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IMPACTS OF SYNTHETIC LIQUID FUEL DEVELOPMENT-
Automotive Market
Volume I. Summary

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IMPACTS OF SYNTHETIC LIQUID FUEL DEVELOPMENT

Automotive Market

Volume I Summary

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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

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*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

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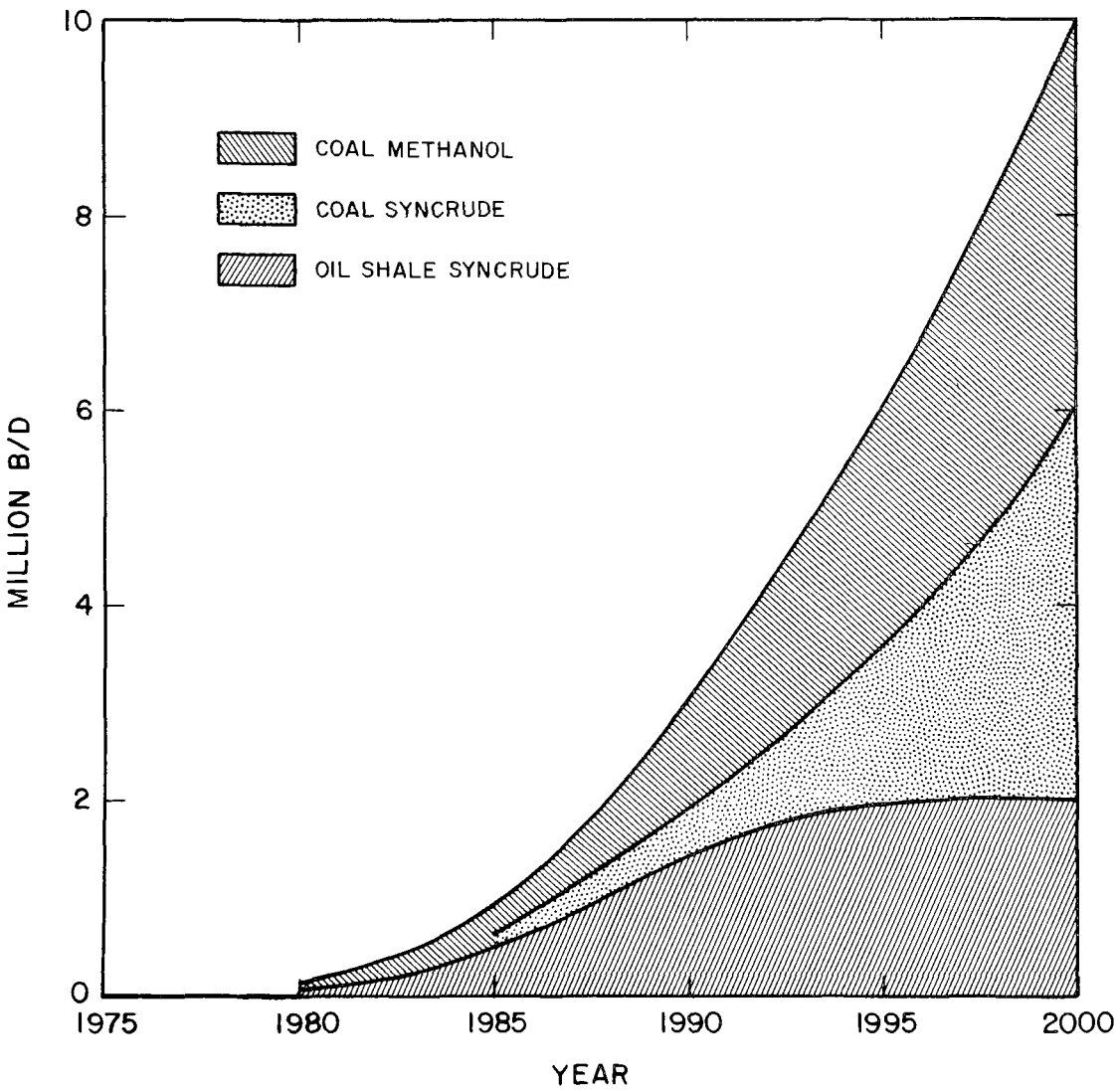
*As long as the syncrude remains a small portion of the crude accepted by any given refinery.

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 indus-

trial 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.

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*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.

GUIDE TO THE READER

This report is divided into two volumes. This first volume consists of an executive summary and a synopsis. The second volume contains chapters devoted to detailed analyses of various aspects of the development of a synthetic liquid fuels industry. Each chapter in Volume II has its own literature citations.

In this first volume, frequent reference is made to chapters in the following volume so that readers may locate the more complete discussions; this intervolume reference is accomplished by indicating the number of the chapter of interest as a superscript. All literature citations are confined to the chapters in Volume II. Many of the figures and tables in this first volume also appear in later chapters; whenever this occurs a two digit number is cited as a source (such as 13-10) to indicate the correlated chapter and figure number in that chapter.

CONTENTS

FOREWORD iii

EXECUTIVE SUMMARY. v

GUIDE TO THE READER. xxi

LIST OF ILLUSTRATIONS. xxiv

LIST OF TABLES xxvi

I INTRODUCTION. 1

A. Nature of the Problem 1

1. Automotive Fuel in Perspective. 1
2. Future Automotive Fuel Options. 4

B. Study Objectives. 5

C. Study Methods 5

D. Organization of the Report. 6

II ALL-OUT CONVENTIONAL PRODUCTION OF DOMESTIC OIL SUPPLEMENTED BY OIL IMPORTS: REFERENCE CASE. 8

A. Sources of Domestic Supply. 8

B. Resource Requirements 9

C. Major Impacts of the Reference Case 12

III PRODUCTION OF SYNTHETIC LIQUID FUELS FROM COAL AND OIL SHALE 14

A. The Technology. 14

1. Syncrude from Coal. 14
2. Methanol from Coal. 15
3. Syncrude from Oil Shale 18

B. Net Energy Ratio. 19

C. Economics of Production 22

D. Institutional Setting for a Synfuel Industry 23

E. Working Premises for a Hypothesized Implementation of a Synfuel Industry 25

IV CRITERIA FOR COMPARING SYNTHETIC FUEL PRODUCTION OPTIONS 26

A. Purpose of Applying Criteria 26

B. List of Criteria 26

C. Application of Criteria 27

V MAXIMUM CREDIBLE SYNTHETIC FUELS IMPLEMENTATION SCENARIO 31

A. Purpose and Assumptions 31

B. The Scenario 32

VI IMPLICATIONS OF THE MAXIMUM CREDIBLE IMPLEMENTATION (MCI) SCENARIO 37

A. Impact Issues 37

1. Industrial Decision Making 37
2. Capital Availability 41
3. Resource Depletion 44
4. Water Availability 45
5. Economic Spin-Off Effects 53
6. Environmental Effects 55
7. Social Consequences 63

B. Summary of Factors Critical to MCI Deployment . . . 71

VII THE EFFECT OF INTRODUCING A SYNFUEL INDUSTRY ON A CONSTRAINED GROWTH BASIS 73

A. Growth Constrained Scenarios 73

B. Implications of Constrained Growth 81

VIII PUBLIC POLICY CONSIDERATIONS RAISED BY THE IMPACT ISSUES 82

A. Financial Aspects of a Synfuel Industry 82

B. Water Rights 84

C. Strip Mine Reclamation and Resource Leasing 86

D. Air Quality Control 86

E. Population Growth Control 88

F. Summary 88

ILLUSTRATIONS

1 Automotive Energy Demand Compared to 1974 Petroleum Supply and Demand 2

2 Historical Growth Scenario--Automotive Fuel Demand and Domestic Supply Projections 3

3 Flow Diagram for Definition of Net Energy Ratio 20

4 Annual Energy Inputs for Construction and Operation of a 50,000-B/D Oil Shale Mining, Retorting, and Upgrading Complex 21

5 Pre-OPEC Crude Oil Situation 40

6 Post-OPEC Crude Oil Situation 40

7 Projected Cash Flow for Domestic Oil and Gas Industry--No Synthetic Liquid Fuels--at a 5-Percent Annual Rate of Inflation 43

8 Projected Cash Flow for Domestic Oil and Gas Industry--Conventional Activities plus Synthetic Liquid Fuels--at a 5-Percent Annual Rate of Inflation 43

9 Primary Concentration of Major Industrial Sectors Expected to Supply the Coal and Oil Shale Industry 54

10 Diagram of a Contour Mine 56

11 Contour Strip Mining 56

12 Diagram of an Area Mine 58

13 Area Strip Mining with Concurrent Reclamation 58

14 Underground Oil Shale Mining by the Room and Pillar Method 60

15 Basis of Population Multiplier Concept 63

16 Total Population Associated with Individual Plant Construction and Operation Building Blocks 65

17 Effects of the Maximum Credible Implementation Scenario on Population in Campbell County, Wyoming 66

18 Maximum Credible Implementation Scenario for Oil Shale Development in Garfield and Rio Blanco Counties, Colorado 67

19 Ten Percent Constrained Population Growth Scenario for Oil Shale Development in Garfield and Rio Blanco Counties, Colorado 75

20 Five Percent Constrained Population Growth Scenario for Oil Shale Development in Garfield and Rio Blanco Counties, Colorado 76

21 Five Percent Constrained Population Growth Rate Scenario for Campbell County, Wyoming, illustrated with Coal Liquefaction Plants and Associated Mines 77

22 Modified Five Percent Constrained Population Growth Scenario for Campbell, Wyoming, illustrated with Coal Liquefaction Plants and Associated Mines 78

23 Five Percent Constrained Population Growth Scenario for Campbell County, Wyoming, in which only Coal Mines are Developed 79

TABLES

1 Domestic Oil Supply, Imports, and Total Demand Under HG3 . . 9

2 Annual Labor, Drill Rig and Steel Requirements for Oil Under HG3 10

3 Annual Capital Investment in Conventional Oil Production for HG3 (1973 dollars) 11

4 Resource Requirements for 100,000-B/D (Oil Equivalent) Synthetic Liquid Fuels Plants 16

5 Net Energy Ratios for Synthetic Liquid Fuels Processes . . . 23

6 Application of Criteria to Synfuel Options: Degree of Impact 28

7 MCI Synfuel Production Schedule 33

8 MCI Cumulative Resource Inputs 34

9 MCI Regional Distribution of Synfuel Production 35

10 States and Regions with Strippable Coal Reserves Sufficient to Support a Large Synthetic Fuels Industry 36

11 Northern Great Plains Synthetic Liquid Fuel Water Demands in the Year 2000 48

12 Northern Great Plains Projected Annual Consumptive Use of Water in the Year 2000 48

13 Projected Non-Oil Shale Water Demand in the Upper Colorado River Basin in the Year 2000 50

14 Comparison of MCI and Five Percent Population Growth Constrained Scenarios, for the Year 2005 80

I INTRODUCTION

A. Nature of the Problem

1. Automotive Fuel in Perspective[2*]

Automotive vehicles--cars, trucks, and buses--are fueled by petroleum products almost exclusively and constitute the single largest use of petroleum (46 percent) in the United States (Figure 1). It is well known that, until the Arab oil embargo in the winter of 1973, demand for automotive fuels was growing steadily while domestic oil production was beginning to fall. Consequently, interest was renewed in the possible development, production, and use of alternative automotive fuels.

An indication of the level of alternative fuel production that may be required in the future for the automotive market is shown in Figure 2, which is adapted from the Historical Growth scenario of the Ford Foundation Energy Policy Project. This scenario assumes that, in spite of higher energy prices, consumers return to their historical patterns of petroleum use and, thus, that demand for automotive fuel grows steadily. Three domestic oil supply subscenarios (HG 1, 2, 3) are given in the Ford Foundation study. In each, domestic oil supplies would increase temporarily somewhat because the higher prices would stimulate previously unprofitable production; however, this increase could not be sustained and, toward the end of the century, domestic supplies would again fall.

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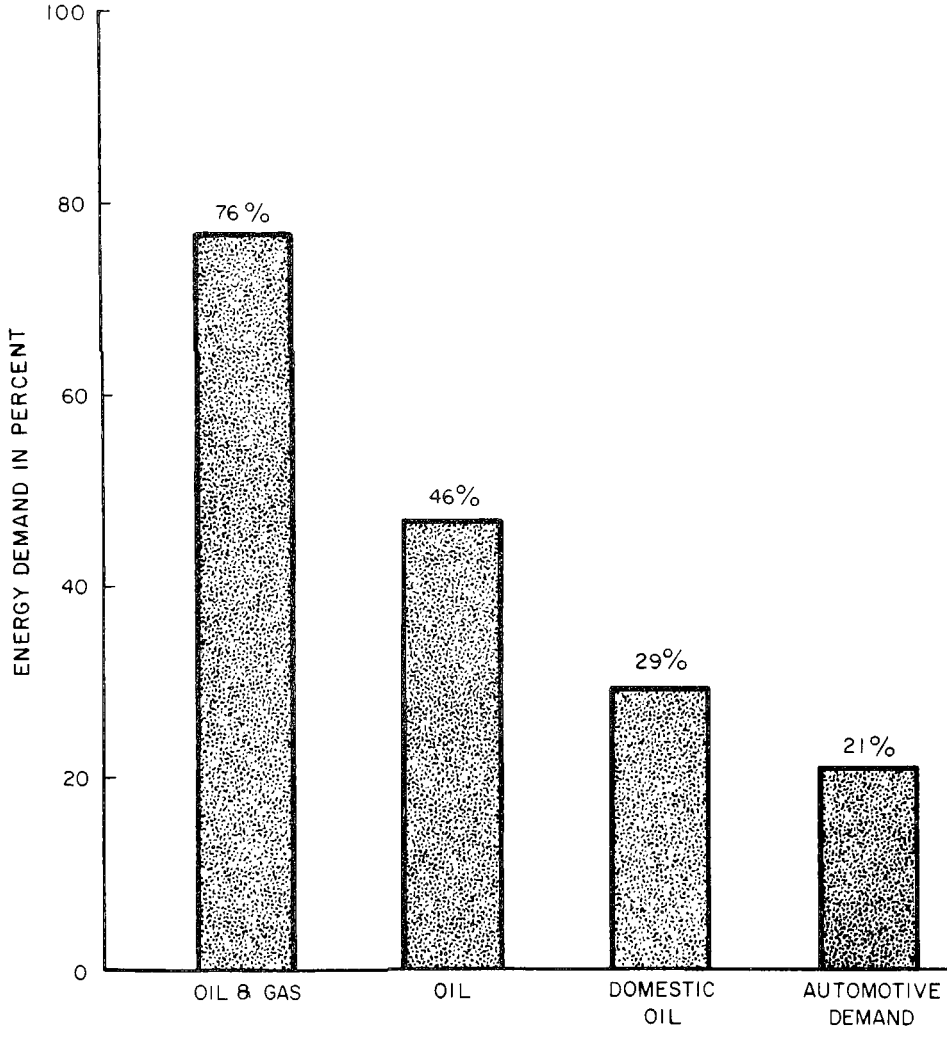
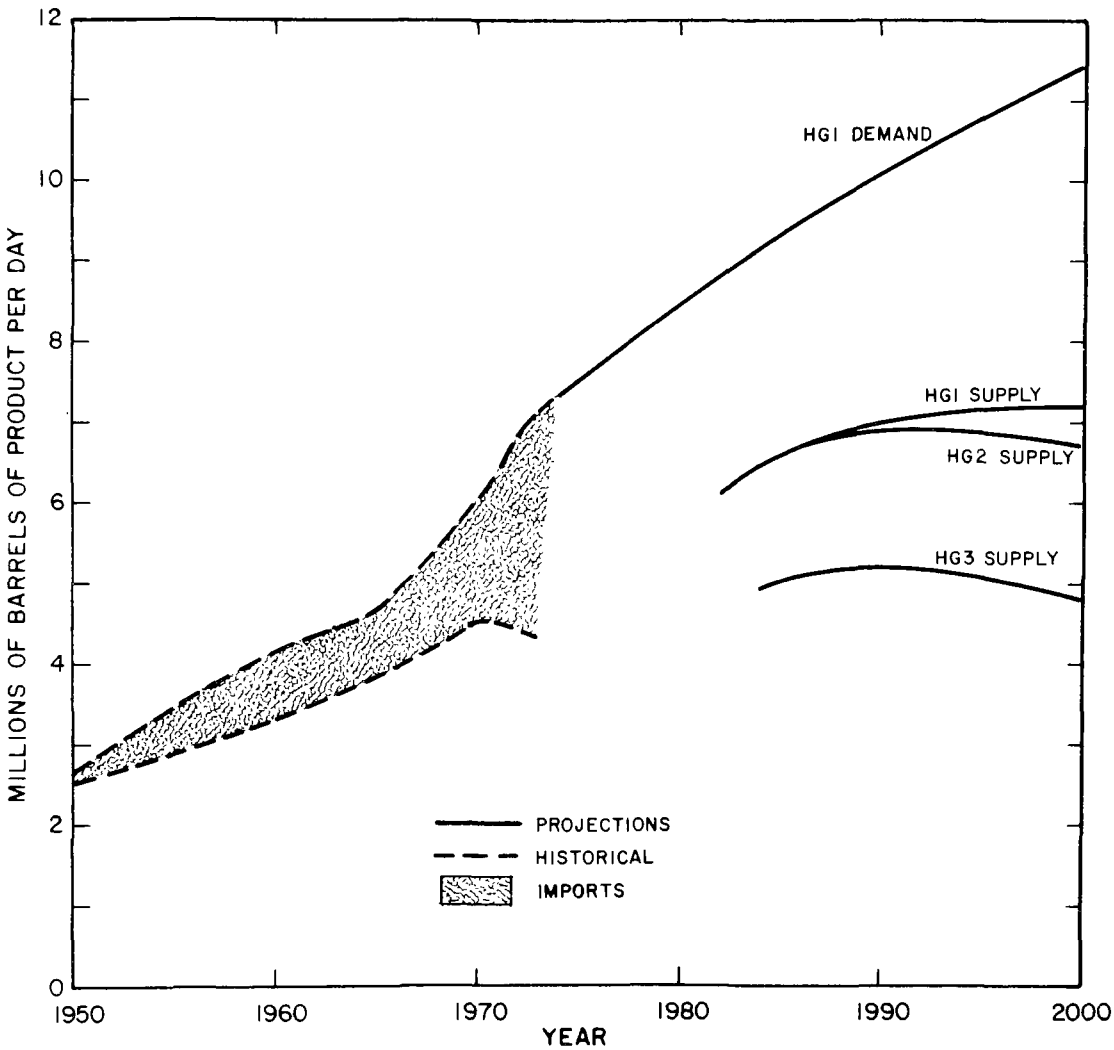
*In this volume, superscripts refer the reader to the chapter in Volumes II and III that discuss the same matter in greater detail.



Source: Figure 2-1

FIGURE 1. AUTOMOTIVE ENERGY DEMAND COMPARED TO 1974 PETROLEUM SUPPLY AND DEMAND



Source: Figure 2-3

FIGURE 2. HISTORICAL GROWTH SCENARIO – AUTOMOTIVE FUEL DEMAND AND DOMESTIC SUPPLY PROJECTIONS

Recent estimates of total U.S. oil resources and reserves made by the U.S. Geological Survey (USGS) strongly suggest that of the three domestic supply curves shown in Figure 2, only the HG3 curve has the barest chance of being realized.[3] Thus, in the year 2000 there could be an automotive fuel shortfall as large as 6 million barrels per day (B/D) (1 million m^3/D). When all other uses of petroleum in the economy are also considered, under the HG3 supply scenario the total petroleum shortfall would be about 18 million B/D (2.9 million m^3/D) in the year 2000.

Consequently, at the end of this century, unless alternative domestic fuel sources are developed or demand is reduced, petroleum imports could be running as high as 18 million B/D (compared to 6 million B/D in 1973). The precision of this estimate is sufficient to provide perspective for the level of alternative fuel production that may be desirable in the future.

2. Future Automotive Fuel Options

There are numerous conceivable options for future automotive energy:

- Reduce demand
  - Through less travel
  - Through improved efficiencies of use
- Change technology (e.g., electric cars)
- Change fuels
  - Develop synthetic gasolines and diesels from coal and oil shale
  - Use methanol derived from coal, wastes, and biomass
  - Use hydrogen produced from coal or by means of nuclear power.

Previous studies performed for the Alternative Automotive Power Systems Division of the Environmental Protection Agency (EPA) examined the technical and economic feasibility of these and other alternative fuels.

The consensus was that until the early part of the next century, the prime candidates for alternative fuels are:

- Gasolines and distillates derived from coal and oil shale
- Methanol derived from coal.

B. Study Objectives

The basic objective of this study was to assess the feasibility of these prime candidate fuels in a much broader sense--their total feasibility when environmental, economic, social, and institutional consequences are taken into account. Moreover, these consequences were to be contrasted to the consequences of an all-out effort to increase production of conventional petroleum--especially in Alaska, offshore, and by advanced (or "tertiary") recovery techniques.

While pursuing this objective, potentially inhibiting factors were to be identified and those that might prove to be critical impediments of the realization of a high level of alternative fuel production were to be singled out for special, expanded analysis.

