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SYNTHETIC LIQUID FUELS DEVELOPMENT:
ASSESSMENT OF CRITICAL FACTORS

Volume III Regionalized Industry
Social Impact
Coal Resource Depletion

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SYNTHETIC LIQUID FUELS DEVELOPMENT
ASSESSMENT OF CRITICAL FACTORS—VOLUME III

REGIONALIZED INDUSTRY
SOCIAL IMPACT
COAL RESOURCE DEPLETION

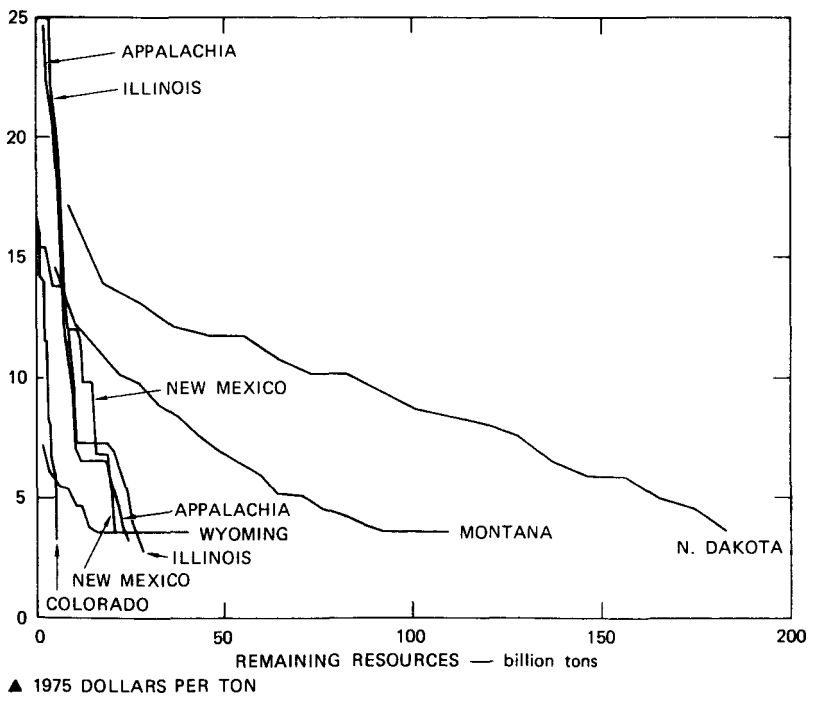
EXECUTIVE SUMMARY

The issues: coal resource depletion rate and regional boom-bust cycles

The United States has vast coal resources. But little analytical attention has been given to the rate of their depletion in a coal-based energy future. Nor has the problem of regional boom-bust cycles associated with intensified coal production and conversion been studied in depth. The study reported here uses a computerized coal depletion model and three plant location scenarios to examine these issues. The objective is to discover ways to moderate adverse impacts of coal production and conversion at an acceptable national cost.

Coal inventories and extraction costs are computer-modeled for eight regions

The Coal Resource Depletion Model inventories the coal resource on a regional basis and derives the quantities of coal extractable at different costs by three technologies — strip and underground mining and in-situ combustion (Figure I). The eight coal regions considered

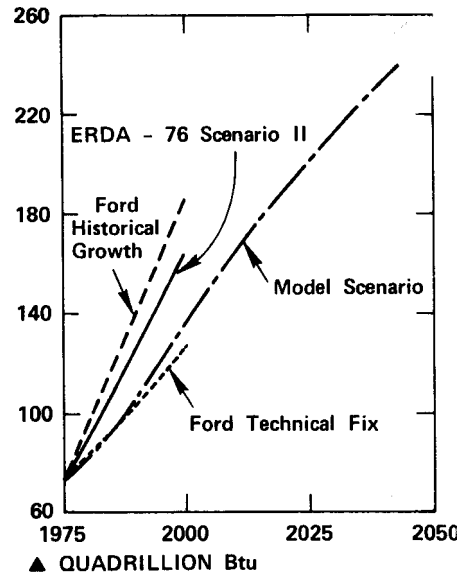


I EXTRACTION COST CURVES — STRIP COAL

in the model include about 90% of the coal resource in the conterminous United States. These boundaries coincide with state boundaries in the six coal-rich areas of the West to allow examination of the effects of state severance taxes on regional production.

The model operates on a demand scenario showing 75% of U.S. energy is met by coal in the year 2050

The basis for the computer model calculations is a plausible coal demand scenario extending from 1975 to 2050. The scenario is conservative in terms of total energy demand (Figure II), but it depicts a "high coal" future in which 75% of the U.S. energy demand is supplied either directly or indirectly by coal. This demand is met by 285 synthetic liquid fuel plants producing 100,000 B/D, 312 substitute natural gas (SNG) plants producing 250 million SCF/D, and 722 coal-fired electric power plants, each with 1,000 MW capacity. In addition, the scenario assumes 890 million tons of coal per year to be required for industrial consumption.



II SCENARIO ENERGY DEMAND COMPARED TO POPULAR PROJECTIONS

Coal production/conversion is examined in three plant location scenarios

The coal demand scenario is examined in three variations that differ primarily in the location of synfuel plants. These variations are the Minemouth, Dispersed, and Limited Minemouth Scenarios.

Minemouth conversion seeks lowest cost regardless of social/environmental impacts

In the Minemouth Scenario, coal conversion plants are allowed to locate near the minemouth in the region that can yield the lowest cost final energy product, without regard either to social or environmental constraints.

Dispersed conversion seeks minimum adverse impacts

At the other extreme, the Dispersed Scenario features the location of synfuel plants in towns and counties with an ample water supply and social capacity sufficient to accept the large synfuel plants without undue disruption. The scenario is made truly geographically dispersed by avoiding, as much as possible, the multiple siting of plants close together. By and large, plants are located in the eastern portion of the United States because of the adequacy of water supply. The Dispersed Scenario requires that the mining of coal be followed by shipment (by rail, barge, or slurry pipeline) to distant conversion sites.

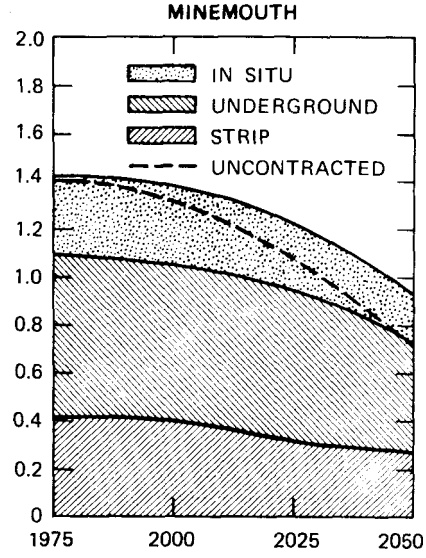
Limited minemouth conversion seeks economic and impact compromise

The Limited Minemouth Scenario is intermediate between the two extreme scenarios. Based on the lessons of the other scenarios, the Limited Minemouth Scenario selectively allows SNG plants to locate at the minemouth because they have the least community and environmental impact on a per-plant basis and because minemouth location of SNG plants yields the largest economic savings relative to the cost of the final product.

All three scenarios show half of U.S. coal is used or obligated within 75 years

The high level of coal use assumed would deplete U.S. coal reso[illegible] much more rapidly than most people appreciate. Indeed, [illegible]y 2050, the coal demand scenario outlined would have consumed

one third of all the coal in the "measured," "indicated," and "inferred" categories (defined by the U.S. Geological Survey) and another sixth would have been promised to plants then in operation (Figure III). Thus, within 75 years about half of the best and most certain U.S. coal resource would have been depleted or obligated. Of course, the actual amount of U.S. coal is unknown, and if the coal in the "hypothetical" reliability category is included, depletion is delayed. Coal in this category, however, has not been mapped; it is only presumed to exist on the basis of geological theory.



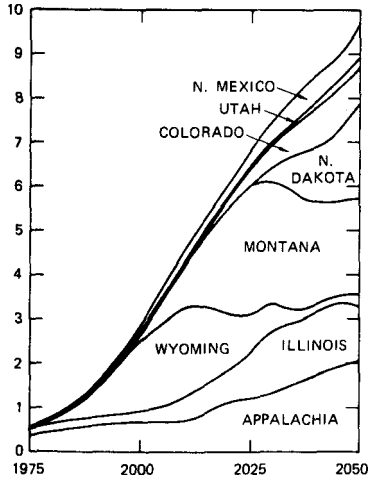
▲ TRILLION TONS

SOLID LINES INDICATE COAL MINED, DASHED LINES INDICATE COAL UNCONTRACTED

III NATIONAL COAL DEPLETION—MINEMOUTH SCENARIO

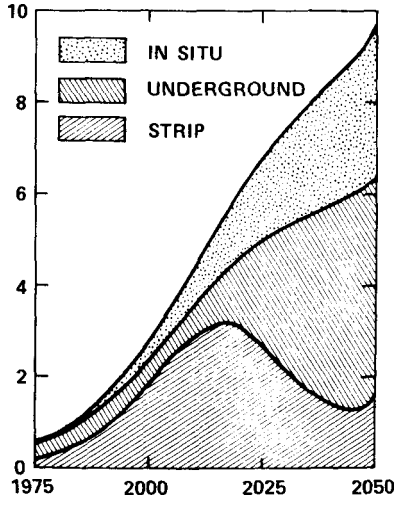
Minemouth conversion causes severe boom-bust cycles in the West

Under the Minemouth Scenario, the coal model shows very rapid build-up of production in the western states followed by very rapid production declines as the cheapest, best coal in the region is depleted. First Wyoming, then Montana, and then North Dakota experience boom cycles. The Wyoming boom is followed by a bust 30 to 40 years later (Figure IV). Until after the year 2000, strip mining accounts for most of the increased production with underground production remaining nearly constant (Figure V).



▲ BILLION TONS PER YEAR

IV REGIONAL COAL PRODUCTION—MINEMOUTH SCENARIO



▲ BILLION TONS PER YEAR

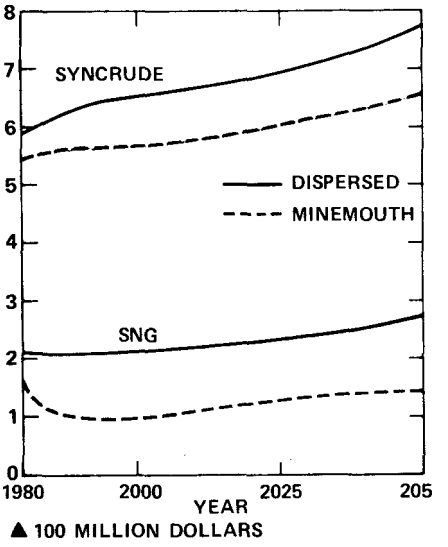
V NATIONAL COAL PRODUCTION—MINEMOUTH SCENARIO

Low cost minemouth conversion is offset by environmental and social impacts

There is much evidence that the industrial facilities assumed abov cannot be absorbed readily by the small, predominantly rura munities most prevalent in the coal-rich areas of the country. ... result, offsetting the obvious national economic benefits of low-cos conversion plant siting near the mines, the Minemouth plant locatio scenario results in significant local and regional costs stemming fror the social disruption of boom-town style rapid urbanization followe by rapid economic decline as the resource plays out. In addition, th Minemouth Scenario implies severe localization of adverse enviror mental effects such as air pollution and water demand for wate thirsty synfuel producing plants.

Dispersed conversion reduces boom-bust impacts but raises synfuel costs

In the Dispersed Scenario, production and conversion activities are spread much more evenly across the nation than in the Minemouth Scenario. This greatly smooths the rise and fall of coal production regionally and provides coal producing regions with much more opportunity to cope with the problems of rapid urbanization and to enjoy a longer-term prosperity. However, realization of the regional benefits of the Dispersed Scenario extracts its high cost — some $100 million per synfuel conversion plant per year (Figure VI). This extra cost arises primarily from the need to transport coal from the mines to distant conversion sites. Clearly, th selling price of the synfuels must reflect this cost increment, som 16% for syncrude and 100% for SNG.



VI AVERAGE ANNUAL PRODUCTION COS PER SYNFUEL PLANT — COMPARISO OF MINEMOUTH AND DISPERSE SCENARIOS

Limited minemouth conversion offers mid-ground fuel cost and avoids boom-bust

Since the nation may not be willing to bear a cost of this magnitud primarily to avoid the adverse effects of the Minemouth Scenario, th compromise Limited Minemouth Scenario was examined to dete mine its potential benefits. Although 26 western counties are involve in the Limited Minemouth Scenario, judicious timing of plant loc tions allows annual growth in those counties to be held at or below 5 (except for the effect of the first plant); this is a rate of growth th many planners consider manageable. Coal production and economi activity are even more uniformly spread in this scenario than in th Dispersed Scenario. This compromise scenario illustrates the poter tial value of a nationally coordinated coal conversion locatio strategy.

No mechanisms are available to assure only limited minemouth conversion

However, at present, there is no public or private entity with eithe the authority or the power to promulgate or enforce a nationa siting strategy designed to reach an acceptable compromise be national economic benefits and regional social and environment

benefits. Accordingly, parties at interest are attempting to prepare for intensified coal development with the policy tools presently available.

States now use severance taxes as a blunt tool for control

Chief among these tools is the state severance tax on coal extraction. Several western states have such taxes (mostly notably Montana with a 30% tax on strip coal) and others are considering them. The coal resource depletion model shows that unilateral imposition of a severance tax by a state tends to shift production to other coal producing regions. Boom and bust cycles are both delayed and reduced in their magnitude. When several states simultaneously impose severance taxes, the effect of each tax is weakened.

Three key policy questions emerge: resource uncertainty, conversion plant locations, demand reduction

The results of this analysis point to three major areas in which policy issues emerge. The first is the longevity of the U.S. coal resource. A long-term energy policy for the nation should include an accelerated exploration and inventory program so that sound information on the size of the resource base will be available soon enough to be useful in making long lasting decisions on energy production and consumption that will be necessary in the next several years. The second policy question is conversion plant location. It will be necessary to stimulate interaction among the parties at interest so that equitable and acceptable plant siting strategies can be worked out to enable amelioration of the effects of rapid production build-up and urbanization. This means that institutions and mechanisms to implement such strategies will have to be established. Finally, the study was predicated on a high coal demand future. But it should be recognized that any strategy that lessens the demand for coal will, in itself, embody a means of efficiently mitigating adverse regional social and environmental impacts of further coal development.

PREFACE

The analysis reported in this volume is a continuation of an SRI study concerned with the impacts that would attend the deployment of a large-scale synthetic fuels industry. The study was begun under the sponsorship of the Environmental Protection Agency and continued under the sponsorship of the Energy Research and Development Administration.* Throughout, the lead project officer, first at EPA, then at ERDA, has been Mr. F. Jerome Hinkle. The SRI project leader has been Dr. Edward M. Dickson.

The study team responsible for this volume consisted of Dr. Irving W. Yabroff, Ms. Cynthia A. Kroll, Dr. Ronald K. White, Dr. Barry L. Walton, Ms. Mary E. Ivory, Mr. Robert E. Fullen, Mr. Leo Weisbecker, and Mr. Roy L. Hays. Their primary contributions are summarized below:

- Coal Depletion Model--Yabroff, Dickson, Fullen, Hays
- Boom-town Phenomena--Kroll, Ivory
- Dispersed and Limited Minemouth Scenarios--Dickson, Weisbecker, Yabroff, Hays, Kroll
- Computerized Impact Generation--White, Walton

The study team believes that this volume represents the first serious analytical attempt to understand the regional and resource base implications of an energy future featuring high coal use.

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*The first two volumes in this series were originally published by EPA under the title "Impacts of Synthetic Liquid Fuel Development--Automotive Market," (EPA-600/7-76-004 a,b). ERDA reissued the same report under the title "Synthetic Liquid Fuels Development: Assessment of Critical Factors," (ERDA 76-129/1 and 76-129/2).

CONTENTS

EXECUTIVE SUMMARY i

PREFACE vii

LIST OF ILLUSTRATIONS xv

LIST OF TABLES xix

1 INTRODUCTION 1- 1

A. Origins of this Work 1- 1

B. Organization of the Report 1- 1

2 COAL DEPLETION MODEL 2- 1

A. Objectives 2- 1

B. Model Structure and Logic 2- 1

C. Model Inputs and Submodel Calculations 2- 5

1. Coal Resource Inventory 2- 5
2. Extraction Cost Factors 2- 7
3. Extraction Cost Calculation for Inventoried Coal . 2- 8
4. Efficiency of Extraction 2-12
5. State Severance Taxes 2-13
6. Transportation Cost Factors 2-13
7. Conversion Cost Factors 2-14
8. Coal Demand Scenario 2-15
9. Plant Location Constraints Specification 2-18
10. Conversion Plant Locations and Start-up Schedule . 2-19

D. Model Outputs for Three Plant Location Scenarios . . . 2-19

References 2-20

3 THE MINEMOUTH SCENARIO 3- 1

A. Coal Production 3- 1

1. Regional Production 3- 3
2. National Coal Production by Extraction Technology. 3- 5

B. Coal Resource Depletion 3- 7

C. Boom/Bust Cycle Implications 3- 7

4 URBANIZATION IMPACTS AND BOOM-TOWNS 4- 1

A. Industrial Growth and Community Development: A Short Description 4- 1

B. Boom-Inducing Industries 4- 3

1. Resource Dependence 4- 4
2. Intense Construction Period 4- 4
3. Long-Term Employment 4- 5
4. Uncertainty 4- 5

C. Boom-Town Phenomena 4- 5

1. Boom-Town Process 4- 6
2. Variations in the Boom Sequence 4- 9

D. Gillette (Campbell County) Wyoming: Boom-Town Example 4-11

1. Growth Process and Population Trends 4-12
2. Energy Industry in Campbell County 4-14
3. Energy Industry Impacts on the Local Area 4-18
4. Variations in Growth Problems 4-28
5. Conclusions from Experience in Campbell County . . 4-29

E. Growth Impacts of the Minemouth Scenario for the Synthetic Fuels Industry 4-31

F. Redistributing Industry to Reduce Impacts: Community Characteristics 4-37

1. Population 4-39
2. Economy 4-41

References 4-47

5 DISPERSED SCENARIO 5- 1

A. Site Selection 5- 1

1. Socioeconomic Factors: Simplified Approach . . . 5- 1
2. Water Availability Criteria 5- 4
3. Transportation Criteria 5- 5

B. Sites Selected 5- 7

C. Model Results 5- 7

1. Coal Production 5- 7
2. Coal Resource Depletion 5-13
3. Comparison of National Production Costs 5-15

D. Implications of the Dispersed Scenario 5-19

References 5-20

6 THE LIMITED MINEMOUTH SCENARIO 6- 1

A. Motivation for the Scenario 6- 1

B. Scenario 6- 2

1. Rules for Preparation 6- 2
2. Plant Relocation 6- 3
3. Effects on Population Growth 6- 5

C. Coal Production 6- 5

D. Lessons of the Limited Minemouth Scenario 6- 8

7 POLICY IMPLICATIONS 7- 1

A. Policy Questions 7- 1

B. Coal Depletion 7- 1

C. Approaches to Plant Siting 7- 3

D. Existing Planning Mechanisms 7- 4

1. Community Development by Industry 7- 5
2. Regulation of Basic Economic Development 7- 5
   a. Federal Government 7- 5
   b. State Government 7- 7
   c. Local Level (City and County) Government . . . 7- 9
3. Regulation of Secondary Development 7- 9
   a. Federal Level 7- 9
   b. State Level 7-10
   c. Local Level 7-11
4. Investment in Critical Services and Development Promotion 7-11

E. Prospect 7-12

References 7-14

APPENDICES

A COAL RESOURCE INVENTORY . . . . . A- 1

1. Quantity of Coal in Each Region and Category . . . A- 2
2. Disaggregation into Individual Seams . . . . . A- 4
3. Heating Value and Sulfur Content . . . . . A- 6

References . . . . . A- 8

B COAL SEAM EXTRACTION COSTS . . . . . B- 1

1. Underground Mining . . . . . B- 1
2. Strip Mining . . . . . B- 2
3. In-Situ Extraction . . . . . B- 4

References . . . . . B- 6

C DERIVATION OF THE EXTRACTION COST CURVES . . . . . C- 1

D TRANSPORTATION COSTS AND DISTANCES . . . . . D- 1

1. Costs . . . . . D- 1
2. Distances . . . . . D- 2

References . . . . . D- 4

E COAL CONVERSION PROCESSES COSTS . . . . . E- 1

1. Coal Liquefaction . . . . . E- 2
2. Coal Gasification . . . . . E- 3
3. Electricity . . . . . E- 4
4. Conversion of In-Situ Syngas . . . . . E- 5

References . . . . . E- 6

F COAL DEMAND SCENARIO . . . . . F- 1

1. Coal Demand . . . . . F- 1
2. 1975 Regional Coal Production . . . . . F- 3

References . . . . . F- 5

G CONVERSION PLANT AND DEMAND GATEWAY LOCATIONS . . . . G- 1

1. Syncrude . . . . . G- 1
2. Substitute Natural Gas . . . . . G- 1
3. Electricity . . . . . G- 5
4. Industry G-13

H PREDICTING IMPACTS . . . . . H- 1

1. Population and Employment Change . . . . . H- 2

a. Employment Generation in Local Communities . . H- 2
b. Population Growth. . . . . H- 4
c. Computerized Population Growth Scenarios . . . H- 5

2. Population Structure . . . . . H- 6
3. Structural Changes in the Community . . . . . H- 7

a. Demand and Supply of Housing . . . . . H- 7
b. Social Services . . . . . H- 8
c. Cultural Impacts . . . . . H- 9

4. Financing . . . . . H- 9
5. Distributional Impacts H-11

References H-12

J USER'S MANUAL FOR COMPUTERIZED GENERATION OF SCENARIO IMPACTS . . . . . J- 1

1. Purpose and Equipment . . . . . J- 1
2. SR-52 Calculator Owner's Instructions . . . . . J- 2
3. Capabilities and Uses . . . . . J- 4
4. Scenarios of Synthetic Liquid Fuel Development . . J- 5

5. Programs . . . . . J- 5

a. General Description . . . . . J- 5
b. Oil Shale Development . . . . . J- 7
c. Coal Development J-19
d. Coal Development, Population J-26
e. Coal Development, Fuel J-40

K WATER REQUIREMENTS FOR THE DISPERSED SCENARIO . . . . K- 1

L LIMITED MINEMOUTH SCENARIO PLANT SITING . . . . . L- 1

M COAL DEPLETION MODEL SENSITIVITY TESTS . . . . . M- 1

1. Severance Taxes . . . . . M- 1

a. Reduction of the Montana Tax . . . . . M- 2
b. Increase in the Montana Tax . . . . . M- 3
c. Increase in the Colorado Tax . . . . . M- 4
d. Increase in the Tax on Both Colorado and Illinois Underground Mined Coal . . . . . M- 5
e. Increase in the Wyoming Tax . . . . . M- 6

2. Delayed Synthetic Fuel Development . . . . . M- 6
3. Sulfur Scrubbing Cost . . . . . M- 9
4. In-Situ Extraction Cost M-11
5. Hypothetical Coal Resources M-14
6. Summary of Model Sensitivity Tests M-15

ILLUSTRATIONS

2-1	Structure of the Coal Resource Depletion Model	2- 2
2-2	Resource Regions used in the Coal Resource Depletion Model	2- 3
2-3	Extraction Cost Curves--Strip Coal	2- 9
2-4	Extraction Cost Curves--Underground Coal	2-10
2-5	Extraction Cost Curves--In-Situ Coal	2-11
2-6	Transportation Cost Factors	2-13
2-7	Scenario Per Capita Energy Demand Compared to 1975 Use .	2-16
2-8	Projection of U.S. Population	2-16
2-9	Scenario Coal Demand by Use Sector	2-17
2-10	Scenario Energy Demand Compared to Popular Projections .	2-17
3-1	Regional Coal Production, 1975 Historical Data	3- 2
3-2	Minemouth Scenario, Regional Coal Production, Year 2000 .	3- 2
3-3	Minemouth Scenario, Regional Coal Production, Year 2025 .	3- 4
3-4	Minemouth Scenario, Regional Coal Production, Year 2050 .	3- 4
3-5	Minemouth Scenario, National Coal Production by Type of Extraction	3- 6
3-6	Minemouth Scenario, Strip Resources Remaining	3- 8
3-7	Minemouth Scenario, Underground Resources Remaining . . .	3- 8
3-8	Minemouth Scenario, In-Situ Resources Remaining	3- 9
3-9	Minemouth Scenario, Summary of Regional Coal Production .	3-10
4-1	Schematic of Community Growth Induced by Industrial Development	4- 2
4-2	Schematic of the Boom and Bust Cycle	4- 7
4-3	Age Group Profiles of Campbell County, Wyoming, 1960 and 1970	4-13
4-4	Mobile Versus Permanent Housing: Gillette and Campbell County, Wyoming	4-20
4-5	Distances from Gillette, Wyoming	4-25
4-6	Minemouth Scenario Population Growth: Campbell County, Woming	4-32

4-7	Minemouth Scenario Population Growth: Seven Counties Centered on Campbell County, Wyoming	4-33
4-8	Work Force in Construction and Manufacturing: Wyoming Counties	4-35
4-9	Work Force in Construction and Manufacturing: Omaha and Kansas City	4-38
5-1	Dispersed Scenario, Incremental Plant Sitings for Three Time Periods and Cumulative Plant Sitings	5- 8
5-2	Regional Coal Production, 1975 Historical Data	5- 9
5-3	Coal Production Comparison: Minemouth and Dispersed Scenarios	5-10
5-4	Dispersed Scenario, Summary of Regional Coal Production .	5-11
5-5	Dispersed Scenario, National Coal Production by Type of Extraction	5-12
5-6	Dispersed Scenario, Strip Resources Remaining	5-14
5-7	Dispersed Scenario, Underground Resources Remaining . . .	5-14
5-8	Comparison of National Coal Depletion for Minemouth and Dispersed Scenarios	5-15
5-9	Average Annual Production Cost Per Synfuel Plant--Comparison of Minemouth and Dispersed Scenarios	5-16
5-10	Components of Production Cost Difference between Minemouth and Dispersed Scenarios	5-17
6-1	Limited Minemouth Scenario Compared to Dispersed Scenario Plant Locations; 1975-2000	6- 4
6-2	Limited Minemouth Scenario in Sweetwater County, Wyoming	6- 6
6-3	Regional Coal Production--Comparison of Scenarios	6- 7
7-1	Comparison of National Coal Depletion for Minemouth and Dispersed Scenarios	7- 2
7-2	Sensitivity Test: Resources Remaining when Hypothetical Resources are Included	7- 3
7-3	Government Role in the Regulation of Basic Economic Development	7- 6
7-4	Government Role in the Regulation of Secondary Development	7-10
7-5	Sources of Funds for Early Investment in Critical Services	7-12

B-1 The LLL In-Situ Coal Gasification Concept . . . . . B- 4

F-1 Assumed Components of U.S. Oil Supply for Coal Demand Scenario . . . . . F- 2

F-2 Assumed Components of U.S. Gas Supply for Coal Demand Scenario . . . . . F- 2

H-1 Basis for the Population Multiplier Concept . . . . . H- 4

J-1 Program Key Codes . . . . . J- 3

J-2 Population Growth Obtained by Running the Example Problem J-16

K-1 River Basin Index . . . . . K- 2

K-2 Missouri River Basin: Synfuel Water Use Compared With Available Flow . . . . . K- 3

K-3 Upper Mississippi River Basin: Synfuel Water Use Compared with Available Flow . . . . . K- 4

K-4 Ohio River Basin: Synfuel Water Use Compared with Available Flow . . . . . K- 5

K-5 Arkansas, Red and White River Basins: Synfuel Water Use Compared with Available Flow . . . . . K- 6

K-6 Lower Mississippi River Basin: Synfuel Water Use Compared with Available Flow . . . . . K- 7

K-7 Gulf Coast Tributaries: Synfuel Water Use Compared with Available Flow . . . . . K- 8

M-1 Sensitivity Test: Montana Severance Tax Reduced to 5% . . . . . M- 2

M-2 Sensitivity Test: Montana Severance Tax Increased to 100% . . . . . M- 3

M-3 Sensitivity Test: Colorado Severance Tax Increased to 30% . . . . . M- 4

M-4 Sensitivity Test: Colorado and Illinois Severance Tax Increased to 30% . . . . . M- 5

M-5 Sensitivity Test: Wyoming Severance Tax Increased to 30% . . . . . M- 7

M-6 Sensitivity Test: Assumed Delay of Synthetic Fuels Industry . . . . . M- 8

M-7 Sensitivity Test: Coal Production Under Assumed Delay in Synthetic Fuels Industry . . . . . M- 8

M-8 Sensitivity Test: Sulfur Scrubbing Cost Reduced 50% . . . . . M- 9

M-9 Sensitivity Test: Coal Production Allocated to Electric Power Generation Assuming Sulfur Scrubbing Cost Reduced 50% M-10

M-10 Sensitivity Test: In-Situ Extraction Cost Increased 50% M-12

M-11 Sensitivity Test: In-Situ Extraction Cost Increased 100% M-13

M-12 Sensitivity Test: Resources Remaining When Hypothetical Resources are Included M-15

M-13 Sensitivity Test: Coal Production When Hypothetical Resources are Included M-16

TABLES

2-1	Coal Resources Summary	2- 7
2-2	Coal Recovery Factors and State Severance Taxes	2-12
2-3	Conversion Costs	2-14
4-1	Gillette/Campbell County Population Trends	4-12
4-2	Employment in Campbell County, 1950-70	4-15
4-3	1976 Population Estimates for Northeast Wyoming	4-34
4-4	Housing Availability, 1970	4-36
4-5	Population and Housing Availability, Kansas City and Omaha-Council Bluffs SMSAs, 1970	4-38
6-1	Synthetic Fuel Plants Relocated for the Limited Minemouth Scenario	6- 3
6-2	Year 2000 Comparison of Average Annual Synfuel Production Cost Per Plant	6- 8
A-1	Coal Region Definitions	A- 1
A-2	U.S. Coal Resources	A- 3
A-3	Assumption of Coal Seam Depth	A- 6
A-4	Average Coal Heating Value and Sulfur Content	A- 7
F-1	Estimated 1975 Coal Production	F- 4
G-1	Dispersed Scenario--Location and Production Start Year of Syncrude Plants	G- 2
G-2	Dispersed Scenario--Location and Production Start Year of SNG Plants	G- 6
G-3	Assumed Distribution of Coal-Fired Electricity Production and Industrial Coal Demand	G- 9
G-4	Assumed Electricity Production and Distribution Centers	G-10
G-5	Assumed Remaining Terms of 1975 Electricity Generation and Industrial Coal Contracts	G-11
G-6	Electric Power Plants--Location, Distribution Center and Year of Start-up	G-12
G-7	Contracts for Delivery of Industrial Coal to Demand Centers	G-14

J-1	Summary of Program Capabilities	J- 8
J-2	Instructions for Oil Shale Series--S1, S2	J-11
J-3	Example Data Input for S Series Programs	J-14
J-4	Sample Data from Series S Programs	J-15
J-5	Program Listing for S1	J-17
J-6	Program Listing for S2	J-18
J-7	Number of Construction and Production Employees for Large Syncrude and Methanol Plants and Associated Mines.	J-21
J-8	Instructions for Coal Series--C1, C2, C3	J-23
J-9	Program Listing for C1	J-27
J-10	Program Listing for C2	J-28
J-11	Program Listing for C3	J-29
J-12	Instructions for Coal Population Series--P1, P2, P3, P4	J-32
J-13	Program Listing for P1	J-36
J-14	Program Listing for P2	J-37
J-15	Program Listing for P3	J-38
J-16	Program Listing for P4	J-39
J-17	Water Demand for Synfuels Production	J-41
J-18	Instructions for Coal Fuel Series--F1, F2, F3, F4 . . .	J-44
J-19	Program Listing for F1	J-48
J-20	Program Listing for F2	J-49
J-21	Program Listing for F3	J-50
J-22	Program Listing for F4	J-51
K-1	Sites with Water Problems in the Dispersed Scenario . .	K- 9
L-1	Plant Siting Changes from the Dispersed Scenario	L- 2

Chapter 1

INTRODUCTION

A. Origins of this Work

This volume reports research undertaken to shed further light on several of the most important consequences of synthetic liquid fuel development uncovered in Volumes I and II of this report series.* The issues addressed are the rate of coal depletion and the regions affected, the boom-town phenomenon including approaches to alleviate or avoid it, and means to avoid the constraint of water availability in the arid West. These issues are closely intertwined because much of the cheapest and best coal is found in the arid West and consequently minemouth conversion of that coal, if done on a large enough scale, will create boom-towns.

