, and Industry, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

This document reports the results of a technology assessment* of selected liquid fuels derived from coal and oil shale. These fuels are considered to be the most likely alternatives to substitute for petroleum-derived fuels or to augment them in the transportation sector in the 1980-2000 time frame. Critical decisions about the sources of fuel supply and the nature of demand must be made in that period due to the steady depletion of the domestic petroleum supply and the influence of a noncompetitive world market.

The means to overcome the limited supply of natural petroleum may take several forms:

- Conservation of scarce petroleum energy by stretching out limited domestic reserves.
- Removal of the national transportation end-use sector from total dependence on petroleum by shifting to other energy forms, particularly those derived from coal, an abundant domestic natural resource.
- Conservation of energy through incremental savings at every step from resource extraction to end-use (a difficult problem since many advanced technologies consume more energy than present processes).
- Acceptance of a lesser level of fuel supply if the social costs of an entirely new supply industry(s) exceed end-use benefits.

The research reported here treats only a part of the total picture, but it nevertheless represents a significant step in the portrayal of the large new industry to meet future fuel demands.

Coal is not being used to manufacture liquid fuels, and thus an industry of the size examined herein does not exist today. Yet, without reducing the level of anticipated future energy demands, new supply industries such as those discribed in this study may be necessary. The results of this analysis clearly indicate that a significant productive capacity may be difficult to achieve from a very large and rapidly growing new industry. Moreover, while petroleum energy may be "saved" by substitution, the synthetic liquids system (from resource to

---

*A study approach that examines many dimensions of anticipated impacts from a given technology--environmental, economic, social, and energy flows.

end-use) is clearly less energy efficient than petroleum utilization. As a consequence, policies regarding these fuels should take into account the critical, constraining impacts examined in this study.

The creation of such an industry may imply private and public sector partnerships in planning the industry's growth, the thoughtful siting of conversion facilities away from coal mines, or designing conversion methods that are pollution-free and low in water consumption. Energy demand conservation and the world price of petroleum will strongly affect these choices.

The results of this work have been subjected to widespread review through presentations and papers given at conferences, symposia, and workshops such as:

- "Energy 10," the 10th Intersociety Energy Conversion Engineering Conference, University of Delaware, August 1975
- "3rd Annual Conference on Energy and the Environment," Oxford, Ohio, August 1975
- "Future Automotive Fuels - Prospects, Performance and Perspectives," General Motors Research Labs Symposium, October 1975
- "Workshops on the impacts of alternative fuels development, University of Montana and Montana State University, December 1975
- "Technology Assessment of Energy Alternatives," Rensselaer Polytechnic Institute, May 1976
- "The Future of Alternative Fuels - Impacts and Options," inter-agency research evaluation seminar, Glen Arbor, Michigan, June 1976

This work was initiated in June 1974, by the Alternative Automotive Power Systems Division (AAPS) and the Office of Energy, Minerals and Industry of the U.S. Environmental Protection Agency (EPA). The AAPS Alternative Fuels Program became a part of the U.S. Energy Research and Development Administration (ERDA) when it was created in January 1975. Continuations have been funded through the ERDA Office of Conservation. In the management of this work, substantial cooperative effort has been maintained that cuts across traditional organizational boundaries. F. Jerome Hinkle (AAPS in EPA, ERDA), James C. Johnson (EPA), and Gary J. Foley (EPA) have shared the role of project manager.

F. Jerome Hinkle

EXECUTIVE SUMMARY

A. Study Objectives and Method

Domestic supplies of petroleum already fall far short of meeting U.S. demand for liquid fuels. In 1973, the shortfall was 6 million barrels per day (B/D) (1 million m^3/D). With plausible growth in demand and decline in domestic oil production, the shortfall may be as large as 18 million B/D (2.9 million m^3/D) in the year 2000. Of this shortfall, about 6 million B/D (1 million m^3/D) can be attributed to the automotive market (cars, trucks, and buses).

It has been widely proposed that synthetic liquid fuels could be substituted for conventional petroleum. Syncrudes and methanol derived from coal and oil shale could possibly lessen or avoid future shortfalls. Several previous studies have examined the technical and economic feasibility of such synthetic liquid fuels. In contrast, the central objective of this study was to examine the feasibility of these fuels in a much broader sense--the feasibility when environmental, economic, social, and institutional consequences are taken into account. These consequences were to be contrasted briefly with those of an attempt to reduce or eliminate the shortfall by means of an all-out effort to develop remaining domestic conventional petroleum resources.