At the conclusion of the work, a set of criteria were to be developed to rate the various options to help formulators of public policy make difficult choices. In addition, public policy alternatives were to be identified that could increase chances for commercialization of these fuels, ameliorate the most adverse consequences, and strengthen any beneficial consequences.

C. Methods of the Study

The study was conducted as a technology impact assessment by a coordinated interdisciplinary project team. The team took the following steps:

- Devised systems descriptions of the options from the basic resources through the end uses.
- Examined the compatibility of the systems with existing fuel systems to judge the ease of incremental implementation--an important step because new fuel systems must evolve from present ones and must be compatible with existing institutions and infrastructure investments.
- Focused attention on those parts of the new systems that differed the most from present fuel systems--because it would be there that impacts would be most unlike those experienced with the present fuel systems.
- Characterized the new system elements in terms of "natural building blocks" (the normal size to be expected from considerations of economies of scale and scales of physical processes).
- Determined the resource inputs (coal, water, capital, labor, etc.) for a given fuel output.
- Constructed a maximum credible implementation (MCI) scenario to serve as a heuristic device to derive the maximum impact situation and thereby identify the critical inhibiting factors.
- Identified other critical factors that are, in many respects, independent of the level of implementation.
- Analyzed in detail the consequences of implementing the MCI giving special attention to the critical factors.
- Prepared a scenario depicting all-out production of domestic conventional petroleum--to serve as a comparison for the development of synthetic fuels.

D. Organization of the Report

Section II of this synopsis presents the reference case, which is an all-out effort to increase domestic oil supply by conventional means and to supplement the supply with imported oil. The Reference Case can be used as a basis for comparison of the impact of the development of a synthetic fuel industry. Section III treats the technology, economics, and institutional setting for a synfuel industry. Criteria that can be used to compare the various synthetic fuel options are applied in

Section IV. In Section V the maximum credible synthetic liquid fuel implementation scenario is described, and its implications are discussed in Section VI. Some effects of a synfuel industry introduced at less than a maximum rate are treated in Section VII. Finally, in Section VIII, the areas in which public policy actions could influence the development and consequences of a synfuel industry are outlined.

II ALL-OUT CONVENTIONAL PRODUCTION OF DOMESTIC OIL SUPPLEMENTED BY OIL IMPORTS: REFERENCE CASE[3]

As a basis for comparison of essential aspects of a synthetic fuels industry, a reference supply case was developed in which the alternative to a synfuel industry was the all-out conventional production of domestic oil supplemented by oil imports. The Reference Case contains a projection of (1) domestic oil supply and the requirements for imported oil, (2) the resources required to increase domestic oil production without synthetic fuels development, and (3) the environmental impacts that could result from this production and importation.

A. Sources of Domestic Supply

Future domestic oil production will depend heavily on the success achieved in three activities and geographic regimes.

- Alaskan resource development (onshore and offshore)
- Frontier (non-Alaskan) offshore resource development
- Recovery by advanced techniques in all areas.

In the year 2000, about 32 percent of domestic oil will come from Alaska and about 30 percent from offshore (lower 48 states). Table 1 shows the projected supply/demand under HG3 (Figure 2).

With or without an all-out production effort, it appears to be impossible for domestic oil production to satisfy the demand curve shown in Figure 2. The recent USGS estimates indicate that the United States will be hard pressed even to produce oil at a level similar to HG3. Such production would entail producing more oil domestically in the next 25 years than the total amount produced previously--and from

resources significantly more difficult to extract. As a consequence, the Reference Case necessarily included an increased level of oil imports.

Table 1

DOMESTIC OIL SUPPLY, IMPORTS, AND TOTAL DEMAND UNDER HG3

(Source: Table 3-2)

Supply/Demand	Quantity 10^6 Barrels per day* (% of Domestic Supply) 1985	2000	Cumulative 1974-2000 (10^9 Barrels) Total	Advanced Recovery
Domestic Supply				
Onshore (lower 48 states)	6.8 (52)	5.0 (38)	63	34
Offshore (lower 48 states)	3.0 (21)	4.0 (30)	28	15
Alaska (onshore and offshore)	3.6 (27)	4.4 (32)	30	16
Total	13.4	13.4	121	65
Imports	11.5	18.4		
Total U.S. demand	24.9	31.8		

*10^6 B/D is about $1.6 \times 10^5 m^3/D$.

B. Resource Requirements

Resource requirements for the HG3 scenario in terms of heavy equipment, labor, steel, and capital investment are shown in Tables 2 and 3.

Table 2

ANNUAL LABOR, DRILL RIG AND STEEL REQUIREMENTS
FOR OIL PRODUCTION UNDER HG3

(Source: Table 3-6)

	Year		
	1977	1985	2000
Exploration Drill Rigs in Use			
Onshore	930	1,250	1,250
Offshore	240	500	500
Alaska			
Onshore	125	150	150
Offshore	26	110	110
Offshore Production Platforms in Use			
Offshore	90	200	200
Alaska-offshore	6	25	25
Labor--Rig and Platform Crewmen Employed			
Onshore	22,000	29,000	29,000
Offshore	24,000	52,000	52,000
Alaska	3,000	8,000	8,000
(Offshore)	(1,600)	(6,500)	(6,500)
Total	49,000	89,000	89,000
Steel--Thousands of Tons* Required			
Onshore	1,400	1,700	1,700
Offshore	1,400	1,400	1,400
Alaska	200	400	400
Total	3,000	3,500	3,500

*One ton is about 907 kg.

Table 3

ANNUAL CAPITAL INVESTMENT IN CONVENTIONAL OIL PRODUCTION FOR HG3 (1973 dollars)

(Source: Table 3-9)

	1977	1985	2000
Onshore Recovery			
Primary and Secondary	1.4	3.9	3.9
Advanced	1.0	1.0	2.6
Subtotal	2.4	4.9	6.5
Offshore Recovery			
Primary and Secondary	0.3	0.9	0.9
Advanced	0.6	0.6	1.3
Subtotal	0.9	1.5	2.2
Alaska			
Primary and Secondary	1.2	1.3	1.3
Advanced	1.0	1.0	2.1
Subtotal	2.2	2.3	3.4
Total	5.5	7.7	12.1

Towards the end of the century over 50 percent of domestic oil recovery should be coming from advanced techniques. That is why the investment split between primary and secondary recovery in Table 3 is weighted heavily on the side of advanced recovery. Some of the production activities involved in oil recovery, especially advanced recovery, are expected to be as costly on a unit basis as the production of synthetic crude oils from coal and oil shale, both of which are still considered uneconomic.

C. Major Impacts of the Reference Case

A summary of the salient impacts of the Reference Case follows.

- Alaskan (onshore)
  - Rapid changes in human populations leading to boom towns with low levels of human amenities and environmental protection.
  - Disruption of established cultures, economies, and values.
  - Damage of fragile ecosystems by petroleum spills, the activity of exploration and production, and establishment of transportation corridors.
  - Damage to the marine environment resulting from ocean transport (and landing) of oil to other states.
- Alaskan (offshore)
  - Same impacts as Alaskan onshore (above).
  - Damage to the marine environment from spills and other accidents.
- Offshore (Continental United States)
  - Impingement on other beneficial uses of coastal zones such as commercial fisheries, recreation, wildlife habitat, aesthetic values.
  - Induced human population in coastal areas owing to increased petroleum-related activity such as port facilities and refineries.
- Advanced recovery
  - Large increase in demand for the chemicals used in tertiary recovery with resulting environmental and health hazards in their manufacture, transport, and use.
  - Increased air pollution from fuel burning for steam generation.
  - Concentration of impacts in heavily populated and polluted Southern California because past recovery techniques for heavy California crude oil has left much oil that is potentially suitable for advanced recovery.

- Imports
  - Economic and political ramifications of economic disruption in the event of another oil embargo.
  - Increased alteration of the coastal zone through increased ship traffic, spills, and construction of single-point offshore moorings and deepwater ports.
  - Increased onshore activity for refining and transport of oil and of induced human population.

Thus, the impacts of the Reference Case will be heavily concentrated in coastal areas--both onshore and offshore and in Alaska. As will be seen later, the nation may have to choose between impacts in the Northern Great Plains and Rocky Mountain states or impacts in the Alaskan and coastal zones unless demand for liquid fuels is significantly reduced through conservation.

III PRODUCTION OF SYNTHETIC LIQUID FUELS FROM COAL AND OIL SHALE

A. The Technology

1. Syncrude from Coal[4]

Coal is abundant and widely distributed throughout the United States. It has been realized for many years that coal could be chemically transformed into liquid hydrocarbons suitable for use as fuel. However, until recently, abundant U.S. petroleum reserves discouraged development and engineering refinement of coal conversion. As a result, the United States has not produced synthetic liquids from coal in commercial quantities. During World War II, however, the Germans manufactured coal liquids for the operation of vehicles and for many years South Africa has produced synthetic gasolines from coal. Coal liquefaction therefore is not a new technology but an old technology ripe for improvement.

Several improved technologies are already nearing commercial readiness.[4] Among these technologies are (by their commonly used name): COED, H-Coal, SRC, and CSF. In all of these, the basic procedure is the production of hydrogen chemically from coal and water followed by the chemical combination of this hydrogen with other coal. At suitable temperatures and pressures, the coal and the hydrogen react to produce a liquid product that is nearly identical to crude oil.*

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*Many of the coal-derived syncrudes are superior to natural crude oils because they are lower in sulfur.

The H-coal process has been selected for analysis in this study because ample data were publicly available, the technology is among the most advanced, and the product is almost entirely a synthetic crude oil with few byproducts.

The H-coal process, like all coal syncrude processes, requires large inputs of natural resources (especially coal, water) and socioeconomic resources (capital, labor). The magnitude of these resources is indicated in Table 4, in which they are compared with other fuel processes considered in the study. The primary residual of the H-coal process is an ash that derives from the foreign mineral matter originally in the coal.

The published literature and discussions with potential syncrude producers make it clear that the natural size of coal liquefaction building blocks will be 25,000 to 30,000 B/D (4,000 to 4,800 m^3/D) during the first stages of commercialization when business risks overshadow the desire to reap full economies of scale. However, in a mature industry, the building block would be about 100,000 B/D (16,000 m^3/D);* plants of this size will have realized nearly all potential economies of scale. In principle, syncrudes could be further transformed by refining to yield consumer products at the same site, but in the early stages of the synfuel industry there is no incentive to do this.

2. Methanol from Coal[4]

The production of methanol from coal is really a wedding of portions of two of the presently more advanced synthetic fuels technologies: synthetic methane derived from coal, and methanol made from

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*For comparison, large, modern refineries are often of the 100,000 B/D (16,000 m^3/D) size.

Table 4

RESOURCE REQUIREMENTS FOR 100,000-B/D* (OIL EQUIVALENT)†
SYNTHETIC LIQUID FUELS PLANTS

(Sources: Tables 6-4, 6-5, 6-6)

	H-Coal Process Syncrude	Lurgi Methanol	TOSCO II Oil Shale Syncrude
Construction			
Capital (millions 1973 $)‡	670	1200	750
Labor (10^3 man-yrs)	7.3	15	5.4
Steel (10^3 tons)	110	200	90
Site (10^3 acres)	1	2	0.6
Operation			
Resource (million tons/yr)	18	26	54
Water (10^3 acre-ft/yr)	29	30	16
Electric power (MW)	140	200	170
Labor (10^3 people)	1.4	1.8	1.7

*A 100,000 B/D plant produces 16,000 m^3/D.

†About two barrels of methanol contain the same energy as one barrel of oil.

‡These estimates are taken from the open literature; since 1973 estimates have escalated at a rate that far exceeds the general rate of inflation in the economy.

methane. The latter technology is well developed because it is the process now used to make most methanol (from natural gas). Because shortages of natural gas have been anticipated more commonly than shortages of oil, the processes for the production of synthetic methane from coal are well developed (although not commercially deployed). The gasification options available include Lurgi, Winkler, and Koppers-Totzek, but the synthesis step is most favorably accomplished by an intermediate pressure process such as the ICI process. Lurgi gasification has been adopted in this study because much data for this process are publicly available and it is a likely candidate for first generation plants.

In the production of synthetic methanol from coal, the first step is the generation of synthesis gas, a mixture of carbon monoxide and hydrogen. This is followed by a synthesis step that converts the gas to methanol.* The methanol process directly yields the final product suitable for automotive use in contrast to the coal liquefaction processes which yield a syncrude which must then be refined. The resource requirements for methanol production from coal are shown in Table 4.

The production of methanol from coal is amenable to development of an in situ process in which the coal is transformed underground to synthesis gas without prior conventional extraction (by mining). In this case, the synthesis gas would be pumped to the surface where it would be converted to methanol.* In situ conversion is expected to require less water and cause far less environmental disturbance than above-ground methods. However, in situ processes are quite speculative and data adequate to the needs of this study do not exist; consequently, only above-ground methanol production is considered here.

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*Under different conditions, methane can be produced from this same synthesis gas.

3. Syncrude from Oil Shale[4]

Certain marlstones contain trapped organic material called kerogen; such minerals are called oil shale. When the stone is pulverized and heated, the kerogen is transformed and a very viscous oil-like substance is released. Vast deposits of oil shale rich in kerogen are found in Colorado, Eastern Utah, and Northwestern Wyoming. The richest deposits are found in a two-county area of Colorado called the Piceance Basin.*

Throughout this century there has been sporadic interest in the oil shale hydrocarbon resource. Because it is the consensus in the oil industry that oil derived from oil shale would be less expensive than liquid fuels derived from coal, considerable attention has been given to oil shale technologies--both above ground and in situ conversion.

In all forms of the technology the basic steps are to crush the rock into small lumps or particles (to facilitate heat transfer and release of the kerogen), to heat the crushed shale, and to collect the viscous oil. Some technologies use hot gases to heat the shale, while others use hot solid materials. In both cases, the heat is generated by combustion of some of the kerogen or recovered shale oil. For in situ processes, combustion of the kerogen is the sole source of heat. Among the candidate above-ground conversion processes are Paraho, TOSCO II, and Union Oil.

The TOSCO II process has been selected for this study because much data is publicly available--especially from an environmental impact analysis of the once planned Colony Development Operation oil shale plant. Unfortunately, there are few publicly available data on in situ processes.

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*This is not a drainage basin; the name refers to the basin-like shape of the geological strata.

No matter which conversion process is used, the viscous oil must be "upgraded" before it will flow readily as a fluid. Upgrading requires the production of hydrogen and its chemical addition to the raw shale oil. Upgrading also lowers the sulfur and nitrogen content of the raw shale oil.

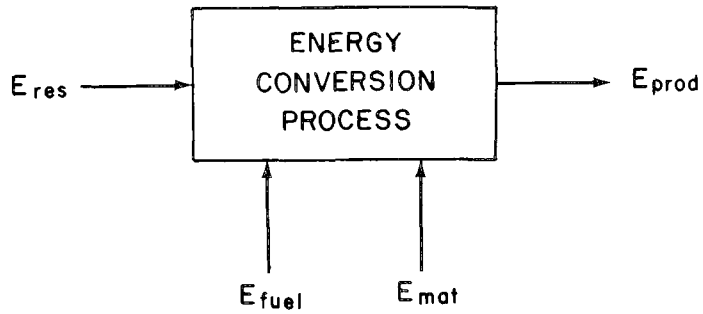
The mining and retorting of oil shale consume large amounts of natural and socioeconomic resources (shown in Table 4). However, unlike the two coal processes whose only residual is an ash that is 10 to 20 percent by weight of the coal consumed, above-ground oil shale processes produce enormous quantities of "spent" oil shale. Indeed, because of voids, the spent shale actually occupies a volume some 10 to 30 percent (depending on the process) greater than the raw shale. This residue requires disposal--an activity that consumes large amounts of water for compaction, dust control, and revegetation. It also requires large amounts of land.

B. Net Energy Ratio[5]

To extract, transport, and convert coal or oil shale to a form suitable for end-use requires energy--both directly in the form of fuel and electricity and indirectly in the form of energy intensive materials. Systematically accounting for all these energy inputs to compute the energy consumption necessary to deliver the energy present in the product can be accomplished in several ways. For this study the net energy ratio mode of expressing this information has been chosen.

The net energy ratio, as illustrated in Figure 3, is defined as the energy content of the product (E_{prod}) divided by the sum of three terms: the energy that was originally present in the raw fossil resource but thermodynamically lost in processing ($E_{res} - E_{prod}$), the fuel or electrical energy that must be used to run the fuel conversion processes (E_{fuel}), and the energy that has been expended in preparing, assembling

and delivering materials used in the process (E_{mat}). Such accounting has been applied to all steps in the sequence from resource extraction to final conversion to products suitable for end use.



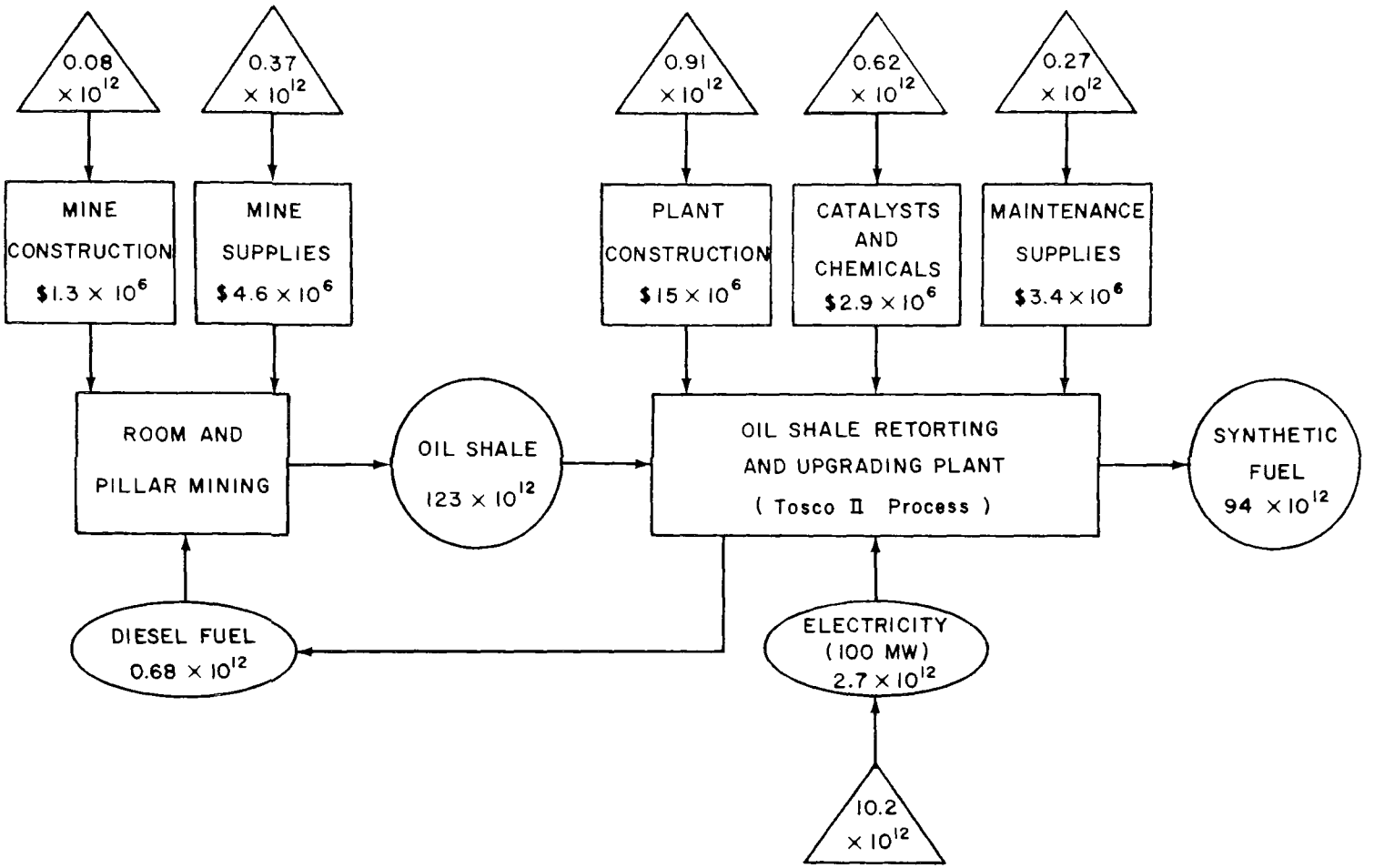
$$\text{NET ENERGY RATIO} = \frac{E_{prod}}{(E_{res} - E_{prod}) + E_{fuel} + E_{mat}}$$

Source: Figure 5-1

FIGURE 3. FLOW DIAGRAM FOR DEFINITION OF NET ENERGY RATIO

Figure 4 shows the application of the concept to an oil shale conversion process. To account for the total use of resource energy in the conversion processes, the energy inputs are reduced to the amounts of original fossil fuel resources required to supply the actual energy forms and materials used. Such resource energy requirements are shown as triangles in Figure 4.