B. Organization of the Report

A computerized model of coal resource depletion has been formulated and used as a tool to address all the issues being considered. This volume begins in Chapter 2 with a description of the coal model--what it is and what it can do--and then uses a coal demand scenario to explore the consequences of a plausible future in which coal plays an increasing role in meeting U.S. energy demands through direct burning and conversion to synthetic fuels.

The model is first used in Chapter 3 to determine the regions that will be affected by a high coal-use future in which coal is converted to synfuel or electricity near the minemouth. We term this the "Minemouth Scenario" as it is a version of the coal demand scenario. The model shows that severe boom and bust cycles would result in the coal extraction and conversion regions with especially heavy impact in Wyoming, Montana,

*E. Dickson et al., "Synthetic Liquid Fuels Development: Assessment of Critical Impacts," U.S. Energy Research and Development Administration, ERDA 76-129/1 and 76-129/2 (1976).

and North Dakota.

The boom-town phenomenon is examined in Chapter 4 with a discussion of its causes and consequences. The boom-town of Gillette, Wyoming, is described to illustrate the problems. Considerations that could be applied to examine whether any given community would be adversely affected by location of coal converting industries are then described and analyzed. The analysis includes a brief comparison of urbanizing effects on small rural communities and larger cities, caused by rapid industrial growth. The conclusion is drawn that there are several rough criteria that can be applied fairly easily to judge whether a community is susceptible to impacts of the boom-town variety.

An extreme approach to alleviating both the boom-town and water scarcity impacts is analyzed in Chapter 5 in the form of the "Dispersed Scenario" version of the coal demand scenario. In this version, western coal is mined and shipped eastward for conversion in plants located in communities with adequate social capacity and water availability to absorb such activity. It is found that this approach to alleviating problems in the West is indeed extreme in that the extra costs of transporting the coal are very large. However, the results provide a guide to the formulation of an alternative, less extreme mitigation strategy.

The essence of this middle ground mitigation strategy is described in Chapter 6 under the rubric of the "Limited Minemouth Scenario" version of the coal demand scenario. In this version, many plants are allowed to locate at minemouth in the West, but the kinds of plants are limited mainly to gasification and electric power plants because they have the least unit impact. Moreover, the timing and location of the plants are constrained so that no affected county experiences more than 5% average annual population growth.

The lessons learned from these three scenarios for plant site location and the governmental policies that can influence plant siting are discussed in Chapter 7--especially the roles of various levels of government in the regulation of economic activity and the effect of severance taxes on coal.

Chapter 2

COAL DEPLETION MODEL

A. Objectives

The Coal Depletion Model was developed to provide an analytical basis for understanding three main issues related to the development of synthetic fuels (synfuels) from coal that may someday substitute for natural petroleum and gas:

- How long U.S. coal resources might last in a future that features a high level of coal use by several competing industries
- Which regions of the county will be affected and in what sequence.
- How rapidly production might rise in a region and how long it might persist (boom and bust cycle).

B. Model Structure and Logic

The model is relatively simple. Its concerns are restricted to the major factors that determine regional coal production and depletion. As shown in Figure 2-1, the model has three main parts: a calculation of the cost of extracting coal resources of varying description, a plant siting and scheduling procedure in response to an assumed demand for coal, and a least-cost selection of coal resource region, extraction technology, and transportation mode between the mines and conversion plants for any given plant. Figure 2-1 also shows the main inputs to the model and its primary outputs. The model was kept simple to enhance its accessibility to users who may wish to alter the assumption.

The major coal resources of the United States were divided geographically into eight regions (Figure 2-2). These regions include 90 percent of the coal resources in the conterminous United States.

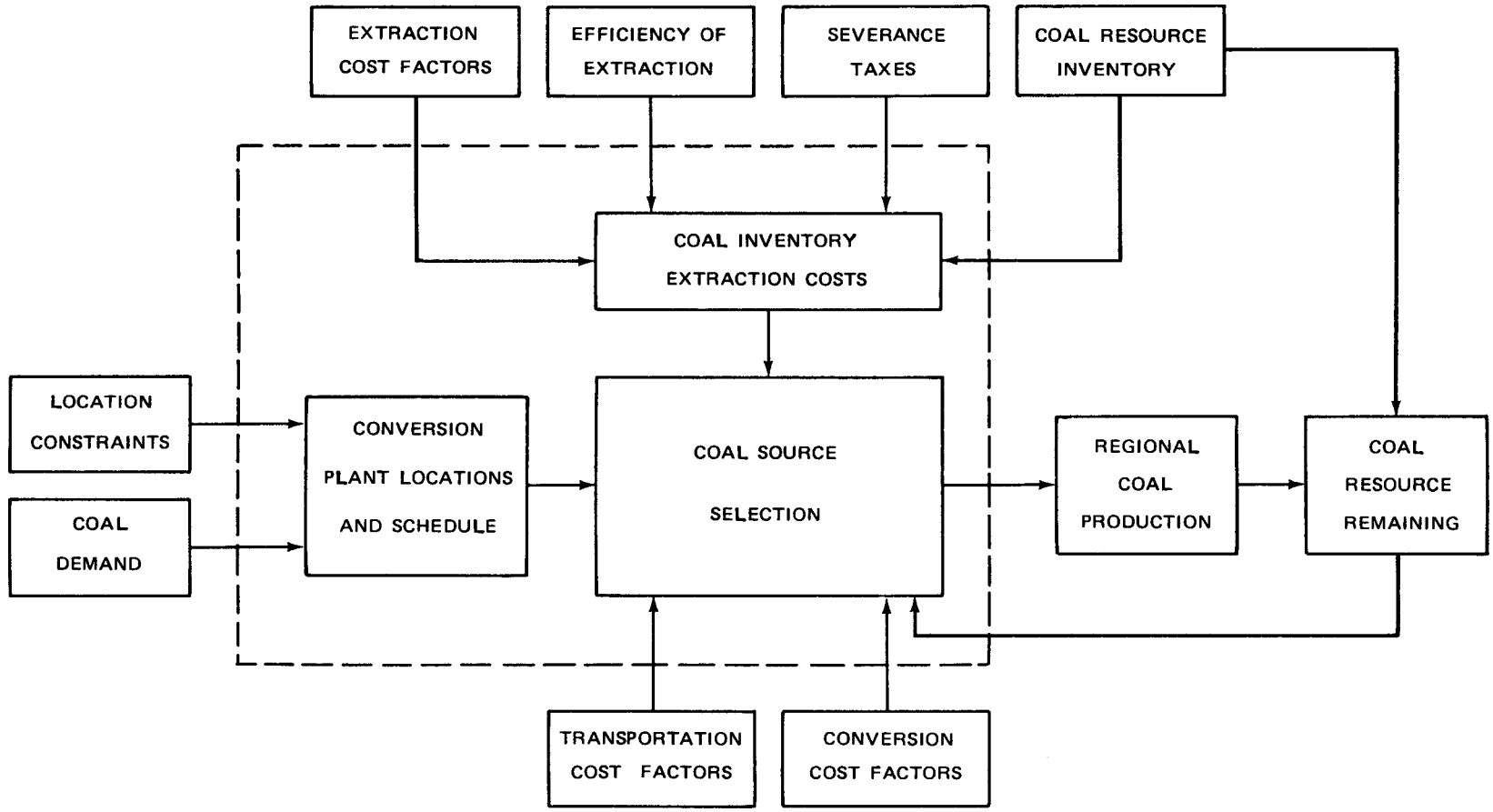

FIGURE 2-1. STRUCTURE OF THE COAL RESOURCE DEPLETION MODEL
ELEMENTS INSIDE DASHED LINE ARE THE MODEL; ELEMENTS OUTSIDE ARE INPUTS OR OUTPUTS

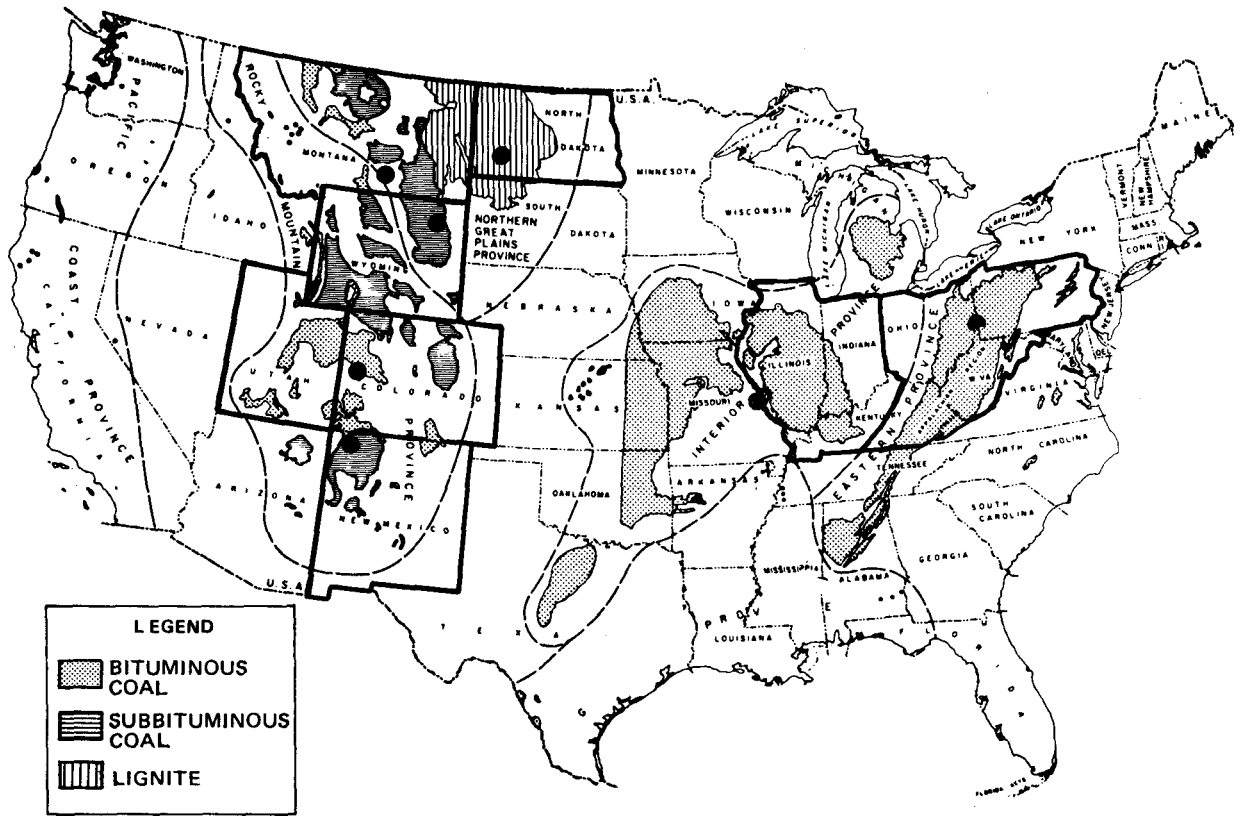

FIGURE 2-2. RESOURCE REGIONS USED IN THE COAL RESOURCE DEPLETION MODEL

HEAVY LINES INDICATE REGIONS; CIRCLES INDICATE TRANSPORTATION GATEWAYS

In each region, a single location, shown as a circle in Figure 2-2 is specified as the transportation gateway from which transportation distances were calculated from the hundreds of plant locations treated in the model.

In the West, boundaries chosen for the coal regions are state borders because there are significant differences in state coal severance taxes. Selecting regional boundaries that correspond to state jurisdictions permits the model to test the effects of different state tax policies on coal production.

The basic assumption of the model is that any large industrial plant that uses coal--conversion to syncrude or substitute natural gas (SNG)* as well as electric power generation--will seek a long-term contract guaranteeing a supply of coal for the plant for its entire expected life-time. Moreover, it is assumed that this contract will have been successfully negotiated before plant operation begins.

There are many choices to be made for each plant's long-term contract. These choices are made among the following:

- Source of coal (coal resource region).
- Extraction technology (strip mining, conventional underground mining, in-situ extraction†).
- Form of transportation from the mine to the plant (unit train, slurry pipeline, rail/barge).

The central event in the model is the calculation, for one plant after another, of the cost of coal extraction, transportation, and conversion for each combination of alternatives that is feasible. The combination that results in the least cost for the plant's product is chosen

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*SNG is sometimes also defined as "synthetic natural gas"; we prefer the newer and less inherently paradoxical definition.

†In-situ extraction is a process in which coal is partially combusted in place in the ground in the presence of oxygen and steam. The resulting gas is brought to the surface and collected. This gas can be used nearby either as fuel for production of electricity or converted by methanation into SNG. See Figure B-1 in Appendix B for an artist conception of one type of in-situ extraction.

for the contract for that plant. The coal chosen and encumbered by contract is then unavailable for consideration by any subsequent plant. The model sequentially negotiates the most favorable contract for each plant.

To yield the primary outputs (regional coal production and depletion) the model keeps an account of the coal remaining unencumbered, the coal production in a given region each year, and the coal still actually remaining in the ground (although some of this has been promised to prior contracts).

Two major submodel calculations feed into the central calculation. First is the preparation of a roster of conversion plant start-up dates, capacities, and locations. Much of this calculation is performed manually. Second is the preparation of an inventory of the amount of coal resource of each type available as a function of extraction cost. This lengthy calculation is performed by computer; once done, the results are stored for repeated use in the central calculation.

C. Model Inputs and Submodel Calculations

The major inputs to the model (Figure 2-1) are the following:

- An inventory of coal resources
- Cost factors for coal extraction
- Calculation of extraction cost for inventoried coal
- Efficiency of coal extraction
- State severance taxes
- Cost factors for transportation
- Cost factors for conversion
- A coal demand scenario
- Specification of coal-using plant location constraints
- List of plant types including years of operation and coal requirements.

1. Coal Resource Inventory

The characteristics and quantities of coal in each region were classified according to three categories (Table 2-1), using published U.S.

Geological Survey (USGS) and Bureau of Mines data.[1-6] The three categories are termed "reliability" categories because they are based on the relative degree of certainty of the coal resource estimates. They are defined as follows:

Reserve Base--Coal seams that have been physically measured, that lie less than 1000-ft deep, and that are greater than 28-in. thick. Coal in this category corresponds to the "reserve base" described by the Bureau of Mines.

Inferred--Coal that has been measured but is not included in the reserve base for various reasons (e.g., seams are too thin) or that has been only estimated based on the assumed continuity of coal seams into areas adjacent to measured resources. While most of the coal in this category is found at depths of less than 1000 ft, some seams are found as deep as 3000 ft. This category corresponds to the "inferred" category defined by the USGS plus part of their "measured and indicated" category.

Hypothetical--Coal estimates based on extrapolation from known resources and more general volumetric estimates based on the geology of the region. Coal in this category is found at depths of less than 3000 ft. This category corresponds to that defined by the USGS.

A fourth category, defined by USGS and termed "speculative," which includes estimates of coal resources that occur below 3000 ft in depth, was not included.

The average heating value and the sulfur content of the coal are also shown in Table 2-1. These characteristics have an influence on the quantity of coal required by each plant and the cost of coal conversion.

The coal resources in each region were further classified according to the quantity suitable for extraction by three technologies: strip mining, underground mining, and in-situ (Appendix A). The in-situ category included all underground coal seams thicker than 10 ft. Finally, these categories were further disaggregated according to seam thickness,

Table 2-1

COAL RESOURCES SUMMARY
(Sources: References 1-6)

Coal Region	Coal Resources (billion tons) Reliability Category: Reserve Base	Inferred	Hypothetical	Quality (10^3 Btu/lb)	Sulfur Content (%)
Appalachia	101	142	39	13.0	>1.0*
Illinois	89	100	150	11.3	>1.0*
Wyoming	53	83	700	8.7	0.5
Montana	108	183	180	8.1	0.5
North Dakota	16	335	180	6.8	0.9*
Colorado	15	114	161	11.7	0.6
Utah	4	19	45	10.5	0.8*
New Mexico	4	57	127	11.5	0.6
Totals	390	1033	1351		

*Rated "high" sulfur in this study.

depth, and quantity. Detailed information from Bureau of Mines information circulars[1-4,6] was used for the characterization of the coal seams of the "reserve base" and was also used to estimate the seam characteristics of the other reliability categories (using the plausible assumptions described in Appendix A).

2. Extraction Cost Factors

To estimate extraction costs for the coal seams inventoried, generalized cost equations were derived from detailed mining engineering cost studies of the Bureau of Mines[7-10] and SRI.[11] These generalized equations (Appendix B) specify the extraction cost in dollars per ton (1975 dollars) as a function of the seam thickness, depth, and quantity for each type of extraction technology.

3. Extraction Cost Calculation for Inventoried Coal

Using the extraction cost factors, the extraction cost (per ton) was calculated for each seam, and the seams were then sorted by extraction cost for each region. By plotting the quantities of coal available at each extraction cost for each extraction technology in each region, curves showing the marginal extraction cost as a function of coal remaining were developed for use in the model (Appendix C).

Figures 2-3 to 2-5 show the extraction cost curves that result when only the first two reliability categories of resources--reserve base and inferred--are included. The curves consist of 20 straight-line segments used to approximate a smooth cost function. To be conservative, we chose to omit the hypothetical and speculative reliability categories.* In these curves, the horizontal axis shows quantity of coal and the vertical axis shows extraction cost in dollars/ton.† The curves for the different technologies extend different distances to the right along the horizontal axis according to the total amount of coal extractable by that technology--at any cost--in each region. Thus, from Figure 2-3, in North Dakota there are now 183 billion tons of strippable coal and, from Figure 2-5, a total of 167 billion tons in-situ coal.

The right-most portion of each curve represents the cheapest, most easily extracted coal and the portions at the left represent the difficult, expensive-to-obtain coals. Naturally, extraction of the cheapest coals would begin first, so, as time proceeds, the coal is contracted, extracted, and consumed progressively from right to left along the curves. For this reason, the horizontal axis has been labeled "resource remaining." Again, from Figure 2-3, one can see that the cheapest strippable coal would cost $3.60/ton to mine; when 33 billion tons had been mined, leaving 150 billion tons remaining, the extraction cost would have risen to $5.90/ton.

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*The hypothetical category is included in a sensitivity analysis described in Appendix M.

†All dollars in this report have the average 1975 value.