The core of the study was the preparation of a Maximum Credible Implementation Scenario (MCI) for the deployment of a synthetic liquid fuel industry based on the use of coal and oil shale to produce synthetic crude oils and methanol. The preparation of the MCI was followed by detailed exploration of the broad consequences if the scenario were to become a reality.

Far from being an advocated implementation scenario, or even an expected future, the MCI is intended only to depict the maximum rate at which a synfuel industry could be implemented under favorable circumstances. The MCI served, therefore, to identify and highlight those consequences that would prove most critical to deployment once the decision was made to have such an industry.

B. The Maximum Credible Implementation (MCI) Scenario for a Synthetic Liquid Fuels Industry

The MCI rests on building-block descriptions of the technologies for making syncrudes from coal and oil shale and methanol from coal. Syncrudes are emphasized rather than synthetic final products such as gasoline because the corporations most likely to produce and market synthetic fuels--the oil companies--have strong economic incentives to make synthetic crudes rather than final products directly.

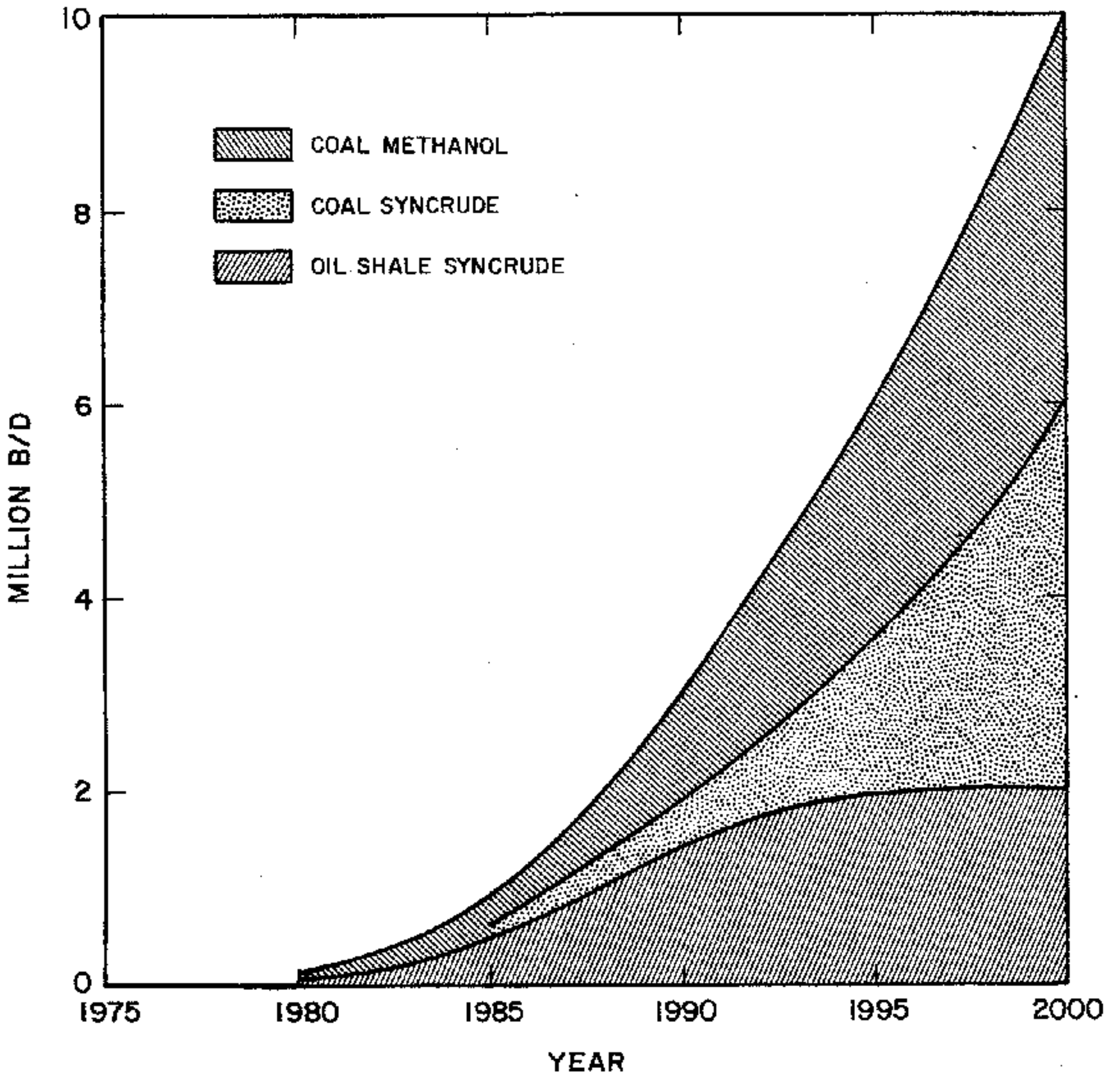
Production of synthetic crude allows it simply to be added to the natural crudes still available to refineries, and with relatively minor modifications to the refineries*, final products essentially identical to present fuels result. This approach has the practical advantage of serving both the needs of oil companies wishing to maintain the usefulness of present investments and of insulating the consumer from change. As a result, syncrudes have received emphasis over methanol in this study. However, future uses of methanol in stationary energy-consuming devices could release petroleum for use in the automotive sector.