As expressed here, the higher the net energy ratio, the more effectively the process utilizes the nation's energy resources. A ratio of 1.0 simply means that the resource energy consumed in making the fuel



Notes: All resource energy inputs and product outputs are in Btu
All dollar figures are in 1973 dollars per year

Source: Figure 5-5

FIGURE 4. ANNUAL ENERGY INPUTS FOR CONSTRUCTION AND OPERATION A 50,000-B/D OIL SHALE MINING, RETORTING, AND UPGRADING COMPLEX

available is equivalent to the energy contained in the final product fuel; for the three fuel conversion processes considered in this study, a ratio less than 1.0 does not mean that the process, in effect, drains society of energy. For example, a net energy ratio of 0.5 means that of three units of energy initially available, one is delivered to end use while two are used in processing. With our definition, electric generation from coal has a net energy ratio of about 0.36 (counting transmission losses). The case of electricity shows that society sometimes willingly accepts a low net energy ratio as the price of converting energy into a desirable form.

Table 5 shows the net energy ratio for the processes considered in this study. Because there is no intermediate product in methanol production, the net energy ratio for the syncrude alternatives are shown both before and after refining to facilitate comparison with methanol. Several important conclusions can be drawn from Table 5. First the coal resource can be used more effectively if syncrude is made than if methanol is made. Second the oil shale process has the most favorable net energy ratio. However, comparison of ratios is more valid for alternative processes using a single resource than for trans-resource comparison. Perhaps the most important use of net energy ratios is in choosing among alternative processes those which are most conservative of basic resources.

C. Economics of Production

As Table 4 shows, the investment requirements for synthetic liquid fuel plants are very large. The estimates shown in Table 4 are in dollars of 1973 value and the more recent estimates are even larger.*

*The escalation between 1973 and 1976 is larger than the general rate of inflation because plant construction costs have been inflating more rapidly than other costs.

Table 5

NET ENERGY RATIOS FOR SYNTHETIC LIQUID FUELS PROCESSES

(Source: Table 5-8)

	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

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

Recent studies conducted for EPA clearly show that the price of syncrude from coal was about two-thirds determined by the initial plant investment. The next most important determinant of cost was the coal feedstock, while the cost of obtaining water contributed very little to the cost of the final product.

To date, potential operators of commercial synthetic fuel plants have concluded that these synthetic liquid fuels cannot be produced and sold at a reasonable profit at competitive prices (even with the present high cost of imported petroleum).

D. Institutional Setting for a Synfuel Industry[9]

Currently, corporations consider synfuel investments to be fraught with too much risk to undertake without some kind of supportive government

intervention. This judgment stems from two basic considerations: First, the fuels produced would cost at least as much as imported oil, even at the high prices set by The Organization of Petroleum Exporting Countries (OPEC); yet OPEC could easily lower the price of imported oil and drive synfuel ventures into bankruptcy. Second, the individual synfuel plant investment requirements are so large and uncertain that it appears to be less of a risk to make smaller individual project investments in exploration for natural crudes; moreover, synfuel plant investments have no exit points that allow capital-saving withdrawal if changing evidence or situations warrant.

The only private institutions likely to undertake synfuel ventures are the oil companies, either singly or in consortia, because they have the most compelling incentive--an existing business with pipelines, refineries, and market facilities that requires a continued supply to remain economically productive. These extant facilities also provide the oil companies with great flexibility to integrate the new fuels smoothly into their existing businesses without establishing new marketing activities. This latter feature also has the property of insulating the consumer from technical change because all such change would be absorbed by the fuel producer. The combined questionable profitability and difficulty of market entry would certainly discourage other potential entrants to the industry (such as the large chemical companies).

This dominating interest by the existing oil companies will inevitably shape the choices of synfuels to be produced. For example, rather than producing directly a final consumer fuel in a single step, the oil industry prefers the production of syncrude because this allows full and flexible use of their existing investments in technology and marketing (including intercompany sales and exchanges).

The study team has concluded, therefore, that the voluntary adoption of the methanol option for automotive fuel is extremely unlikely because,

unlike syncrudes, methanol would not fit as readily into the existing system and would require a separate distribution system and modification of marketing facilities.

Nevertheless, the scenarios developed later in this report depict methanol production on a large scale in the expectation that it will be used in large stationary facilities (such as electric utilities). Since such use would release petroleum for possible use in the automotive market, this production of methanol still fits the objective of the study.

E. Working Premises for a Hypothesized Implementation of a Synfuel Industry

The corporations that can be expected to play the dominant roles in commercialization of synfuels do not perceive the technical options as equally ready for deployment. Oil shale conversion is generally thought to be the first synthetic liquid fuel option likely to occur. Thus, the rest of the study is based on the following working premises:

- Syncrude is the most institutionally preferred product and will dominate.
- Oil shale will be the first source of syncrude.
- Methanol technology is closer to being commercially ready than coal syncrude technology and would play an indirect role in the automotive market by releasing petroleum supplies.

IV COMPARISON CRITERIA FOR SYNTHETIC LIQUID FUELS OPTIONS

A. Purpose of Applying Criteria

Besides the obvious comparison of economic cost that will be applied by industrial participants, consumers, and the federal government, several other noneconomic criteria should enter the determination of which synthetic liquid fuels should be produced and the relative rate of industrial development that should accompany production. These criteria are necessary because of the widespread and long-lasting consequences that would result from the deployment of a synfuel industry.

While, in principle, such criteria could be used to rank the candidate fuels and resources, one cannot expect all stakeholders to agree on the rankings. Since each stakeholder will bring different values to the process, each will give different weights to the various factors. Therefore, it is too much to hope that a clear-cut preference for one alternative will be reached by all stakeholders. What can be hoped, however, is that the application of these noneconomic criteria will assist stakeholders to perceive more readily the interactions among the consequences of the several options and the tradeoffs that may be necessary.

B. List of Criteria

The SRI study team believes that the following criteria should be considered in synthetic liquid fuels development:

- Technical
  - Resource use intensity (amounts needed to produce a given amount of fuel) of water, energy minerals, labor, capital, and land.
  - Net energy ratio of fuel systems

- Environmental/social
  - Geographic concentration of development
  - Impacted human populations (number, proximity, culture)
  - Impacted living forms (number, degree affected, reversibility of effect)
- Economic/institutional
  - Feasibility of evolutionary adoption of new fuel into existing systems
  - Opportunity costs (what is foregone by these uses of a resource)

These criteria have evolved from the considerations in this study. The summary application of the criteria presented below is based on the findings synopsized in the remainder of this volume and on their fuller presentation in Volume II.

C. Criteria Application

The criteria are applied below to seven variants of the fuel options:

- Syncrude from oil shale
- Syncrude from coal
  - Western
  - Illinois
  - Appalachian
- Methanol from coal
  - Western
  - Illinois
  - Appalachian.

Table 6 ranks the variants in terms of the criteria set forth above. The degree of impact (resource consumption, net energy ratio, geographic concentration, humans and ecosystems affected, and the potential for evolutionary integration into existing systems) is designated by "Most,"

Table 6

APPLICATION OF CRITERIA TO SYNFUEL OPTIONS: DEGREE OF IMPACT
(Most, Average, Least)*

	Syncrude				Methanol		
	Oil Shale	Coal			Coal		
	Colorado	West	Illinois	Appalachia	West	Illinois	Appalachia
Resource Intensity							
Fossil material used	Most	Average	Least	Least	Most	Most	Most
Energy consumed	Least	Average	Average	Average	Most	Most	Most
Water consumed†	Most	Most	Least	Least	Most	Least	Least
Capital invested	Average	Least	Least	Least	Most	Most	Most
Labor required	Least	Least	Least	Least	Most	Most	Most
Land area mined	Most	Least	Average	Most	Least	Average	Most
Geographic concentration	Most	Least	Least	Least	Least	Least	Least
Humans impacted	Most	Average	Least	Average	Average	Least	Average
Ecosystems impacted	Most	Average	Least	Most	Average	Least	Most
Difficulty of Evolutionary adoption	Least	Least	Least	Least	Most	Most	Most

*With respect, only, to the options shown in this table.
†Relative to availability.

"Average," and "Least." The result is a coarse measure of the favorability of developing each of the variants.

Even though the criteria and the rating systems are coarse indicators of the degree of favorability, it is apparent from Table 6 that no single option is most desirable in every respect. Instead, pursuit of any of the options will necessitate acceptance of social, economic, institutional, and environmental tradeoffs. For example, it is apparent that the methanol option is inferior to the syncrude option and that development in Illinois has generally fewer adverse consequences than development elsewhere. However, Table 10 (Section V) shows that the Illinois area could not itself sustain the industry for long. Therefore, less favorable options would also have to be pursued if the synthetic liquid fuel industry were to become as large as hypothesized in the Maximum Credible Implementation (MCI) scenario presented in the next section (V).

The manner in which these criteria will be weighted depends heavily on who are the decision makers. Pragmatically, one must anticipate that the most economically related criteria will be the first, most heavily weighted ones. Other criteria may ultimately be translated into a form that will allow their inclusion into the economic framework,* but until then criteria such as reversibility of environmental damage will have to be considered separately.

One important additional criterion that is poorly suited to presentation in the form of Table 6 is the "opportunity cost" of using a resource. Opportunity cost is a term used in economics to measure the value of a foregone opportunity. To some extent this cost is included

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*By such measures as pollutant taxes, or the cost of achieving control of air pollutant emissions.

in the economic cost of acquiring the resource, but since much of the coal resource and most of the oil shale resource are on government lands and made accessible by government leasing on a competitive basis, it is highly unlikely that the total opportunity cost to society will be included. Opportunity cost is a concept that is particularly useful in differentiating between coal and oil shale. There is no known "economic" use for oil shale other than oil recovery, while coal can be burned to generate electricity and provide heat, or it can be used to produce synthetic gases that can substitute for natural gas. Therefore, using coal for liquefaction processes may very well entail larger societal opportunity costs than oil shale conversion. It is possible that when all the trade-offs have been examined, there may be a national consensus that oil shale should be developed up to an "acceptable" level if only to stretch out the more versatile coal resource.

V MAXIMUM CREDIBLE SYNTHETIC FUELS IMPLEMENTATION SCENARIO[6]

A. Purpose and Assumptions

As a device to uncover and elucidate the maximum impact situation, a scenario was prepared that attempts to depict the maximum rate at which a synthetic fuels industry could be deployed. Examination of the maximum impact situation was selected so that the adverse and beneficial consequences would stand out in boldest relief, and, as a result, decision makers might better perceive factors that might critically impair deployment of the industry.

The Maximum Credible Implementation (MCI) scenario assumes, for purposes of impact analysis, that all fuel conversion activities will occur close to the mines. While the nature of the oil shale resource requires this assumption (because the quantities of raw ore are so large they cannot conceivably be transported long distances economically), coal could be shipped long distances from the mine for conversion. However, to allow processing facilities to be distant from the resource would introduce a complex multitude of options that are beyond the scope of this study.*

A key underlying assumption, of course, is that there is an economic incentive for the industry to develop. This necessarily means that the fuels can be produced at a profit and yet be sold at prices

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*A subsequent study at SRI, funded by the Energy Research and Development Administration (ERDA), is addressing remote siting options for coal conversion facilities.

competitive with imported natural petroleum. It also is assumed that, once begun, there is a continuing incentive to deploy the technology. Since such a climate does not now exist, the scenario is not a prediction of the industry that will develop but is merely an outline of a plausible situation.

The rate of industrial deployment depicted in the MCI is determined mainly by presumed physical, economic, and business risk limitations rather than by adverse impacts. Of course, adverse impacts will exist. Their analysis constitutes much of this report's substance.

There are several very important aspects of the MCI that must be emphasized because they strongly affect the analysis that follows:

- The 10-million B/D (1.6 million m^3/D) of oil equivalent energy of the MCI cannot, alone, substitute for the 18-million-B/D (2.9 million m^3/D) imports projected under the HG3 scenario discussed previously (Figure 2).

- The MCI is heavily skewed towards the Rocky Mountain and Northern Great Plains regions of the country for two reasons: First, the coal and oil shale resources are most abundant there. Second, the nature of the deposits and the pattern of government ownership of western resources greatly facilitate acquisition of the reserves needed to guarantee a plant's lifetime operation.

- For coal-derived syncrude to be economically competitive with imported oil, the coal resources used must be low in cost and this greatly favors use of western coals amenable to strip or open-pit mining.

B. The Scenario

Table 1 (Section III) showed the building block sizes and their resource requirements for each technology. Table 7 depicts the MCI fuel production schedule, and Table 8 gives a schedule of the cumulative in-

puts (in 5-year intervals). Table 9 summarizes the synfuel output by regions of the United States and reflects several variables:

- Location of fossil reserves (Table 10)
- Current state or regional political sentiment towards mining and synfuel production (because these will affect the siting of plants in the next decade).
- Institutional barriers such as the ability to acquire enough coal resource to supply a plant for its lifetime.

Table 7

MCI SYNFUEL PRODUCTION SCHEDULE
(Million B/D)*

(Source: Table 6-1)

	Year				
	1980	1985	1990	1995	2000
Syncrude from oil shale	0.1	0.5	1.5	2.0	2.0
Methanol from coal†	0.05	0.3	1.0	2.5	4.0
Syncrude from coal	0	0.09	0.5	1.5	4.0
Total	0.15	0.89	3.0	6.0	10.0

*10^6 B/D is about $1.6 \times 10^5 m^3/D$.
†Oil equivalent energy.

Table 8

MCI CUMULATIVE RESOURCE INPUTS

(Sources: Tables 6-4, 6-5, 6-6)

	Year				
	1980	1985	1990	1995	2000
Construction	Cumulative Amount				
Capital (billions of 1973 $)	1.34	7.90	26.5	54.5	89.2
Labor (10^3 man-yrs)	12.9	38.1	257	593	973
Steel (10^6 tons)*	0.19	1.15	3.91	8.5	14.2
Site (10^3 acres)†	1.6	9.9	34.1	77	132
Operation	Annual Amount				
Coal (million tons/yr)‡	13	94	350	920	1760
Oil shale (million tons/yr)‡	54	270	810	1080	1080
Water (10^3 acre-ft/yr)§	31	196	685	1505	2680
Electric power (10^3 MW)	0.27	1.58	4.95	10.5	14.0
Labor (10^3 people)	2.6	17.9	50.5	100	162

*10^6 tons is about 907×10^6 kg.
†10^3 acres is about $4.05 \times 10^6 m^2$.
‡10^6 tons/yr is about 907×10^6 kg/yr.
§10^3 acre-ft/yr is about $1.2 \times 10^6 m^3$/yr.

Table 9

MCI REGIONAL DISTRIBUTION OF SYNFUEL PRODUCTION
(10^6-B/D oil equivalent)*

(Source: Table 6-3)

	Year				
	1980	1985	1990	1995	2000
Coal					
Wyoming	0	0.06	0.39	0.99	1.95
Montana	0	0	0.08	0.58	1.6
North Dakota	0.025	0.125	0.275	0.650	1.05
New Mexico	0	0.05	0.15	0.20	0.20
Illinois	0	0.08	0.33	0.78	1.4
Kentucky	0.025	0.075	0.205	0.48	0.90
West Virginia	0	0	0.08	0.18	0.45
Ohio	0	0	0	0.15	0.45
Oil Shale					
Colorado	0.1	0.5	1.5	2.0	2.0
Total	0.15	0.89	3.0	6.0	10.0

*10^6 B/D is about $1.6 \times 10^5 m^3/D$.

Table 10

STATES AND REGIONS WITH STRIPPABLE COAL RESERVES SUFFICIENT TO SUPPORT A LARGE SYNTHETIC FUELS INDUSTRY

(Source: Table 6-8)

States and Regions	Strippable Reserves (10^9 tons)*	Number of 100,000-B/D Plants Sustainable for 20 Years at 20×10^6 tons/year
Montana	43	110
Wyoming	24	60
North Dakota	16	40
Illinois/western Kentucky	16	40
West Virginia/ eastern Kentucky	8.7	22

*10^9 tons is about 907×10^9 kg.

VI IMPLICATIONS OF THE MAXIMUM CREDIBLE IMPLEMENTATION SCENARIO

The MCI has many implications for U.S. society, institutions, and environments. The seven areas that the study team judged were most important because of their magnitude or the breadth of their impact are discussed individually below. Although the discussions that follow imply that these categories are independent, there are, in fact, many cross-links in the impacts. For example, in the arid West, the availability of water is linked with the socioeconomic effects on communities

A. Impact Issues

1. Industrial Decision Making[9,10]

Industrial decisions to deploy commercial-scale synthetic liquid fuel plants are obviously necessary to achieve the level of production hypothesized in the MCI scenario--unless the federal government decides to develop an enormous nationalized synthetic fuels industry. Since only the petroleum industry is well-positioned to develop and integrate synthetic liquid fuels into its business, the perceptions of the future held by major oil companies and their perceived available decision options become crucial to the future shape of the synthetic liquid fuels industry.

Several commonly held misconceptions about the oil industry are relevant to the future of synthetic liquid fuels. The first misconception is that there is a single "price" for crude oil in the world market determined by balancing supply and demand. Ever since the OPEC cartel set artificially high world prices for crude oil, the market place has not determined price. Moreover, even without OPEC, there would be a variation in the price asked for crude oils because of the variations in quality of oils. For example, because of air quality controls, the sulfur content of crude oils used for burning is a very important determinant of price. In addition, U.S. oil prices are regulated by the federal government.* Interventions by the federal government greatly complicate the process of corporate decision making because the stability of the regulations is uncertain. Similarly, the institutional stability of OPEC and its oil pricing policies is uncertain.

Another misconception about the oil industry is that there is a single "cost" of producing crude oil with which the cost of syncrudes might be compared. In reality, domestic oils are produced at a wide range of costs that depend on such things as the difficulty of drilling, ease of extraction from the field (self-pressured or pumped), the rate of production, and rents or royalties. In general, the longer production continues in a field, the less favorable recovery becomes. Therefore, the operating costs of production generally increase with the age of a field. In the United States there are hundreds of thousands of

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*In an effort to hold down costs to the consumer, oil produced from wells in operation before 1972 is called "old" and subject to a price ceiling, while oil produced from wells not in operation in 1972 is considered "new" and can be sold at uncontrolled prices. Additionally, a program of "entitlements" designed to spread among refiners the effects of high cost imported oil is in effect. These definitions have been changed several times through legislation.

so-called stripper wells producing at a rate of less than 10 B/D (1.6 m^3/D); many of these wells represent last efforts to recover oil from old fields by conventional means.

Compared with the small range in market prices for crude oil, the range in production costs is very large--from just tens of cents per barrel for Saudi Arabian oil to many dollars per barrel for most domestic oils. Of course, a company ceases production from any given well when its production costs equal the price it could bring on the open market because this would be a zero-profit situation. For a similar reason, because the oil industry believes that oil shale and coal syncrudes will cost more to produce than it would cost to purchase even high cost OPEC oil, they refrain from starting syncrude production.

To illustrate how oil companies compare syncrudes with their other options, Figure 5 shows the relationships among crude oil costs and prices and the expected syncrude costs in 1973 before the Arab embargo and Figure 6 shows the relationships after the Arab embargo, with syncrude costs still uncompetitive, but less so than previously. The cross-hatched area in Figure 6 represents possible conventional crude production activities that were previously unprofitable but which would now be profitable;* the dotted area represents the new conventional crude activities that should still prove more profitable than syncrude production if the world price of oil were to rise further.

Since decision makers in the oil industry see so many conventional crude oil options still available that are more attractive than syncrudes, it should come as no surprise that oil companies do not build syncrude plants. Moreover, the possibilities encompassed by the dotted

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*As long as OPEC kept its price up.