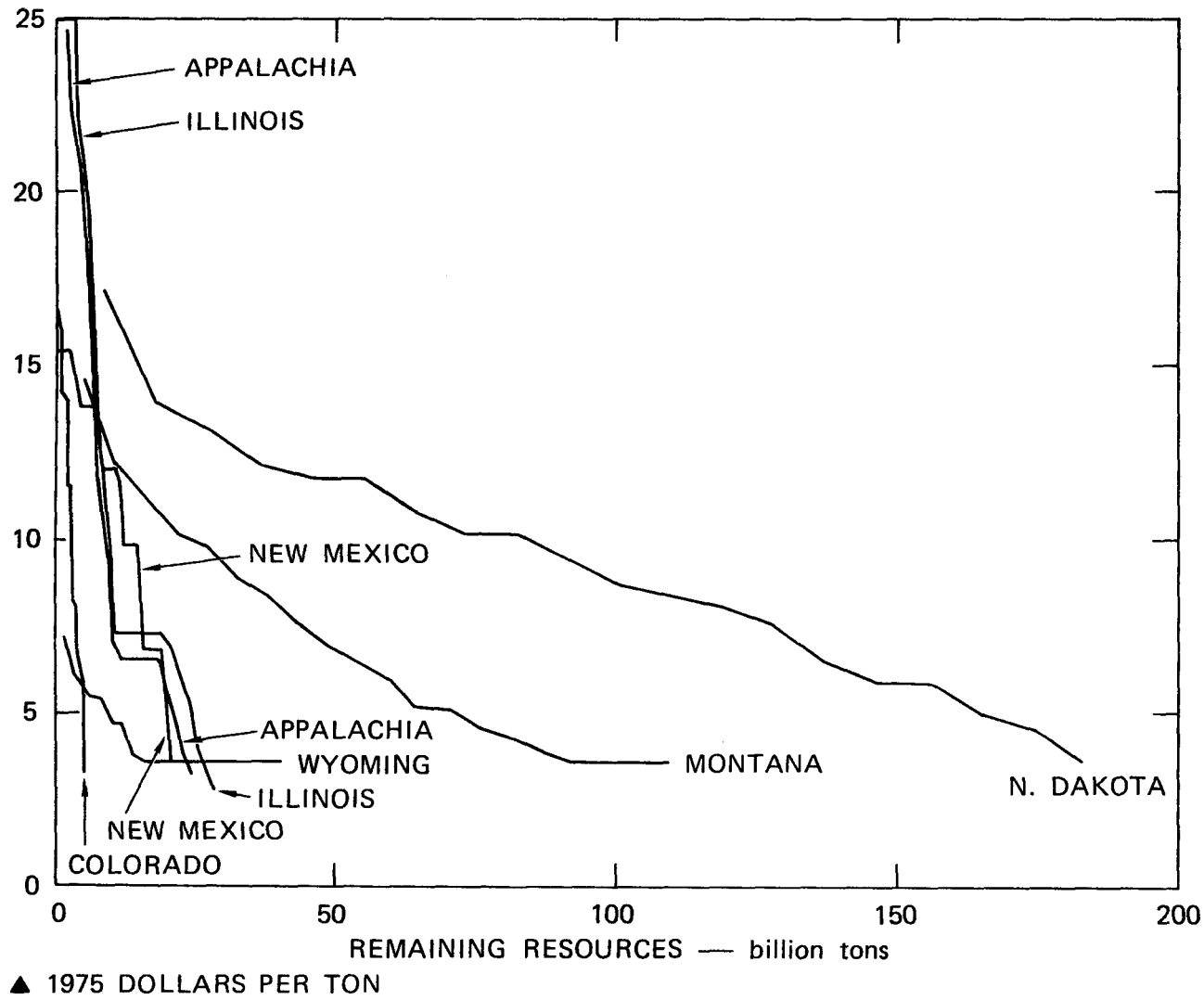

FIGURE 2-3. EXTRACTION COST CURVES -- STRIP COAL

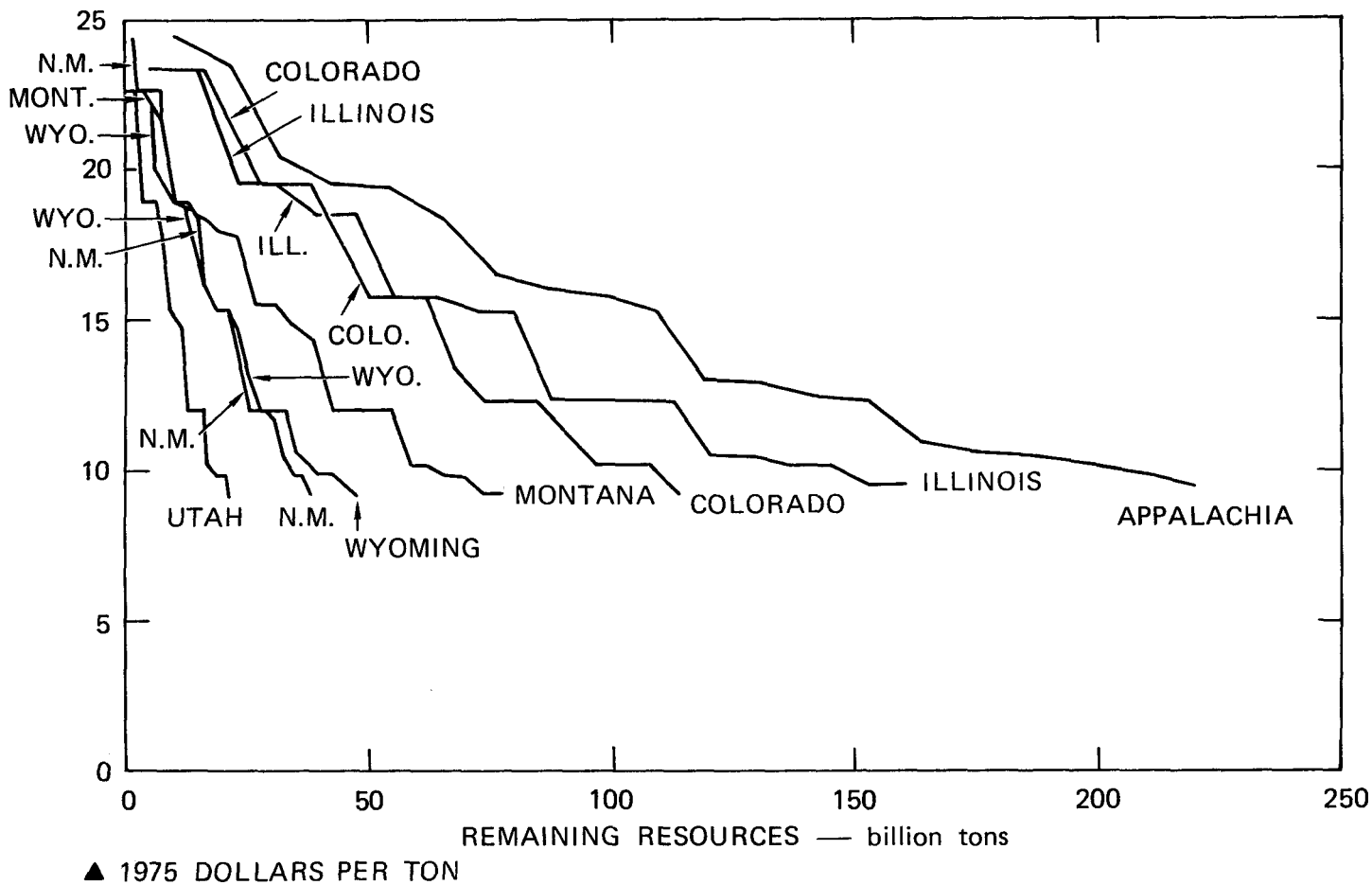

FIGURE 2-4. EXTRACTION COST CURVES -- UNDERGROUND COAL

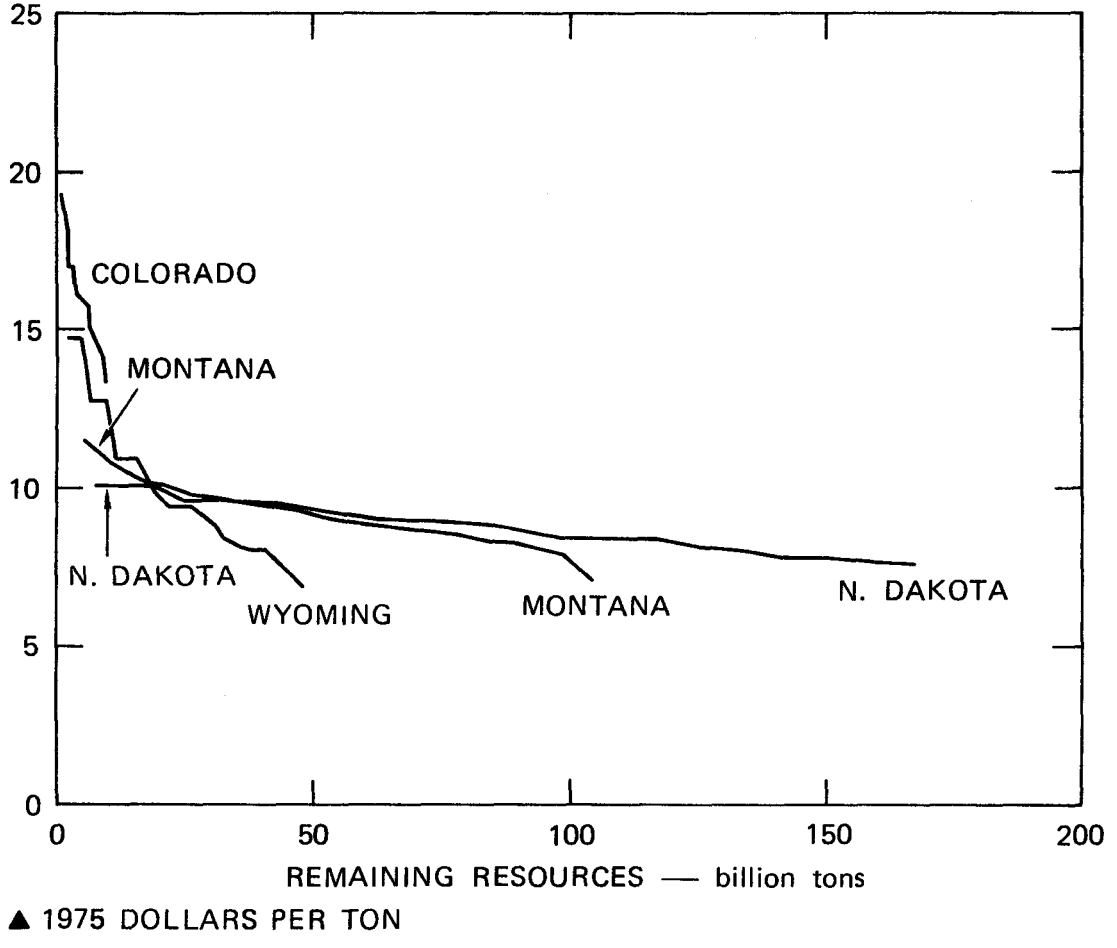

FIGURE 2.5. EXTRACTION COST CURVES – IN-SITU COAL

As the heart of the model calculates the cost of extracting the coal required over a plant lifetime, it takes into account changing extraction costs over the quantity of coal needed; the model calculates the average cost for the quantity needed by the plant over its lifetime.

The curves shown in Figures 2-3 to 2-5 cannot be used in the heart of the model calculation without supplemental information. Data concerning the efficiency of coal extraction and applicable severance taxes must be used to augment the curves.

4. Efficiency of Extraction

As the model calculates the amount of coal needed over the lifetime of a plant, it also takes into account the fact that no extraction process is 100 percent efficient and that some coal is always left behind. The "coal recovery factor" is a fraction that depicts the thoroughness of the extraction process. Recovery factors for underground mining and in-situ extraction used were 57 percent and 60 percent, respectively. As shown in Table 2-2, the recovery factor for strip mining varied by region to reflect the average thickness of the seams in each region.

Table 2-2

STRIP COAL RECOVERY FACTORS AND STATE SEVERANCE TAXES

Coal Region	Strip Recovery Factor	State Severance Tax	
		Strip	Underground and In-Situ
Appalachia	0.80	0	0
Illinois	0.80	0	0
Wyoming	0.97	4.8%	4.8%
Montana	0.95	30.0%	4.0%
North Dakota	0.95	0	0
Colorado	0.90	75¢/ton	50¢/ton
Utah	0.90	0	0
New Mexico	0.95	1.25%	1.25%

5. State Severance Taxes

The state severance taxes that were added to the extraction costs are also shown in Table 2-2. These taxes were current in March 1976, with the exception of Colorado. At that time, the Colorado taxes shown had been passed by only one of the two houses of the legislature.

6. Transportation Cost Factors

Unit trains, slurry pipelines, and barge transportation are represented in the model. The cost of transporting coal from each coal region to each plant by these means was derived from the information in Figure 2-6.

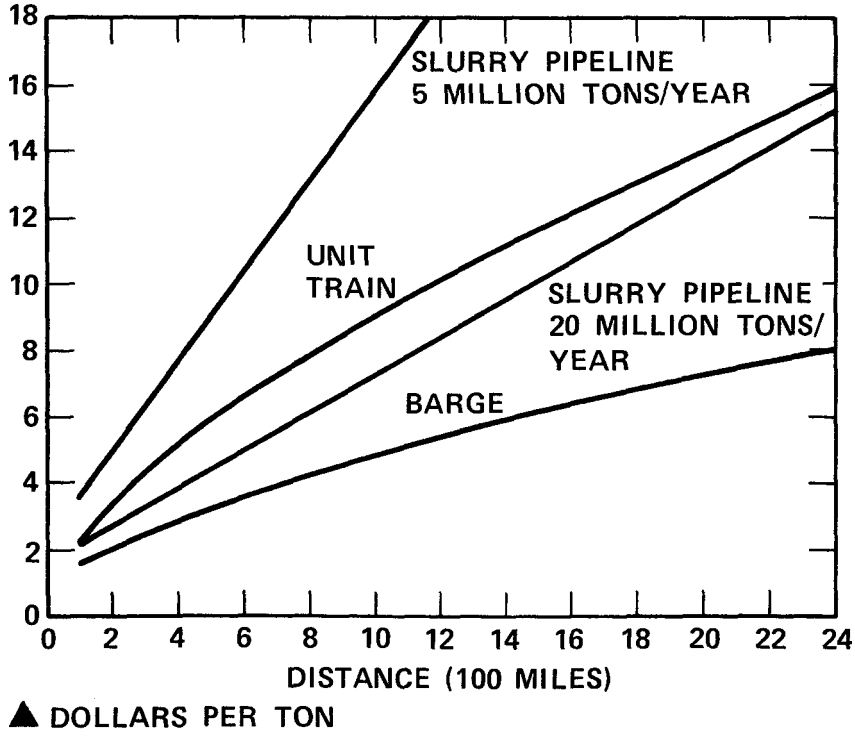

FIGURE 2-6. TRANSPORTATION COST FACTORS

The unit train and barge costs were obtained from large amounts of rate data, which were fitted to a curve by linear regression techniques. The slurry pipeline costs were obtained from detailed engineering design studies. The equations and other assumptions used in developing these curves are described in Appendix D.

7. Conversion Cost Factors

The coal conversion cost factors used in the model calculations (Table 2-3) are representative of the conversion technologies. It is expected, of course, that in operation particular processes will vary from these costs. The derivation of the conversion costs shown in Table 2-3 is presented in Appendix E.

Table 2-3

CONVERSION COSTS
(excludes coal extraction)

Conversion Process	Cost ($/10^6 Btu of product)	Efficiency (Btu product/Btu coal)
Syncrude from coal		
Bituminous coal	2.60	0.68
Subbituminous coal	2.60	0.63
SNG from coal	1.70	0.56
Electricity from coal		
Low-sulfur coal	3.51	0.35
High-sulfur coal	4.51	0.35
SNG via Syngas*		
Thick seams (50-200 ft)	0.56	0.76
Thin seams (10-50 ft)	0.56	0.54
Electricity via Syngas		
Thick seams (50-200 ft)	2.57	0.31
Thin seams (10-50 ft)	2.57	0.22

*Syngas is the gas obtained from in-situ extraction. These costs may be optimistic. See Appendix M for sensitivity tests that use higher costs.

Coal with an average sulfur content greater than 0.6 pounds per million Btu (Table 2-1) was classed as "high" sulfur coal in accordance with EPA's source performance standard for large power plants. A sulfur scrubbing cost was added to the cost of the conversion of high-sulfur coal to electricity.

8. Coal Demand Scenario

Total National Energy Demand--In developing a coal demand scenario for the coal model, a plausible scenario of the total future U.S. energy demand was first prepared.

The total energy demand scenario spans 75 years, from 1975 to 2050. The time span was deliberately made long so that a significant depletion of coal would be evident. Assuming that ultimately rising prices and government policies toward conservation would both constrain demand on a per capita basis, it was assumed that the per capita use of the three most common energy forms (electricity, gas, liquid) will level off as shown in Figure 2-7. As can be seen, saturation of personal demand was not assumed to occur quickly except for gas--the form of energy already in shortest supply. Liquid fuel demand was assumed to increase until early in the next century and electricity demand assumed not to level off until late in the next century. Over the next few years, the annual electricity demand growth rate shown is about 3 percent. Per capita electricity demand is shown reaching a constant level in 2100 of three times that in 1975. Industrial demand for coal was assumed to follow the same growth pattern as electricity.

The per capita energy demands were converted into national fuel demands using the U.S. Department of Commerce series E projection of the U.S. population to the year 2020 (Figure 2-8).[12] A linear extrapolation of the implied growth rate was made to extend the projection to 2050.*

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*This extrapolation projects zero population growth in the United States by 2065.

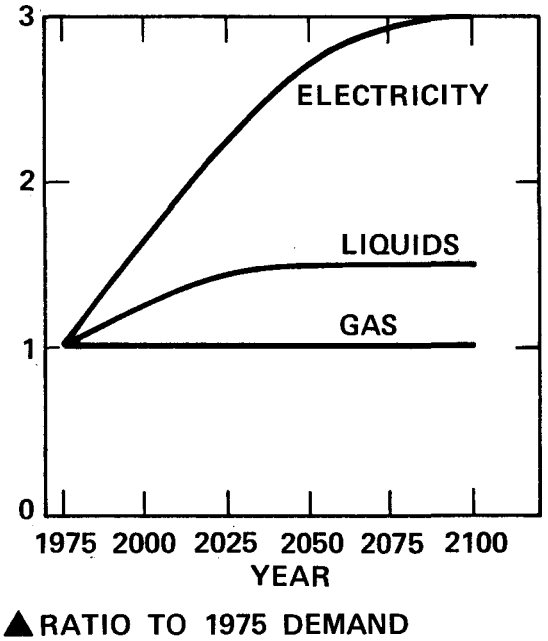

FIGURE 2-7. SCENARIO PER CAPITA ENERGY DEMAND COMPARED TO 1975 USE

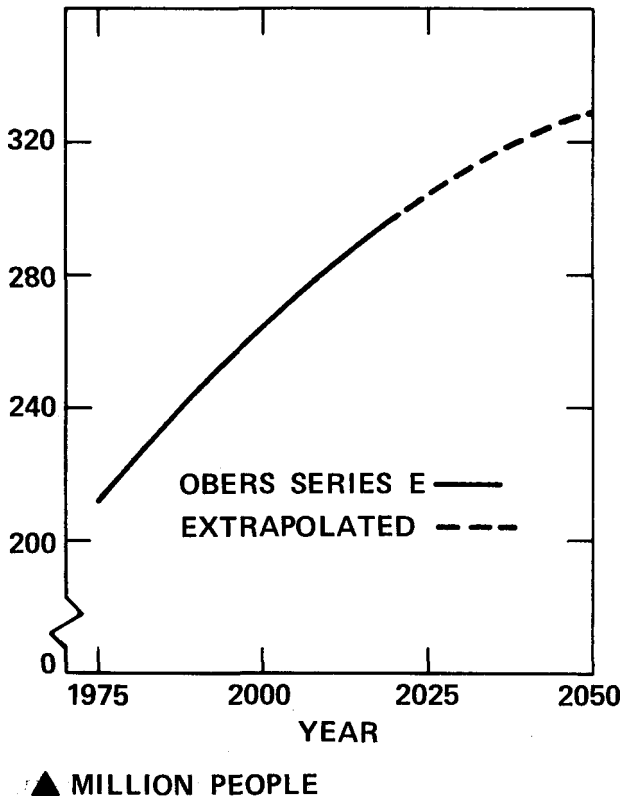

FIGURE 2-8. PROJECTION OF U.S. POPULATION

Coal Demand--Multiplying the per capita fuel demands by population and then subtracting plausible supplies of domestic and imported oil and gas gave the fuel requirements to be satisfied by the use of coal (Figure 2-9). (For details, see Appendix F.) In this operation, oil imports were assumed to be nearly constant, and coal was assumed to be used to produce half of the total electricity supplied. (The other half was assumed to be supplied by a combination of nuclear, hydro, solar, and geothermal energy.) Oil shale was assumed to rise to a level of 2 million B/D towards the end of this century and remain constant thereafter. For simplicity, imports of natural gas or liquified natural gas were assumed to be zero.

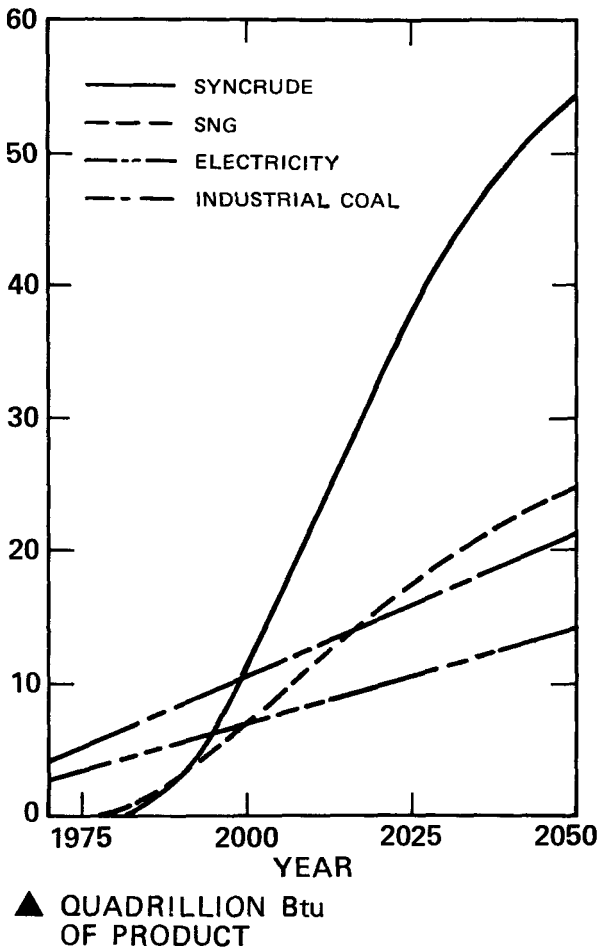

FIGURE 2-9. SCENARIO COAL DEMAND BY USE SECTOR

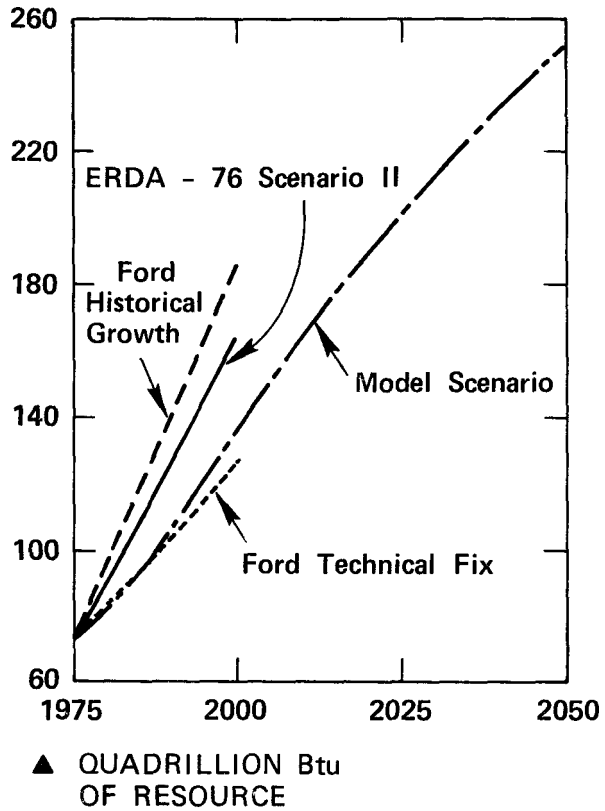

FIGURE 2-10. SECNARIO RESOURCE ENERGY DEMAND COMPARED TO POPULAR PROJECTIONS

Aggregating the fuel demand by energy type allows comparison with other future fuel demand scenarios as shown in Figure 2-10. Here, the coal demand scenario developed for this study is compared with two energy projections from the Ford Energy Policy Project[13] and with the high-demand synthetic fuels scenario of the U.S. Energy Research and Development Administration.[14] This comparison shows the total energy demand scenario used in the Coal Depletion Model to be conservative compared with the ERDA and Ford Energy Policy study projections. If a higher energy demand scenario had been used in our calculations, then coal production would have had to increase and depletion effects would have been evident earlier and all the boomtown effects implied would have been more acutely felt.

9. Plant Location Constraints Specification

The model was intended to be used to explore the implications of pursuing various plant location strategies as a means of ameliorating adverse rapid urbanization (boom-town) and water demand impacts. To facilitate this purpose, external constraints on the locations of plants were applied consistent with the coal demand shown in Figure 2-9. This resulted in three scenarios: two extreme cases, the Minemouth Scenario and the Dispersed Scenario, and one intermediate case, the Limited Minemouth Scenario.

In the Minemouth Scenario, the model locates all synthetic fuel plants close to the minemouth in that coal region which minimizes the cost of the conversion plant's product without regard to water availability or social impacts stemming from population influxes.

The Dispersed Scenario, by contrast, distributes the synthetic fuel plants throughout the eastern half of the United States at locations where there is both adequate water and social capacity to absorb the population increase with minimal disruption.

The third scenario, termed Limited Minemouth, allows about half of the plants to locate at the minemouth but leaves the other half in the eastern United States. The plants allowed near the minemouth are those that have the least impact, and the annual growth rate in any county affected is held to about 5 percent.

The locations of electric power generation and industrial coal plants are the same for each scenario; only the locations of the synthetic fuel plants are different.

The three scenarios each call for 285 syncrude plants, each producing 100,000 B/D, 312 SNG plants, each producing 250 x 10^6 SCF/day, 722 coal-fired electric power plants, each of 1000 MW capacity, and 890 million tons/year of industrial coal demand to be in operation by the end of 2050.

10. Conversion Plant Locations and Start-Up Schedule

The coal demand scenario and plant location constraints specification were used to prepare a detailed list of coal-using plants (Appendix G). The time spans modeled were 75 years (1975 to 2050), for the Minemouth and the Dispersed Scenarios and 25 years for the Limited Minemouth Scenario. The types of plants specified were: synthetic crude oil, substitute natural gas (SNG), coal-fired electric generation, and industrial.*†

The following items were listed:

- Location (city or town)‡
- Demand type (syncrude, SNG, electricity, industrial)
- Annual production (trillion Btu of product per year)
- Year operations begin
- Plant lifetime (years).

D. Model Outputs for Three Plant Location Scenarios

The results of the model calculations for the three scenarios are grouped into two categories: regional coal production and regional coal depletion.

It should be kept in mind that the levels of coal production described by the model could only occur if there were no limiting factors other than the resource depletion, production, and relative costs that are represented by the model. In reality, of course, many constraints not represented in the model quite likely would severely limit production to levels much less than some of those indicated. Such constraints include limitations on available financing, allowed environmental impacts, institutional barriers, and logistical bottlenecks. Even though such constraints cannot be reflected in this simple model, the model's results provide a useful qualitative comparison of the effects of synthetic fuel plant siting strategies on coal production, depletion, and costs. The reader should pay more attention to qualitative trends than to specific magnitudes because this simple model cannot predict magnitudes accurately.

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*Each technology has different limitations on the quality of coal that it can accept.
†Exports are included in the industrial category.
‡In the Minemouth Scenario, plants choose their own locations.

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Chapter 3

THE MINEMOUTH SCENARIO

- Time span: 1975-2050
- By 2050
  - 285 syncrude plants: 100,000 B/D capacity
  - 312 SNG plants: 250 x 10^6 SCF/day capacity
  - 722 coal-fired electric power plants, 1000 MW
  - 890 million tons/yr of industrial coal demand
- Synfuel plants located at minemouth
- Sites chosen in coal region giving lowest cost synfuel
- No concern for boom-town phenomena
- No concern for water availability
- No coal transport cost factor

The Minemouth Scenario, because it allows the Coal Depletion Model to select synfuel plant locations solely on the basis of minimized extraction and conversion costs, is less complex than the Dispersed Scenario in which transportation costs must be considered in addition to extraction and conversion cost factors and plant sites must be specified.

A. Coal Production

Figures 3-1 through 3-4 show the historical 1975 coal production and production under the Minemouth Scenario at three selected times during the 75-year period of the scenario. Nearly all of the coal production in 1975 occurred in the Appalachian and Illinois regions with very little in the West (Figure 3-1).

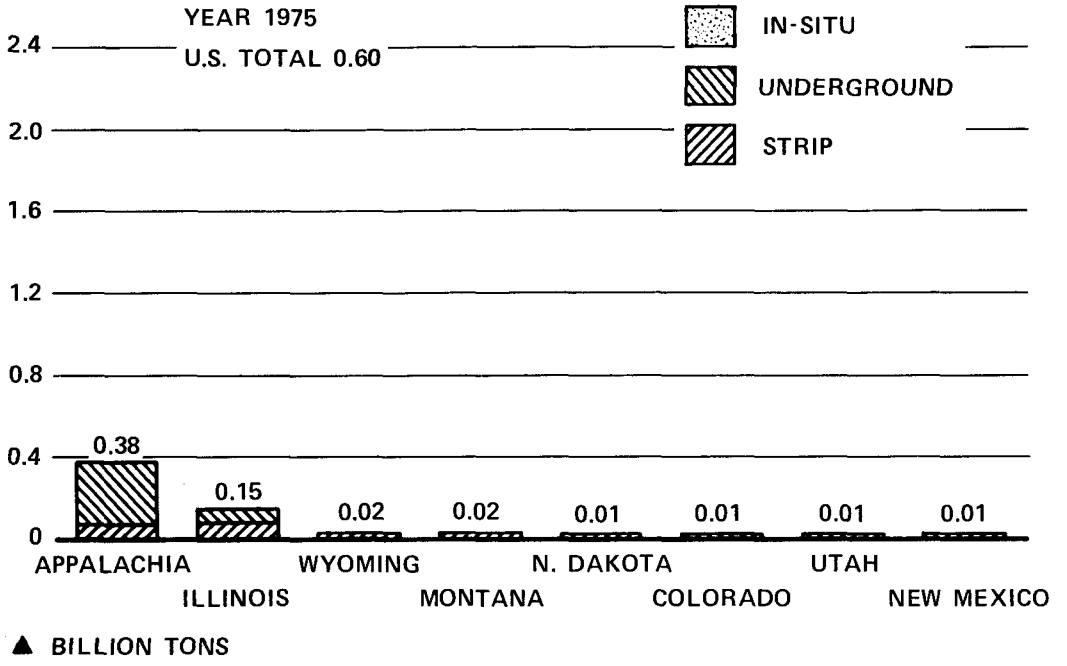

FIGURE 3-1. REGIONAL COAL PRODUCTION, 1975 HISTORICAL DATA

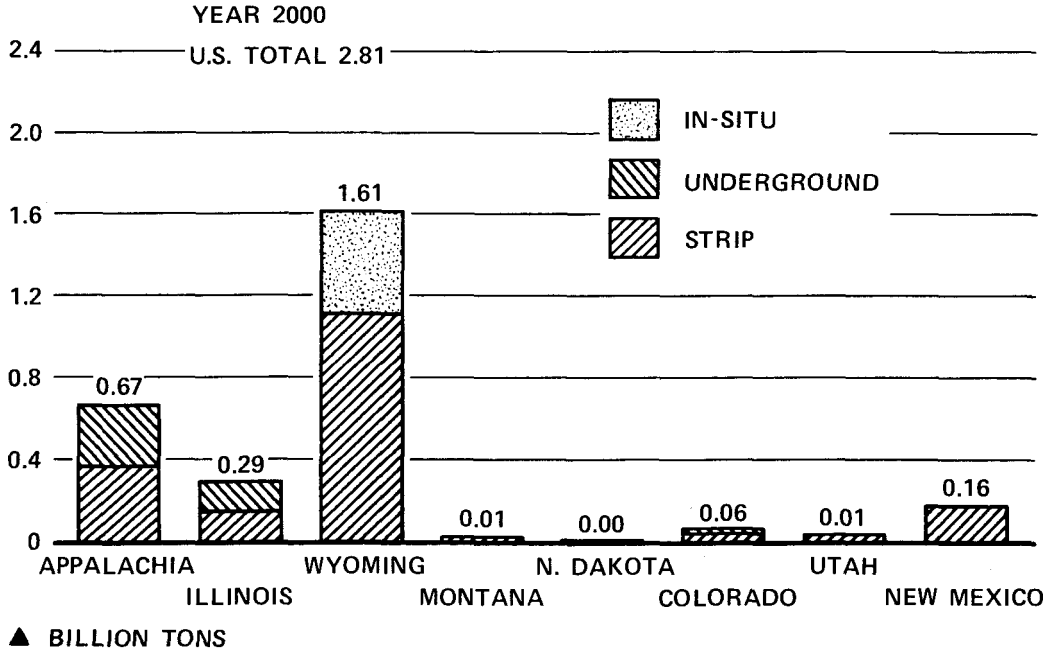

FIGURE 3-2. MINEMOUTH SCENARIO, REGIONAL COAL PRODUCTION, YEAR 2000

1. Regional Production

By the year 2000, however, there is a marked change. Production doubles in Appalachia and Illinois, mainly because of contracts with electricity plants and industry.

But the most dramatic change occurs in the West where production in Wyoming soars and Colorado and New Mexico experience a six- and fourteen-fold increase, respectively (Figure 3-2). This marked increase in western production occurs because the Coal Depletion Model selects Wyoming as the site for nearly all of the synfuel plants and as the source of coal for one-third of the electricity plants under this scenario. Wyoming is chosen by the model because of that state's thick seams of strippable coal (which means low extraction cost) and in-situ extractable coal (which has low conversion costs).

National production by this time under the Minemouth Scenario is increased by more than a factor of 4, primarily reflected in the boom in Wyoming production.

By the year 2025, the cheapest coal has been mined and increased extraction costs make Montana more attractive than Wyoming in spite of Montana's slightly less attractive coal and relatively high severance tax (Tables 2-1 and 2-2). Montana, therefore, undergoes a production boom (Figure 3-3) of even greater magnitude than did Wyoming because it occurs at a time of greater demand for coal for synthetic fuel. Except for the high, 30 percent, severance tax charged for strip mined coal, Montana would have been competitive with Wyoming for coal contracts earlier.