For reasons of data availability and technological state of the art, this study has focused on the H-coal process for producing syncrude from coal, the TOSCO II process for producing syncrude from oil shale, and a

*As long as the syncrude remains a small portion of the crude accepted by any given refinery.

combined process for producing methanol from coal--a Lurgi gasifier followed by methanol synthesis. For all of these technologies the required resource inputs (capital, labor, fossil material, water, steel, and electricity) and the fuel outputs have been specified for the 100,000-B/D (16,000-m^3/D) plant size that seems likely to characterize the industry.

The MCI is summarized in the following figure. Notice that the MCI alone would not entirely eliminate the 18 million-B/D shortfall expected in 2000.



MAXIMUM CREDIBLE IMPLEMENTATION SCENARIO

C. Consequences of the MCI

1. Industrial Decision Making

The United States does not have a synthetic liquid fuels industry in place today because, in the past, such fuels could not be produced at costs competitive with conventionally produced oil. Even with the high prices of oil paced by the Organization of Petroleum Exporting Countries (OPEC) cartel, syncrudes and coal-derived methanol are not yet competitive with natural crude oils. Moreover, the rise in oil prices has made many previously uneconomic conventional petroleum options worth exploring, and companies are now vigorously pursuing those that appear economic. Until the risks of such ventures increase to intolerable levels or the relative cost of producing synthetic fuels falls, prudent business investment practice will emphasize conventional petroleum in preference to synthetic liquid fuels. Thus, unless the market place changes dramatically, or governmental policies provide sufficient economic offsets or incentives, there will be few or no synthetic liquid fuels produced--and the MCI will remain only a hypothetical exercise.

2. Capital Availability

The capital investments required by the MCI are large, and thus there is reason to inquire whether financing a synthetic liquid fuels industry is in fact possible. Application of a simple model of the aggregate petroleum industry in the United States indicates that even if historical rates of return on investment in the oil industry are maintained, and if the rate of inflation is 5 percent, then a future, integrated evolutionary natural-plus-synthetic petroleum industry could not finance the MCI out of its cash flow. There would be a continuing need for attracting capital to the industry. However, in 1995, new borrowings would rise to only twice the fraction of national capital formation presently absorbed by the petroleum industry. Therefore, while capital availability may appear to be a major limitation, it probably is not a fundamental constraint.

3. Resource Depletion

The cumulative amount of coal required by the MCI over the assumed 20-year lifetimes of the plants is very large. On the basis of Bureau of Mines estimates of strippable coal reserves, the MCI could be sustained for about 70 years on strippable coal if no other demands were placed on that resource. When other demands (such as electric generation and substitute natural gas production) for this coal are taken into account, the reserves would last for only about 40 years--enough for only two generations of synthetic fuel plants. After that, the more costly, more dangerous to mine, deep reserves would have to be used.

Net energy ratio estimates have been made for the synthetic fuels considered here. Such estimates take into account all the energy resources needed, directly and indirectly, to produce a fuel. The energy contained in the product fuel is then divided by the quantity of the energy resources consumed in its production. The higher the ratio, the more effectively the fossil resource is used. The ratios shown in the following table indicate that the coal syncrude option is more conservative of coal resources than the coal-derived methanol option.