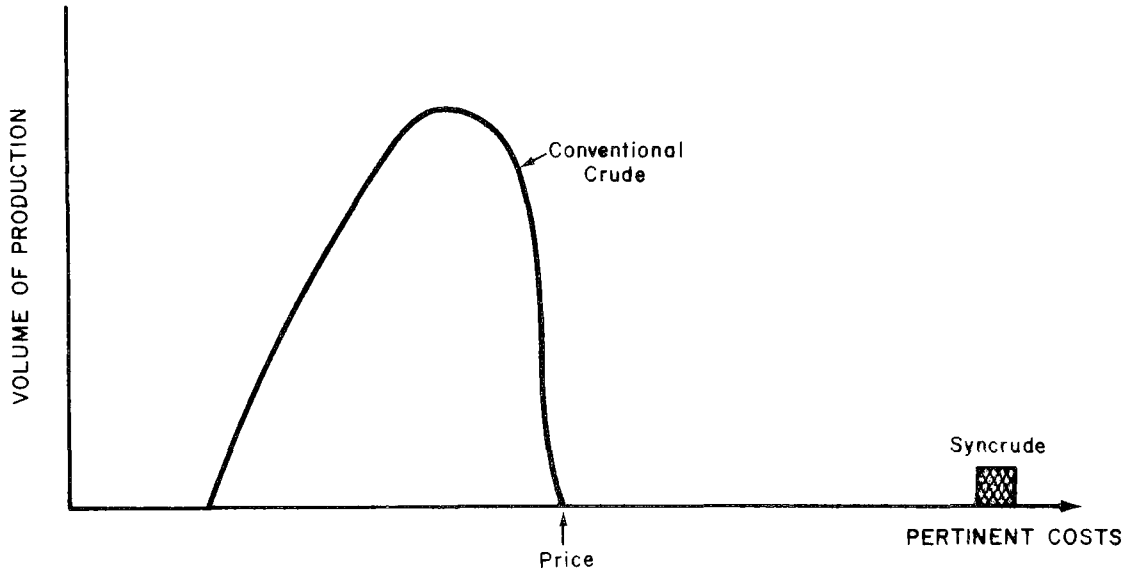

FIGURE 5. PRE-OPEC CRUDE OIL SITUATION

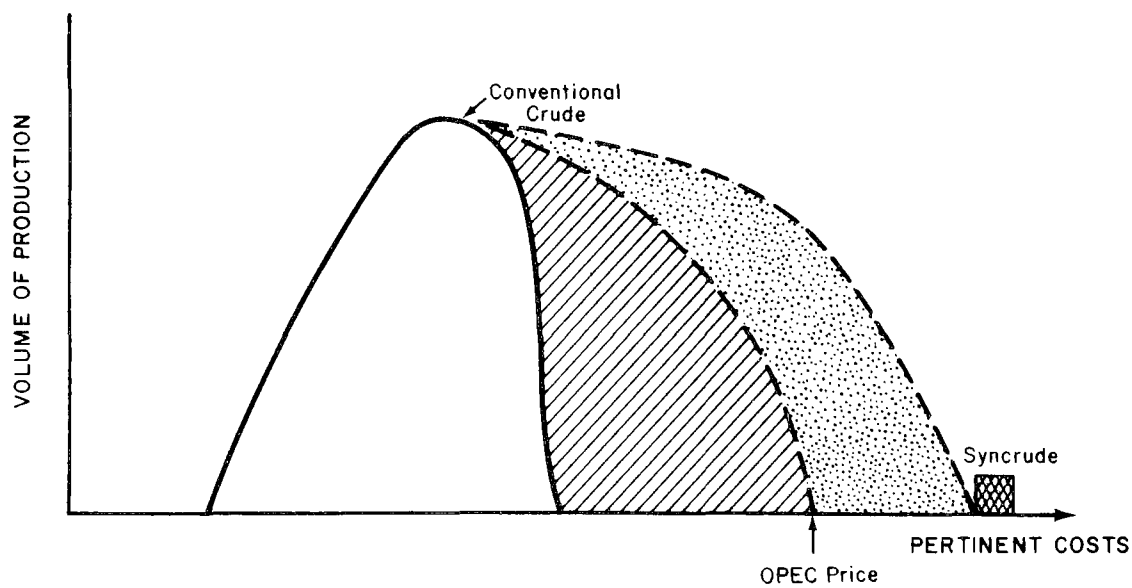

FIGURE 6. POST-OPEC CRUDE OIL SITUATION

and cross-hatched areas in Figure 6 are so large and so unknown (because their previous unprofitability had led to their neglect) that oil company decision makers must consider several major uncertainties:

- The actual amounts of oil that can be found and produced at costs less than syncrude (cross-hatched area of Figure 6).
- The rate at which world petroleum prices might rise compared with the time it takes to go from exploration to production of syncrude.
- The time when syncrudes might be less costly than OPEC oil.
- The possibility that OPEC might reduce prices, again rendering some of the new alternatives uneconomic.
- The question of whether U.S. energy policy will remain stable enough to accept the risk of producing high cost crude oils.

These sobering considerations appear to lead oil companies to continue to study synfuels but to refrain from starting construction on actual plants.

There is one final and fundamental uncertainty. The opportunities for oil exploration and production raised in the cross-hatched and dotted area of Figure 6 are uncertain because no one knows the actual amount of resources that might be located and produced in that price range. By contrast, the production of the syncrudes is certain once a plant is built, but the major uncertainty lies in the actual cost of constructing and operating the plant for these commercially untried processes.

2. Capital Availability[8]

The MCI implicitly assumes that once the synthetic liquid fuel industry becomes profitable, deployment on a large scale could be financed. Industrial investment is normally financed either through

retained earnings or in the national capital market through the instruments of stocks, bonds, and loans.

The assumption that the existing petroleum industry could raise the $89 billion (1973 dollars) cumulatively required to the year 2000 during a gradual transformation of itself into a synthetic liquid fuel industry requires scrutiny. The marshalling of such a large amount of capital must be appraised not only with respect to the industry's financing ability but also with respect to its implied share of total U.S. capital formation. Although financing the synthetic liquid fuels industry stood out as a potentially very critical obstacle, it appears that the nation could accomplish it readily.*

The proper analysis is in terms of the oil industry cash flow. It must be recognized that each profitable synthetic fuels plant would generate retainable earnings that could be used to finance more plants. In fact, because the future conventional petroleum industry will itself become increasingly capital intensive,† adding the financing requirements for the MCI to the future financing requirements for the conventional petroleum industry does not change the situation greatly. This finding is demonstrated in Figures 7 and 8 for an economy with a general annual rate of inflation of 5 percent. Figure 7 shows the expected cash flow situation for a future oil industry based on conventional petroleum alone, while Figure 8 shows the cash flow situation for an evolving combined conventional-plus-synthetic petroleum industry.‡ In both figures, much of the growth shown arises from the inflation alone (at a 5-percent

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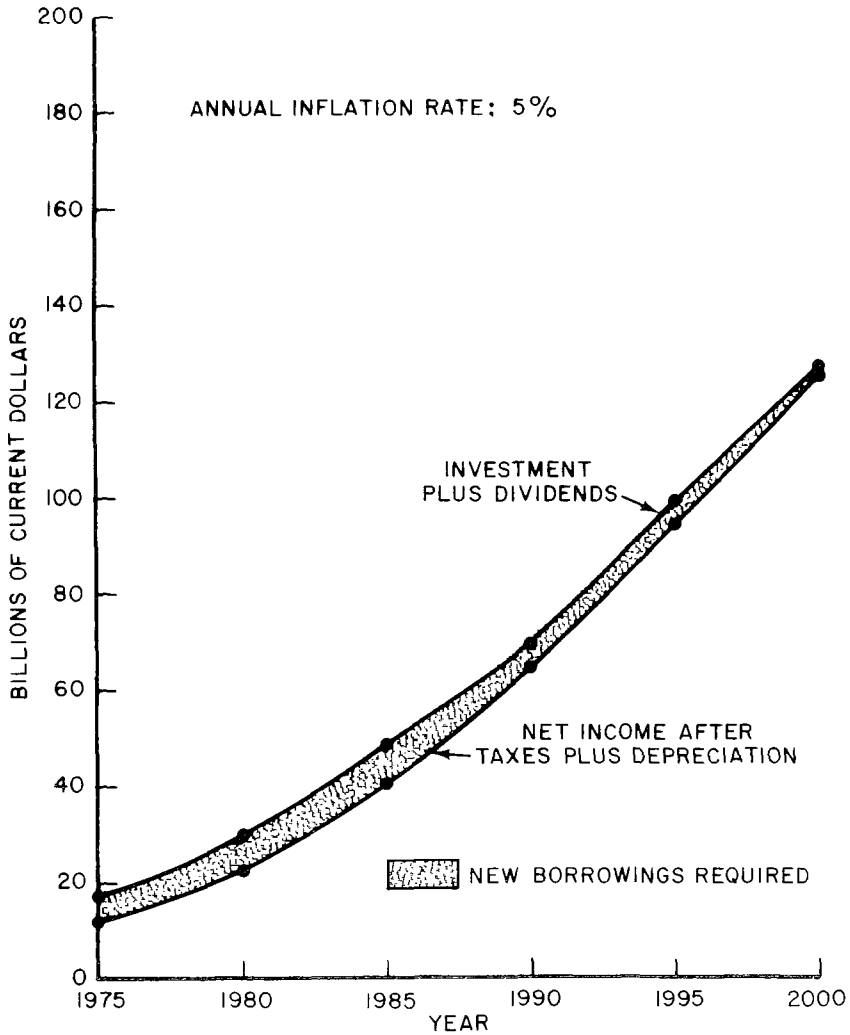
*Presuming that the industry can be made profitable; an unprofitable industry would be impossible to finance.[10]

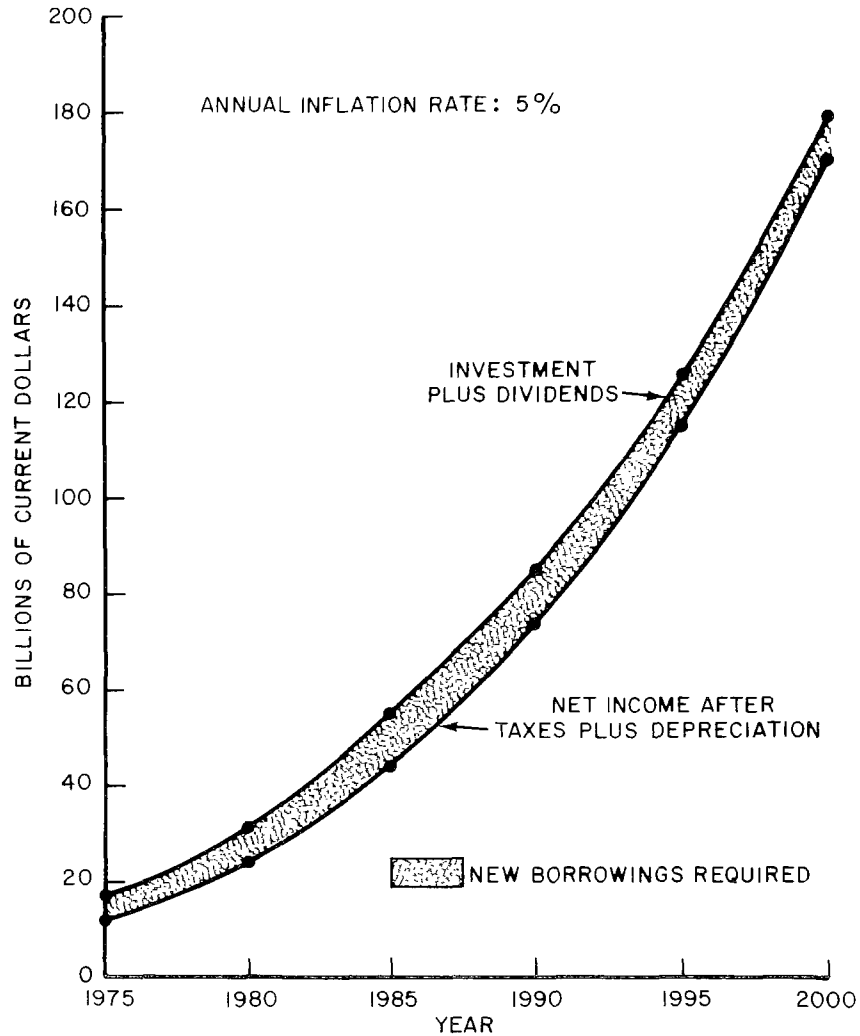
†Toward the end of the century domestic sources of petroleum will probably have capital investment requirements comparable to that of the synthetic liquids industry.[3]

‡The petroleum industry implied by HG1 plus the synfuels industry of the MCI scenario.



Source: Figure 8-3

FIGURE 7 PROJECTED CASH FLOW FOR DOMESTIC OIL AND GAS INDUSTRY – NO SYNTHETIC LIQUID FUELS – AT A FIVE PERCENT ANNUAL RATE OF INFLATION



Source: Figure 8-4

FIGURE 8. PROJECTED CASH FLOW FOR DOMESTIC OIL AND GAS INDUSTRY – CONVENTIONAL ACTIVITIES PLUS SYNTHETIC LIQUID FUELS – AT A FIVE PERCENT ANNUAL RATE OF INFLATION

inflation rate, the general price level doubles roughly every 14 years). As Figures 7 and 8 show, the industry cannot finance itself from cash flow alone and new capital must be attracted each year. This continued need for new borrowing is caused by the inflation because depreciation credits accrue in dollars of diminished purchasing power that cannot actually finance plant replacement. In the year 2000, the combined industry requires about $9.2 billion in new borrowings compared to the conventional petroleum industry's requirement of $2.2 billion.

In the early 1970s, the petroleum industry constituted about 9 percent of total U.S. fixed business investment, but under the MCI, by 1995 the combined natural and synthetic oil industry percentage would double. Given the two decades to adjust, it seems likely that the U.S. economy could accommodate to this increased fraction of business investment being made by the fuels industry.

3. Resource Depletion[6]

Table 10 shows that if liquefaction and methanol synthesis were the sole uses of coal, the demonstrated strippable reserve base* could sustain about 270 synfuel plants, each producing 100,000 B/D (16,000 m^3/D) for their assumed 20-year long economic lifetimes. Since the coal derived fuel production of the MCI would require 80 such plants in operation in the year 2000, the industry could be sustained at that level for only about 70 years on strippable coal reserves. However, if the very substantial increases in coal consumption expected for coal gasification and electricity generation are also considered, then the strippable coal reserves of Table 9 would last only about 40 years. This implies that

*Estimated in 1974 by the Bureau of Mines. This estimate is optimistic because it includes inferred but unproven resources.

a massive shift to the more expensive, more dangerous-to-mine underground reserves would be necessary early in the twenty-first century if the synthetic fuels industry were to continue.

4. Water Availability[19,20]

a. Legal Situation

In the states east of the Mississippi River identified as candidates for mine-mouth synthetic liquid fuel plants (Table 5), precipitation is high and fairly evenly distributed during the year. There are many streams and large rivers. In those states ample water appears to be available to supply the needs of the water-intensive synthetic liquid fuel conversion plants.[20]

The use of water in the water-rich eastern states is governed by riparian law (stemming from English common law). Under riparian water law, rights to water are attached to the lands through which or by which a stream flows. There are complex rules concerning the transferring of water (from legally entitled lands) to other uses (such as cities not situated on the streams). However, the abundance of water in the East has generally left administration of the law flexible and without even an enumeration of claimants and the basis of their rights.[20]

In contrast to the East, the states of the West considered in Table 9 are arid, and precipitation is highly seasonal. As a result, an entirely different approach to water rights has evolved in which use of water is governed by the appropriation system. Under this system, there are no riparian water rights; instead, the first claimant to water is entitled to it, although he is often required to demonstrate his claim by removing and using a certain amount of water in a stream. Because this system does not require the claimant to possess lands near

the stream, the water is often conveyed long distances in water works before being used.[19]

While the appropriation system establishes the basis for a record-keeping procedure and a means to ascertain ownership of water rights, in actuality, the situation is not so simple. Besides problems of inadequate records, there is uncertainty about the relative rights to water held by the federal government, the states, and the Indian tribes who reside in the West.

In the aggregate, there is enough water physically present in the West for the MCI, but it is almost always in the wrong place and the rights to it are disputed. As a result, the understanding, untangling, and resolution of the institutional issue of water availability in the western states is a critical issue in the development of a synthetic liquid fuels industry.

Because about 50 percent of land in the affected western states is in the federal domain, much of the water flowing in western rivers originates on federal land. Potentially, the federal government can assert claim to this water because it was never transferred to the states when they were created out of the federal domain. Since federal law takes precedence over state law, this could render previous allocations under state law effectively invalid.

Indian water rights are also a central issue because there are two (still untested) theories of Indian water rights. The first is that the Indians possess native rights to the water by virtue of being the first inhabitants of the land. The second is that when the federal government created the Indian reservations by treaty, the Indians were also accorded water rights (but of uncertain quantity). Both theories give Indian rights priority over most other claimants because they are older than nearly all other claims.

Since Indian water rights, at worst, derive from a treaty with the federal government, they take precedence over state rights. Consequently, many existing and relatively recently acquired water rights may be rendered useless even though the claimants adhered to all the state's formal procedures for establishing claims.

Although, from the above discussion, the federal government and the Indians would seem to be dominant in the water picture of the western states, historically it is the states that have played the major role as disbursers of rights. The roles of the federal government and Indians are only now rising to the fore. Most states have permit systems for allocating water within their borders, but Colorado did not institute its permit system before the Colorado River was over-allocated. The discrepancy between physical and legal availability in the Colorado River has not yet become important generally only because many rights go unused or only partially used.

In addition to administering water within their borders, western states are parties to interstate compacts that divide the waters in major rivers among the states for further allocation to users within their borders.

b. Water Quantities[19]

Table 9 showed major development in three states of the upper Missouri River basin. As shown in Table 11 the water needed in these states to support the MCI in the year 2000 is about 1.39 million acre-ft per year for both mines and conversion plants. Other demands for water are also expected to grow, including a reservation for maintenance of in-stream values. These other demands are expected to total 2.89 million acre-ft per year as shown in Table 12.

Table 11

NORTHERN GREAT PLAINS SYNTHETIC LIQUID FUEL WATER DEMANDS IN THE YEAR 2000

(Sources: Tables 6-3 and 19-7)

State	Quantity (10^6 acre-ft/yr)*
Wyoming	0.584
Montana	0.479
North Dakota	0.326
Total†	1.390

*10^6 acre-ft/yr is about $1.2 \times 10^9 m^3/yr$.
†Total does not add due to rounding.

Table 12

NORTHERN GREAT PLAINS* PROJECTED ANNUAL CONSUMPTIVE USE OF WATER IN THE YEAR 2000

(Source: Table 19-6)

Use	Quantity (10^6 acre-ft/yr)†
Coal gasification and electric power generation	0.620
Revegetation	0.031
Municipal	0.014
Agricultural	1.900
Fishery habitat and wildlife improvement	0.320
Total‡	2.890

*Wyoming, Montana, North Dakota.
†10^6 acre-ft/yr is about $1.2 \times 10^9 m^3/yr$.
‡Total does not add due to rounding.

When compared to the 5.97 million acre-ft per year (7.4 billion m^3/yr) unallocated and available (measured at Sioux City, Iowa) in low water years, one can conclude that there is more than ample water to meet all future needs in the basin in the year 2000.

While there may be ample water on a multistate basis, the local occurrence of water does not match the distribution of coal and lignite in these states. As a result, on a local and regional level, if the MCI were to be implemented with mine-mouth plants, there would be severe water shortages and shortfalls unless new storage facilities and aqueducts were built to redistribute the water. Such redistribution could often involve existing federal water storage reservoirs constructed by the Bureau of Reclamation. However, nonagricultural use of water in these reservoirs is being challenged because the Bureau of Reclamation's enabling legislation specifies that its work should benefit agriculture.

In Colorado, the availability of water for the oil shale conversion component of the MCI is less favorable. Since it would be vastly too expensive to transport oil shale out of the basin for conversion and disposal, the conversion industry must either secure water from the Colorado River or develop the still largely unmeasured ground water sources. In the year 2000, oil shale conversion plants under the MCI scenario would use 0.321 million acre-ft per year (400 million m^3/yr) while other demands are expected to total 6.14 million acre-ft per year (7.6 billion m^3/yr) as summarized in Table 13. However, the Colorado River Compact* allots only 5.8 million acre-ft per year (7.2 billion m^3/yr) to the upper Colorado River Basin in which the oil shale lies.

Future withdrawals for any purpose will exacerbate the already high salinity of the lower Colorado because it will mean less

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*A compact among Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada, and California.

flow to dilute salty return flows in the lower basin. Water delivered to Mexico is already too saline and desalting plants are planned to honor U.S. obligations to Mexico.

Table 13

PROJECTED NON-OIL SHALE WATER DEMAND IN THE UPPER COLORADO RIVER BASIN IN THE YEAR 2000

(Sources: Chapter 19 and Table 19-10)

Use	Quantity (10^6 acre-ft/yr)*
All existing	3.710
Future	
Coal gasification	0.140
Electric power generation	0.475
Mineral production	0.115
Municipal	0.750
Agricultural	0.800
Environmental protection (fish, wildlife, water quality)	0.150
Total	6.140

*10^6 acre-ft/yr is about 1.2 x 10^9 m^3/yr.

The cost of water is only a very minor component of the total cost of producing syncrude from oil shale. As a result, the oil shale industry could easily afford to pay much more for water than could agricultural interests without there being a significant effect on the cost of their product. By contrast, most agriculture in the region, which is dependent on irrigation, requires low cost water to produce crops at competitive costs. Agricultural interests in the Upper Colorado Basin are concerned that enough political pressure will develop in favor of oil shale to force future allocations of water away from farming and ranching to the synfuel industry, partly on the basis of the willingness of the fuel industry to pay a high price. Water allocations governed by

the willingness to pay for water would certainly result in the diversion of water from agriculture to the oil shale industry--at least for future allocations. It is not apparent, however, that existing agriculture would necessarily lose water because 4 million B/D of oil shale syncrude (twice the MCI) could be produced with 0.8 million acre-ft/year (1 billion m^3/yr) of water identified in Table 13 as needed for future growth in agriculture.

c. Transport of Coal to Save Water[19]

Unlike oil shale, coal can be shipped economically to water-rich areas for conversion. The two methods of coal shipment potentially most appropriate for western coal are unit trains and coal slurry pipelines.