As extraction costs rise, Appalachian and Illinois coal become more competitive with western coal for synthetic fuel coal contracts. Thus Appalachian production nearly doubles again between 2000 and 2025, while Illinois production nearly quadruples. Consequently, by 2025, production in Appalachia and Illinois is nearly four and eight times 1975 levels.

Figure 3-3 also shows that Colorado and New Mexico are beginning to attract new contracts as a result of showing competitive extraction

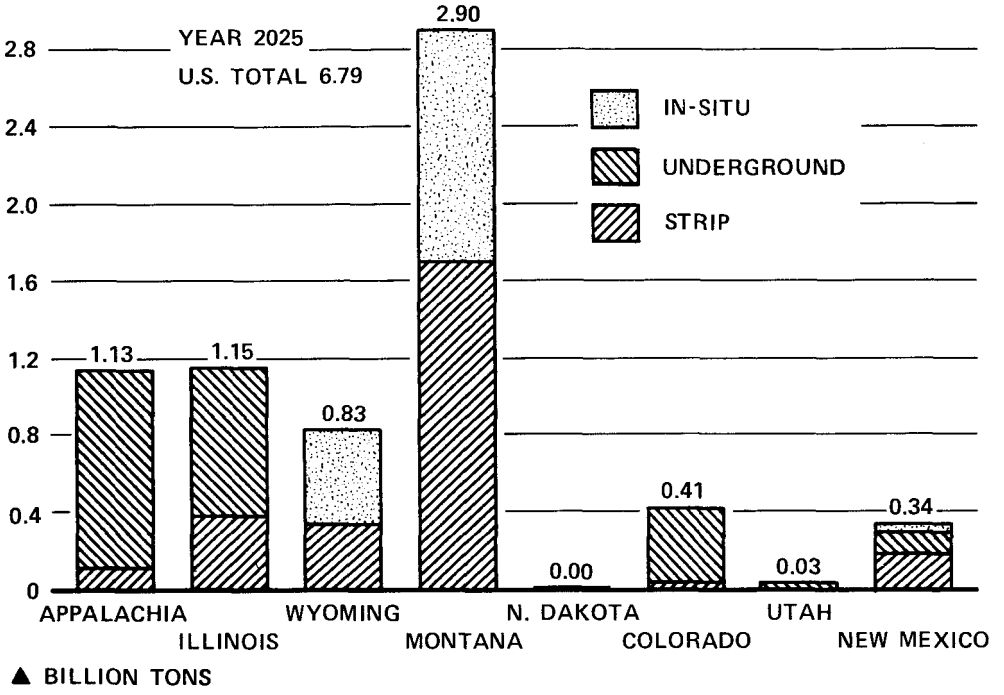

FIGURE 3-3. MINEMOUTH SCENARIO, REGIONAL COAL PRODUCTION, YEAR 2025

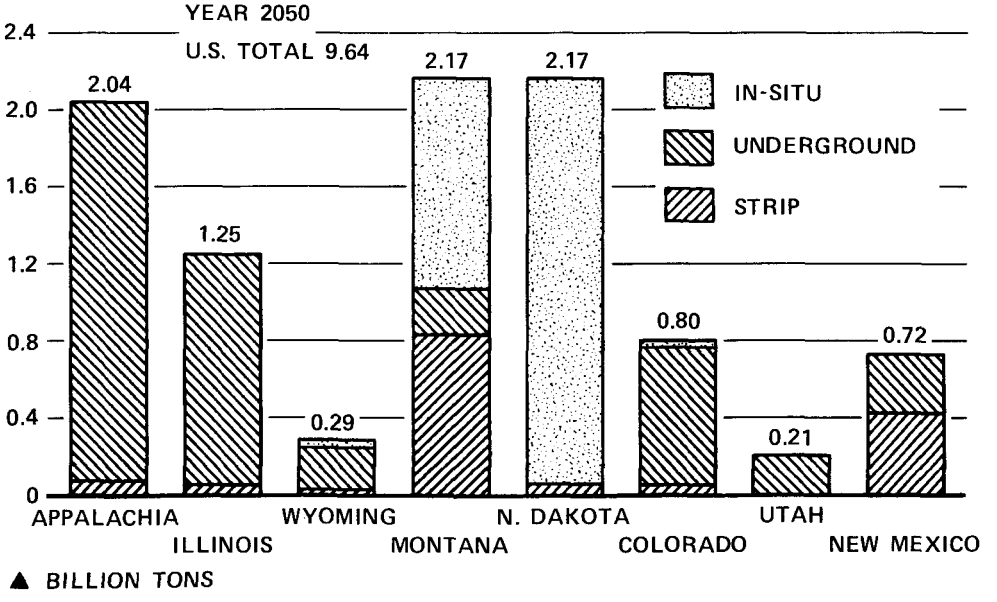

FIGURE 3-4. MINEMOUTH SCENARIO, REGIONAL COAL PRODUCTION, YEAR 2050

costs. New Mexico production thus doubles between 2000 and 2025 while Colorado production increases nearly seven-fold.

National production by 2025 is more than double that of 2000, and more than 10 times that of 1975.

By 2050, there is a further realignment of production. Relatively little production remains in Wyoming (Figure 3-4), and it is primarily underground. Montana production is past its peak and is declining. In-situ extraction in North Dakota for conversion to SNG becomes competitive with Montana production because Montana mining costs have risen enough to compensate for the low heating value of North Dakota lignite. Thus North Dakota now experiences its production boom (Figure 3-4). Production in Appalachia, Colorado, and New Mexico doubles and Utah production increases by a factor of 7 by 2050. The latter regions have not reached their peak production, which would surely occur if the scenario were extended in time. Even so, production in Appalachia is five times its 1975 level and Illinois is eight times its 1975 level.

National production between 2025 and 2050 increases another 40 percent (Figure 3-4) to a level 16 times that of 1975.

2. National Coal Production by Extraction Technology

Regional coal production is aggregated in Figure 3-5 to show national coal production under the Minemouth Scenario between 1975 and 2050 for the three types of mining technology. Underground production is relatively constant during the first 25 years when strip mining provides the increase in coal production. By about the turn of the century, however, the cheaply minable strip coal resources have been already taken and underground production along with in-situ increase to take up the slack. Toward the end of the period, depletion causes extraction costs to rise sufficiently (average extraction cost rises by a factor of 2.5 during the 75 years) that the higher cost strip resources (such as those in North Dakota and New Mexico) become competitive with the underground resources, thereby increasing strip production again.

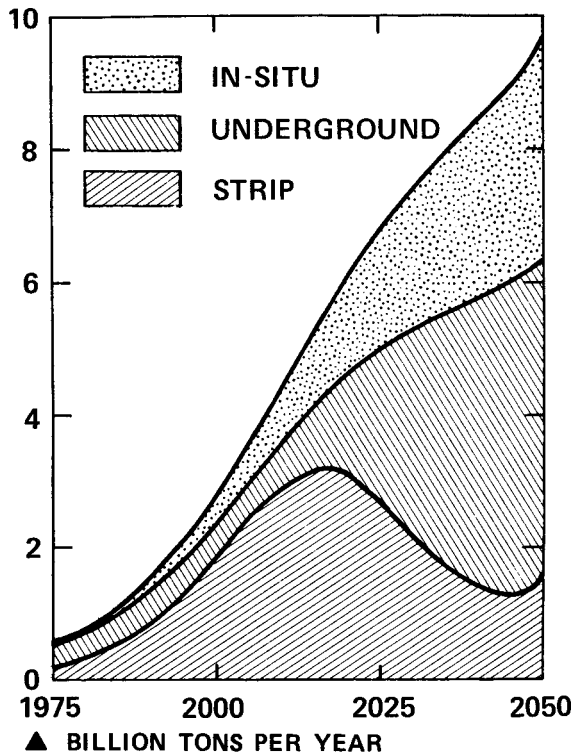

FIGURE 3-5. MINEMOUTH SCENARIO, NATIONAL COAL PRODUCTION BY TYPE OF EXTRACTION

B. Coal Resource Depletion

The coal depletion resulting from strip mining in the Minemouth Scenario is shown in Figure 3-6 and 3-7. In this scenario, strippable coal is heavily depleted in the three key regions--Appalachia, Illinois, and Wyoming. Considerable quantities of strippable coal are left in North Dakota and Montana. Wyoming strip coal is depleted rapidly in the Minemouth Scenario because this scenario allows many synthetic fuel plants to locate in that region.

Underground western coal, on the other hand, shows relatively little depletion (Figure 3-6b). In-situ coal shows almost complete depletion in Wyoming and about 50 percent depletion in Montana by 2050 (Figure 3-8). Considerable in-situ resources remain, however, in North Dakota.

C. Boom/Bust Cycle Implications

Figure 3-9 summarizes the regional coal production resulting from the Minemouth Scenario. The western coal regions, one after the other, would be expected to experience increases in production to a high level (1 to 3 billion tons per year) followed by a decline to a lower level. This boom cycle, in the case of Wyoming, is followed later by a bust. Because Montana and North Dakota have more coal, the bust would not come as quickly. Such boom and bust cycles result from exploitation of the most attractive coals in a region as long as they last and the consequent shift of production to another region. Not surprisingly, Wyoming, with seams of strippable coal in excess of 50-ft thick and with correspondingly thick underground seams extractable by in-situ methods, is the first state to experience this cycle. Following Wyoming, Montana and North Dakota exhibit the boom cycle; Colorado, New Mexico, and Utah no doubt would show the same kind of cycle if the scenario were extended beyond 2050.

The Appalachian and Illinois coal regions provide most of the coal for electricity generation plants and industrial use since most of this demand is in the East. Both of these regions would be expected to

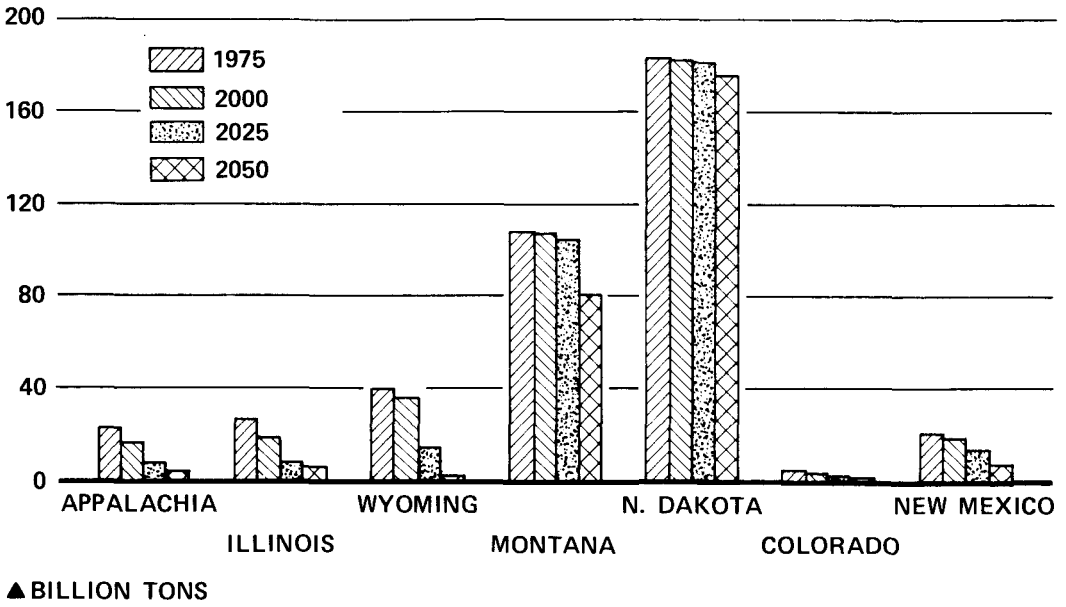

FIGURE 3-6. MINEMOUTH SCENARIO, STRIP RESOURCES REMAINING

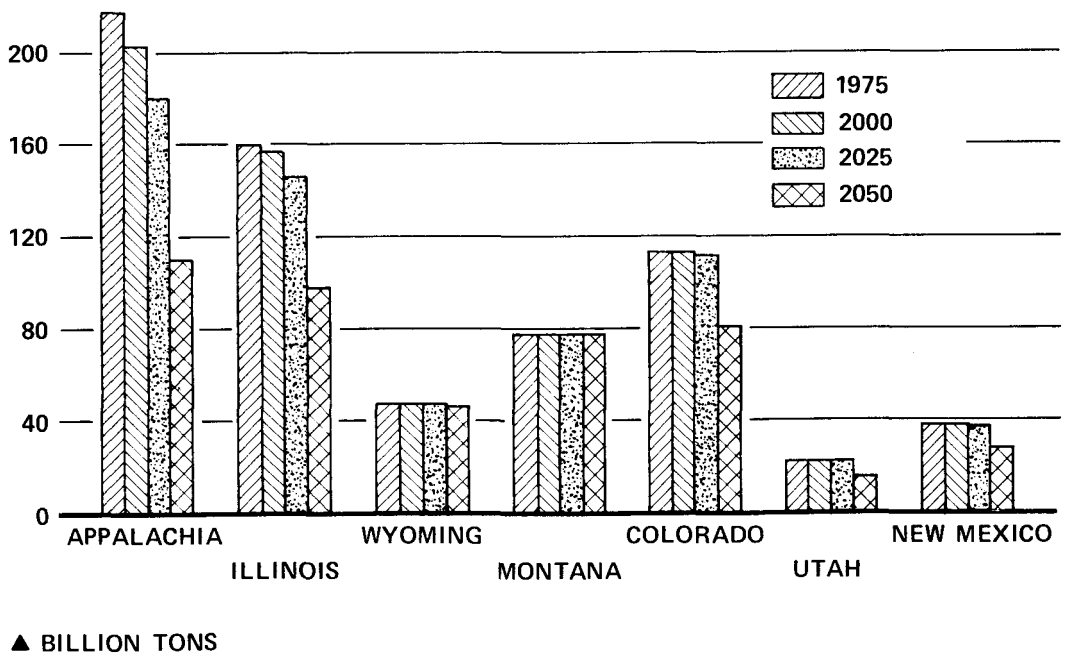

FIGURE 3-7. MINEMOUTH SCENARIO, UNDERGROUND RESOURCES REMAINING

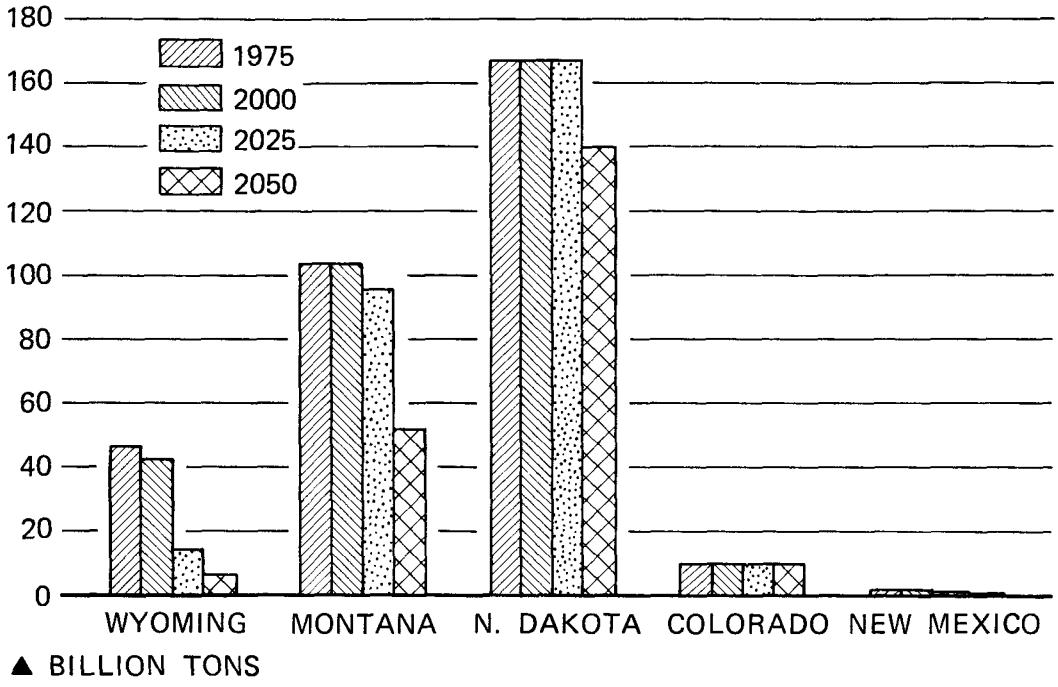

FIGURE 3-8. MINEMOUTH SCENARIO, IN-SITU RESOURCES REMAINING

undergo an extended but strong increase in production due to the increasing demand of electricity plants and industry. Their strippable coal nears depletion (within 35 years) and their underground coal production, by 2050, exceeds eight times their 1975 production.

The following chapter discusses the implications of boom/bust cycles for communities.

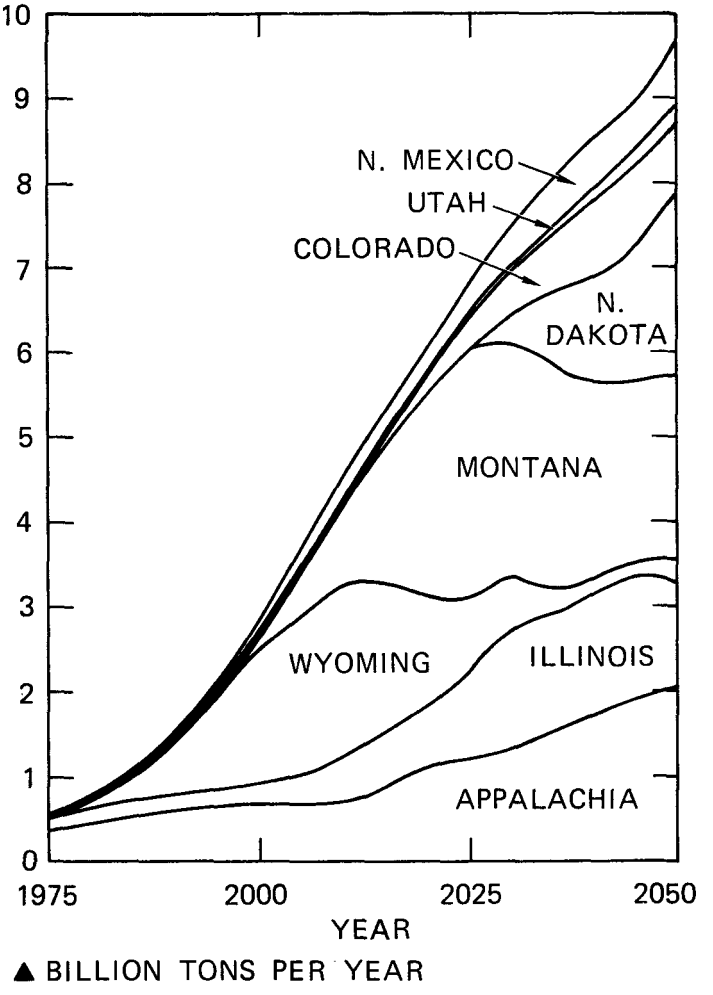

FIGURE 3-9. MINEMOUTH SCENARIO, SUMMARY OF REGIONAL COAL PRODUCTION

Chapter 4

URBANIZATION IMPACTS AND BOOM-TOWNS

The boom-bust cycles created under the Minemouth Scenario are a familiar consequence of industrial development in regions typified by small, rural, mainly agricultural, communities. The study reported here included an analysis of the impacts of a synfuels industry on such communities. This chapter first treats the relationship of industrial growth and community development and outlines the characteristics of the boom-town phenomenon as a prelude to illustrating the effects of the boom-town process on a rural community that has already undergone the process as a result of energy resource development. The variation of impacts as a function of community size is then explored. This is followed by a discussion of considerations that can go into site selection to minimize deleterious effects of industrial development on communities.

A. Industrial Growth and Community Development: A Short Description

The relationship between community growth and industrial development is illustrated in Figure 4-1. The development of a new industry (or the expansion of an existing industry) implies that the demand for labor will increase in the region where the industry is located. More jobs will be available both in the industry itself and in secondary activities that are needed to support the basic industry. For example, secondary activities for strip mining would include construction of the facilities, construction and maintenance of roads and other transportation services, and maintenance service for transportation equipment and primary activity equipment if this is not incorporated in the initial production process. The jobs may be filled by unemployed workers in the region, by shifts of workers in the region from other employment sectors, by higher work force participation, or by migrants into the region. When the original population of the community is small and the new industry has a large work

force, the majority of the work force will come from outside the county.

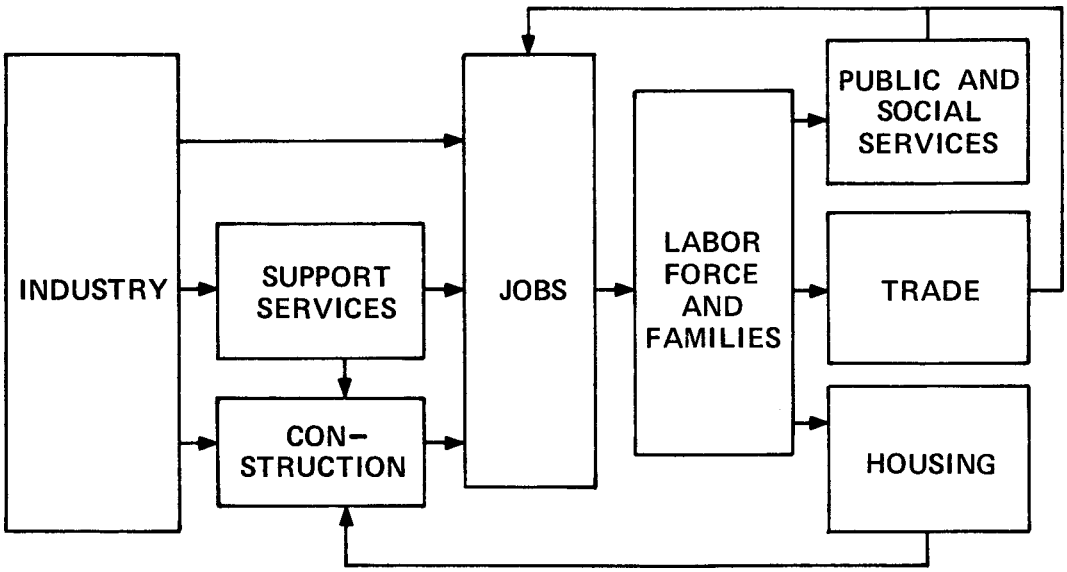

FIGURE 4-1. SCHEMATIC OF COMMUNITY GROWTH INDUCED BY INDUSTRIAL DEVELOPMENT

The new industry will then cause an increase in local population. This new population will put demands on various kinds of services--housing, retail service, and public and social services. These increased demands create more job openings. These may in turn be translated into more jobs for local residents or a further population influx. Employment expands in housing construction, public government, welfare, and general retail services.

To many communities, the prospect of this type of growth is attractive. The local population expects that the expansion of job opportunities will raise family incomes, enabling young adults to find employment within the community, and help pay for an increase in the amount and

quality of services in the community. However, this image of prosperity may never materialize.

In the early stages of the industry's growth, most of the new jobs may go to people from outside the local community. For skilled jobs in particular, the industry is unlikely to hire local, untrained labor if skilled labor can be imported more quickly than local residents can be trained.

Importation of a higher paid labor force into the community does not necessarily mean that the local community will be richer in either private economic activities or public services although some local individuals may benefit from this change. The growth process described here takes place over time, and at many points supply has not adjusted to meet demand, and the level of service required by the population is not being met. Reasons for service lag have been described in Volume II of this series[1] and are also discussed later in this chapter.

The result of the growth processes may fail to be as attractive as the community hopes. If the industry fluctuates in size and durability, services and population may never reach a stage of equilibrium at which benefits of growth have been realized. Even when growth brings about a higher standard of living overall in the community, many of the pre-boom community residents may not share in this aggregate increase in welfare.

B. Boom-Inducing Industries

The growth process of some industries fosters unbalanced community growth and boom-bust cycles by their (1) dependence on natural resources located in nonmetropolitan areas, (2) high but temporary demand for construction workers, (3) rapid build-up of longer-term employment, and (4) inherent uncertainty throughout the entire growth period. Each of these factors is an important consideration for the synthetic fuels industry.

1. Resource Dependence

In making the choice of where to locate, an industry considers several factors--availability and transportation costs of raw materials, transportation costs of the final product (location of markets), local labor availability, and costs of importing labor. Mineral extraction must occur at the natural resource site. Other industries weigh the cost tradeoffs among all of the factors mentioned above.

Industries using bulky or heavy raw materials as their major input will try to reduce input transportation costs by locating near the necessary resource. Labor availability is relatively unimportant in these industries because labor is more mobile than the resource. This type of industrial development is likely to take place in isolated, sparsely populated areas, and to cause major changes in the region.

For a synthetic fuels plant, the cost of transporting the raw material (coal) far outweighs the cost of transporting the final product--gas or oil. While many other costs would also be considered (differences in labor costs, labor turnover rates, transportation of water) before a final location choice, industry is presently considering plant locations near the coal resources. Most of the large coal deposits are distant from metropolitan and industrialized regions, and therefore minemouth conversion will cause major changes in presently rural regions.

2. Intense Construction Period

When mining or manufacturing begins in a low density rural area, necessary labor both for construction and for operation of the facility will not be available in the region. Many construction workers must move into the community temporarily. For a liquefaction plant, for example, construction may take several years and reach a peak work force of 2,900. With families and additional service workers, several thousand new people may move in for a temporary period of time. The nearest town or towns grow in sudden jumps, and face the dilemmas of a boom town.

3. Long-Term Employment

A boom industry uses much more labor than the existing economic activities in the region. For example, a mine or a synthetic fuels plant demands many more workers than ranching or farming activity as practiced in many of the coal resource areas. While these operations may begin slowly for the first months, they reach full operating capacity within a few years. From the viewpoint of a small town (of a few thousand), this creates severe and rapid change.

4. Uncertainty

When the value of the resource or the long-term demand for the resource is uncertain, the problem aspects of boom towns may be intensified. When supply of the resource is uncertain, the secondary aspects of development such as housing will be delayed until the primary industry is well under way, causing short-term scarcities in many services. Uncertainty over the technology has similar effects. Uncertainty of long-term demand encourages the industry to develop the resource as fast as is technologically and economically feasible. This situation discourages a gradual, steady growth rate and encourages rapid increase in output. In the synthetic fuels industry, demand for the product will be affected by the international price of oil (an unstable parameter), the cost and availability of other energy sources, and, from the point of view of a region, variations in regional coal prices over time. This last factor may result from changes in technology or in environmental regulations. Where uncertainty is a long-term factor in the industry, investors may be discouraged from making long-term investments in the developing regions.

C. Boom-Town Phenomena

Boom towns occur when new economic activity in a small city or town or a rural region causes rapid population growth and a major shift towards an urban lifestyle. Natural resource development is frequently a cause of boom growth in small towns, but rapid development of an industry may also produce such growth. A boom-town community may experience as

many (or more) problems as profits in the course of its growth. Social institutions and secondary economic activity rarely change rapidly enough to accommodate the new industrial population. Major portions of the boom community suffer from high living costs, inadequate social services, and cultural conflicts with other residents.

1. Boom-Town Process

The incidence of problems varies over the lifetime of the boom community. A boom-town may go through several stages: (1) pre-boom status quo, (2) pre-development speculation, (3) construction boom, (4) industry operations boom, (5) stable operations with short-term shadow booms, (6) industry decline and local economic recession (Figure 4-2). Certain social and economic problems are associated with each stage. These are described below.

Pre-Boom Community--A potential boom-town is a small retail and population center, with at most a few thousand people, in a sparsely populated region. Most communities of this type in the United States are supported by agricultural or recreational use or by small scale resource development. Previous to their rapid economic growth, most modern boom communities had economies that were either stable or declining. These communities have little need for growth control measures or growth regulating agencies. Consequently, they have no established institutions capable of solving the problems of changing development patterns. The people in many of these areas have shown long-term, traditional resistance to regulation and are slow to accept the need for development control.