Resource depletion under a scenario of rapid growth in consumption such as the MCI occurs far sooner than is commonly appreciated. As a result, this aspect of the industry is critical to national energy policy.

NET ENERGY RATIOS FOR SYNTHETIC LIQUID FUEL PROCESSES

	Conversion Step	Resource-to-Fuels System*
Oil shale	2.3	1.6
Coal liquefaction		
Wyoming coal	1.5	1.1
Illinois coal	1.8	1.3
Methanol		
New Mexico coal	0.66	0.65

*Including refining of syncrudes and 1000 miles of pipeline shipment of syncrude or methanol.

4. Water Availability

Synthetic liquid fuel processes all consume large amounts of water. Synthetic fuels are also expensive to make and, thus, to achieve favorable economics, low-cost strip-minable coal must be used as long as it is available. Most of the available strippable coal is in the arid West where the location of fuel conversion plants would place severe stress on available water supplies.

Much of the relevant coal resource in the West is in the upper Missouri River Basin (specifically, Montana, Wyoming, North Dakota) where many of the MCI conversion facilities would likely be located. There would be adequate water physically present in the basin to support the MCI even in view of other expected future demands. However, this water resource would almost never be in the same place as the coal resource. Therefore, for mine-mouth conversion facilities to be viable, extensive new water works such as aqueducts and interbasin transfers would have to be constructed.

In contrast to the East, where water is abundant and rules governing its allocation have not been crucial to its equitable use, water rights in the arid West are complex, uncertain, and often contested. The rights to the water in the Missouri River Basin that would have to be transferred, however, are very uncertain, partly because the water rights of the federal government and Indian nations in the area have not yet been adequately defined.

For coal, at least, there remains the option of transporting the coal to water-rich regions for conversion. The transport of coal by railroad consumes essentially no water while transport via slurry pipeline can reduce the water requirement to about half that required for fuel conversion. While there remains considerable uncertainty about the relative economic desirability of the two modes, the railroads have been successful so far in blocking several proposed (and competitive) slurry pipelines.

Oil shale is found primarily in arid northwestern Colorado, not far from the Colorado River. However, unlike coal, oil shale cannot be shipped economically for remote conversion. As a result, conversion must take place near the mine and, consequently, the water must be drawn from supplies of the upper Colorado River Basin. Other expected future demands in the year 2000 indicate that implementation of the MCI would result in a water shortfall in the upper basin because total demand would exceed Colorado's allocation under the interstate compacts which allocate the Colorado's annual flow.

However, water earmarked in the inventory for future agriculture expansion could sustain twice the level of oil-shale syncrude production shown in the MCI without resort to interbasin transfers.

Because water for irrigation is essential to agriculture in the arid west, the physical and institutional availability of water for the production of synthetic fuels in the dry western states is a highly charged issue--one that is critical to the future of a synfuels industry and its ability to augment petroleum supplies.

5. Strip Mine Reclamation

Strippable coals suitable for synfuels are found most abundantly in the West, Illinois, and Appalachia. In all three regions, reclamation of stripped mined lands is difficult but it is least difficult in the Illinois area because of its relatively level terrain, its thick soils that can be easily revegetated, and its ample moisture. In the West, arid conditions and thin, poor soils make revegetation difficult even in the level terrain where most coal is found. In Appalachia, the abundant moisture works to the detriment of reclamation because strip mining is done along contours of hillsides and the mined and reclaimed slopes are easily eroded after mining.

Reclamation of strip-mined lands has become an important national issue, one that has resulted in strong, but twice vetoed, bills from Congress. Until reclamation practices are better demonstrated and until federal and state policy on strip mining and reclamation stabilize, this issue will remain a critical stumbling block to deployment of the industry and to the design of generally acceptable environmental protection measures.

Reclamation following oil shale extraction and conversion is difficult because the spent shale residue actually occupies more volume than the raw shale (because of voids) and requires large quantities of water for compaction and dust control. Spent shale cannot be readily revegetated. In addition, the leaching and the subsequent runoff of salts that could pollute ground and surface waters are not easy to control.

6. Air Pollution Control

The air pollutant emissions expected from the fuel conversion plants using best available controls have been compared to emissions permitted under existing standards for analogous operations. Oil shale plants will require improvements in control technologies for particulates and sulfur dioxide to enable single plants to meet plausible (Class II) ambient air quality standards.