A unit train is a train dedicated to a single use; it shuttles back and forth between the source of its cargo and end use locations. A unit train that carries coal from mine to processing point typically consists of 100 cars, each capable of carrying 100 tons (9.1×10^4 kg) of coal. Even though the train returns to the mine empty, such 10,000-ton (9.1×10^6 kg) unit trains are the cheapest method of moving coal by rail.

Coal slurry pipelines are relatively recent developments. The largest in the U.S. is a 273-mile (440 km), 5-million ton per year (4.5 billion kg/y) pipeline that links the Black Mesa mine in Arizona to the Mohave Power plant on the Colorado River in Nevada. In the formation of a slurry, finely crushed coal is mixed with water in about 50-50 proportions. The mixture can be pumped readily through a pipeline. At its destination, the coal is dewatered in centrifuges.

Slurry pipelines require only about one half as much water per ton of coal as a coal liquefaction plant. Thus, by exporting coal

from a mine by slurry pipeline to the location of a coal liquefaction plant elsewhere, the water demand in the mining region is reduced by half. Railroads, of course, require almost no water in the mining region.

Both railroads and slurry pipelines have advantages and disadvantages. The advantages of railroads include the ability to phase in incrementally, flexibility of routes, and existing facilities. The disadvantages of railroads include the susceptibility to labor disputes, disruption to crossing auto traffic, and noise. The advantages of slurry pipelines include high reliability, small labor force, immunity to weather, ability to traverse more rugged terrain than can railroads, aesthetics of being placed underground, and the movement of coal for less money and energy cost than that entailed in rail transport. The disadvantages of slurry pipelines include fixed route, restriction to single product, and exports of water from water-poor regions.

Currently there is controversy about the relative desirability of slurry pipelines and railroads for coal transport. Railroads generally oppose slurry pipelines because they want the coal hauling business themselves. Since slurry pipelines would usually have to cross railroad rights of way, the railroads have been refusing to grant crossing rights. Congress is considering bills that would grant slurry pipelines powers of eminent domain to enable them to cross railroad rights of way.

Although, as presented here, the question of the use of slurry pipelines for coal shipment is centered on the issue of water availability, it is easy to see that the question quickly broadens to include the future viability of railroads and their value to society above and beyond hauling coal.

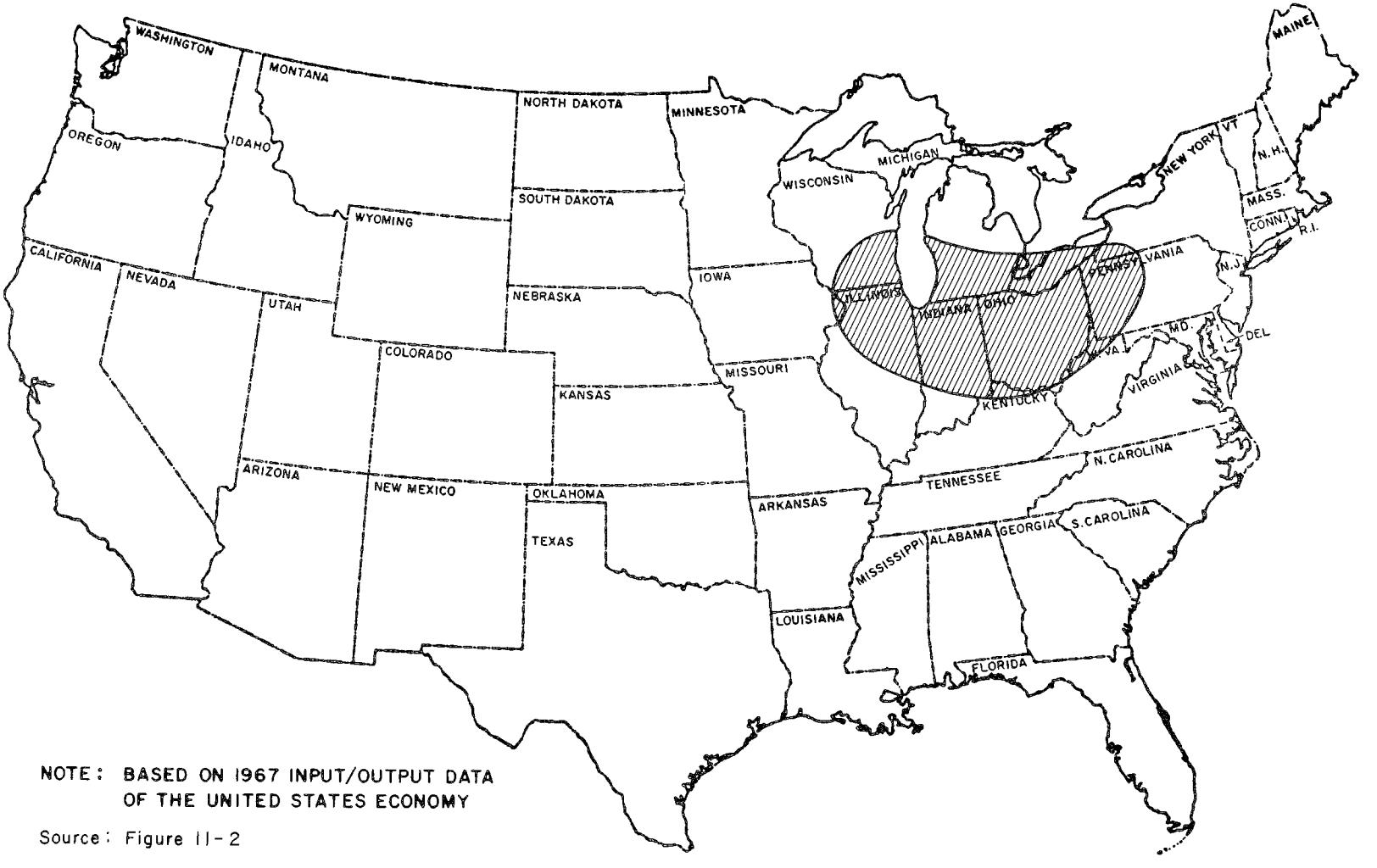
5. Economic Spin-Off Effects[11]

The deployment of a synthetic liquid fuels industry will naturally affect many supporting industries and the labor market. The industrial sectors that will be most affected by the mining of the fossil resources, their transport, and the construction of conversion facilities are steel (raw and finished specialty goods), railroads, explosives and heavy equipment. Such industries are heavily concentrated in Illinois, Indiana, Ohio, Michigan, and Pennsylvania. Thus, although the development of a synthetic liquid fuels industry might be heavily concentrated in the resource-rich states of the West, substantial economic and employment spin-offs would result in the states with the heavy support industry. Figure 9 shows the geographical concentration of this economic spin-off.

Steel needed to support the MCI would result in the energy industry gradually increasing its share of the total steel produced in the United States from about the current 7 percent to about 11 percent.

While the gross figures for steel availability do not suggest problems, the availability of specialty steels, castings, forgings, and special equipment such as mining draglines, compressors, and pumps will quite likely present a bottleneck because lead times are already long in the fabrication industries and they cannot expand capacity rapidly. Currently, there are only one or two suppliers for some items. In addition, coal liquefaction, oil shale, and methanol facilities require large pressure vessels made of special steels and will have to compete for these vessels with the expanding coal gasification and nuclear power industries

Although the MCI assumes conversion facilities near the mine, transportation of the coal to distant locations is sometimes considered. Railroads presently carry 78 percent of all coal to market, and this amounts to 20 percent of all rail traffic. If the MCI coal were all



NOTE: BASED ON 1967 INPUT/OUTPUT DATA OF THE UNITED STATES ECONOMY

Source: Figure II-2

FIGURE 9. PRIMARY CONCENTRATION OF MAJOR INDUSTRIAL SECTORS EXPECTED TO SUPPLY THE COAL AND OIL SHALE INDUSTRY

transported by rail for conversion far from the mine, over 300,000 more hopper cars would be required, and this exceeds the expected production capacity for such cars. These cars also require castings and forgings adding yet another strain on this component of the steel industry.

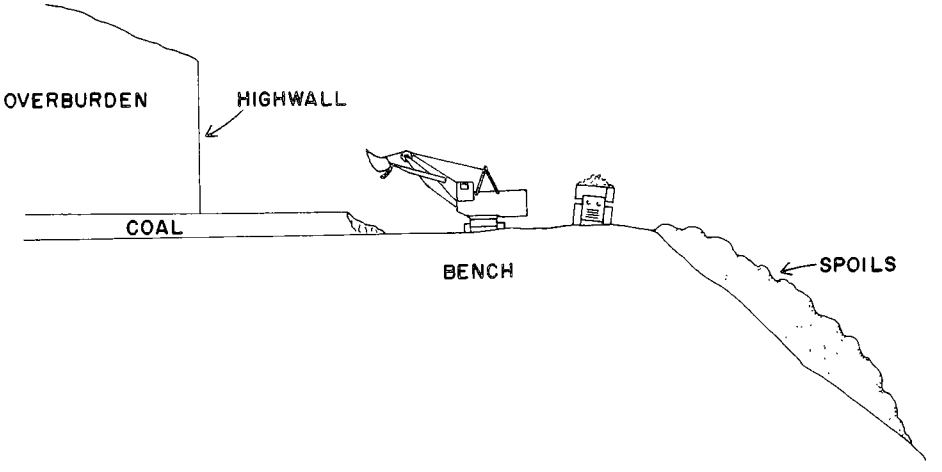
6. Environmental Effects

a. Reclamation of Coal Strip Mines[13,15]

Mining of both coal and oil shale presents severe environmental problems that cannot be alleviated simply. As noted earlier, the high production cost of synthetic liquid fuels from coal will necessitate the use of the cheapest possible coals--those obtainable by strip mining.

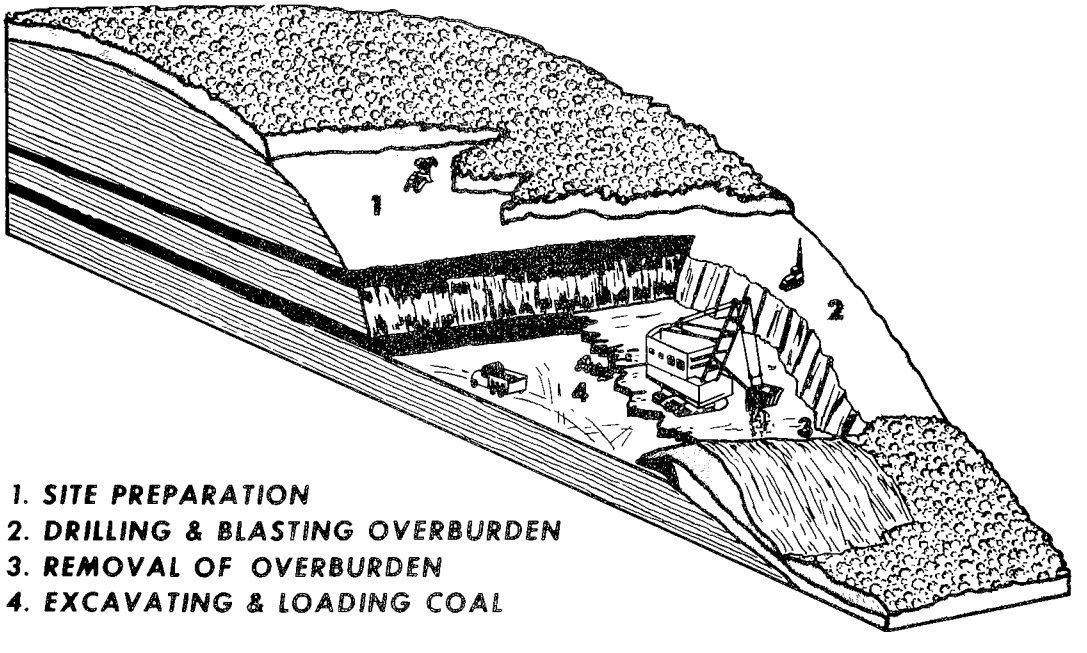
Strip mining for coal requires different equipment and procedures in different regions of the country because of the variation in the nature of the coal deposits. In Appalachia, strip mining takes place along hillsides where thin seams of coal outcrop. Extraction of such coal entails digging into the hillside until the thickness of the overburden becomes so great that its removal precludes economical recovery of the coal. For many years, after the overburden was removed it was merely pushed down the hillside away from the mining activity and abandoned. As a result, the many mined-out hillsides in Appalachia are badly scarred with the highwalls, benches, and downslopes spoil piles (see Figures 10 and 11) as well as a multitude of poorly built, abandoned mine access roads. These scars erode easily in the heavy rains and are slow to revegetate naturally.

Today, most strip mining in Appalachia employs improved materials handling procedures designed to eliminate much of the downslope disturbance by returning overburden to the bench and breaking down the highwall after the coal has been removed. Provided that toxic spoils



Source : Figure 13-5

FIGURE 10. DIAGRAM OF A CONTOUR MINE



Source : Figure 13-6

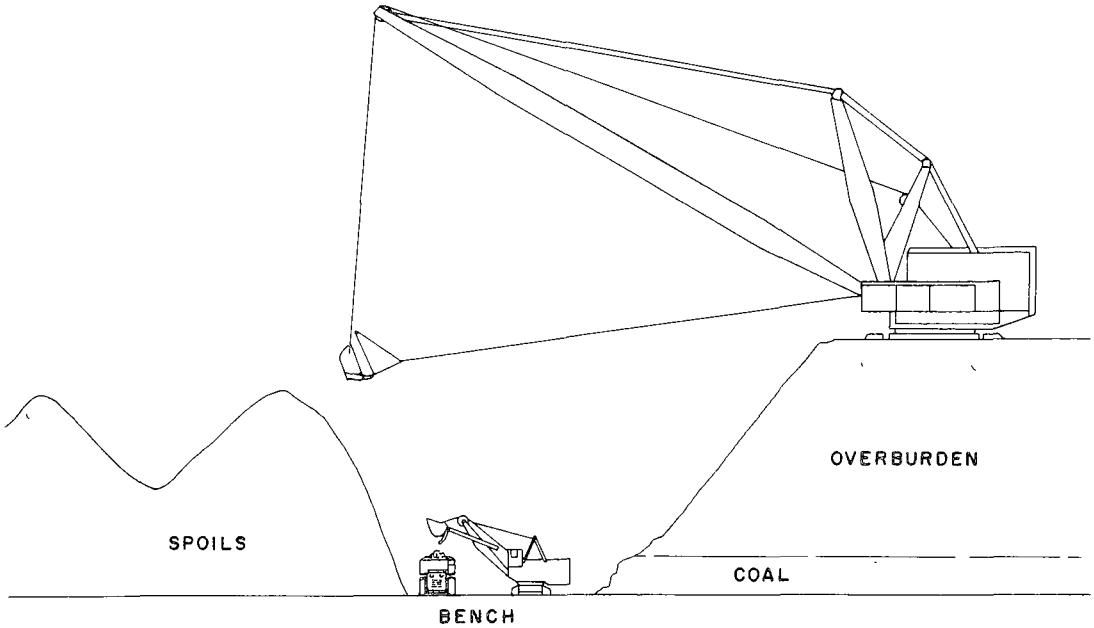
FIGURE 11. CONTOUR STRIP MINING

are buried deep and the best soils are replaced on the top, the disburbed land can be revegetated. The ample moisture in Appalachia would make revegetation and reclamation reasonably successful if the hillsides were not steep. The steep hillsides and large amount of land disturbed per unit of coal produced makes reclamation in Appalachia costly to achieve and protect against erosion until revegetation has stabilized the surface.

In the Midwest, the Northern Great Plains, and parts of the West, where coal lies near enough to the surface to allow strip mining, extraction of the coal is much more straightforward. The overburden is removed from a large area, coal is removed, and then the spoils are replaced in the hole. Since the coal underlies relatively flat terrain in large sheets that are also generally thicker than in Appalachia, far less area is disturbed per unit of coal removed. Indeed, in parts of the Northern Great Plains coal, seams are 30 to 100-ft (9 to 30 m) thick and mining can assume the form of an open-pit operation that resembles quarrying (see Figures 12 and 13).

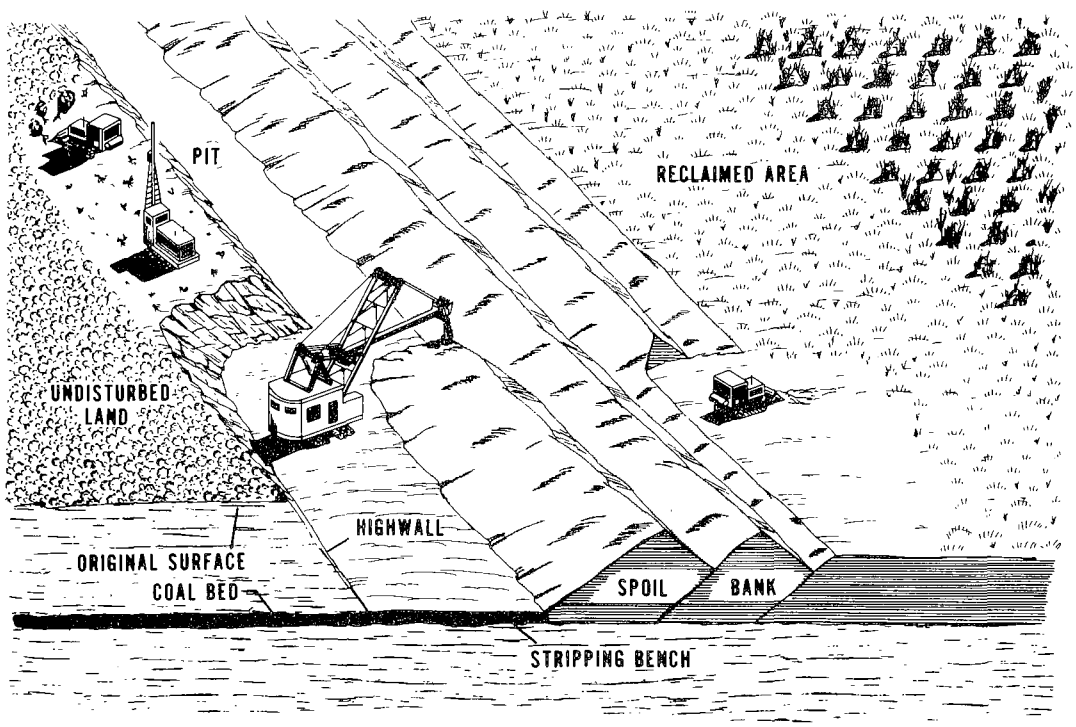
In the Midwest, the deep soils, ample rainfall, and relatively level terrain make reclamation fairly successful whenever it is planned as an integral component of the mining plan. Were it not for the arid conditions in the West and Northern Great Plains, reclamation there would be similarly successful. However, the low and very seasonal pattern of rainfall in these regions makes it difficult to reestablish self-sustaining vegetation. Although some success has been demonstrated, there has not been time enough to insure that the new vegetation can survive without continued human care.

Restoration of mined lands is an issue that has stirred the national consciousness and has resulted in repeated attempts to pass strict federal and state strip-mine reclamation laws. Because of this and the likely focus of future strip mining activities in the arid West, reclamation of mined lands is a critical factor in the deployment of any



Source: Figure 13-8

FIGURE 12. DIAGRAM OF AN AREA MINE



Source: Figure 13-9

FIGURE 13. AREA STRIP MINING WITH CONCURRENT RECLAMATION

significant synthetic liquid fuels industry--even one much smaller than the MCI.