Pre-Development Speculation--As soon as plans for economic development become known, some changes in population and economic activity occur. These may include a speculative real estate market, some investment by local merchants in expanding their service capabilities, and migration of people seeking employment into the potential development region. The cost of land and housing may begin to rise before any construction or industry operations occur. In some cases, investments may

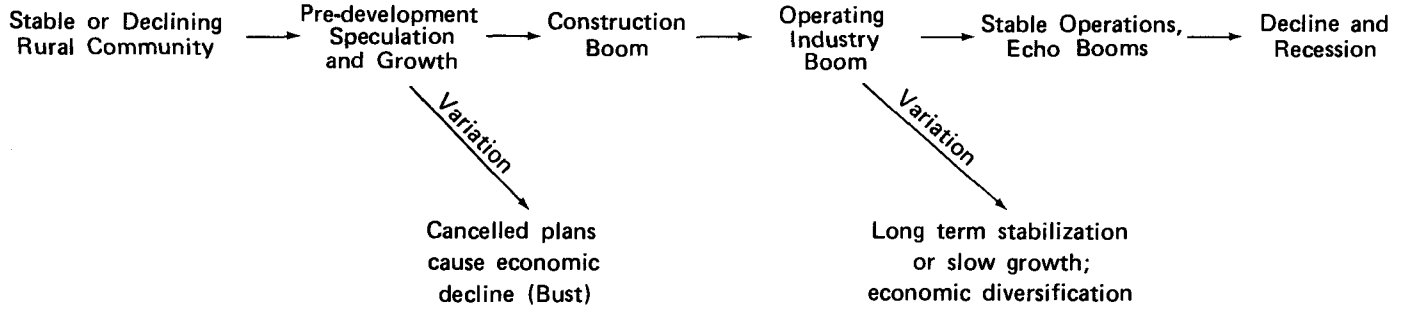

FIGURE 4-2. SCHEMATIC OF THE BOOM AND BUST CYCLE

meet the needs of the initial influx of population but be inadequate for the needs induced by a fully operational industry. In rarer cases, investment and inmigration may overshoot the actual needs induced by the industry, leading to losses for speculators. Often communities hold back on public investment during this time.

Construction and Operation Boom--Many of the most severe problems occur with the buildup of the industry and its early operational phase. The largest influx of people occurs during this period. Existing public services and retail activities are overwhelmed with new demands. The service structure may never catch up to the peak level of construction population, because the construction growth spurt is temporary. Investors are reluctant to support the short-term needs of a population which will have left before investment costs have been recovered.

The population associated with the industry operations is (at least as a net figure) a longer-term population. The service structure will eventually build up to meet the needs of this population. However, this may occur many years after the first spurt of growth. The original population and first newcomers will experience the service lags which accompany rapid growth. In addition, population changes and the expansion of economic and social activities create inevitable changes in the social structure of the community. Long-term cultural conflicts may result from these changes.

Stable Operations--If the industry continues long enough (usually several decades) the community will adjust to meet its new size. Fluctuations in population may still occur but they will be less severe although they are sometimes large enough to cause echo booms. These booms may occur in two different ways. The adult population may increase sharply over a period of a few years, as the young children of the early newcomers to the community reach adulthood. If the dominant industry has been stable in size, then there are likely to be more job seekers than available positions during this period. This type of echo population

boom may send the community as a whole into a period of high unemployment (possibly short term).

Another type of echo boom occurs during periods of replacement construction. If the industrial activity continues beyond the lifetime of the initial plant, a new construction phase occurs. If the industry has remained the dominant economic activity in the area over this period of time, it is likely that there will still be an inadequate supply of construction workers within commuting distance to the plant. In this case, a temporary influx of construction workers will be necessary to complete the reconstruction work. Housing and service shortages are likely to occur at this time.

Decline--Finally, many boom industries have limited lifetimes and do not increase the region's attractiveness for other major economic activities. When the operational period of the industry ends, the community loses its primary economic base. Theoretically, this would imply a simple transfer of workers from one region to another. In practice, people are not so easily mobile. Many tend to remain in a region seeking further work or community regeneration long after decline has begun. Furthermore, capital investments for fixed secondary activities (e.g., a shopping center) are not easily transferrable. Owners will avoid abandoning these investments as long as possible.

2. Variations in the Boom Sequence

There are often variations in the full cycle of boom and bust (Figure 4-2). These include anticipated growth followed by a bust, when industry changes development plans; long-term stabilization, when the industry is sequenced to last for many decades or when the growth of other unrelated basic economic activities in the region relieves the community of its dependence on a single industry; and continued growth and diversification of economic activity, at a slower rate.

Speculative Growth and Bust--When an industry reduces or discontinues a previously announced investment, local communities may go through an accelerated version of the boom-bust cycle. Pre-development private speculation occurs without the long-term returns on investment if the anticipated economic growth does not occur. In addition, job seekers may move into the community. The community makes some major capital investments to accommodate this new population, but overdemand of services is still common during the growth period.

When the industrial development fails to occur, a period of decline occurs, and many recent newcomers move out. Public debts carry over from the growth period and become a large expense for the long-term population.

Long-Term Stabilization or Slow Growth--Stabilization occurs most readily when the basic resource for the economic activity is renewable. Recreational use, agricultural activity, and logging operations may thus stabilize over long periods of time, if there is stable demand for the activity's product. This may also occur if the nonrenewable resource supply is abundant enough to last for a century or more. However, when the industry depends on a resource that may be exhausted in a few decades, the industry itself cannot stabilize.

Stabilization or slow growth can occur in the community, however, if the initial economic base becomes diversified enough to relieve the community of its dependence on a limited, exhaustible resource. For example, improved transportation developed for the initial industry and a supply of trained labor may make the area more attractive to other major industries. There is no evidence that this is occurring in areas presently devoted to mining and power generation. Instead, the high costs, unattractiveness, and overcrowding of the growing communities often discourages other industries from entering the region.

D. Gillette (Campbell County) Wyoming: Boom-Town Example

Case histories of boom-town experiences,* particularly those related to the impacts of energy development in western towns, were studied extensively to (1) determine the kinds of problems that occur with rapid growth, (2) to identify critical factors in the rapid urbanization process that determine the severity of impact, and (3) to identify potential reactions to the urbanization process. In total, the case histories studied provide a broad perspective of a range of experiences. However, the diverse focus of these studies meant that distributional issues were often not addressed. Therefore, to overcome some of the data deficiencies, local government officials, elected and appointed, and energy company planners were interviewed and readily available data sources were consulted. Field trips were made primarily to gain an overview of present energy development activities and to determine pertinent community issues.

Census data for 1970 was used to provide the necessary base for examining basic theories of the effects of rapid growth. A much higher level of research funding would have been necessary to gather (on a uniform basis) and analyze more recent data.

The primary site selected for analysis to illustrate boom-town impacts was the town of Gillette in Campbell County, Wyoming. Gillette/Campbell County was chosen for two reasons. One, it is a community that has experienced a boom from energy development (oil and gas production). Two, it is an area likely to undergo further rapid growth as a result of other forms of energy development (coal mining, coal conversion to gas/liquid fuel, and electric power generation).

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*See, for example, References 2 to 8.

1. Growth Process and Population Trends

Over the past two decades, Campbell County has been transformed from a region with ranching as a primary economic activity to a region dominated by energy development activities. Gillette has grown from a small agricultural service center to a larger residential center for employees from the oil fields and coal mines. This transformation has left the town with many characteristic boom-town problems--a very tight housing market, overcrowded schools, high demand and poor supply of social services, and cultural conflicts between the long-term agricultural population and the new community of miners and construction workers.

Between 1960 and 1970 Gillette's population doubled (from 3600 in 1960 to 7200 in 1970). Population in early 1976 was estimated at approximately 10,000. Campbell County's growth rate has paralleled Gillette's growth (Table 4-1).

Table 4-1

GILLETTE/CAMPBELL COUNTY POPULATION TRENDS

	1940	1950	1960	1970	1976
Gillette	2177	2191	3580	7194	10000
Campbell County	6048	4839	5861	12957	17000

Sources: Census, 1960, 1970
Planning Dept., Gillette (1976 figures).

Changes in the population structure have been as significant as the changes in size. The change in age distribution is immediately apparent from Figure 4-3. The median age in Campbell County dropped from 29 in 1950 to 27 in 1960 to 23.4 in 1970 (the median age in both Wyoming and the United States was 27.2 in 1970).

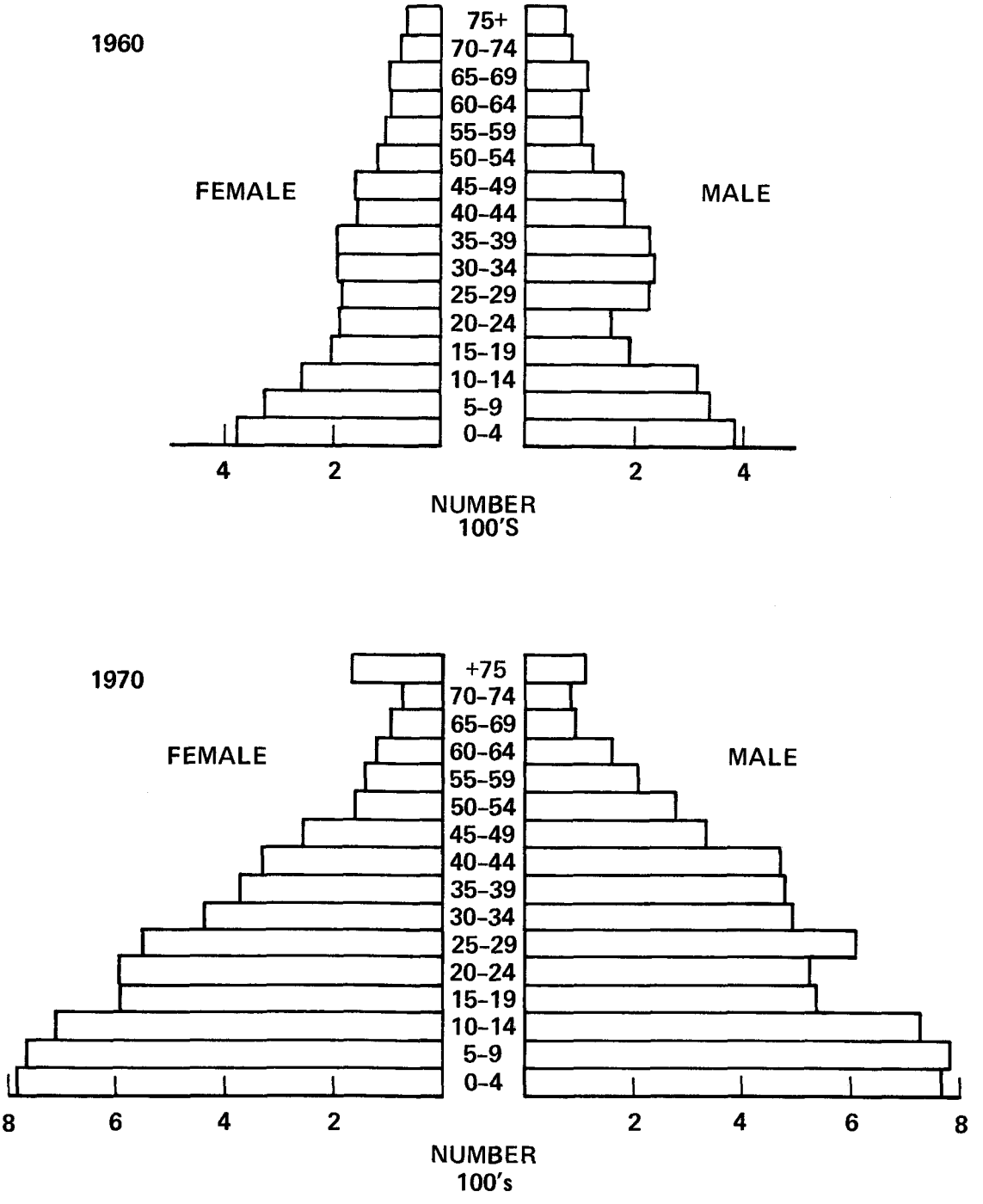

FIGURE 4-3. AGE GROUP PROFILES OF CAMPBELL COUNTY, WYOMING, 1960 AND 1970
THE CHANGE IN AGE STRUCTURE OF THE POPULATION IS READILY APPARENT

This change in the age structure represents a major change in the development patterns of the county. For much of the twentieth century Campbell County had a small, stable population engaged in agricultural activities. Occasionally, impermanent energy exploration projects brought a few small population increases and declines,[2] but the average population started a steady trend upward only after 1950. The age distribution of the population in 1960, shown in Figure 4-3, and an earlier history of moderate stability and decline indicates that through the early part of the 1950s many of the young adults left the community. This trend began to reverse in the 1960s and it is apparent from Figure 4-2 that by 1970 the county was characterized by a new type of development with long-term implications. Campbell County had experienced a growth increase much greater than any previous rate of increase, and many more younger people were remaining or moving into the county. The social and cultural changes that followed this growth and the lag in accommodating to this growth have caused many of the problems that Gillette and Campbell County face today. The following sections explore how these problems arose and the relationship of these problems to the industrial expansion.

2. Energy Industry in Campbell County

The expansion of the production of energy resources in Campbell County is responsible for the major employment increases since 1960. Table 4-2 shows the sizable employment increase in the mining sector in Campbell County between 1950 and 1970. In 1970, this employment represented mainly employees in oil drilling. Since 1970, coal strip mining activities have added several hundred more mining jobs to the county.*

The shift to mining as a significant economic base has affected other aspects of the economy of Campbell County. Employment in secondary

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*Conversations with city officials and officials of AMAX Company's Bel Ayre Mine.

Table 4-2

EMPLOYMENT IN CAMPBELL COUNTY, 1950-1970

Year	Agriculture	Mining	Construction	Manufacturing	Communications, Utilities & Transportation	Trade	Services	Total
1970	601	1323	268	156	455	1448	552	4803
1960	670	258	189	18	132	640	294	2277
1950	912	57	150	25	11	452	208	1919

Sources: U.S. Bureau of Census, Characteristics of the Population, Wyoming, 1950, 1960 and 1970.

industry, wholesale and retail trade, services, and public administration also has increased. The proportion of secondary and service sector jobs to basic jobs has increased substantially from 1950 to 1960 and 1970. Between 1950 and 1960, when the number of basic jobs did not change substantially, there were major increases in wholesale and retail trade, in communications, public utilities, and transportation,* and in social services. From 1960 on, the proportion of service and secondary jobs to primary jobs has remained fairly constant (at 1.2 or 1.3 if construction is considered a secondary job).

The economy in Campbell County, then, as is true in much of the United States, is providing more services per capita population than it did 25 years ago. This has implications for the amount of population growth induced by the expansion of primary jobs in the county. Campbell County's population increase between 1960 and 1970 was six times as great as the net increase in jobs in agriculture, mining, manufacturing, and construction.

The basic employment growth in Campbell County in the past ten years has been associated with resource extraction industries. By their nature, these industries have many boom-inducing characteristics. For example, oil and gas production and coal mining inevitably depend on the location of the natural resource. A company wishing to exploit the particular resource must locate its workers within the region of the resource. In Campbell County, resource development is being carried out within the central portion of the county, so that most population growth from these

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*Much of the large increase in employment in this category is closely related to the increase in industrial activity rather than (as are most of the "services") to an increase in demand from the population. Theoretically, then, some of this growth could be counted as part of the primary job sector. However, the purpose here is to highlight the total number of jobs created by the basic industry itself. For this purpose, subsidiary industries are considered to be part of the secondary employment generated by industry growth, except where subsidiary employment figures are included as part of the basic employers' estimate of employment levels.

activities has occurred within the county (primarily in and around Gillette) rather than in the larger cities of Sheridan and Casper, to the west and to the south.

Large employment increases are associated with both the construction and operation periods of those activities. Many more construction workers are required to build these resource development facilities than are available or than are demanded on a continuous basis by the community. The extraction operations for both oil (and gas) production and coal mining require many more workers than would ranching over a similar area. In addition, these activities require a very different skills mix than did previous economic activities in the county.

Finally, there is a large element of uncertainty over the future activities of these industries in the region. Some of these elements are described in a State of Wyoming report on coal development in the Powder River Basin.[2] The most striking include uncertainty over the demand for these products and uncertainty about industrial plans.

While it seems certain that oil, gas and coal will continue to play an important role in the United States and in the world economy, demand for these products from specific regions is more likely to fluctuate. Changes in the price of imported oil, changes in environmental regulations related to the use of high sulfur coal, and technological changes (from new methods of extracting sulfur from coal to new types of power generation), can induce a change in the demand for western energy resources. It is difficult to obtain long-term projections for these resources, and even more difficult for a community to rely on projections that it can obtain.

This uncertainty cannot be avoided even over planning periods that would be considered brief for these industries (e.g., 10 years). Even those energy companies that are very open about their energy expansion plans are uncertain about their future investments in the region. For example, the Wyoming State Department of Economic Planning and Development survey of energy company plans for Campbell County between 1974 and 1985 indicates an uncertainty of 4395 primary jobs in the energy industry,

from a low estimate of 1392 jobs (considering only projects where contracts are signed or in preparation and plans have been publicly announced) to a high estimate of 5757 (which includes developments currently under consideration by the energy companies but whose realization is indefinite).*

3. Energy Industry Impacts on the Local Area

The energy industry, through inducing growth in jobs and a concurrent growth in population, has been accompanied by many of the impacts previously mentioned as typical boom-town problems. Those currently most prevalent in Campbell County include (1) a very tight housing market, especially in rental homes and mobile homes, (2) need for new waste water treatment facilities, (3) increases in public agency responsibilities, (4) health care service shortages, especially of dentists and medical specialists, (5) shortages in retail goods and services combined with an increase in the cost of living, (6) major changes in the social and cultural character of the community, (7) aesthetic blight and uncontrolled sprawl, and (8) an inequitably high burden on portions of the pre-boom population which do not participate in the economic benefits of growth. Until recently, capacity of public schools was also below that needed by the incoming population, and medical facilities were considered to be in short supply.

The Housing Market--The tightness of the housing market is often the first problem mentioned by public officials in Campbell County as a companion of growth. It is manifested in several ways: high costs for both rental and owner-occupied housing, extremely low numbers of vacancies in rental housing, an abnormally high reliance on mobile homes as a lower cost alternative to standard housing, and high costs and low vacancy rates even within the mobile home market.

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*Reference 2, p. 45.

By 1970, the median housing value in Campbell County ($20,700) was well above the median housing value in the United States as a whole ($17,000). Such high housing values continue to be reflected in the cost of housing. A small three-bedroom home, with 1000 square feet of space in Campbell County, would cost approximately $45,000.* A similar home in a noninflationary but still growing community (for example in the communities of Kansas City, Missouri, and St. Claire County, Illinois), would cost $25,000 to $30,000.†

Many of Campbell County's new residents have turned to mobile homes as an alternative to permanent dwellings (Figure 4-4). Before 1960, single family permanent dwellings were the dominant housing type in the region (78 percent) and only a small fraction (11 percent) was mobile homes. Between 1960 and the present, well over 50 percent of the newly added housing was in the mobile home category.‡

The purchase price of mobile homes can be as high as a single family home in some other regions of the country. The purchase price of the unit may range from $12,000 to $24,000, and a lot within the city limits may cost an additional $7,000. Financing payments on mobile homes are less than payments for new single family homes ($350/month over 15 years for mobile homes compared with $450/month over 30 years for single family homes in Gillette).§ In addition, property taxes are lower on mobile homes than on permanent dwellings. This is due not only to comparative market values of mobile and permanent homes but also to differential assessment practices, which allow for yearly depreciation on mobile homes and yet assume that permanent homes appreciate in value over time.§

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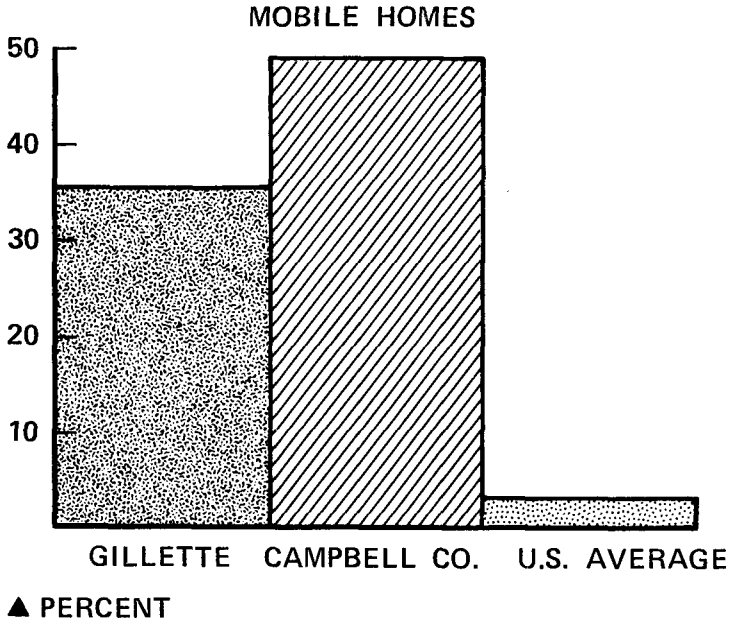
*Quoted by members of the City-County Planning Department.
†Chamber of Commerce, Kansas City Metropolitan Area; St. Claire County Planning Department.
‡U.S. Census of Housing, 1960, Wyoming, p. 52-22.
Cost data supplied by the City-County Planning Department, Gillette, Campbell County.
§County Assessor's Office, Campbell County, Wyoming.



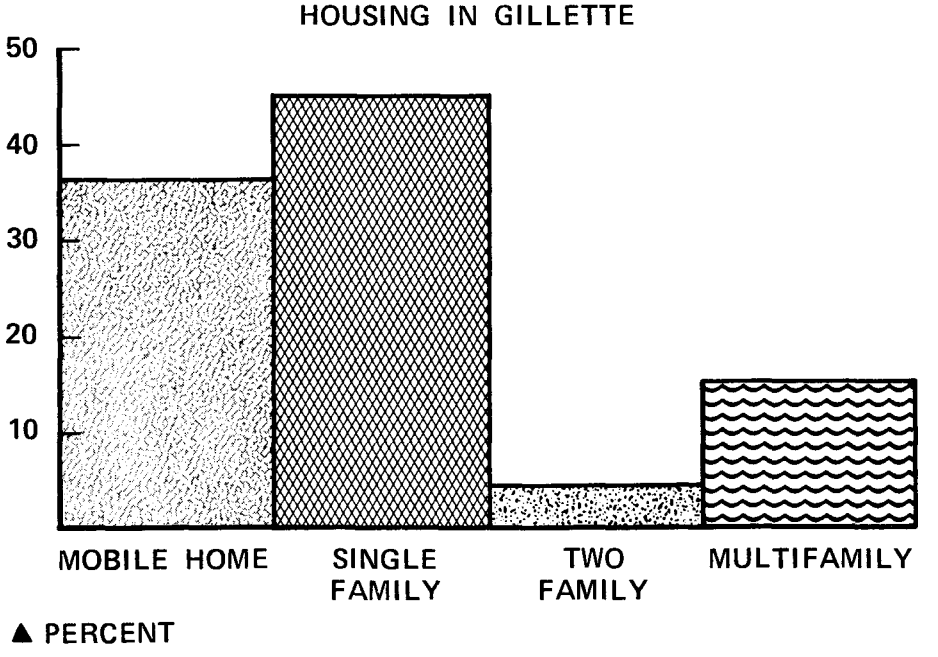


FIGURE 4-4. MOBILE VERSUS PERMANENT HOUSING: CITY OF GILLETTE AND CAMPBELL COUNTY, WYOMING

Despite the local housing trend toward quickly assembled, "temporary" units, overall the community has a very low vacancy rate. The vacancy rate for owner-occupied housing is similar to that in much of the rest of the United States--between 1 percent and 2 percent. However, the high cost of this type of single family housing appears to have deterred many potential buyers,* and they have turned to alternatives. Vacancy rates are extremely low in the alternatives to owner-occupied single family housing. While in the nation as a whole the rental vacancy rate is about 6 percent, in Gillette the rental vacancy rate is less than 1 percent and a similar vacancy rate prevails for mobile homes. Even when mobile home units are available for sale, developed lot sites are not available.

Uncertainty in the industry and the relative isolation of the community are two factors which make it difficult to obtain financing for new housing. Developers are reluctant to build in advance of demand because they have no assurance that the boom in employment will continue and because there is little prospect of alternative sources of employment moving into the region to maintain the current level of growth if a recession occurs in the energy industry. Developers willing to accept the risk of a premature bust in the industry may be unable to find financing for such an investment.

Even were financing available, housing costs would be high due to high construction costs. Both labor and materials must be imported from outside the county. The cost of labor will be high because of the competition for the scarce skilled labor and the benefits a company must offer to import labor to a remote region.

Most of the new housing that has been built in the area was financed by the energy companies. Further housing construction is planned

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*Many people living in mobile homes have indicated that they would move to single family permanent homes if more choice in terms of cost or location were available. See Reference 5.

by these companies. For example, ARCO is currently planning a housing and mobile home development in Reno Junction, south of Gillette. So far, efforts on the part of the energy companies appears to have reduced the severity of the housing problem, but it is far from being eliminated. Current efforts at providing housing are directed at matching current supply, rather than at overcoming other problems that have been created by the housing shortage (such as the price of housing). Present plans are to sell new housing developed or financed by the energy companies at current market prices in the area.*

Waste Water Treatment Facilities--Because of soil conditions in Campbell County, the population increase has meant that the county (especially the city of Gillette) must develop an entirely new system of waste water disposal. The city of Gillette applied for and received an EPA grant to fund a new facility. This is now under construction. The facility was designed to have excess capacity, but the city now projects that, because of further population growth, by the time the facility is completed, its entire capacity will be needed.† It may be difficult to obtain outside funding in the short run for new facilities; therefore the facility will be completed just as a new problem in waste disposal begins.

This service lag problem has several sources. First, the natural disposal capacities of the soil are inadequate for an urban settlement. Second, the city has had to provide an entirely new system, rather than just additional increments in an existing system, to cope with growth. Third, the local government felt that the community's tax base was inadequate to finance this growth. The city has therefore had to turn to outside funding sources. The process of obtaining these funds has been a long-term effort.

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*Conversation with ARCO Community Planning Staff, Denver, Colorado.
†Mayor Eni, Gillette, Wyoming.

In the interim, the effects of this service lag are apparent in both current housing capacity and visually in present settlement styles (from the location of housing to visible evidences of poor drainage). City officials are still uncertain whether the community will have either the ability or the willingness to finance this service for further increments of growth.

Public Agency Responsibilities--The number of employees in local government in Gillette has increased by a factor of 5 since 1960.* The increase in demand for services from the public sector has led to an increase in the responsibilities of public agencies. Government has become more complex with a larger number of employees and a wider variety of jobs. In 1960, the city government was a skeletal structure, with only a few essential jobs covered--city clerk, city superintendent, and police. Since that time, two more departments have been added--planning and administration--and the number of employees in each department has increased.

This major increase in administration and planning efforts shows an awareness in the city of the need for anticipating directing future growth. This need has begun to be met by the city, several years after rapid growth became a major problem. Many of the programs are in the midst of development. The planning department, for example, started in 1974.

Health Care Services--Shortages in health care services plague many rural areas. Communities often view improved health care services as one of the benefits of urbanization. However, these improvements have lagged behind growth in Gillette. In 1976, several doctors moved into Campbell County. In addition, a bond issue for a new 80-bed hospital was approved. However, medical care from dentists and specialists remains a problem, one which probably will not be solved at existing levels of urbanization.

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*City Budget Department.

Isolated rural areas often have difficulty attracting medical personnel. Neither population growth in these rural regions nor an increase in regional income has guaranteed that more dentists, physicians, or surgeons will move into the area. Climate, cultural activities, social settings, and high levels of urbanization all seem to be much more effective means of attracting specialists in the medical profession into a region.* Thus the boom community is likely to face this as a long-term problem. Shortages in medical personnel fluctuate, but they can be severe during some periods of the rapid growth phase.

Retail Goods--The effects of growth on retail trade in the region have been mixed, from the point of view of the local residents. Certainly, a greater variety of goods and services are available within the city and county compared with pre-boom days. However, prices for retail goods in the county are high and many items must still be purchased elsewhere.

For daily needs, such as food and entertainment, Gillette acts as a closed economy in an inflationary situation. Other service centers of comparable size or larger (such as Sheridan and Casper) are more than an hour's drive from Gillette (Figure 4-5). The two closest towns of the next size--Sundance and Buffalo--are each 60 miles away. Because the future population of Campbell County is uncertain, new businesses have moved into this apparently profitable situation more slowly than might otherwise be expected.

Character of the Community--Perhaps the longest lived impacts of the industrialization process are the cultural and social changes that occur in the community.[1] In Gillette, these changes are most

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*There is a wide body of literature on this subject. See, for example, References 9 to 14.

apparent in the changes in traditional rural social institutions and the changes in attitude toward government.