Single coal liquefaction plants would be able to meet emissions and Class II "non-degradation" ambient air quality standards. However, application of a pollutant dispersion model to a complex of four plants under worst-case conditions in Wyoming's Powder River Basin shows that a multiple-plant complex within an air basin would generally require use of improved air pollution control technology for particulates.

This conclusion remains tentative, however, because many candidate states for plant locations have not yet specified the non-degradation standard classes that will apply.

7. Boom Towns

The concentration of numerous fuel conversion plants in a small area--such as might result from implementation of the MCI with mine-mouth plants--would lead to rapid and sustained population growth in what are now essentially rural communities. Under the MCI, population growth could easily be in excess of 9 percent in Wyoming's Campbell County and 17 percent in the Colorado oil-shale region. Many planners consider an annual growth rate of 5 percent to be at the edge of manageability. Consequently, the location of conversion plants in the resource extraction region would set the stage for the creation of boom towns. Towns undergoing boom growth tend to lack social and physical amenities and a sense of community. Moreover, tax revenues collected from the industrial base, which are necessary for the provision of essential public services, tend to lag the onset of the demand for such services. These deficiencies result in a social malaise evidenced by high rates of divorce, suicide, alcoholism, worker absenteeism, and reduced worker productivity. Frequently inadequate sanitation facilities and poor access to medical care combine to impair physical health.

The phenomenon of the boom town also creates value conflicts between the former residents and the newcomers. These value conflicts in turn deter community agreement on measures to cope with growth and their implementation.

Mitigation of boom-town effects could be a critical factor in the establishment of a synfuel industry primarily because of the effect of the boom town on the reception afforded the industry by the region and on the quality and stability of the work force attracted.

8. Summary of Critical Factors

Unless they were to be resolved, the several critical factors that have emerged in the preceding discussion could severely constrain deployment of a large synthetic liquid fuel industry. These factors are:

- Industrial decisions to deploy a synfuels technology
- Resource depletion
- Water availability
- Strip mine reclamation
- Air pollution control
- Boom towns

Since most of these critical factors relate to questions of rates of growth or the geographical concentration of the industry, they point to controlled growth or dispersion of the industry as possible avenues of resolution.

D. Evaluation of Alternatives

1. Evaluation Criteria

In deliberations of the role of synthetic liquid fuels in national energy policy, it is natural to ask which, if any, of the fuels considered here should be favored. From a national perspective, as opposed to a corporate or consumer outlook, there are several important considerations in weighing the relative attractiveness of the synfuel options. Beyond the obvious and strictly economic factor of cost are questions of the allocation of national resources and the balancing of adverse and beneficial consequences not necessarily adequately reflected in the economic cost.

Important criteria include

- Resource intensiveness
  - Fossil materials used
  - Energy consumed versus energy yield
  - Water consumed
  - Capital invested
  - Labor required
  - Land area mined
- Geographic concentration
- Social systems impacted
- Ecosystems impacted
- Difficulty of evolutionary adoption

2. Criteria Applied to Synfuel Options

A comparison, on the basis of these criteria, of the coal syncrude and methanol alternatives using Western, Illionis, or Appalachian coal and the oil shale option reveals that no one option is best in every respect; each one has undesirable consequences. Nevertheless, it is apparent that mining and processing of Illinois coal to make syncrude is the least disruptive coal-based option. However, since Illinois alone cannot support the MCI, deployment of an industry on the scale of the MCI clearly means acceptance of some less desirable tradeoffs.

Since coal has other potential uses (especially in electricity generation and gasification) society may, in effect, forego opportunity by converting coal to liquid fuel instead of converting oil shale, a resource with no other use.

3. Synfuels Options Compared with All-out Conventional Oil Production

Given that the MCI alone cannot close the gap between domestic fuel supplies and demand and that it would have large adverse consequences, perspective on the future of automotive fuel can be gained by considering the alternative of all-out development of remaining domestic conventional oil resources.

All-out development would require production from now until the year 2000 of more oil than the United States has produced cumulatively to date and from resources significantly more difficult to extract. Moreover, imports could not be eliminated by this means.

The primary sources of oil would be Alaskan on-shore, Alaskan offshore, lower 48 states offshore, and advanced (tertiary) recovery everywhere. When the same criteria that were applied to the synfuel options are applied to all-out conventional production, the impacts turn out to be nearly all adverse. The results of the impacts would be concentrated in the Arctic and the coastal zones of both Alaska and the lower 48 states.