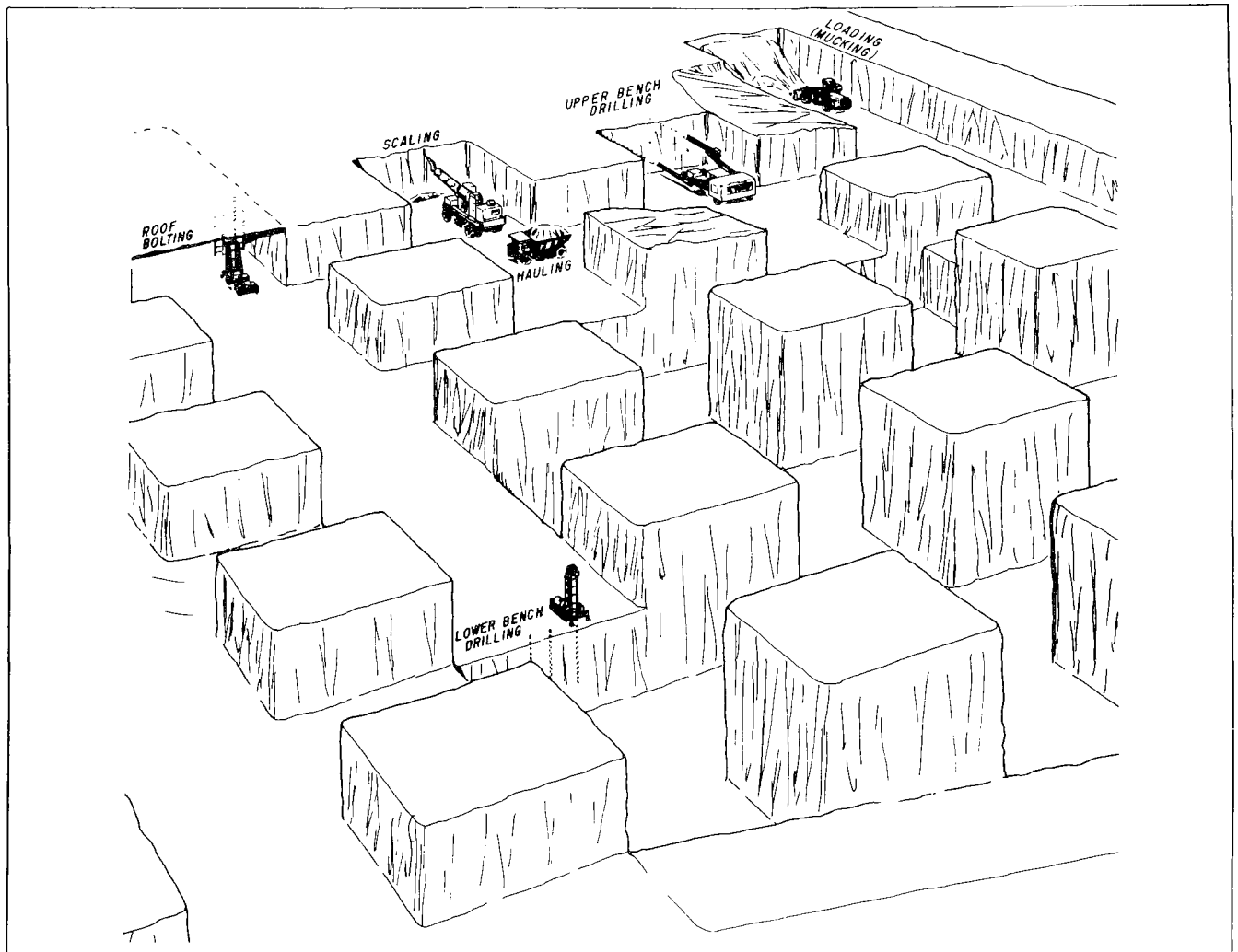
b. Reclamation of Mined Oil Shale Lands[14,15]

The mining and restoration of oil shale lands is a considerably different matter. The volume of oil shale that must be handled to produce a given quantity of synthetic crude is about three times the volume of coal that would be handled for the H-coal process (see Table 4) Not only is the volume of material extracted and processed larger, but the volume of waste material requiring disposal is also vastly larger because the volume of spent shale exceeds the volume of raw shale.

Oil shale usually occurs in deposits so thick that the mining of it underground resembles quarrying (except under a roof) as shown in Figure 14. Open-pit surface quarrying would often also be suitable. In either case, in principle, spent shale could be returned to the mines once mining activities had ceased. In practice, however, disposal somewhere else would be required during early stages of the industry. Some additional disposal sites would be required to accommodate the excess volume of spent (compared to raw) shale. Since oil shale country is heavily cut with canyons, the general expectation is to fill canyons with spent shale. Revegetation of this spent shale has not been successfully demonstrated on a large scale and over a long enough period to be certain that it can survive after human attention wanes. Disposal and reclamation of spent oil shale is a critical environmental factor.

c. Air Quality[16]

By any measure, the synthetic liquid fuels plants being considered here are large, heavy industrial plants and are potential sources of air pollutants.



Source: Figure 14-1

FIGURE 14. UNDERGROUND OIL SHALE MINING BY THE ROOM AND PILLAR METHOD

Three classes of nondegradation standards have been defined by the Environmental Protection Agency for regions presently possessing air quality equal to or better than federal secondary standards:

- Class I--only slight degradation of air quality*
- Class II--allows modest decline in air quality, compatible with light industry or carefully controlled heavy industry.
- Class III--essentially equivalent to the federal secondary standards.

Emissions from each of the three processes selected for this study have been examined under the assumption that the best available emission control technology would be applied and that the most relevant ambient standards are the federal Class II "nondegradation" standards.

The best available controls appear to be inadequate for a single oil shale conversion plant (with the emission levels available to this study)† to meet Class II standards. Particulates and sulfur dioxide emissions require 85 and 72 percent more control, respectively.

A single coal liquefaction plant could successfully meet Class II standards without additional control of emissions. However, dispersion modeling of the air quality impact of a complex of four liquefaction plants in Wyoming's Powder River Basin under worst-case

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*Class I standards are so strict that they, in effect, preclude industrial activity, and therefore essentially contradict the assumption that the conversion plants exist.

†Revised emissions for the TOSCO II process have recently been released in the draft Environmental Impact Statement for the "Proposed Development of Oil Shale Resources by the Colony Development Operation in Colorado" (December 1975).

wind conditions shows that although a single plant could meet Class II standards, additional control of particulates would be required to enable a complex of plants to meet the standards. Since the MCI hypothesizes about 18 plants in Wyoming in the year 2000, probably with 5 to 10 in the Powder River Basin area, it is apparent that development and use of improved air quality controls technology will be essential to meet plausible ambient air quality standards.

Although it appears that a complex of well-controlled plants would not result in air quality as bad as that found in many major cities, there would be major deterioration below present levels. Since holding air quality deterioration to the level of Class II standards requires controls beyond the best available today, air quality control represents a very important critical factor in deployment of a synthetic liquid fuels industry. If states do not select their ambient air quality standards uniformly, then the industry will tend to locate in the areas with the least stringent standards.

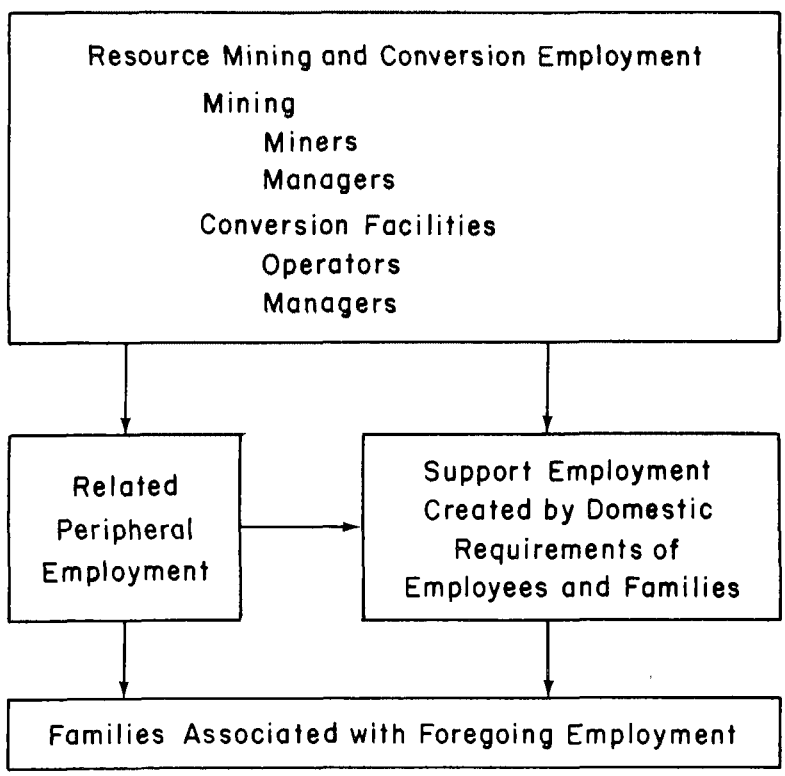
d. Urbanization[17]

Rapid rates of population growth in areas now sparsely populated leads to the creation of boom towns in which environmental quality protection measures are usually inadequate. Sewerage, storm run-off, solid waste disposal, and other environmental protection facilities usually cannot keep pace with the population influx and, as a result, environmental quality can be seriously impaired at the local level. In addition, new population increases demands for outdoor recreation--demands that often result in excessive hunting, fishing, use of off-road vehicles, and vandalism of archeological or scenic resources. (Social effects of boom towns are described later.)

7. Social Consequences

Establishment of a synthetic liquid fuels conversion plants in the vicinity of the mines will result in urbanization of previously rural areas. Table 9 (above) shows the hypothesized MCI geographical distribution of the industry and indicates that some sparsely populated western states, especially parts of Montana, Wyoming, North Dakota, and Colorado, would be at the center of much of this activity.

Each mine or conversion plant can be considered to create new primary employment that would be supplemented by secondary industrial and domestic support employment for workers and their families. Figure 15 shows how primary jobs create additional employment. The overall



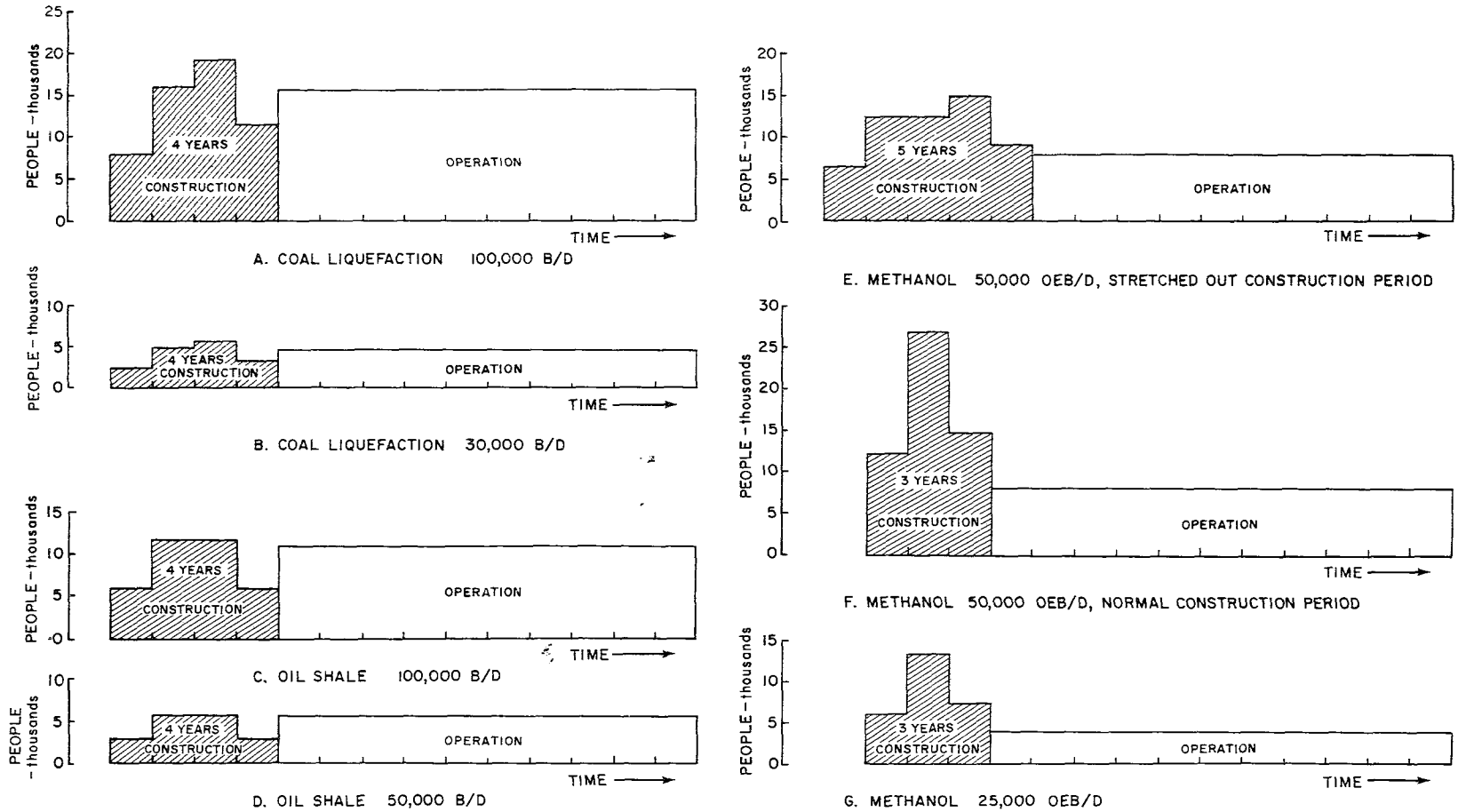
Source: Figure 23-2

FIGURE 15. BASIS OF POPULATION MULTIPLIER

population change can be summarized by defining a population multiplier--a number which, when multiplied by the number of primary jobs, indicates the total associated population. There is considerable uncertainty in the exact value appropriate for population multipliers for the industries in question, but a value of 6.5 has been used since values near this have been judged appropriate to these areas in the past.

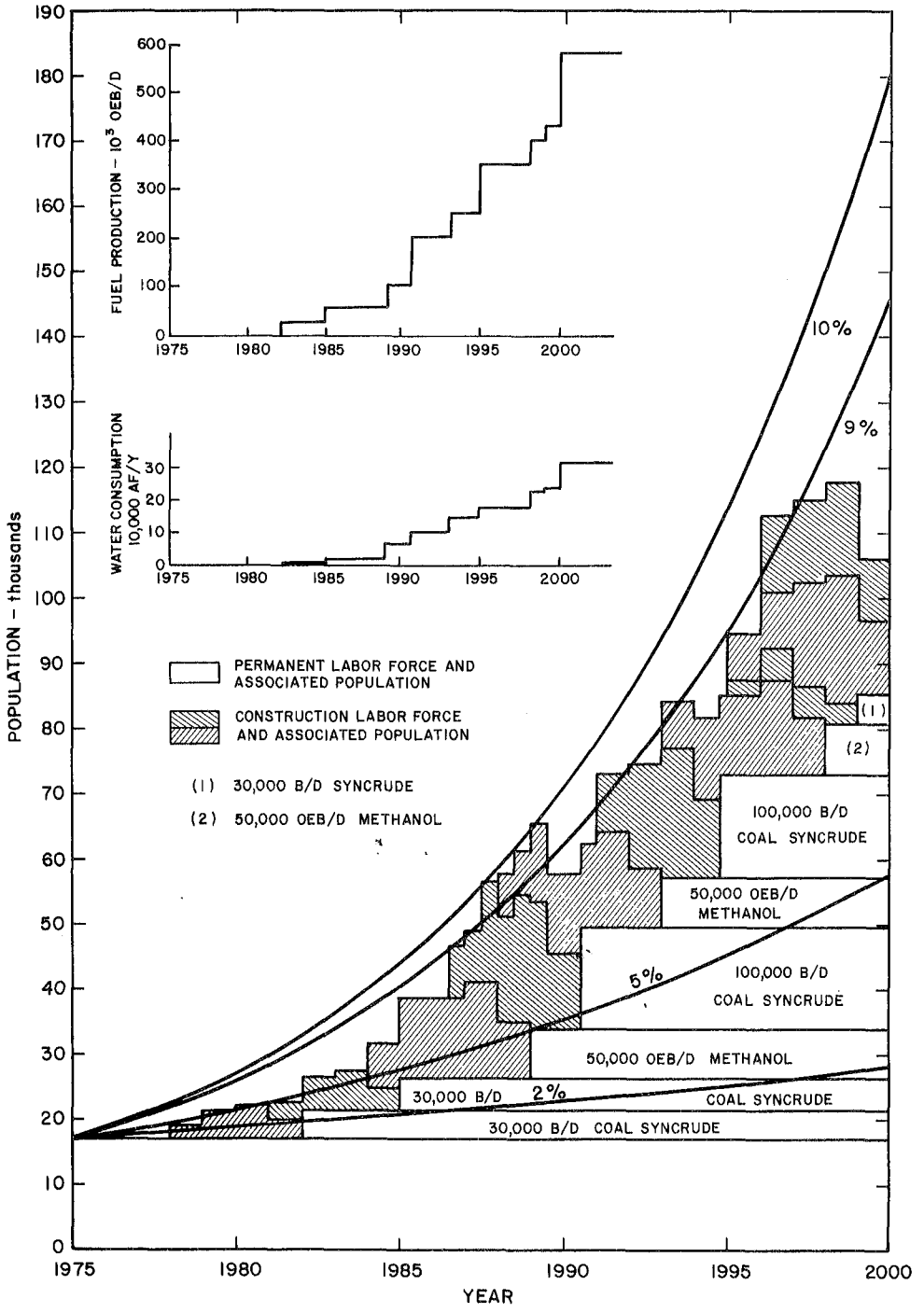
Figure 16 presents time profiles of the total population (including the multiplier effect) expected to be induced by the various kinds and sizes of plants considered in the MCI. For example Figure 16 shows that a single 100,000-B/D (16,000 m^3/D) coal liquefaction facility would have an associated population of more than 15,000 people during its operational phase. If one considers as an example Campbell County in Wyoming's Powder River Basin in which the 1975 population is only about 18,000 people, it is evident that even a single coal liquefaction plant could profoundly alter small existing communities. Figure 17 shows the effect of the MCI on population growth in Campbell County from now to 2000--presuming that only one quarter of the Wyoming activity indicated in Table 9 located there. The population growth rate shown in Figure 17 averages about 9 percent per year, but in some years there are large jumps--as much as 10,000 people in a population of 60,000. Such abrupt changes are not easily absorbed by communities. Figure 18 shows the effect of the MCI on the oil shale region of Colorado. The average annual population growth is about 17 percent.

Whether population growth and community alteration are beneficial or detrimental is a matter of opinion--opinion, which strongly depends on the background, location, and economic interests of the holder. For example, some feel that urbanization is beneficial because of the likely attendant economic prosperity, while others feel that economic prosperity is not worth the change in lifestyle and loss of solitude. Still others believe that the attendant environmental effects



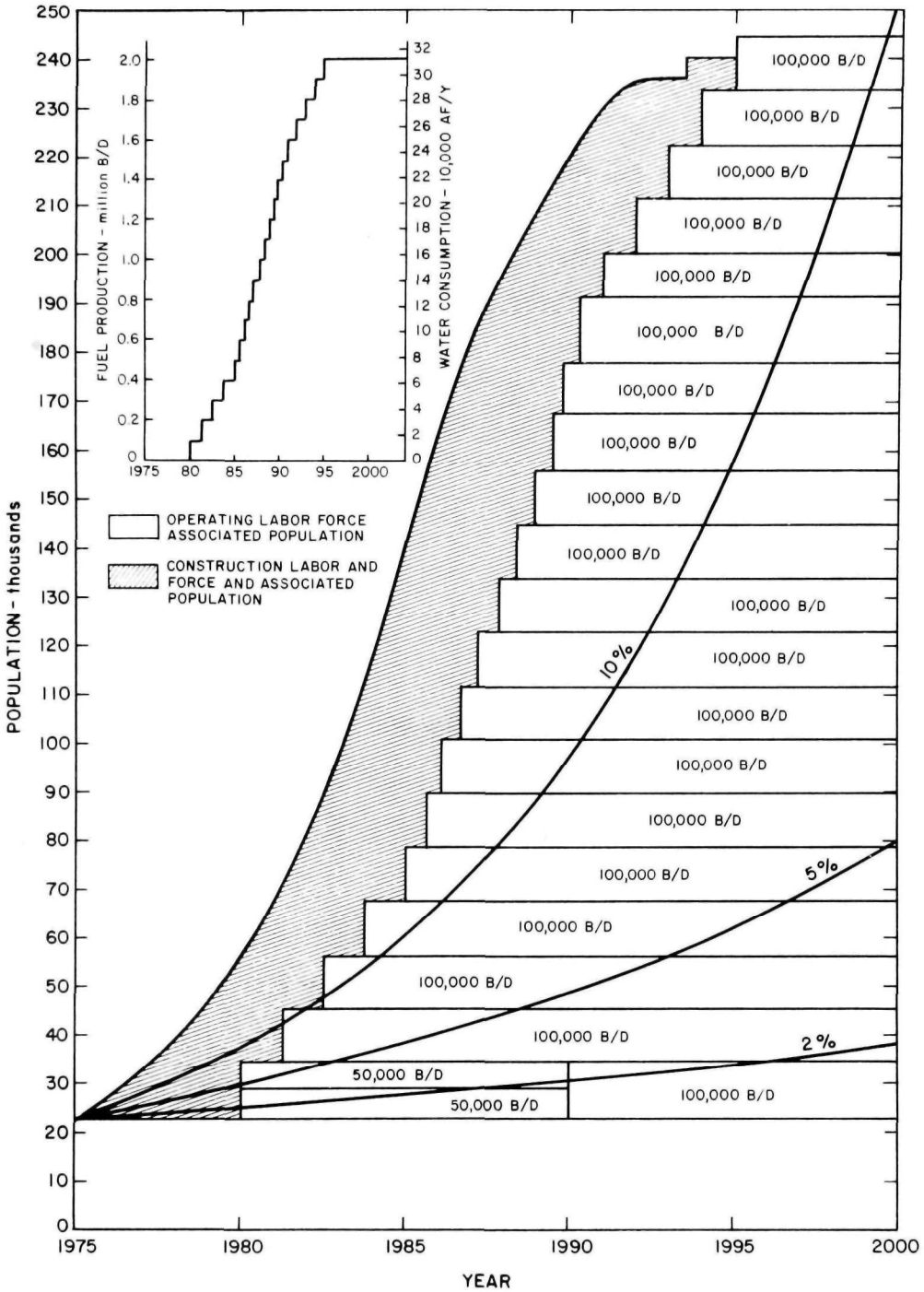
Source: Figure 22-1

FIGURE 16. TOTAL POPULATION ASSOCIATED WITH INDIVIDUAL PLANT CONSTRUCTION AND OPERATION BUILDING BLOCKS. All building blocks include the mines that supply the plants. The actual labor force is multiplied by 6.5 to account for induced secondary employment and families. The data for these building blocks come from the scaling factors derived for the Maximum Credible Implementation Scenario.