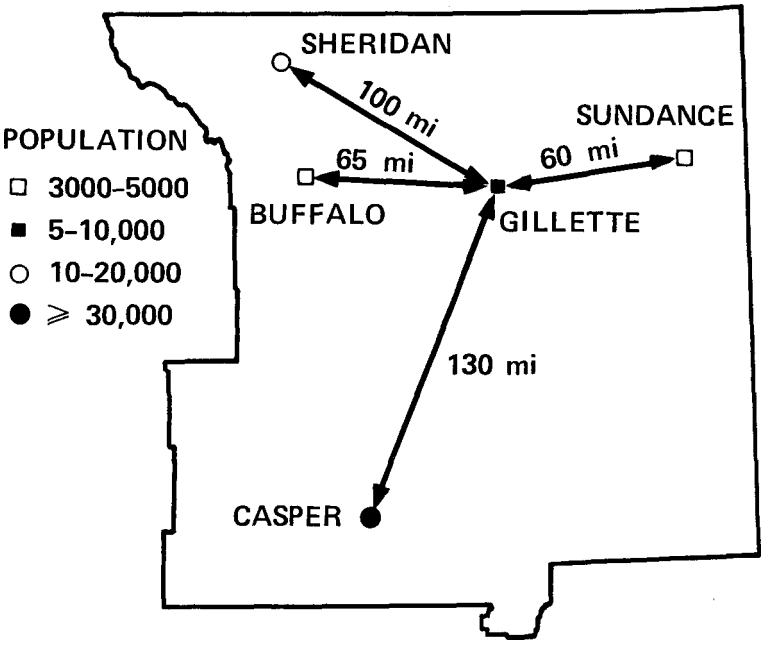

FIGURE 4-5. DISTANCES FROM GILLETTE, WYOMING

Some visible institutional changes are changes in the roles of local retail outlets and changes in the roles of social and welfare institutions. Until the rapid growth trend began in the 1960s, the dominant retail trade activity occurred in Gillette's downtown area. Small shops served in secondary roles as places for community contact. This service of the local store has broken down as the result of the rapid growth and turnover in population.

The declining informal institutions have been replaced by formal services. For example, the community now has a recreation center, financed by the county. It also has welfare and counseling programs; these services are often in high demand.

Blight and Sprawl--The rapid growth of the region has caused steady deterioration in the visual quality of the local communities (particularly Gillette and its surrounding residential area). Growth has occurred in an environment of no planning and no management, not even to the extent of using basic civil engineering services for determining road and utility improvement needs. Street improvements have lagged far behind the buildup of many new residences, and there is little upkeep of older city streets. House construction concentrates on minimal needs, and landscaping lags far behind housing construction. Finally, there appears to have been very little development of public open space. Gillette and Campbell County have chosen to fulfill other, more essential, needs first. Efforts at internal community organization have preceded those at landscaping the exterior.

However, some steps are being taken, as reflected in development regulations, to induce private developers to provide amenities. These concern mainly open space provisions. Furthermore, the planning department is encouraging building permit controls that would concentrate development around the city of Gillette and reduce the tendency toward uncontrolled, sprawled development at the periphery of the city.*

Burdens on Older Residents--In any boom community, who pays for growth becomes an important issue. Despite the lack of tangible, measurable evidence, the pre-boom residents of Gillette and Campbell County who have not benefited from growth are paying proportionally more for community growth than are many of the newcomers who most benefit from that growth. This can be seen by looking at what happens to the older segments of the population as the community grows.

First, as we have seen in Figure 4-2, the long-term community residents tend to be older than the newcomers to the community. A large portion of the long-term population will not be employed in the new

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*City-County Planning Department.

industry. A few shop owners benefit indirectly, through increased trade, but the majority, basically a ranching population, will receive little of the new money flowing into the community, unless they sell their land interests.

Long-term residents who stay in the community will experience the costs of this growth as members of a social group, as participants in the local economy, and as property owners.

First, long-term residents have little choice but to experience the changing character of the community, including the loss of informal networks and the visual evidence of urban sprawl.

Second, this group is faced with higher prices, both for hiring labor and for purchasing household goods. Even unskilled workers can find higher paying jobs with the mining companies than with their previous places of employment--ranches or local stores. Ranchers, small business owners, and people on fixed incomes find it harder to switch jobs, however, and face rising prices in the community without a parallel rise in income.

Third, a large proportion of the financial burden for the growing community is likely to fall on the long-term residents. This follows from the financing system in Gillette and Campbell County. Most of the cost for new services is recovered from property owners. Older residents are likely to own property that is assessed at a higher value than that owned by newer residents. This is particularly true of residential property. Most of the new residents in the community live in mobile homes, while many of the older residents live in permanent dwellings, which they have owned for many years. Permanent homes, despite their age, are likely to be assessed at a much higher rate than new mobile homes.* Thus, long-term low income residents find their taxes increasing to pay for services such as schools, recreation, and public administration, which are primarily used by residents with higher incomes who live in less expensive housing.

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*Campbell County Assessor's Office.

The total tax bill for residents can vary enormously depending on the taxing jurisdiction. Counties that have energy activities within their taxing jurisdictions may be able to maintain low taxes for residential property owners. In that case, long-term residents may still be paying more of the tax bill than their newer counterparts, but the total bill may be small. However, in the city of Gillette, and in counties that receive the growth but not the tax income from energy developments, tax bills may suddenly become extremely high for the long-term residents of the area.

Gillette and Campbell County illustrate both the problems and some of the potentials of a community that is undergoing rapid urbanization. Whenever possible, the city and county governments have tried to increase services to all sectors of the population. Early reaction to projected schooling needs and construction of a recreation center and a new hospital facility are examples of the benefits that can accrue to a growing community. However, when the population has relied solely on private development activities to satisfy needs, new growth has been characterized by high costs and a supply that lags demand. If this type of development continues and the community maintains its "temporary" character, it is likely to lead to high population turnover rates and continued strain on the social fabric of the community.

4. Variations in Growth Problems

Gillette's experience of energy development is fairly typical of experiences throughout the western energy states in both the Northern Great Plains Region and the Four Corners Region of the United States (see References 1, 15, and 16). However, there are some variations in this theme, both in the types of problems that occur and the basic development situation.

Negative effects may be exacerbated when the community has little control over or contact with the basic economic activity. For example, Sheridan, Wyoming, is experiencing spillover effects from mining activities in Montana. It has many of the problems described for Gillette and Campbell County without any of the tax base increase provided by the

industry.* In Colorado's Garfield and Rio Blanco Counties growth in anticipation of a boom has repeatedly been followed by bust, as oil shale development speculation varies. Recent booms have led to development problems (e.g., illegal mobile home developments) on the outskirts of small communities in the region, yet the prospect of energy company money to cope with these problems is dwindling as companies abandon recent oil shale development projects.†

Rapid growth communities can benefit under some circumstances. In Tullahoma, Tennessee, for example, development of an aeronautical research center, which was projected to have a long life span, brought in a group of employees who became active in community development issues and successfully supported moves to improve the educational system and medical care in the local community. Because the burden of these services was not passed disproportionately to the older population, the general assessment of the impacts of the project seems to be positive.[3]

A similar situation seems to be developing around the Monterey Coal Mine in Macoupin County, Illinois. Here, many of the new jobs have gone to local residents, so that the population growth rate is slower than in other energy development communities. In addition, several of the new residents working for the company have taken a lead in improving medical services in the county, by supporting a bond issue to build a new medical facility and by funding efforts to attract more medical personnel to the county.‡

5. Conclusions from Experience in Campbell County

The experience of Gillette and the rest of Campbell County, as in many other energy development towns, provides evidence that the rapid development of a resource base can have serious social and economic

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*Wyoming State Department of Economic Planning and Development.
†ARCO, for example.
‡Conversations with Monterey Coal Mining Officials and state-funded regional planning staff in Carlinville, Illinois.

impacts on the local communities. Several characteristics of the situation seem to support negative impacts. These include:

- The original size of the community: small communities are particularly prone to many of the boom-town effects identified here.
- The size of the industry in relationship to the size of the community, and its dominance over all other local economic activity.
- The attitude of the new residents toward the community: new workers view their residence in Campbell County as impermanent, and thus feel little responsibility toward participating in its development.
- The isolation of the community from larger urban centers.
- The reluctance of communities to invest in public services in advance of growth.
- The uncertainty of energy company development plans.

Several factors may support the argument that negative impacts are outweighed by benefits of growth. First, some members of the original community receive higher wages as the community grows. Their job opportunities increase and they are no longer tied to low paying agricultural or retail trade jobs. Second, some property owners receive large windfall benefits through leasing surface rights to energy companies. Third, many of the problems that exist in boom communities also are shared by regions that have no energy development activity. Tight housing markets and higher priced public services are problems shared by many different kinds of communities.

These are valid points, but they need not change the basic conclusions. The fact that some people benefit to some degree from growth does not contradict the findings that the distributional impacts may be inequitable or that the total net costs to the community may be high. The fact that fiscal problems may also occur in other kinds of communities, for other reasons, does not imply that these are in consequence less of a problem.

Our original conclusions can be supported by the argument that the consequences of boom-town growth are neither an efficient development of community resources nor an equitable distribution of these resources. As long as state and local governments agree on this assessment of the problem, they will use the means available to them to redirect resource development toward different goals.

E. Growth Impacts of the Minemouth Scenario for the Synthetic Fuels Industry

The impacts of present mining-related growth on Campbell County are minor compared with those that could occur if the synthetic fuels industry were built up in the West at the rate calculated by the model for the Minemouth Scenario. Within this scenario, between 1975 and 2000, 80 plants (synthetic fuel and electric power) would locate in Campbell County, 40 other plants would locate in the six counties contiguous to Campbell County in Wyoming, Sheridan, Johnson, Natrona, Converse, Crook and Weston counties, and local strip mine operations would provide coal for these plants and for export. (This assumes that plants locate in counties in proportion to the amount of coal reserves available in each county.)

The population growth that could occur from this rate of development is illustrated in Figures 4-6 and 4-7.* Figure 4-6 shows the population that would occur in Campbell County if all population growth associated with industrial development occurring in the county also took place within the county borders. Campbell County would grow from 17,000 to 700,000 by 1997, and then drop back to about 670,000 by 2000. If this occurred, the county would sustain a growth rate of about 16 percent a year, for 25 years. This is an extremely rapid rate of expansion.

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*These growth projections assume the plant employment levels described in Appendix J, and a total population multiplier of 6.5. Background to population multiplier estimates is provided in Appendix H. Figures 4-6 and 4-7 were prepared using the small scenario impact generating model described in Appendix J.

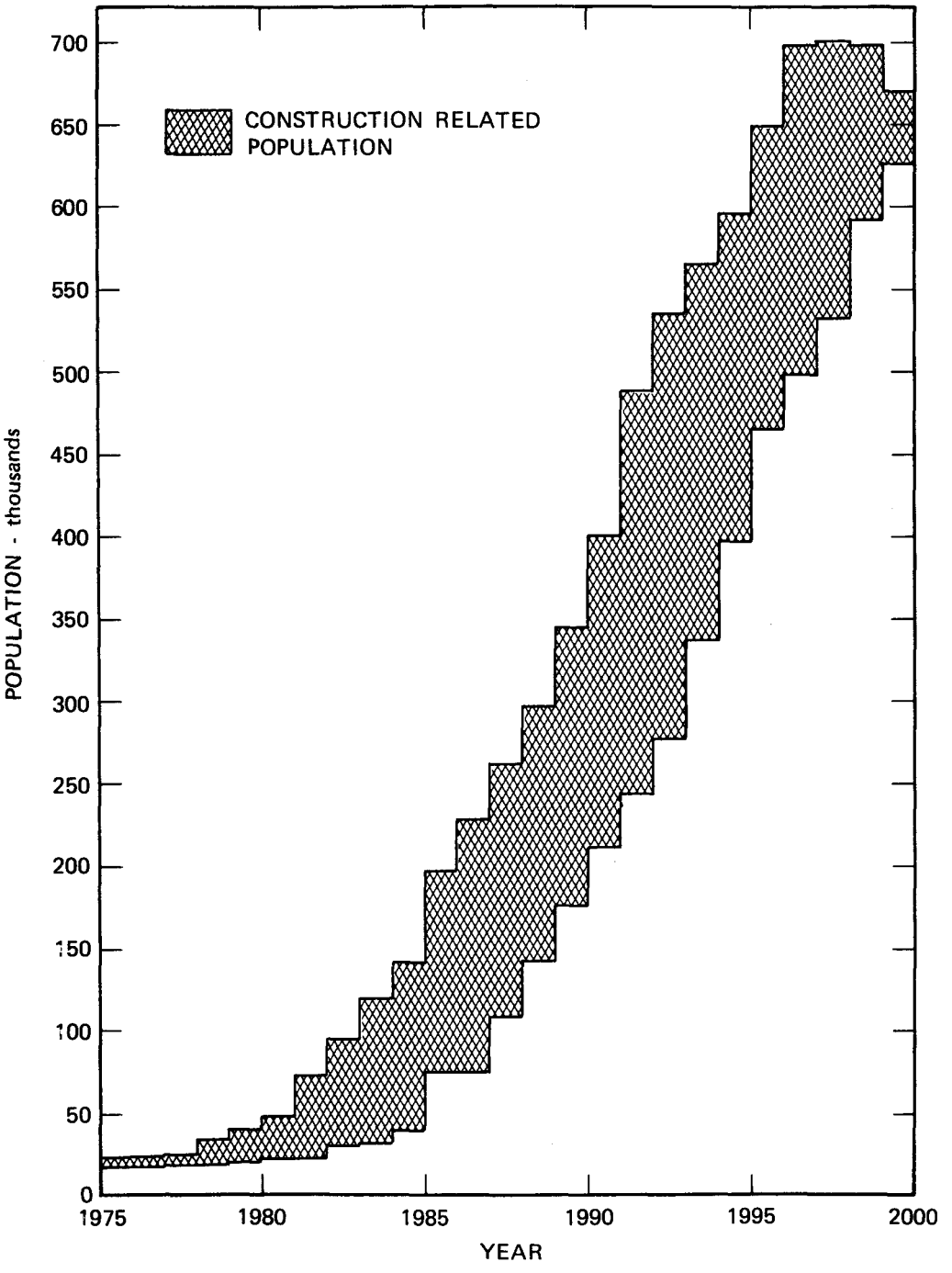

FIGURE 4-6. MINEMOUTH SCENARIO POPULATION GROWTH: CAMPBELL COUNTY, WYOMING

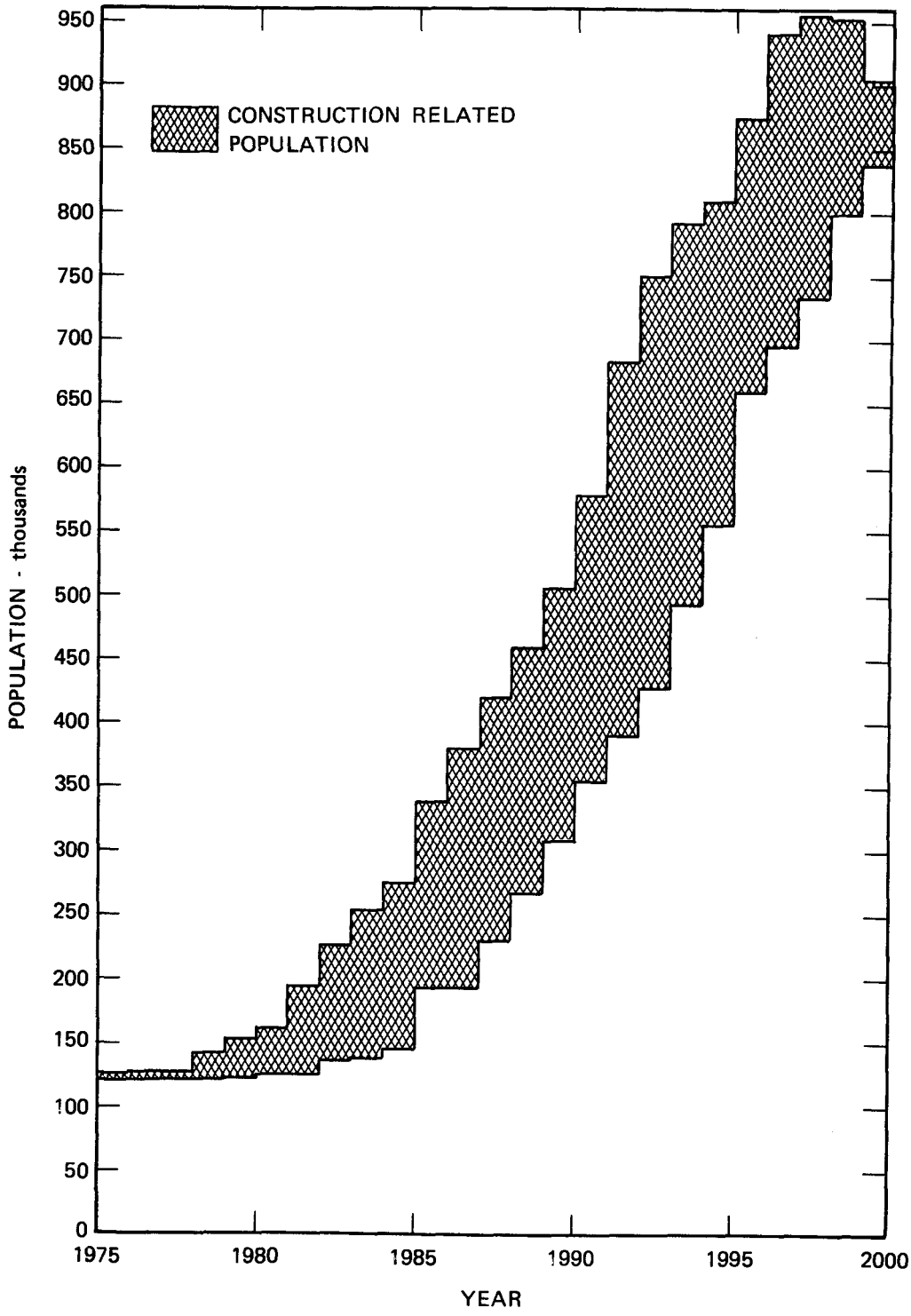

FIGURE 4-7. MINEMOUTH SCENARIO POPULATION GROWTH: SEVEN COUNTIES CENTERED ON CAMPBELL COUNTY, WYOMING
CAMPBELL, CROOK, CONVERSE, JOHNSON, NATRONA, SHERIDAN, WESTON

In fact, a substantial portion of this population is likely to locate in contiguous counties. Figure 4-7 shows the population growth picture for the northeast region of Wyoming (Campbell, Converse, Crook, Johnson, Natrona, Sheridan, and Weston counties), if it is assumed more realistically that the location of new population related to the industry's growth is only limited by the commuting distance to the area of industrial activity. The region would grow from 120,000 in 1975 to 911,000 in 2000, with a peak of 956,000 in 1997. This would be a sustained growth rate of almost 9 percent per year for 25 years, on average throughout the region. Growth is likely to concentrate around existing population centers, such as Gillette, Sheridan, Casper, Sundance, Buffalo, Douglas, and Newcastle, with the three largest centers, Gillette, Casper, and Sheridan, receiving the most growth.

These population centers are likely to experience growth rates of 10 percent per year or higher, over the 25-year period, and thus would grow by a factor of 10 or more during this time. Presently, these communities are unprepared either to provide the work force for or to absorb the population associated with even one synthetic fuel plant. Table 4-3 gives population estimates for the region in 1976. Table 4-4 contains information on housing stock and availability in the three largest counties, and Figure 4-8 shows work force availability in these counties compared with work force demands by different types of synthetic fuel plants.

Table 4-3

1976 POPULATION ESTIMATES FOR NORTHEAST WYOMING

County	Population
Campbell	17,500
Converse	8,700
Crook	5,200
Johnson	6,900
Natrona	62,500
Sheridan	19,300
Weston	6,100

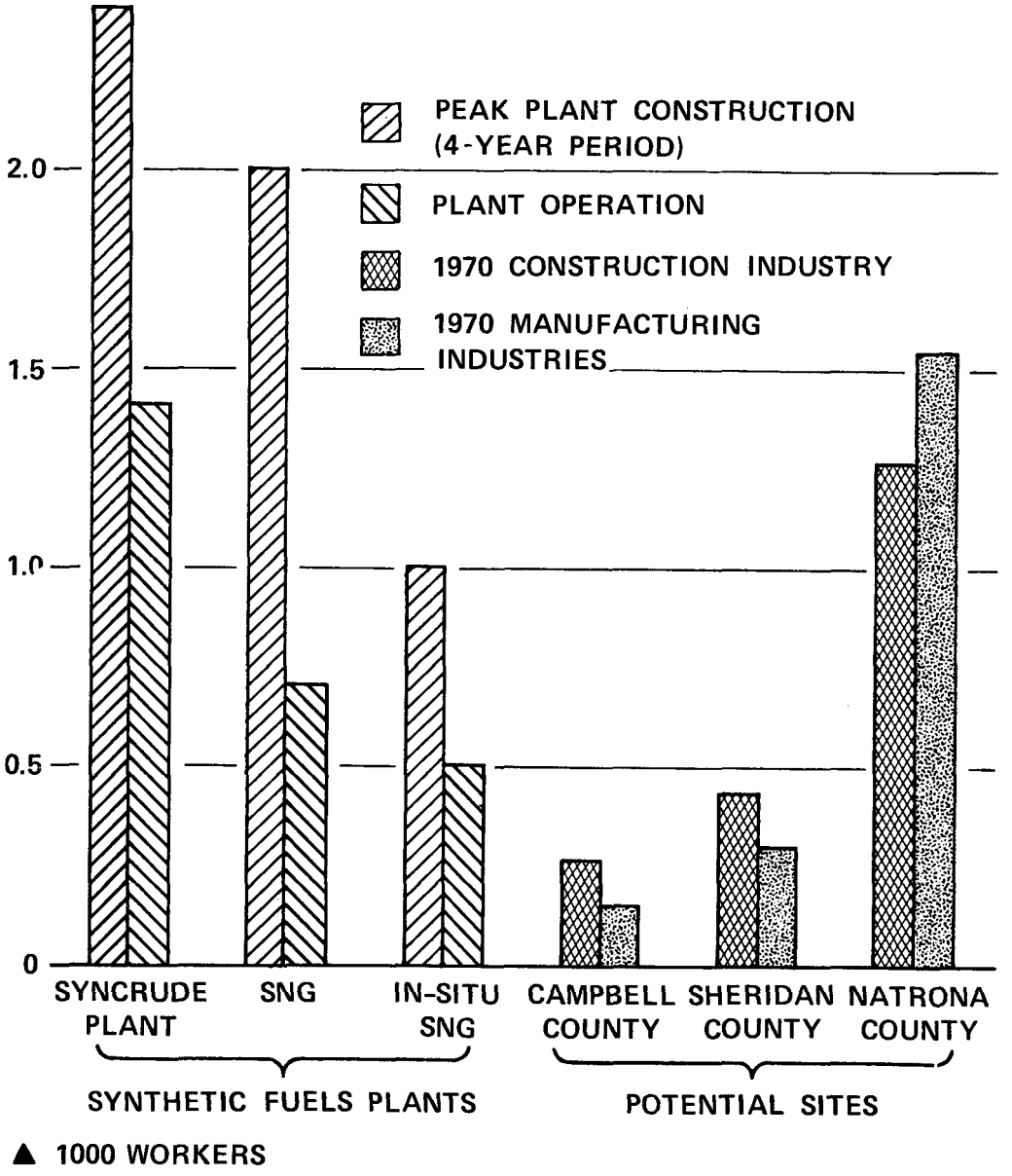

FIGURE 4-8. WORK FORCE IN CONSTRUCTION AND MANUFACTURING: WYOMING COUNTIES

Table 4-4

HOUSING AVAILABILITY, 1970

County	Total Units	Median Housing Values ($)	Vacancy Rates (%)	
			Homeowner	Rental
Campbell	3,900	20,700	1.0	1.5
Sheridan	6,800	14,000	2.4	8.5
Natrona	17,000	17,100	1.3	7.6

These statistics illustrate the poor capacity of the region for absorbing industrial growth. The existing communities are small compared with their projected future size (Table 4-3). The work forces needed for synthetic fuels industries is not presently available in these counties. Figure 4-7 shows the present work force employed in each county in all construction and manufacturing activities, compared with the work force required for three different types of synthetic fuel plants. This comparison indicates that even a single plant in the region would have to import the majority of its employees.

However, as Table 4-4 indicates, there would be little housing available for new residents in these counties. A single syncrude plant, ignoring both support activities (including strip mining) and employment generated in secondary services, would bring in about 1400 families during its operating phase. Of the three counties mentioned in Table 4-4, only Natrona County would be likely to have the number of vacant housing units that would be required by this population. However, the available housing units would not necessarily be suited to the needs of the new population.

The Minemouth Scenario level of growth of the synthetic fuel industry would lead to a tremendous rate of growth in the entire northeastern region of the state. There are currently no indications that local communities, the state, the federal government, or private industries are prepared to cope with the demands that would be placed on the local region by this rate of growth. Furthermore, by the end of the 25-year period,

employment in the industry will begin to decline. This will create either high unemployment ratio or a sudden decline in property values and community finance capacities, as people leave the region. Without some kind of "coping mechanism" the region is likely to experience all of the worst problems of a rural area that has grown too fast and an urban area that cannot meet the needs of its residents.

Coping programs would be difficult to implement at this scale. The new growth would be equivalent to building a new city for 800,000 people (or several smaller cities for 100,000-200,000 people). This is an event which has rarely been accomplished in world history in a previously un-urbanized area. Such development can be extremely expensive. It requires a high degree of centralized planning, at least at the state level, which is currently nonexistent in the United States.

These impacts would be greatly reduced if the industrial development took place in much larger communities. This is evident from looking at the current growth absorbing capacities of the Omaha and Kansas City SMSAs.

Again, looking at three indicators: population, housing availability and present work force, the contrast to the small places previously discussed is apparent (see Table 4-5 and Figure 4-9). Both metropolitan areas have large work forces, which could provide at least some of the labor required by the synthetic fuels plants. In addition, the basic housing stock is much larger than that which is available in northeastern Wyoming. Vacancy rates are relatively high and costs relatively low, compared with both the western coal region and the country, on the average.

Industrial location can be an opportunity rather than a burden to large urban areas by providing employment for the local population and increased economic diversification for the region.

F. Redistributing Industry to Reduce Impacts: Community Characteristics

The conclusions from Gillette's experience have direct relevance in planning the distribution of the synthetic fuels industry throughout the

Table 4-5

POPULATION AND HOUSING AVAILABILITY,
KANSAS CITY AND OMAHA-COUNCIL BLUFFS SMSA's, 1970

	Population	Total housing units	Median housing value($)	Vacancy Rates (%) Owner occupied	Rental
Kansas City	1,254,000	436,000	16,000	1.4	10.2
Omaha	540,000	174,000	15,000	1.1	7.9

Source: U.S. Census of Population and U.S. Census of Housing, Summary Volumes, 1970.

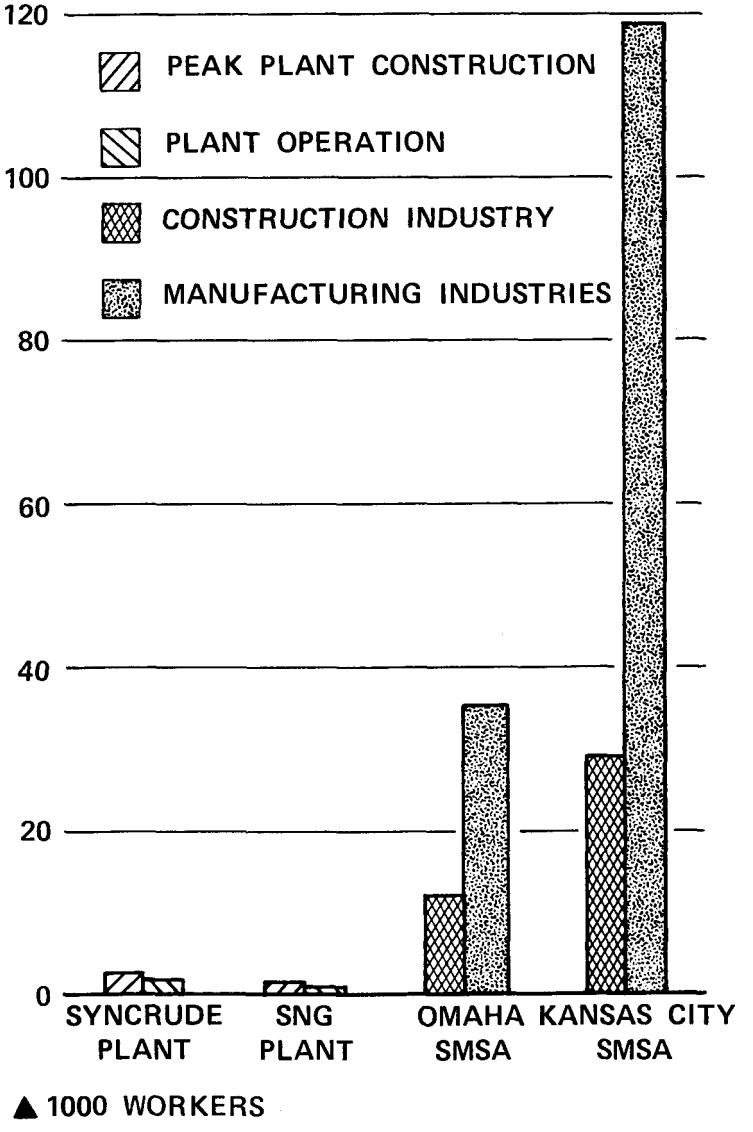

FIGURE 4-9. WORK FORCE IN CONSTRUCTION AND MANUFACTURING: OMAHA AND KANSAS CITY

nation. Demographic, economic, land use, social service, political-administrative, and attitudinal characteristics of a community can all be factors critical to determining the local impacts of a large industry. The implications of each characteristic for site suitability are described below.