Thus, energy policy makers who may view the impacts of the MCI with alarm should realize that the alternative impacts, while clearly different in form and location, may be no more acceptable.

D. The Effects of Constraining the Growth of a Synfuels Industry

Constraint exercised in the rate of growth allowed a synfuels industry in any given area coupled with restriction of the plant size has been found (by analysis) to be an effective means to resolve many of the adverse impacts of the MCI. In particular, the growth of communities can be slowed to keep pace with the ability of local governments to provide and finance public services, to smooth abrupt jumpts in population size that interfere with orderly growth, and to somewhat ameliorate the issue of water rights so that it can be approached and resolved in an atmosphere less tense than might otherwise prevail.

Constrained growth scenarios imply the acceptance of a reduced schedule of fuel production or the exportation of coal to remote regions for conversion. If it is presumed that the remote sites chosen are those with adequate water availability and appropriate socioeconomic institutions already in place to accept modest growth, the remote siting concept can also serve as a mechanism to mitigate many adverse impacts. Although the remote siting approach could not be fully explored in this study*, it appears to hold promise.

F. Public Policy Considerations Raised by the Projected Impacts of a Synfuel Industry

The chief public policy considerations raised by this study concern the steps that appear necessary if near-term implementation of a synthetic liquid fuels industry is desired and the consequences that would require resolution once the industry began to develop. These two classes of consideration are often intertwined.

---

*The concept is currently under examination at SRI in a study for the Energy Research and Development Administration.

1. Financial Aspects of the Industry

Before industry and sources of capital will consider investment in synthetic liquid fuels, the products must be shown to be soundly competitive economically. Until then, synfuel investment will be considered far more risky than alternative investments competing for scarce capital. Without a massive change in the cost of national petroleum in the market place, or federal intervention to provide the economic means to offset the inherently inferior returns (or losses) on synfuel investments, no synfuel industry will appear.

2. Water Availability

The issue of water availability, both with respect to actual physical quantities and access to and priorities of water rights must be greatly clarified. In the meantime, the uncertainties translate into risks that not only inhibit realization of a synfuel industry but also inhibit development of alternative water uses in water-poor regions.

The issue of exporting coal from resource-rich regions by coal slurry pipeline is now before Congress. The subject has acted to broaden the question to involve the health and vitality of the U.S. railroad system, which suggests a long and complex debate.

3. Resource Leasing and Strip-Mine Reclamation

These issues are joined because much of western coal and most of the oil shale is on federal land and mining can take place only after acquistion of a lease from the Department of the Interior. For several years, leasing of coal lands has been suspended, but when it resumes the Department of the Interior is expected to require reclamation of strip-mined lands largely in accord with rules in the twice-vetoed strip-mine bills.

Clarification and implementation of the new leasing and reclamation provisions is essential before a sizable synthetic liquid fuels industry could be developed.

4. Air Quality Control

Since complexes involving multiple synfuel plants apparently will not be able to meet Class II degradation standards, it is essential that improved emission controls be developed and/or that the non-degradation air quality standards that will be applicable be decided by the states. Moreover, until new-source emission standards are issued for synfuel plants, designers can only use standards for analogous facilities as plausible guidelines.

Until these issues are clarified, investment in synfuel plants will be inhibited and states will be unable to foresee adequately the air quality implications of synfuel plants.

5. Boom Towns

The federal government may stimulate the synthetic liquid fuels industry as a matter of energy policy. At the same time, and perhaps through the same mechanisms (such as loan guarantees or public financing), the federal government might be able to stimulate the provision of "front-end" money to communities by industry as a means to avert the tax lag phenomenon largely responsible for the adverse quality of life in boom towns. Government acceptance of such contributions as a proper cost of constructing and operating a synfuel plant could legitimatize the practice and make it routine.

6. The Role of Conservation

The public policy considerations discussed above are concerned with mitigating various negative aspects of synthetic liquid fuels developments. Another, more certain, way of mitigating such impacts would be to reduce the need for synthetic liquid fuels by means of vigorous energy conservation programs. Although conservation itself certainly has some potential negative impacts, most would probably be widely distributed across the country in contrast to the highly concentrated consequences of synthetic fuels developments. The federal government has already perceived that conservation is an aspect of energy policy deserving much attention; programs of The Energy Research and Development Administration as well as the Federal Energy Administration are attacking the question with increased vigor.