Source: Figure 22-2.

FIGURE 17. EFFECTS OF THE MAXIMUM CREDIBLE IMPLEMENTATION SCENARIO ON POPULATION IN CAMPBELL COUNTY, WYOMING. Assumes that one quarter of all the Scenario's development in Wyoming occurs in Campbell County. This assumption is expected to be on the low side.



Source: Figure 22-10

FIGURE 18. MAXIMUM CREDIBLE IMPLEMENTATION SCENARIO FOR OIL SHALE DEVELOPMENT IN GARFIELD AND RIO BLANCO COUNTIES, COLORADO. The resulting *annual population growth rate is about 17 percent.*

(mining, air pollution, use of scarce water resources, etc.) would be intolerable, yet some believe that the nation's need for liquid fuels should override all other considerations.

Certain social consequences of deploying a liquid fuel industry of the size of the MCI in rural areas seem indisputable:

- Creation of a boom town rate of growth and atmosphere.
- Dislocation of the traditional economic base.
- Alterations of the lifestyle of the resource region, from rural to urban-industrial.
- Value conflicts between the newcomers and old timers.

Each of these effects give rise to important social problems.

a. Boom Towns[21,23]

Population growth rates that lead to boom towns, create problems in the establishment and maintenance of reasonable community services. The absence of such services can severely diminish the quality of life. One of the first manifestations of a rapid population growth is a housing shortage. When this occurs, especially in rural or semirural areas with weak zoning, temporary mobile home units substitute for permanent structures. When rapid growth is sustained, these temporary buildings tend to become a permanent rather than transitory feature of the community. This tendency is reinforced because many of the new residents are uncertain how long they will remain in the community, and, as a result, they are skeptical of investing their savings in substantially built homes or commercial buildings.

Another problem endemic to rapid growth is the lag of vital public community services behind their need. There are several causes: first, the need for public investments generally precedes the collection of tax revenues that can pay for them. Second, previously

rural communities, possessing an attitude of independence of action free of social controls urban residents take for granted, are reluctant to accept the planning bureaucracy necessary to organize and coordinate a rapidly growing community.

The first community services to fall behind needs are those that require construction before construction of shelter and business can proceed--potable water supplies and sewerage, for example. Next to lag are those that require trained staff, equipment, and specialized buildings--police and fire protection, hospitals, schools, and welfare counseling, for example. In addition to the lag in public community services, there is usually a lag in privately provided community services--doctors, dentists, and recreational businesses such as theaters and bowling alleys.

Boom towns are usually marked by instability and a high incidence of social malaise--divorce, mental health disorders, alcoholism, crime and suicide--partly because of the attitudes of people attracted to such towns and partly because of the lag in provision of services affecting the quality of life. It is not difficult to see that the effects tend to be reinforcing. An indifferent sense of community, the prevalence of personal problems, and an abundance of temporary or make-do facilities discourages both economic and psychological investment in a permanent, more satisfying community. These effects also contribute to a reduced productivity of workers.

Not all small communities oppose development, and they often induce industries to locate in their vicinity. Frequently the inducement is a forgiving of property tax for several years. This practice naturally adds considerably to the problem of tax lag.

However, some local governments that anticipate a boom caused by industrialization have sought to avert the tax lag problem by requiring prepayment of industrial taxes or requesting, in advance, corporate contributions for hospitals and schools. Acceptance of this notion of providing "front end" money to help avert problems of growth is apparently gaining ground with the major petroleum companies most likely to develop synthetic fuels. They apparently see the practice as enlightened self-interest, for they recognize the productivity benefits of a stable work force living in a satisfying community. Moreover, provision of substantial front end money to a community often adds little to the hundreds of millions of dollars necessary to construct any of the plants considered and has considerable benefit for the corporate image.

b. Value Conflicts[21,23]

In many of the potentially affected communities in western states, the idea of development of coal or oil shale mines and fuel conversion plants is not warmly received because the residents feel they lack a meaningful voice in the decisions that affect their future. The origins of such feelings are easy to discover:

- Coal or oil shale mineral rights are generally held by the federal government while local residents own the surface rights.
- Mineral rights are paramount over surface rights and the federal government can lease* the mineral rights without the surface owners' permission.
- Coal mining, petroleum, and electric power companies seeking to mine and convert the coal represent "outside" interests.
- Pressures for development arise from a national need, while the most acute social and environmental impacts would be felt at the local level.

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*In effect, sell.

As a result, the feeling that the local or regional interests are being subordinated to the national interest is common.* Moreover, local people often recognize that once the process of industrialization begins, their attitudes, values, and political orientations would be displaced by those of the new settlers who will be economically dependent on the new industrialization.

Because of the very real problems associated with boom rates of growth, and the value conflicts that arise between the local or regional interest and the national interest, coping with the social effects of synthetic liquid fuel development will be very important--so important that the social consequences of boom towns are a potential critical inhibiting factor to deployment of the industry.

B. Summary of Factors Critical to MCI Deployment

Several of the considerations discussed above are critical factors, for without alteration in their disposition, deployment of a large synthetic liquid fuels industry will founder. The critical factors can be summarized as follows:

- Economic and risk factors affecting corporate decision making
  - Synthetic fuel compared to conventional fuel costs must be accurately determined.
  - Federal policies towards synthetic fuels subsidization require clarification.
- Water demands compared with its availability
  - Physical transfers of water may be indicated.
  - Institutional resolution of water rights and their transfer is essential.

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*Conversely, in the country at large, the feeling that the national interest was being held hostage to narrow local interests could easily arise.

- Reclamation of mined lands
  - Acceptable procedures that will result in stable ecosystems after close husbandry ceases must be demonstrated.
  - Rules and regulations must be established and stably maintained so that business decisions can be made.
- Air pollution control
  - Nondegradation air quality classifications must be established for candidate regions so that decisions can be made.
  - Emissions control technologies must be improved; otherwise a complex of plants will not meet established standards.
- "Boom" growth rates (especially in the West)
  - Planning and mitigation measures must be undertaken before, rather than after, damage occurs.
  - New mechanisms for cooperation among all levels of government and industry are needed.
- Value conflicts in the West
  - Conflicts between newcomers and previous residents concerning industrialization will occur.
  - Conflicts between states of between regional interests and the national interest will arise.

Although many of these impacts appear to be extremely undesirable and could easily give rise to the sentiment that the idea of a synthetic liquid fuel industry should be abandoned, the impacts of the major alternative course of action--all-out production of domestic oil (Section II) would also lead to significant undesirable impacts. Therefore, the nation and its energy policymakers are faced with an array of very serious tradeoffs that cannot easily be decided to the simultaneous satisfaction of large segments of the public.

VII THE EFFECT OF INTRODUCING A SYNFUEL INDUSTRY ON A CONSTRAINED-GROWTH BASIS

Many of the impacts raised by the critical factors in MCI deployment listed in Section VI-B can be alleviated by limiting the number of conversion plants in a given area since this also restricts the rate of population growth and the amount of water consumed. This would require shipment of coal to other regions for conversion. Dispersing the coal conversion industry, however, does not alleviate problems of mined land reclamation and corporate risk.

Following the procedures in Figures 17 and 18, controlled growth scenarios have been prepared so that their implications for fuel production, population growth, and water demand can be examined. These controlled growth scenarios are presented and discussed below.

A. Growth Constrained Scenarios[22,23]

The growth constrained scenarios that follow relate to experience in urban growth patterns. Annual growth rates of 10 percent or more are essentially unmanageable because urban services continually lag the population and the effects of "boom" growth become chronic. Annual growth rates of 5 percent are also high and considered difficult, but not impossible, to handle.*

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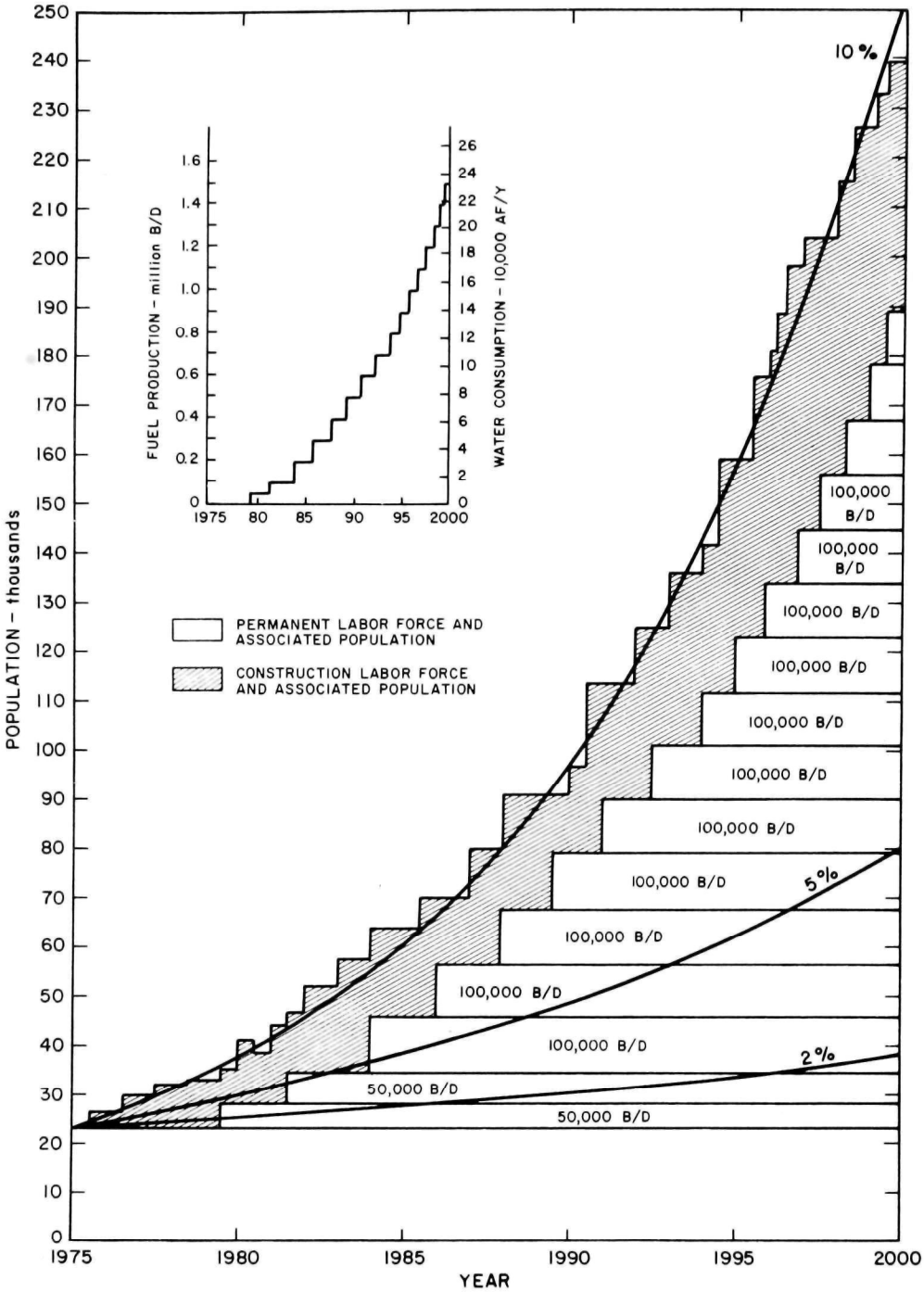
*During the decade of 1960 to 1970 Santa Clara County, California, one of the fastest growing counties in the nation, exhibited about a 5 percent annual growth rate. Yet as part of the four-county urban metropolis in the San Francisco Bay Area, Santa Clara County was able to draw upon services (such as hospitals) in nearby communities which would not be available in the rural resource-rich areas under consideration in this study.

It is assumed in the scenarios that existing small cities and towns serve as nuclei for settlement and receive about 80 percent of the new population with the remaining 20 percent settling nearby. The population multiplier applied to primary jobs in mining and conversion facilities has again been assumed to be 6.5.

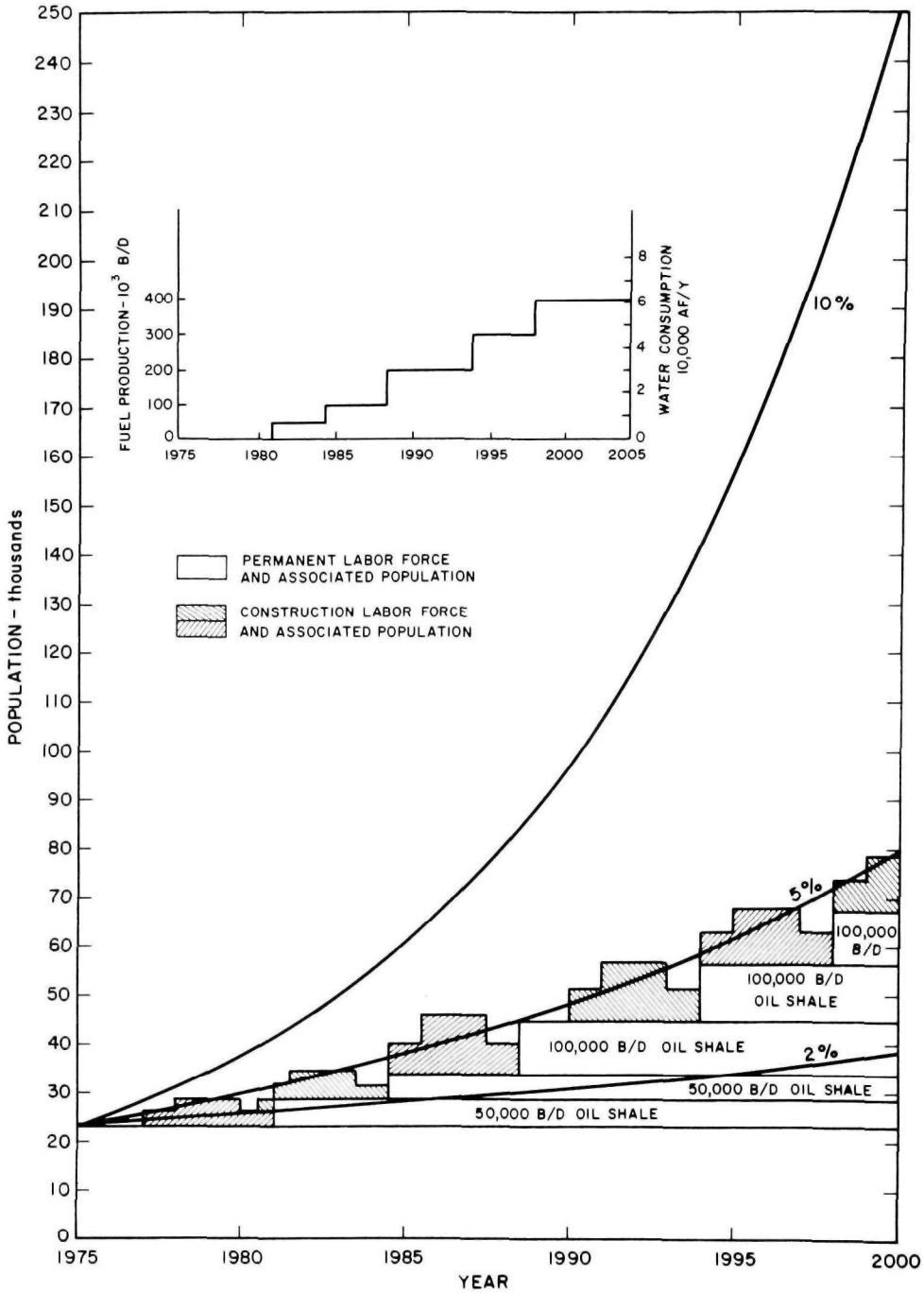
Figures 19 and 20 show, respectively, 10 percent and 5 percent population growth constrained scenarios for the oil shale region of Colorado. These seem tame compared to the growth rate of about 17 percent implied by the MCI and shown in Figure 18. Of course, the fuel outputs in the year 2000 are correspondingly less than the 2 million B/D (320,000 m^3/D) of the MCI--1.5 million B/D (240,000 m^3/D) in the 10 percent case and 0.4 million B/D (64,000 m^3/D in the 5 percent case. Water demands also decline proportionately to the fuel output.

Figure 21 shows a 5 percent population growth constrained scenario for Campbell County, Wyoming, and can be compared with Figure 17. As in the oil shale case, the total liquid fuel produced in the region is much reduced--down from the 600,000 B/D of the MCI scenario to about 300,000 B/D (48,000 m^3/D) in the year 2000. In Figure 19 the abrupt jumps in population, which cause large problems in communities, remain; however, Figure 20 shows that the abrupt jumps in population can be avoided by restricting conversion plants to the 30,000-B/D (4,800 m^3/D) size and by carefully phasing the start of construction. In this case the same 300,000 B/D (48,000 m^3/D) can be produced by the year 2005 but with a population growth history that is considerably more manageable. Figure 22 clearly illustrates the potential value to the impacted community of controlling plant size and construction starts while only delaying the achievement of the 300,000-B/D fuel output by 5 years, to the year 2005.



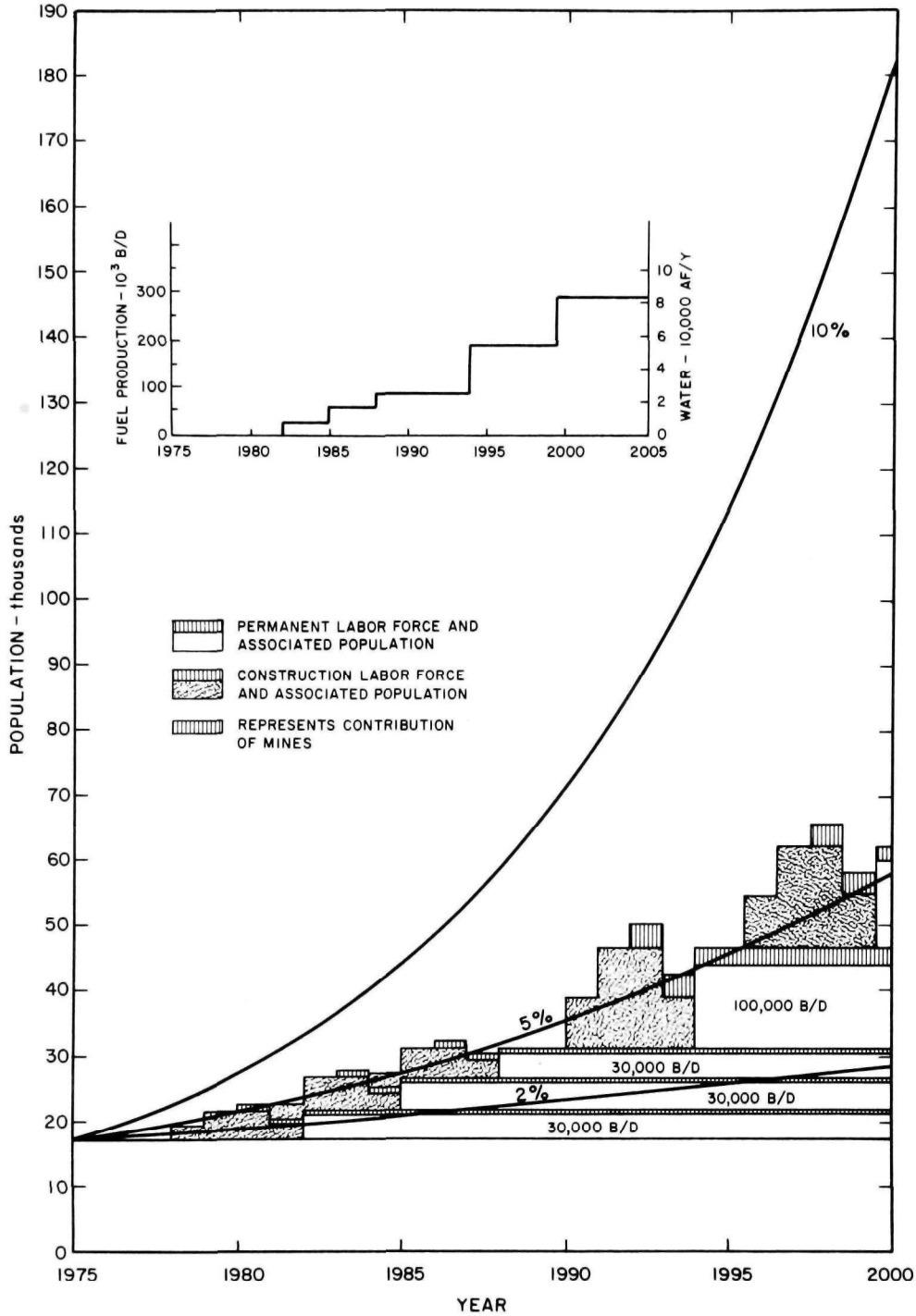
Source: Figure 22-9

FIGURE 19. TEN PERCENT CONSTRAINED POPULATION GROWTH SCENARIO FOR OIL SHALE DEVELOPMENT IN GARFIELD AND RIO BLANCO COUNTIES, COLORADO