1. Population

The kind and degree of social impacts of a fuel conversion plant are closely related to the characteristics of the population already living in the surrounding community. The greater the difference between the incoming population and the local residents, the more likely it is that conflicts will arise. (See Reference 1, Chapters 21 and 23, and Reference 17 for a discussion of these conflicts.) The magnitude of these conflicts, and, in general, of the new demands on the community structure will be directly related to the size of population increase, relative to the size of the long-term population in the area.

Existing Population Size--The degree of change induced by introducing a new industry into a region is a function of the size of the base population of the recipient region: 15,000 new people cause a major change in a town of 10,000. This number of new people in a city of 200,000 could still cause change but of much lesser degree. In the first case, the population influx could be sufficient to bring rapid urbanization to a sparsely populated area. Changes in service structures are necessary when a small rural town must provide urban services for its new population. In the second case, basic urban services can be expected to already exist. Although the new population would increase the demands for services, there would be no need to change the community structure to accommodate these demands. Thus, in the main, there would be fewer major social impacts if fuel conversion plants were located in more populous areas.

Population Growth Rate--The rate and direction of change may be as important to a community as is its present situation, as is demonstrated by population trends. A rapidly growing city of 50,000 has very

different concerns than a city of the same size that is declining. The growing city may be most concerned with controlling the direction of growth and thus tightening land use controls while the declining city may relax all fiscal requirements and environmental controls to encourage industry to move back into the town.

However, population growth rate alone is not useful in assessing a community's ability to accommodate new industry but is meaningful in the light of other factors, such as economic trends, existing land use characteristics, and existing infrastructure. For example, an urban area with a declining population may be eager to accept new industry and may already have the physical facilities to support the industry. On the other hand, a rural area with a declining population may be less able to benefit from industrial growth and less able to bear the costs of growth.

Age Distribution--Often an industry has associated with it a specific type of labor force. Certain age groups will be represented more than others in the industry's work force. If the incoming population is a significant proportion of the total community population, then a comparison of the age structure of the incoming population with that of the existing community can suggest some potential social difficulties. For example, a community with a high proportion of elderly residents is likely to develop serious social conflicts arising from an incoming population that consists largely of young adults and their families.

Even where the incoming residents are few compared with existing residents, disparities in the age distribution can indicate that levels of services may be inadequate for people in the incoming age groups. When this happens, costs of absorbing these in migrants will be higher than would normally be expected from the size of the change.

As with the population growth rate, this factor interacts strongly with other community characteristics. The significance of this impact will depend on total population size, on other characteristics of the existing and incoming labor forces, and on existing social services in the area.

Other Characteristics of the Local Labor Force--How much a new industry will affect a community depends first on whether new people will come into the area, and whether the new jobs will be absorbed by the resident population. In addition, this depends on how similar in-migrants' needs and demands are to those of the current population. These questions can be answered in part by comparing the existing local population and the type of labor the incoming industry tends to employ. The type of labor force present in the region, as well as its availability and transferability, becomes important in forestalling boom effects. If the incoming company can hire many of its employees from the existing labor force, the community is likely to benefit through increased income levels and reduced unemployment rate. If new population brought in by a company has needs and interests similar to those of the local residents, many of the conflicts documented earlier could be avoided.

2. Economy

Two elements are important in describing the economic setting of a site: the existing basic economy of the region and the present and expected future trends in the economy.

Existing and Basic Economy--Rural and urban economies differ in the principal kinds of economic activity of the majority of the population. While employment in agriculture dominates a rural economy, employment in the urban sector is basically nonfarm and may include manufacturing and commerce, which in turn support a wide variety of professional activities.[18]

This variation in type of employment operates on a continuum. Large proportions of the population of most rural U.S. areas are engaged in nonfarm activities, and many urban regions contain subregions that are primarily agricultural. In considering this continuum, we can expect that (for most cases) the negative impacts of a fuel conversion plant in an area will vary inversely with the degree of urbanization in that area. This occurs because an energy plant will be more compatible with its surroundings if similar types of activities already take place in the area.

Existing and Expected Trends--However, suitability for plant location might well be different between locations that appear at first glance to have similar economic profiles. In some areas, the introduction of a major new industry could upset an existing stable economy, causing growth in some sectors of the economy and decline in other sectors. If labor is not transferrable between different sectors of the economy, this can increase unemployment among the local population. Even if unemployment does not occur in this process, the growth caused by the new industry can change the quality of life of the community. The community may feel that these changes are more costly than beneficial.

In other areas, a community may have an apparently similar existing economy that is actually in flux. For example, agricultural activity may be steadily declining in the region, perhaps because development patterns and technological changes have made outside areas more competitive for agricultural activity. In this case, the area may be interested in changing its economic balance. Industrial growth could become a means for recapturing lost income. While this may not absorb the unemployed population resulting from loss in agricultural activity, it may well be a more attractive alternative than regional depression.

Thus, it is important to consider the long-term development trends in a region as well as the snapshot, one-point-in-time picture of the existing economy. In general, areas that show a continuing tendency towards increasing urbanization will be less sensitive to negative impacts of industrialization than those that are maintaining a deliberate urban-rural balance by depending on low levels of industrial activity or by exercising discretion in choosing the kind of industrial activity to be located in the region.

There will be exceptional instances in which this assumption does not hold. One is a community in which urbanization is already proceeding so rapidly that many of the social problems indirectly associated with rapid economic development because of accompanying population growth already exist (e.g., inadequate social services, a tight housing market). Here, the community may already have reached its short-term capacity to

Infrastructure--Costs of utilities, roads, and other transportation facilities grow in a step-like function rather than continuously and in direct proportion to the level of activity. When one power-generating plant reaches capacity, another must be built; to relieve congestion on a road, an entire new lane or road must be built; development of a new mass transit system is a major effort, although later additions to the service in smaller increments may be possible. Therefore, the existing status of such facilities is very important in assessing the impacts of growth. An assessment of the flexibility of the existing infrastructure will be useful in choosing alternative sites. An urbanized area may be able to use existing facilities to absorb the increased population when a rural, low density region would be forced to make major capital investments.

Housing--Some of the most significant impacts of rapid urbanization can be observed in the housing market.

Several elements in the existing supply of housing indicate an area's potential for developing a tight housing market. They include the present housing stock, price range for housing, vacancy rates, and current rate of development and construction costs. A tight housing market is indicated when there is little housing available for new occupants, when the cost of this housing is high compared with the quality, and when projections of new development are lower than projections for housing demand.

Social Services--As with basic infrastructure, new social services are not always developed incrementally, matching one unit of social services to one unit of population. There are often thresholds for providing services economically. Below these thresholds, a community may feel that it is too costly to provide the service at all. Thus, for example, a rural area may lack basic hospital, police, and fire protection services, which would become increasingly necessary as the population grew.

absorb industrial activity, and it would be an inappropriate site for an energy conversion plant location, at least in the near future.

Land Use--Current land use in an area may be well suited to the development of new industry. Certain areas may already be set aside for industrial use; roads and utilities serving the area may have excess capacity; housing may be available for the increased population. However, other potential sites may lack all of these qualities. In these areas, the cost of the industry to the community can be high. Short-term impacts are likely to include traffic congestion, tight housing markets, and aesthetic impacts. While the community may accommodate to some of these effects over the long run, the visual changes that accompany industrial growth and residential expansion will be very long term.

Land use impacts will be least apparent where the new growth is compatible with existing development. This is most likely to occur in areas in which development is already urban in character but where congestion points have not been reached.

The impacts of a new industry in an area in part depend on the existing mix of rural, residential, industrial, and commercial uses. Colorado, Wyoming, and Montana are apprehensive of fuel conversion activities because these bring with them land use activities different from current ones. Regions with existing industrial bases would be less sensitive to the social impacts of fuel conversion facilities (although they might be more sensitive to environmental impacts).

Intensity of land use is an important measure of impact potential in this context. This element provides an indication of the degree of urbanization in a region. Up to a certain point, operating costs per capita that devolve on the community that accept a fuel conversion plant would vary inversely with the intensity of development. However, at some point, a congestion level may be reached. It may prove extremely costly for areas with highly intense land uses to accept further development.

In the long run, in terms of social services, a rural community may benefit more from a given growth increment than would an urban community, if this allows members of the rural community access to social services that they had lacked previously. However, in practice, especially in the 5- to 10-year period immediately following a population boom, this does not seem to be the case. Communities with minimal social services are unable to catch up with rapid increases in demand. Instead, those services that exist become excessively over utilized, and the quality of service decreases both for long-term residents and newcomers.

A community with a low level of social services will have more costly short-run impacts than one with high levels of existing social services. The potential for this effect is indicated by the ability of existing social services to expand. A basic question to be asked is which social services are available now. The structure of services that are available can then be categorized and catalogued. Significant costs are likely wherever it is evident that services are too low to be quickly expanded for a larger, denser population.

Political and Administrative Structures--A community's ability to respond to changing demands, to provide new services where needed, and to protect the basic interests of its new and old citizens as the change takes place depends in part on the governmental tools available to it through state and local legislation. A community with land use control powers and taxing powers has much more control over its future than does one which lacks these powers.

Important factors in this area are (1) the relationship of political boundaries to the expected patterns of growth, (2) legislative, planning, and taxation powers held by concerned communities, and (3) the existence of governmental agencies that can address growth related issues. High social costs are likely when the political boundaries do not encompass the expected growth areas, when the communities involved must rely on higher levels of government to control and pay for local development, and when there are presently no administrative bodies that would take responsibility for anticipated problems.

Public Attitudes--Acceptance of a project by local citizens may be a critical factor in the project's level of success. For this type of project, the public's attitude toward industrial growth is relevant. Pro-growth communities may be willing to accept the costs that accompany growth because they feel that benefits accompany these costs. Conflicts are more likely to arise in communities in which sizable factions question industrial growth. Attitudes expressed by stakeholders and through newspapers and other public documents will indicate the existence of these concerns. However, short of a public referendum, it may be difficult to measure the extent to which these concerns are shared, unless the community as a whole has taken a stand on the issue of growth (e.g., in describing future development goals).

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Chapter 5

DISPERSED SCENARIO

- Time span: 1975-2050
- By 2050
  - 285 syncrude plants: 100,000-B/D capacity
  - 312 SNG plants: 250 x 10^6 SCF/day capacity
  - 722 coal-fired electric power plants: 1000-MW capacity
  - 890 million tons/yr of industrial coal demand
- Synfuel plants located to mitigate boom-town phenomenon and water constraints
- Only large cities have more than one plant

The dispersed Scenario is more complex than the Minemouth Scenario because synfuel plant sites are chosen to mitigate the boom-town effects and to lessen the burden on limited water supplies. Accordingly, sites are chosen mainly in the eastern half to the United States near rivers or reservoirs, near transportation facilities (railroads and/or waterways) and in communities with a social capacity large enough to absorb the population influx brought about by the construction and operation of a synfuel plant.

A. Site Selection

1. Socioeconomic Factors: Simplified Approach

Ideally, selection of sites for synfuel conversion facilities would entail examination of the social capacity of the candidate communities with respect to the many measures of a community's ability to absorb a population influx (Chapter 4). This applies especially to a community that is likely to have a different age and educational attainment profile than the existing population. In particular, one should determine

- Population size
- Rate of change of population
- Housing availability
- Retail services
- Public and social services
  - educational
  - waste disposal
  - fire and police

Application of this ideal approach to the many candidate sites in the United States would cost more than the resources available to this study. Moreover, we found that much of the desired data were often not readily available. Consequently, we had to settle for a simplified approach in which only three demographic parameters were used to screen candidate sites. These parameters were intended to eliminate candidate sites in which urbanization impacts would be similar to those currently occurring in western boom-towns.

The first parameter was population size. Only those towns, cities, or counties that had at least 30,000 people (1970 census) were nominated for a plant site. The figure 30,000 was selected because a 100,000-B/D syncrude plant would bring a peak influx of about 18,900 people during construction and about 13,000 during the operation phase. Similarly, an SNG plant would bring a peak influx of about 14,600 people during construction and 5,900 during the operation phase.

Large cities were deemed most suitable and small rural counties with a cluster of towns with aggregate population of 30,000 were deemed least suitable but acceptable. In general, the most acceptable sites were to receive plants earliest in the scenario time span and those sites that were suitable only when considered at a county level were restricted to the end of the scenario time span. For plants required up to the year 2000, one plant was allowed within a 20-mile-diameter circle containing one or two towns having a combined population greater than 30,000; two plants were allowed if the combined population was greater than 55,000; and three plants were allowed if the combined population was greater than 75,000. Highly urbanized regions were dealt with on a case-by-case basis.

After the year 2000, these same criteria were applied at the county level rather than to individual towns or pairs of towns. Since most counties in the eastern United States are smaller than 500 square miles, they also correspond to an area about 20 miles in diameter.

In the early years of the scenario, a few exceptions to the rule of locating in the eastern portion of the United States were made by locating plants in the northern tier of states to make up for the anticipated loss of Canadian crude oil and natural gas supplies. Although some portions of the Northwest would have met the water and social capacity criteria, plants were not located there under the assumption that Alaskan crude oil and natural gas would supply these regions and, hence, it made more sense to locate synfuel plants in the East.

The second demographic parameter considered was whether the communities already deemed acceptable by the population size criteria had shown stable, increasing, or decreasing population during the past decade. We assumed that communities that had experienced declining population would most welcome the population influx brought about by a synfuel plant and, moreover, were most likely to have spare social capacity. Therefore, such communities were selected earliest. Next to be selected were communities with a history of stable population. Last to be selected were communities already experiencing growth from other stimuli. It was assumed that these communities were least able to absorb additional growth without undue stress to the structure of community services.

The third parameter considered received emphasis during the early period of the scenario and served primarily as a final screening for candidate sites that had passed the previous screening only marginally. For such sites, the supply of housing available in 1970 was examined. (This parameter seldom changes radically in a short time.) If there was little spare housing (as measured by less than a 6 percent vacancy rate for rental units and less than a 3 percent vacancy rate for owner-occupied units), then use of the site was delayed until other more favorable sites had been used.

Once this screening was made, plant locations were made within the nominated categories at random. In addition, the scenario was made truly dispersed with many communities being specified so that large concentrations of plants in urbanized areas were avoided. In our previous analysis* it was shown that concentration of plants had a very definite adverse affect on ambient air quality.

2. Water Availability Criteria

The first, rough water availability criterion used for the Dispersed Scenario was that the yearly average flow rate of the nearby stream should be sufficient to satisfy the water demand of synfuel plants. This is only a first order approximation to the set of water criteria that would be used in the actual siting of a plant. However, analysis of the final Dispersed Scenario siting schedule showed that this alone was an adequate approximation for this study.†

A closer, more detailed examination would have eliminated sites and could have necessitated more use of multiple plant sitings or heavier use of some areas that were purposely used only lightly--such as the Great Lakes Basin. Alternatively, a closer examination would have necessitated added costs for water resource facilities such as dams and reservoirs or conjunctive use of ground water or recycled waste water at certain sites at certain times.‡

Site specific availability of ground water was not examined, but in the humid eastern third of the nation where most of the Dispersed Scenario plants were sited, ground water is characteristically abundant.

Water quality was not considered, but treatment, if required, would increase the costs. In our previous analysis* it was assumed that

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*"Synthetic Liquid Fuels Development: Assessment of Critical Factors, Volumes I and II."

†Appendix K shows in detail the water used by the Dispersed Scenario.

‡This would have the effect of increasing the cost of the Dispersed Scenario but would not significantly affect the conclusion because the cost of water and its treatment is, relatively, a very small cost of producing synthetic fuels.

there would be no waste water discharged to streams but that it would be evaporated in ponds. While this is an adequate assumption for the arid West, in parts of the humid East the precipitation exceeds the surface evaporation and therefore evaporation ponds are not feasible. However, we continued with an equivalent assumption, namely that treatment of waste water could achieve a zero waste discharge (although the cost of this was not determined).

Although it would appear that the Great Lakes could support a significant synfuels industry, use of water in the Great Lakes Basin was not emphasized because of the institutional constraints controlling levels and flows, the dependence on associated hydropower, and a projected large growth of water consumption in the basin. The annual average outflow from Lake Erie is about 212,000 cfs of which 7,000 cfs flows through the Welland Diversion. The Treaty of 1950 between the U.S. and Canada specifies flows to provide for the scenic beauty of Niagara Falls. The treaty requires 100,000 cfs over the falls during daylight hours and 50,000 cfs at all other times. This says that, on the average, 105,000 cfs is available for power production during daylight hours and 155,000 cfs at other times. There is high-head generating capacity at Niagara Falls designed to utilize such flows. Accordingly, additional consumptive use of the Great Lakes Basin water production upstream of Niagara Falls would either degrade the scenic beauty of Niagara Falls or reduce the production of power. An additional 46,000 cfs flows from Lake Ontario (the lowest of the lakes) to the sea. Further complication of the consumptive use of Great Lakes water is the need to maintain levels of the lakes for navigation. The maintenance of levels and flows in the lakes is a matter of international treaty.

3. Transportation Criteria

All candidate sites that survived the screening for social capacity and water availability were next examined for the availability of nearby rail or waterway transportation for the shipment of coal to conversion plants.

The actual capacity of the rail transport system to one plant or more plants was not examined. Instead, it was assumed that, if rail service existed, then the capacity of the corridor could be upgraded if needed, given the long time-span of the scenario. Rail network information was obtained from a U.S. railway atlas.[1]

Several major waterways could be used to move large amounts of coal throughout the country. The capabilities of these waterways depends on the depth of the navigation channel, the capacity of the locks, and the capacity of transfer (loading/unloading) facilities. Channel depths are maintained by dredging and by maintaining river stages through flow maintenance in navigation dams. Problems can arise when the waterway freezes, when the flow is low and when the use of water in the locks is high. Consequently, some waterways are limited in their use to the season of ice-free water while others are limited in their use by seasonal or dry-year low flows. Transportation of large amounts of coal could greatly increase the lockage flows at the same time that coal conversion would be diminishing flow because of large consumption. As a result, the Dispersed Scenario would worsen the problems of waterway transportation in dry years; however, it was beyond our resources to examine this question quantitatively. A waterway atlas was the source of information for this analysis.[2]

In addition to sites that could receive coal from mining regions directly by barge, a site was also deemed acceptable whenever it appeared that a combination of rail and barge transport could serve it.

For transportation of the product synfuels from the conversion plants to demand centers, it was assumed that existing pipelines would be used or be augmented by additional pipelines. The central portion of the United States is especially heavily networked with pipelines. Accordingly, transport of products was given little attention compared with the transportation of the coal feedstock for the plants.

B. Sites Selected

The sites and schedule of their use for the Dispersed Scenario were cast in graphic form for ready assimilation. Figure 5-1 shows the evolution of the Dispersed Scenario in the time intervals 1975-2000, 2001-2025, 2026-2050, and the cumulative sites, 1975-2050. These synfuel sites (along with the sites of coal-consuming electric power plants and industrial plants common to all scenarios) are tabulated in Appendix G.

C. Model Results

1. Coal Production

Figure 5-2 shows U.S. coal production in 1975. Figure 5-3 shows the regional production resulting from the Dispersed Scenario for years 2000, 2025, and 2050, with a side-by-side comparison of production under the Minemouth Scenario in the same years.

By the year 2000, in the Minemouth Scenario, coal production in Wyoming is responsible for much of the increase in U.S. production above the 1975 level, but in the Dispersed Scenario the Appalachian and Illinois coal regions account mainly for the increase in production. This eastward shift in production results, of course, from the eastern location of most of the synthetic fuel plants in the Dispersed Scenario and the concomitant high cost of transporting coal from the West to the East. Indeed, in 2000, production in Appalachia is nearly three times that of 1975, and production in Illinois is more than five times that of 1975, while in the Minemouth Scenario production in those regions is less than doubled. Wyoming production is about one quarter what it is in the Minemouth Scenario, yet it is still 22 times greater than its 1975 level.

In Figure 5-3, Appalachia and Illinois are seen to reach higher levels of production and at an earlier time in the Dispersed Scenario than in the Minemouth Scenario, while production in the West is lower and peaks later. Indeed, peak Appalachian and Illinois production in the Dispersed Scenario occurs 10 years earlier and is 20 percent higher than in the Minemouth Scenario. Since the strippable coal in those regions is

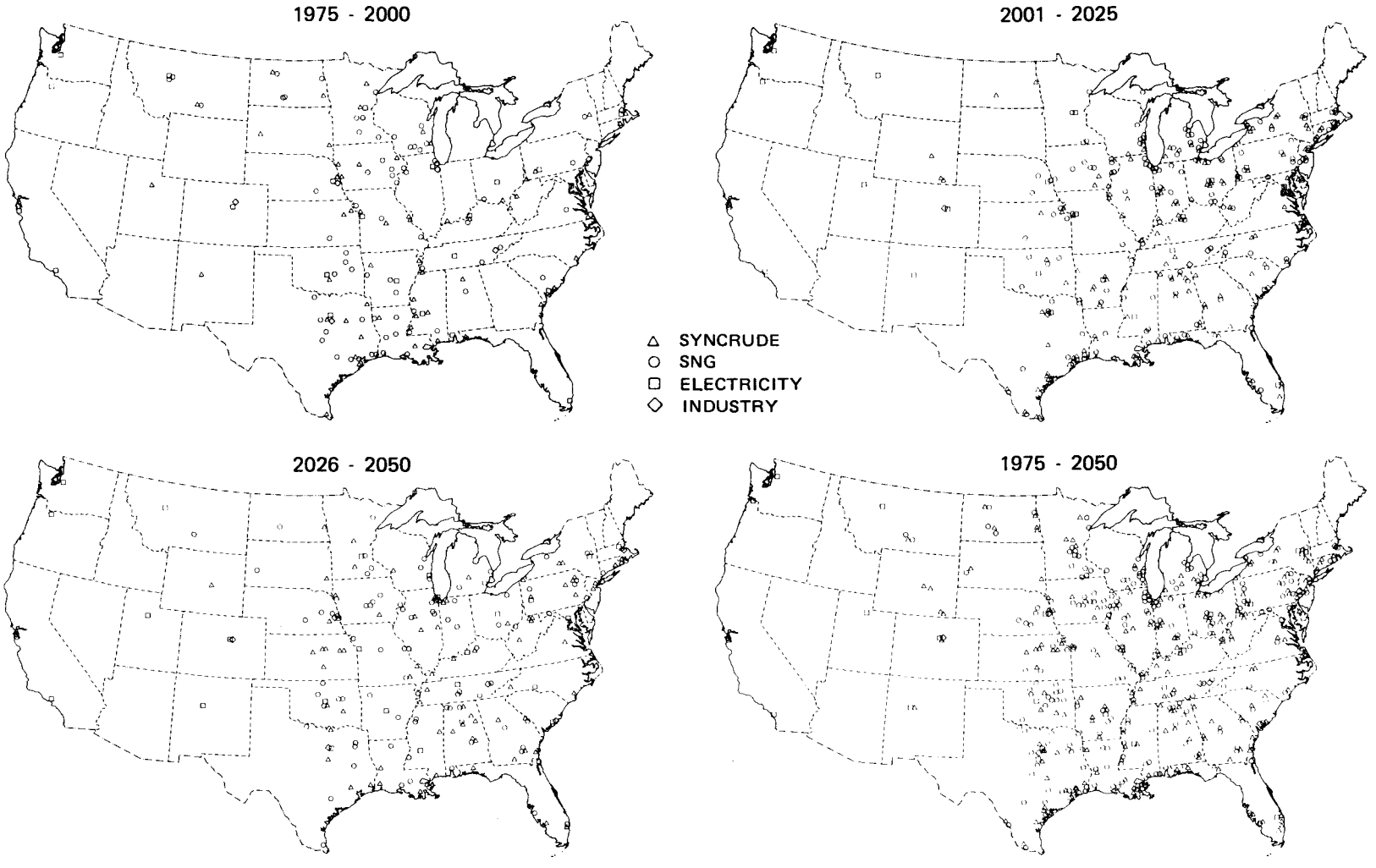


FIGURE 5-1. DISPERSED SECNARIO, INCREMENTAL PLANT SITINGS FOR THREE TIME PERIODS AND CUMULATIVE PLANT SITINGS

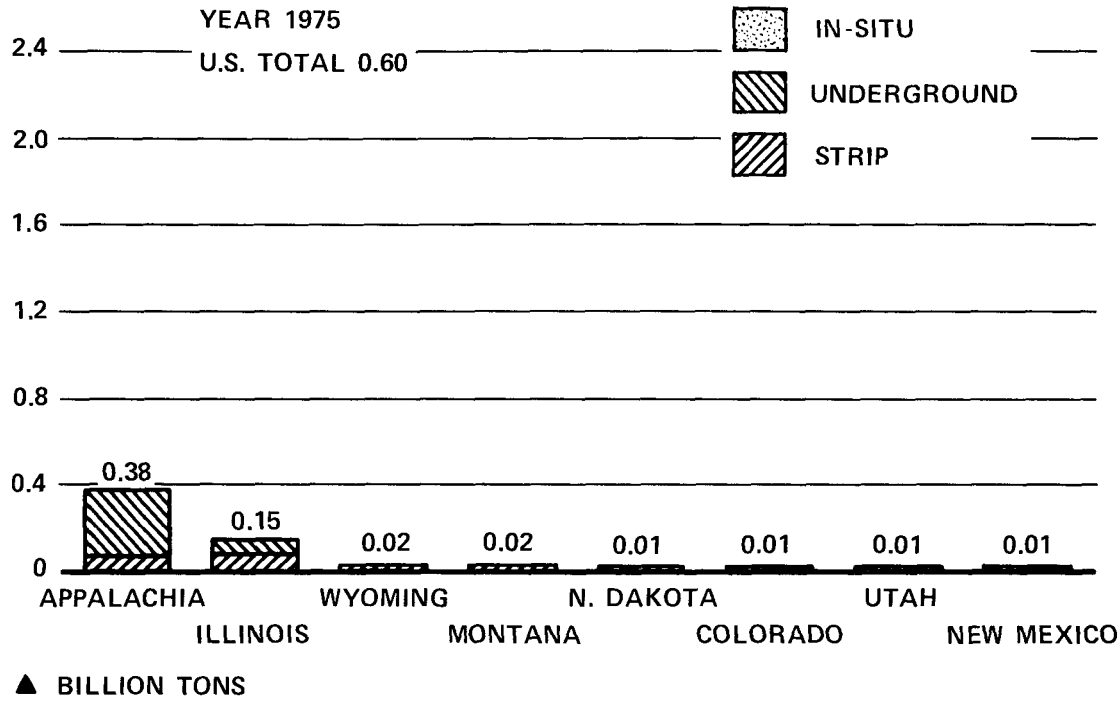
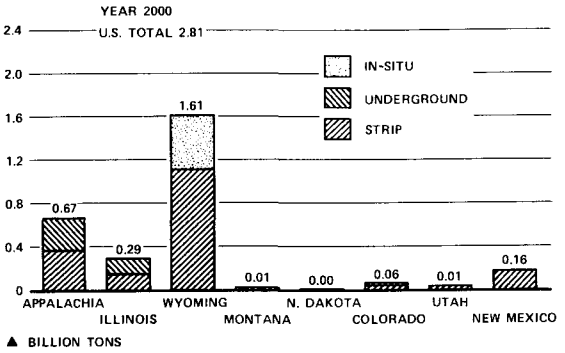
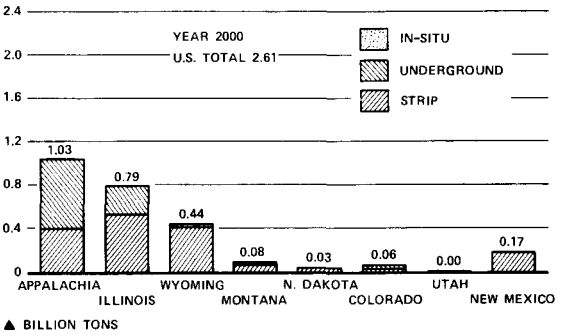


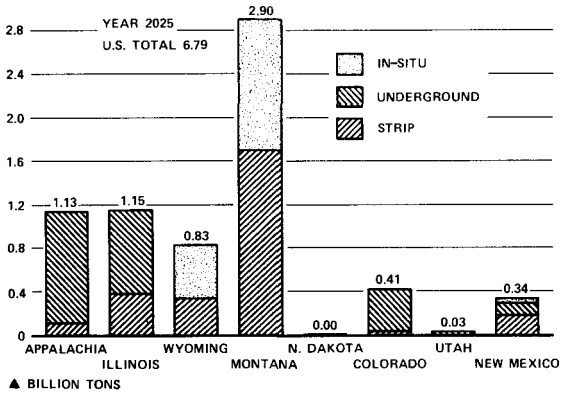
FIGURE 5-2. REGIONAL COAL PRODUCTION, 1975 HISTORICAL DATA

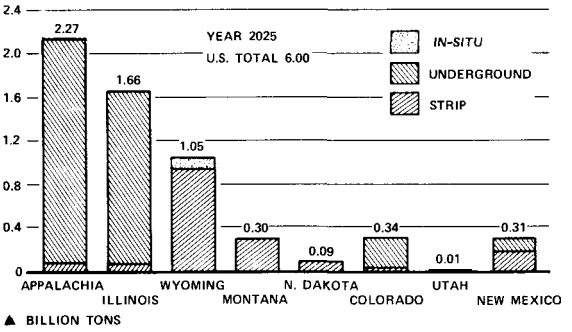
nearly depleted by then, peak production in those regions is primarily underground.