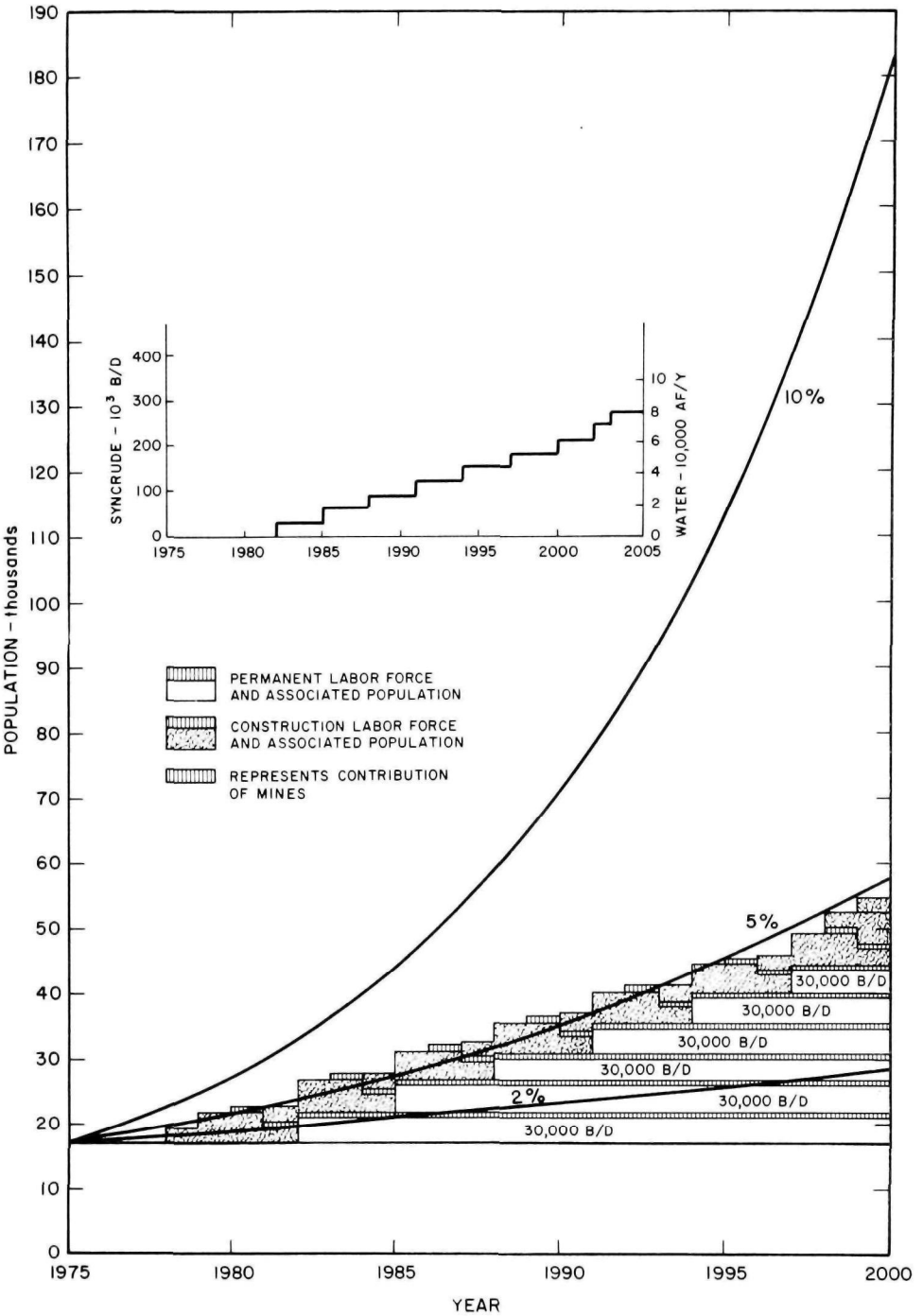
Source: Figure 22-8

FIGURE 20. FIVE PERCENT CONSTRAINED POPULATION GROWTH SCENARIO FOR OIL SHALE DEVELOPMENT IN GARFIELD AND RIO BLANCO COUNTIES, COLORADO



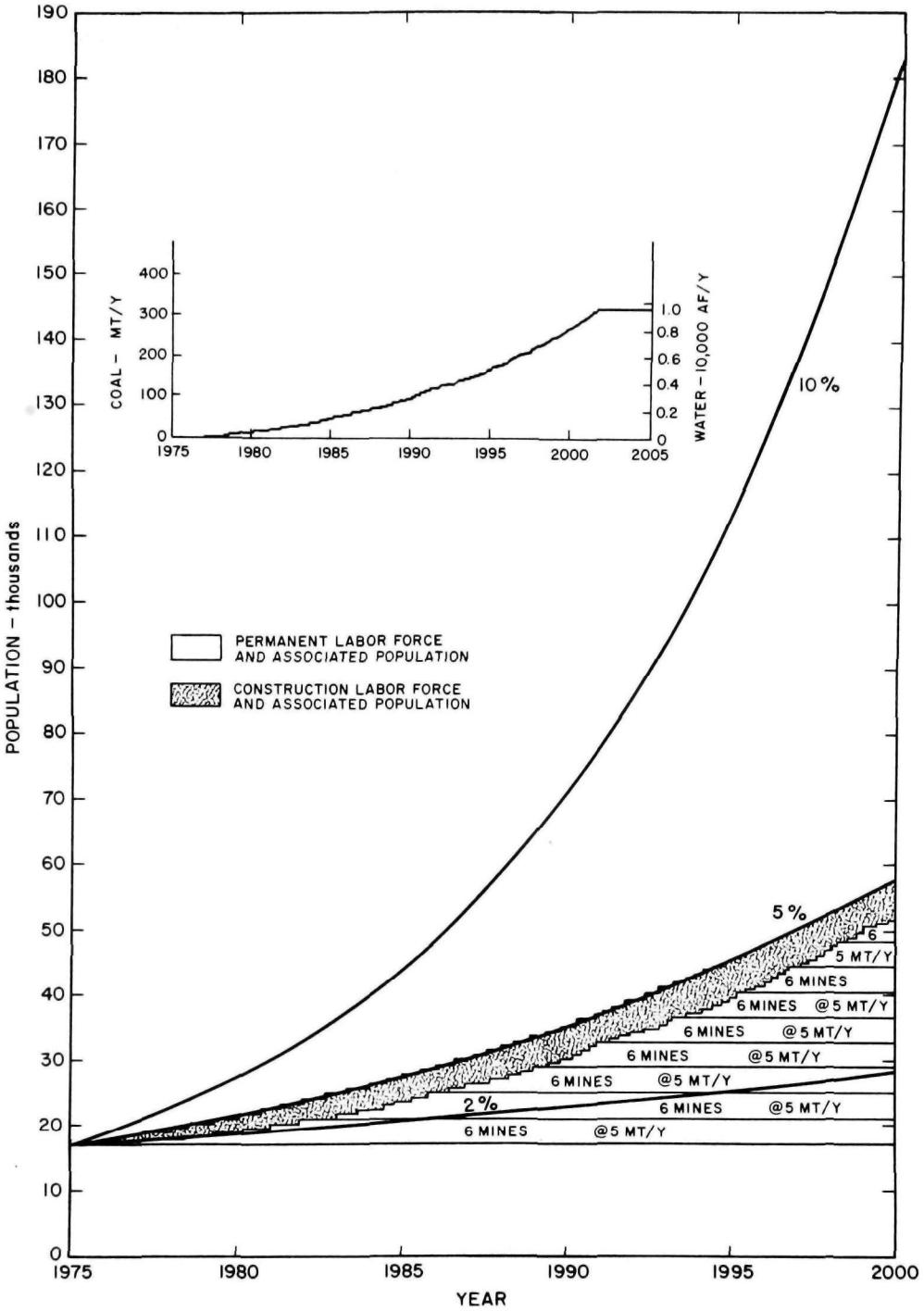
Source: Figure 22-3

FIGURE 21. FIVE PERCENT CONSTRAINED POPULATION GROWTH RATE SCENARIO FOR CAMPBELL COUNTY, WYOMING ILLUSTRATED WITH COAL LIQUEFACTION PLANTS AND ASSOCIATED MINES. The larger sized plants cause rapid changes in population.



Source: Figure 22-4

FIGURE 22. MODIFIED FIVE PERCENT CONSTRAINED POPULATION GROWTH SCENARIO FOR CAMPBELL COUNTY, WYOMING ILLUSTRATED WITH COAL LIQUEFACTION PLANTS AND ASSOCIATED MINES. By building only the smaller sized coal liquefaction plants, large fluctuations in population can be avoided



Source: Figure 22-5

FIGURE 23. FIVE PERCENT CONSTRAINED POPULATION GROWTH SCENARIO FOR CAMPBELL COUNTY, WYOMING IN WHICH ONLY COAL MINES ARE DEVELOPED. Under these conditions growth in population can be made very smooth. By 2000, 54 mines, each producing 5 million tons/year, would be exporting 270 million tons of coal per year.

Figure 23 shows that a coal-rich area such as Campbell County, Wyoming, can control its future even more by allowing coal mines but disallowing conversion plants, thereby forcing coal to be shipped to other regions for conversion. The growth rate shown in Figure 23 is almost smooth, and yet mining activity reaches a very high level--some 300 million tons per year (270 billion kg/yr) in the year 2000. (This level of production can support about 17 coal syncrude plants.) This mitigation measure of exporting coal from the region is much less feasible in regions with low quality coals, such as the lignite areas of North Dakota, and is not available at all to the oil shale regions.

Table 14 compares fuel production, water demand, and total population for the MCI and the 5-percent population growth constrained scenarios of Figures 18 and 20.

Table 14

COMPARISON OF MCI AND FIVE PERCENT POPULATION GROWTH CONSTRAINED SCENARIOS, FOR THE YEAR 2005

	MCI	Growth Constrained	Coal Export by Rail
Campbell County (coal)			
Fuel production (10^3 B/D)*	600	300	--
Water demand (10^3 acre-ft/yr)	300	80	~0
Population (10^3 people)	108	55	52
Garfield and Rio Blanco counties (oil shale)			
Fuel production (10^3 B/D)*	2000	400	--
Water demand (10^3 acre-ft/yr)†	314	60	--
Population (10^3 people)	244	78	--

*10^3 B/D is about 160 m^3/D.
†10^3 acre-ft/yr is about $1.2 \times 10^6 m^3$/yr.

B. Implications of Constrained Growth

While the implications of the growth constrained scenarios are favorable for the communities involved, they clearly result in much less fuel production and thus may not be favorable to the national interest. It seems clear, however, that the difference in fuel production could be made up by locating conversion facilities in other regions.

Although the local impacts are lessened in the growth constrained scenarios, many underlying problems persist:

- The need for front-end money for community services.
- Value conflicts between previous residents and newcomers.
- Occasional abrupt changes unless both plant size and construction timing is closely managed.
- Water demands that strain water allocation procedural institutions.
- Air quality degradation and other adverse environmental impacts.

Managing these impacts would still require planning to a degree untypical in such areas. New degrees of government and industrial cooperation would be required to put growth constraints into practice.

An important side benefit of the growth constrained approach it permits time for those on whom the responsibility for water allocation rests to face up to the problems and to devise a solution in an atmosphere that is less tense than it might otherwise be.

VIII PUBLIC POLICY CONSIDERATIONS RAISED BY THE IMPACT ISSUES

There are many ways in which public policy--especially at the federal level--can affect the prospects for realization of a synthetic liquid fuels industry and thereby help determine the consequences of such an industry.

The federal government has broader concerns than merely the profit realized on a synthetic fuel plant. It recognizes the need to provide a stable long-term domestic source of energy to the nation and appreciates the long lead time necessary to put a new industry in place. The deployment of synthetic fuels plants is also seen as an instrument of foreign policy by the federal government. At the same time, since the government is concerned with human welfare and environmental quality, it is also rightfully interested in the adverse as well as beneficial aspects of the synthetic fuels plants.

A. Financial Aspects of a Synfuel Industry[9,10]

For synthetic liquid fuels to be produced commercially, the parties who must either raise or provide the large amounts of capital needed must be convinced that the plants will provide a profit and that the associated risks are commensurate with the expected return on investment. Currently, the sentiment is that there are many far less risky investment opportunities open to both the oil industry (such as investing in more conventional sources of oil or diversifying) and the investment bankers who have many investment opportunities beyond the energy industries.

The federal government has been debating measures designed to get the synthetic liquid fuels industry under way--at least far enough along to determine more accurately its true economic, environmental, and social costs. The government has considered various forms of subsidization:

- Loan guarantees
- Federal lending
- Tax incentives
- Price supports
- Guaranteed product purchases.

Such measures have been debated in Congress, but, so far, none has been accepted. The U.S. Energy Research and Development Administration (ERDA), however, does have a limited budget allocated to demonstration plants.

One possible federal alternative that has not yet received much attention is direct federal participation in investment. In World War II, the federal government financed synthetic rubber plants (because sources of natural rubber fell into enemy hands) and these plants were operated by industry under contract. After the war was over, the plants were sold--usually to the previous operating corporation. Although the analogy is not wholly apt (because wartime conditions do not prevail and the alternative of importing oil still exists), this approach appears to offer several advantages over the more indirect approaches to subsidization:

- Successful historical precedent
- Clear cut federal role
- Involvement of industrial expertise
- Intended transfer of plants to industrial ownership
- Option of aborting industry if impacts warrant.

Besides government intervention in the financial aspects of the synthetic fuels industry, the federal and state governments could, perhaps,

stimulate the industry by clarifying and solidifying policy with respect to

- Coal and oil shale resource leasing procedures
- Coal and oil shale strip mine regulation legislation
- Crude oil price regulation.

The corporations most likely to develop and operate a synthetic liquid fuels industry view the present uncertainty in these subjects as a large risk that inhibits their entry into the synfuel business.

B. Water Rights[19]

As noted above, the availability of water is potentially an important constraint on development of the synthetic fuels industry in many locations. Federal and state policies with regard to water resources and rights are at the heart of the matter. Here, too, uncertainty in either the form of the policies or their stability is perceived as a risk, not only to industry but to the other claimants to the water.

Several possible federal water-related policy actions could significantly mitigate adverse water-related impacts while stimulating the industry:

- Encourage shipment of coal from water-poor regions for conversion elsewhere.
- Coordinate federal, state, and Indian interests in water to eliminate conflicts among the regulators of water rights.

As discussed previously, the shipment of coal from resource-rich but water-poor regions may sometimes be better accomplished through the use of coal slurry pipelines in preference to unit trains. However, until definitive action either for or against the power of eminent domain needed by the slurry pipeline companies comes from Congress, neither the pipeline companies, the railroads, nor the potential users

of either mode know the constraints that will be operative in the future. If the decision goes against slurry pipelines, it may be necessary to promulgate public policies intended to revitalize the railroads to ensure that they can handle the traffic implied.

Coordination of federal, state, and Indian water interests will probably require:

- A comprehensive inventory of federal and Indian rights and requirements.
- New laws providing compensation for the "taking" (legal sense) of water rights predating the 1963 Arizona vs California decision.
- Redrawing of interstate water compacts.
- Development of federal-interstate compacts for arid but resource-rich regions.

The need for additional legislation at the state level is apparent to set forth

- Preservation of in-stream values (aesthetics, wildlife, etc.)
- Relationships between groundwater and surface water
- Rules governing the transferability of water rights.

At both the state and federal level, the economic value of water in arid regions should be reexamined because pressures to base new water allocations on the basis of the highest bid are growing. Historically, federal water projects have provided water to agriculture at very low prices.* As a result, irrigated agriculture has received an indirect subsidy; continuation of that federal policy and practice should be reexamined for its compatibility with future federal policy intended to stimulate a synthetic fuel industry.

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*Even, some argue, below its true cost.

C. Strip Mine Reclamation and Resource Leasing

Much of western coal and most of the oil shale are owned by the federal government even though the surface estate is often in private hands. States and Indian tribes control other resources. There has been a moratorium on federal leasing since 1973. Since leasing is a contract between private parties (even when the government is involved), any stipulations that are acceptable to both parties are admissible. When federal leasing resumes, the Department of Interior is expected to make it a practice to require that strip-mine reclamation follow rules very similar to those twice vetoed in strip-mine legislation. Thus, it appears that much of the rejected legislation will be applied by administrative action. Although such regulations are stringent, many spokesmen in the industries likely to develop coal resources assert that the uncertainty of whether or when reclamation rules will change is more constraining than the proposed rules themselves.

Reestablishment of federal leasing and a policy of requiring a standard set of provisions would help remove some uncertainty about where and when fossil mineral resources would be available to a synthetic liquid fuels industry.

D. Air Quality Control[16]

1. Ambient

Federal primary ambient air quality standards are intended to protect human health and, in principle, are not to be violated anywhere. Federal secondary standards are intended to protect economic and other values and are stricter than primary standards but are not so readily attained. Moreover, in some states, such as Colorado, state air quality standards are stricter than federal primary standards. It is up to the states to specify the standard that will apply in a given area. Many of

the resource-rich regions that are candidates for location of the first synthetic liquid fuels plants have very clean air, and thus one of the nondegradation standards should apply. (See Section VI-A-6c.) However, states have been slow in designating the classes that apply. This uncertainty inhibits deployment of a synthetic liquid fuels industry.

Imposition of standards for sulfates is quite likely in the future. Since synthetic liquid fuel plants emit sulfur dioxide that can be photochemically transformed to sulfates in the atmosphere, standards established for sulfates will affect the synthetic fuels industry. It would be preferable for these standards to be set before plant design (and choice of coal resources) is undertaken.

2. Emissions

Since there is no commercial synthetic liquid fuels industry today, there are no new-source emission standards for the industry to use in designing synfuel plants. The best designers can do is use analogous new-source standards that have been set for fossil-fueled boilers and coal drying. Until actual new-source standards are set for the coal conversion and oil shale plants, no one can be sure of the extent to which today's best available controls will be adequate or will require improvements.

3. Acceptability

Since air quality limitations have been shown in this study to be potentially a limiting factor in the synthetic liquid fuels industry, before an industry could be deployed the following regulatory policies will require clarification.

- Ambient air quality standards to be applied in any given area.

- New-source emissions performance standards clearly applicable to the industry.
- Current disagreement about the acceptability of tall stacks (these disperse pollutants over a larger region but often offer compliance with local ambient standards).

E. Population Growth Control (Boom Towns)

Meeting the challenge of producing synthetic fuels while avoiding the worst aspects of rapid population growth in rural regions and the creation of boom towns will not be easy. Nevertheless, the federal government through its control of leasing of mineral rights, its potential control of vital western water supplies, and its possible financial participation in the industry. has the opportunity to exert influence on the rate and location of synthetic fuels development.

It may prove feasible, for example, to require that corporations accepting federal investment assistance provide advance financial contributions to impacted communities. Government acknowledgment of such front-end contributions to communities as a proper business expense would do much to legitimatize the practice. In a similar fashion, the federal government might use its mineral leasing contracts to require that any coal extracted be processed at locations distant from the mine.

Federal and state governments, moreover, could jointly establish planning assistance grants to impacted areas, perhaps through the Economic Development Administration.

F. Summary

The areas in which governmental policy initiatives seem warranted are mainly those in which there now exists an undue amount of uncertainty about future federal (or state) action:

- Financing and mitigating the risks of synthetic liquid fuel plants.
- Resource leasing procedures and stipulations
- Strip-mine reclamation requirements.
- Uncertainty in water allocation institutions.
- Air quality standards.
- Control of population growth (boom towns).

Clarifying policies in these areas would greatly facilitate the combined government/industry efforts to assess the viability of a synthetic liquid fuels industry.

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16. ABSTRACT

This study assesses the impacts of the development of synthetic liquid fuels from coal and oil shale; the fuels considered are synthetic crude oils from coal and oil shale and methanol from coal. Key issues examined in detail are the technology and all of its resource requirements, net energy analyses of the technological options, a maximum credible implementation schedule, legal mechanisms for access to coal and oil shale resources, financing of a synthetic liquid fuels industry, decision making in the petroleum industry, government incentive policies, local and national economic impacts, environmental effects of strip mining, urbanization of rural areas, air pollution control, water resources and their availability, and population growth and boom town effects in previously rural areas.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
coal	boom towns	synthetic fuels technology	
oil shale	water resources	net energy analysis	
synthetic fuels	strip mining		
methanol	control technology		
air pollution	incentive policies		
environmental impact			
economic impacts			

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