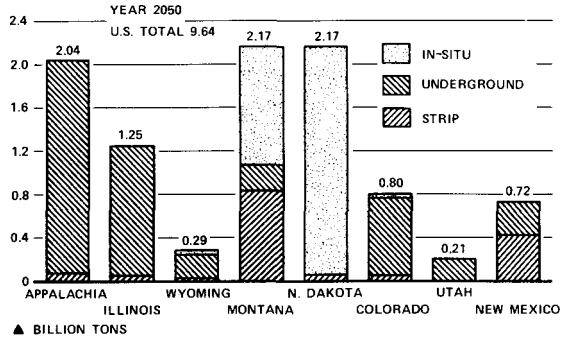
Figure 5-4 compares regional production in a different format and reveals these differences in the scenarios very clearly. In the West, an even greater difference in peak production between scenarios is shown for Wyoming, Montana, and North Dakota--the three regions that produce most of the western coal during the 75-year period modeled. The peak of production is about halved in both Wyoming and Montana, as well as shifted to a later time. Peak production in North Dakota is likewise shifted to a later time, but in both scenarios it apparently would occur after 2050 and thus its amount is not calculated by the model.

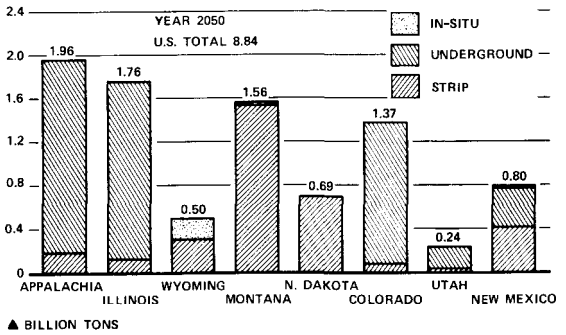












MINEMOUTH SCENARIO

DISPERSED SCENARIO

FIGURE 5-3. COAL PRODUCTION COMPARISON: MINEMOUTH AND DISPERSED SCENARIOS. TOTAL PRODUCTION DIFFERS IN THE TWO SCENARIOS BECAUSE REGIONAL SHIFTS RESULT IN THE USE OF COALS OF DIFFERENT HEATING VALUES.

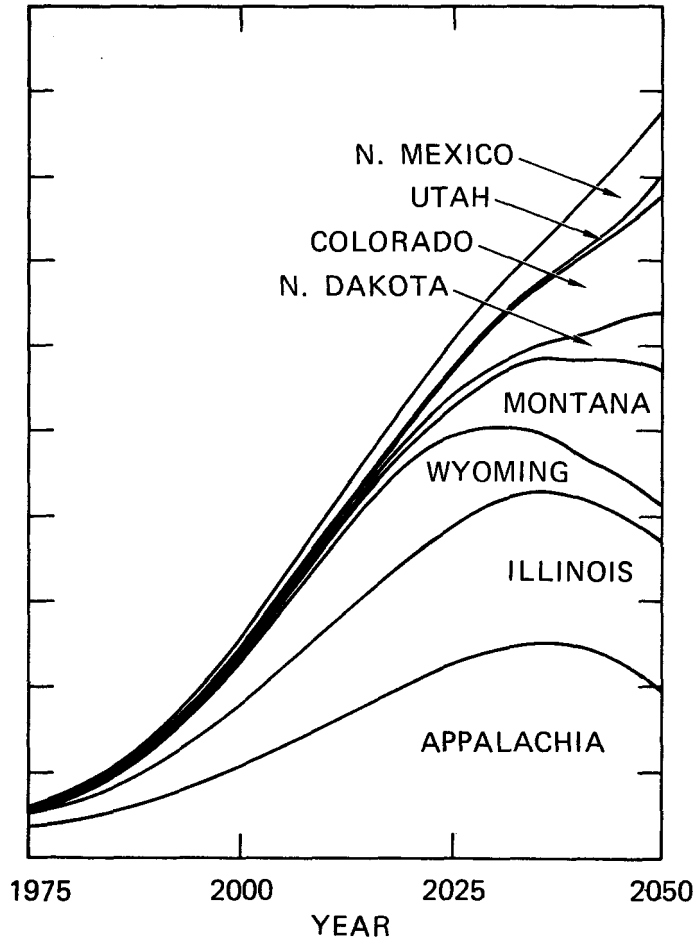


FIGURE 5-4. DISPERSED SCENARIO, SUMMARY OF REGIONAL COAL PRODUCTION

Colorado is the exception to this pattern because its underground production reaches a higher level in the Dispersed Scenario than in the Minemouth Scenario, primarily because the higher heating value of the coal results in less Colorado coal having to be transported per unit of final product. This gives Colorado coal additional economic attractiveness in the Dispersed Scenario.

Figure 5-5 shows the national production by type of extraction. Again, as in the Minemouth Scenario, underground production remains almost constant until nearly the year 2000.

The most obvious difference in results between the Minemouth and Dispersed Scenarios is that the requirement that synthetic fuel plants locate in the East rather than at the minemouth tends both to reduce the coal production in the West and to spread it in time. In compensation,

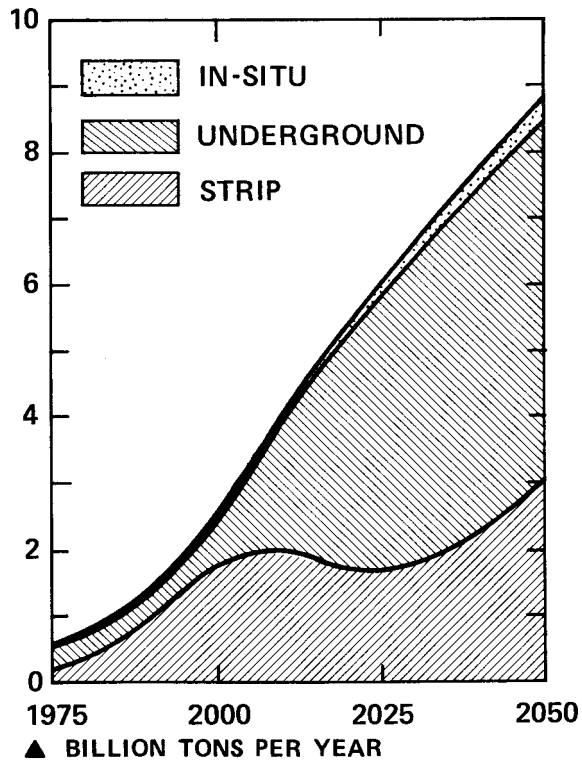


FIGURE 5-5. DISPERSED SCENARIO, NATIONAL COAL PRODUCTION BY TYPE OF EXTRACTION

production in the East and Midwest is increased with their peak production occurring earlier and the period of high production lasting longer.

2. Coal Resource Depletion

Coal resource depletion for the Dispersed Scenario is shown in Figures 5-6 and 5-7.

As in the Minemouth Scenario, under the Dispersed Scenario, almost all of the strippable coal is depleted by 2050 in the three key regions--Appalachia, Illinois, and Wyoming. However, Montana and North Dakota, which contain 70 percent of the strip-minable coal in the United States, retain most of their supply at the year 2050.

Underground coal is heavily depleted in Appalachia and Illinois--down to less than 30 percent of the present amount. Western underground resources remain relatively untouched.

A negligible amount of depletion of in-situ resources occurs in the Dispersed Scenario because the model assumes that in-situ extraction requires minemouth conversion (and the only minemouth plants allowed in the Dispersed Scenario are a few electric power plants).

The national coal depletion for the Minemouth and Dispersed Scenarios is shown side by side for comparison in Figure 5-8. Both scenarios indicate that by 2050 approximately one third of the 1.4 trillion tons of coal estimated to exist in the eight coal regions in the model has been used. Another sixth is already under contract for future use. The third already mined includes nearly all of the reserve base as well as some of the inferred resources. Thus, in 2050 only half of the initial resources remain available for future contracts and these are the less desirable, more expensive coals. They consist of resources that have not been measured to date, as well as those that are presently considered to be uneconomical to mine. Thus, the coal demand portrayed in these scenarios skims off the identified, easily mined resources within 75 years. To use the remainder would require a major exploration and measurement program and would incur higher extraction costs.

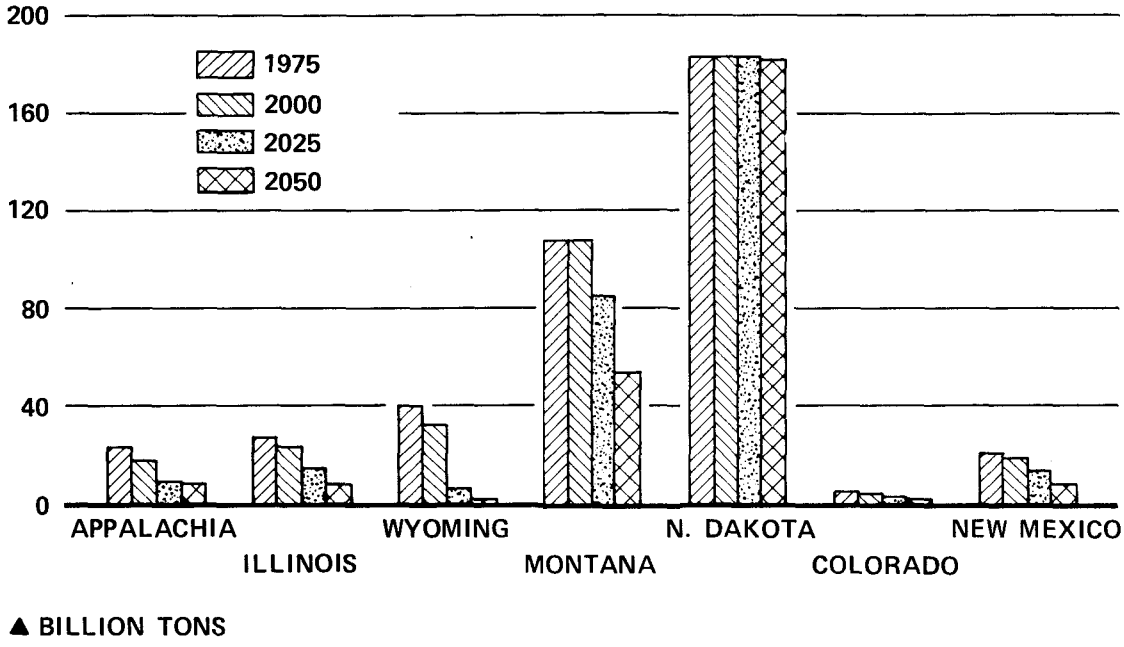


FIGURE 5-6. DISPERSED SCENARIO, STRIP RESOURCES REMAINING

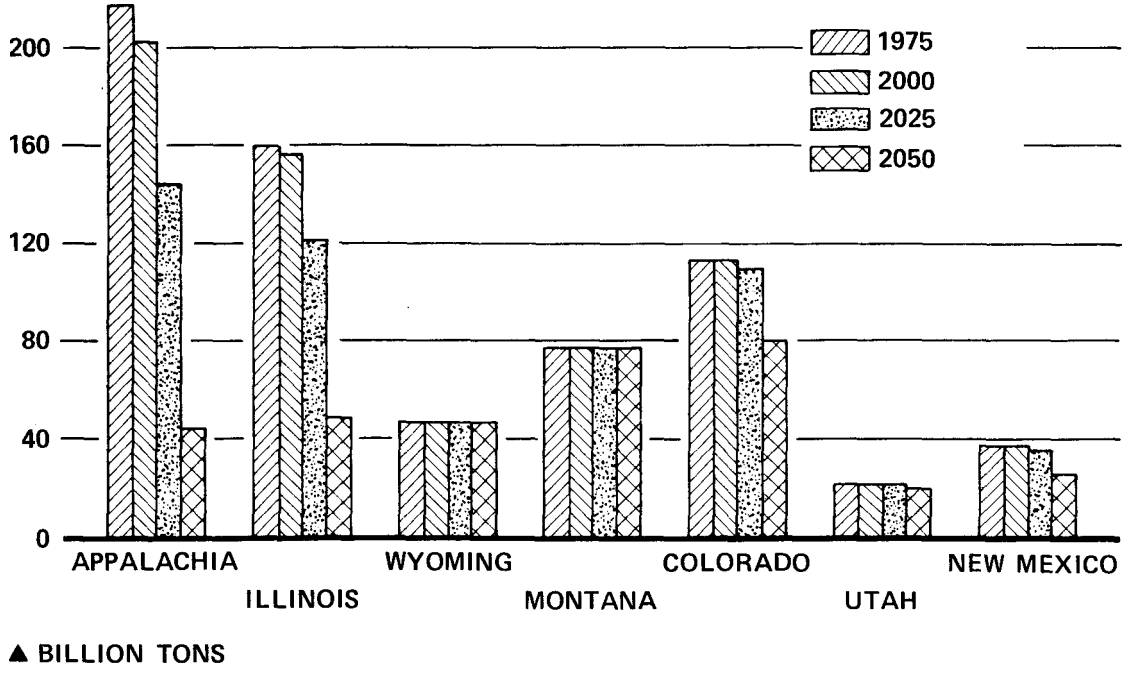


FIGURE 5-7. DISPERSED SCENARIO, UNDERGROUND RESOURCES REMAINING

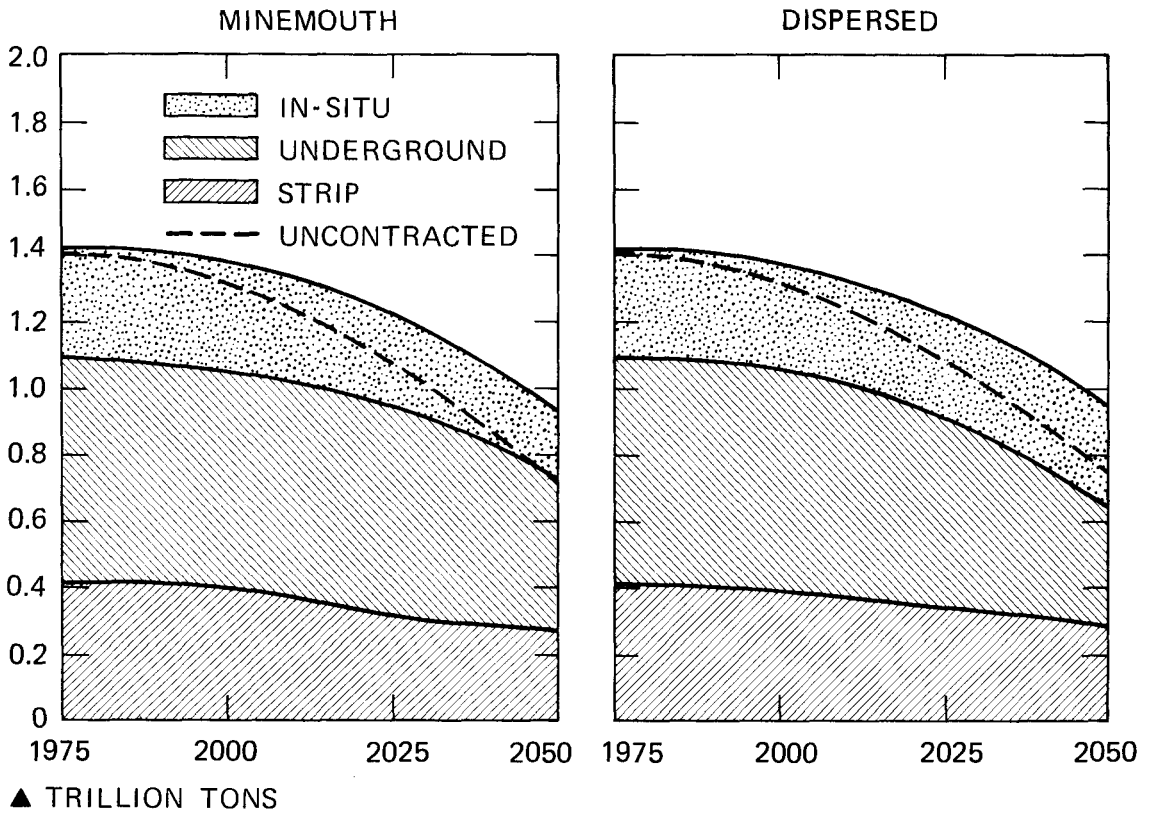


FIGURE 5-8. COMPARISON OF NATIONAL COAL DEPLETION FOR MINEMOUTH AND DISPERSED SCENARIOS
SOLID LINES INDICATE COAL MINED, DASHED LINES INDICATE COAL UNCONTRACTED

3. Comparison of National Production Costs

Both scenarios ignore the cost of piping the syncrude or SNG to a distribution point common to the two scenarios* because such calculation would involve a distribution network analysis considerably more complicated than this model warrants. Moreover, pipeline shipment costs of syncrude and SNG are a small fraction of the cost of transporting the

*For syncrude, this common distribution point would not necessarily be existing refineries since the new refinery capacity required for both scenarios could be located near the conversion plant locations. Consequently, the common distribution points would be for product storage prior to end-use distribution. The common distribution points for SNG are likewise facilities for consumer distribution.

coal required to produce the same amount of synthetic product.* Consequently, the pipelining cost difference between the two scenarios would be but a small fraction of the total production cost difference.

Figure 5-9 shows the average annual production cost per plant for synthetic fuels in the two scenarios. The Minemouth Scenario is

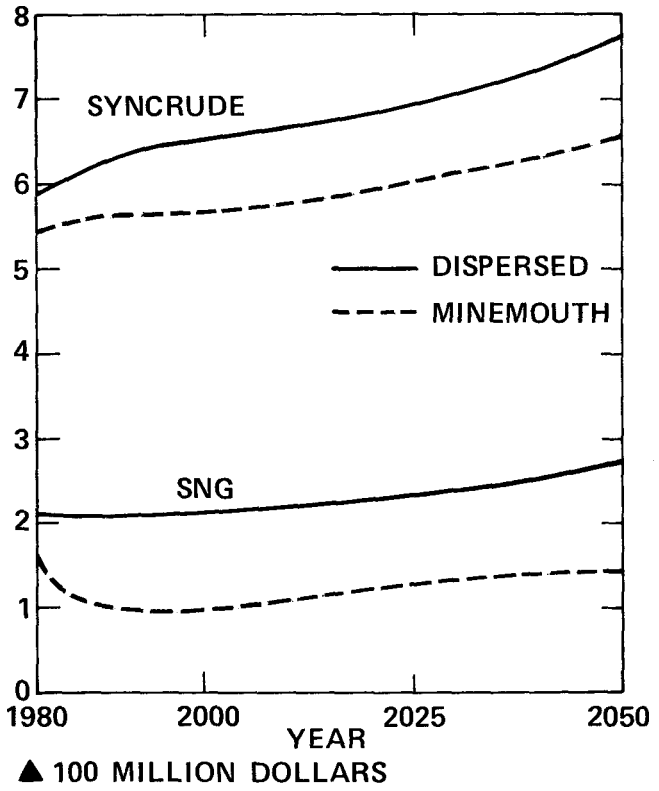


FIGURE 5-9. AVERAGE ANNUAL PRODUCTION COST PER SYNFUEL PLANT -- COMPARISON OF MINEMOUTH AND DISPERSED SCENARIOS

*For a typical case of 1000 miles of transportation of 20 x 10^6 Btu/ton coal, unit train costs are 70¢ per 10^6 Btu of syncrude produced, while pipelining syncrude costs 5¢ per 10^6 Btu. Comparable figures for SNG are 80¢ per 10^6 Btu of SNG produced for unit train transportation of coal and 30¢ per 10^6 Btu for pipelining SNG.

cheaper by approximately 100 million dollars per plant per year. Another way of expressing this cost is to say that realization of the social and environmental benefits of the Dispersed Scenario results in costs about 16 percent higher for syncrude and 100 percent higher for SNG. Components of this cost difference are shown in Figure 5-10. Two-thirds of the difference in production cost of syncrude between the two scenarios is attributable to transportation necessary in the Dispersed Scenario. The remaining third of the difference arises because there is much

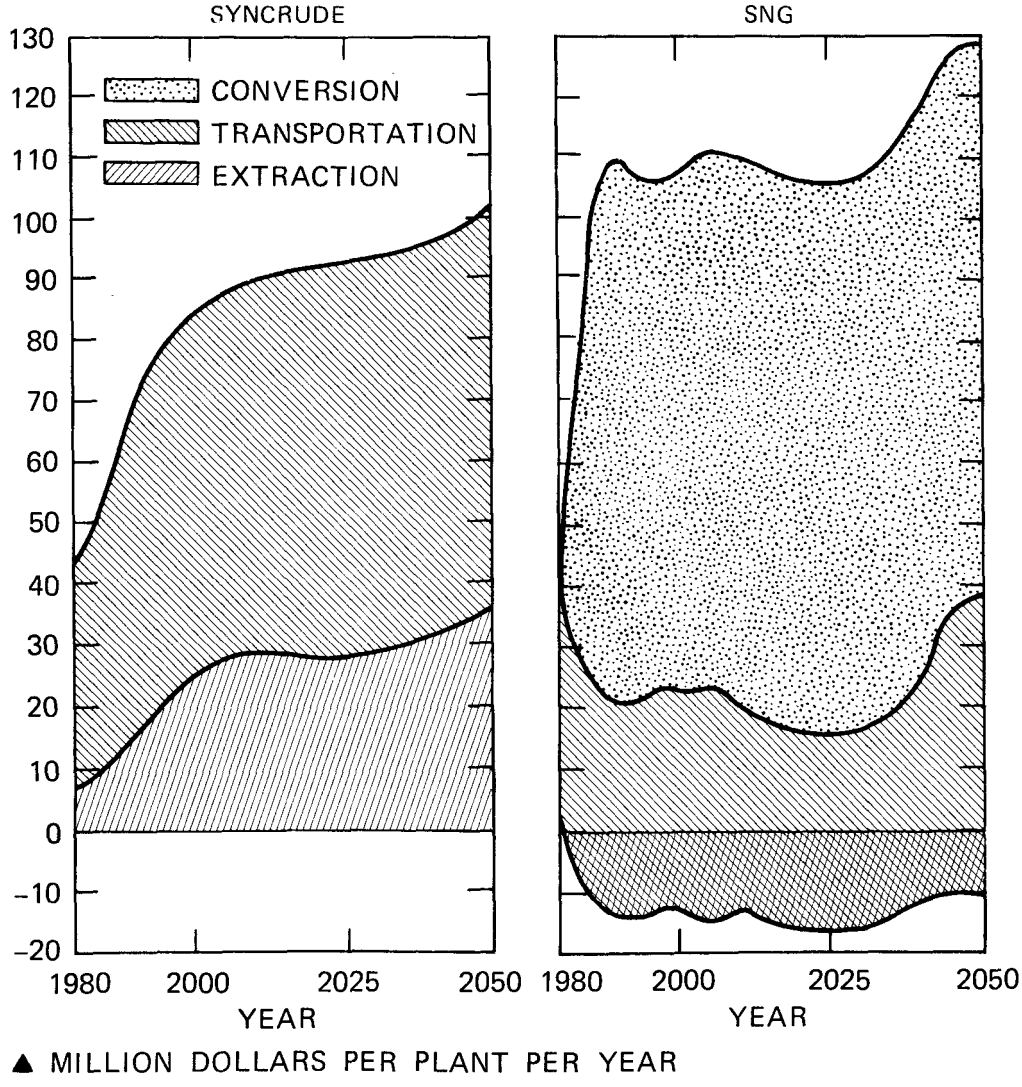


FIGURE 5-10. COMPONENTS OF PRODUCTION COST DIFFERENCE BETWEEN MINEMOUTH AND DISPERSED SCENARIOS
THIS IS A DISAGGREGATION OF DIFFERENCES SHOWN IN FIGURE 5-9.

cheaply-mined strip coal in the West but much less in the East (Figure 2-3). Since the Minemouth Scenario uses much more of these cheap resources than does the Dispersed Scenario, a greatly reduced average extraction cost results.

The cost differences for syncrude shown in Figure 5-10 increase with time as a result of several factors. First, the extraction costs increase because of the early depletion of the inexpensive strip coal in the East in the Dispersed Scenario and the subsequent switch to greater dependence on underground-mined eastern coal. The transportation costs for the Dispersed Scenario increase with time as the demand for western coal, with its high transportation costs, increases in the face of the rising cost of eastern coal.

The situation for SNG production between the two scenarios (Figure 5-10) is somewhat more complex than for syncrude because of the extensive use of in-situ extraction in the Minemouth Scenario. While in-situ extraction is more expensive than strip mining, conversion of the synthesis gas collected in the extraction process to SNG is much less expensive than above-ground conversion of coal. The extraction cost difference shown in Figure 5-10 is negative, indicating that while the average extraction cost for the strip coal used in the Dispersed Scenario is lower than the in-situ production of syngas in the Minemouth Scenario, the lower conversion cost of the in-situ produced syngas more than compensates. In total, the SNG cost difference between the two scenarios comes from two effects: first, reduced transportation costs under the Minemouth Scenario (accounting for about 30 percent of the total difference) and second, the use of in-situ extraction and conversion in the Minemouth Scenario (accounting for approximately 70 percent of the difference).*

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*The initial increase in the differences for SNG shown in Figure 5-10 can be traced to the assumption that in-situ extraction would not be available before 1985. Thus, the 1980 contracts call for strip coal.

D. Implications of the Dispersed Scenario

A key consequence of the plant location strategy of the Dispersed Scenario was that coal production in the West was reduced and spread more evenly among regions. Also, the production booms in Wyoming and Montana were delayed and reduced in magnitude. Moreover, by the very nature of its preparation, the Dispersed Scenario generally alleviated the worst boom-town problems and lessened demand for water in arid regions.

Thus, in general, it can be stated that the regions and communities that would be adversely affected by the Minemouth Scenario greatly benefit from the Dispersed Scenario.

Unfortunately, as was shown in Figure 5-9, realization of local benefits would result in a rather high national cost--some $100 million per plant per year for syncrude and SNG.* Even if the general public were to become sensitive to the problems caused by rapid development of coal-based energy technologies--especially in the arid, rural West--it seems highly unlikely that the public would accept such a high cost for mitigating such impacts.

Consequently, the Dispersed Scenario can, almost surely, be regarded as representing an overreaction, an overavoidance of problems of western energy development. Therefore, in the next chapter we explore an intermediate, or middle ground, scenario to see if it might be possible to mitigate many of the adverse local effects of the Minemouth Scenario without incurring the high costs of the Dispersed Scenario. This compromise scenario is termed the Limited Minemouth Scenario because many plants are again allowed to locate near the mine.

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*This translates to a cost increment of 6.5¢/gallon for syncrude and $1.10/10^3$ SCF for SNG.

REFERENCES FOR CHAPTER 5

1. Rand McNally Handy Railroad Atlas of the United States, Rand McNally and Company, Chicago, New York, San Francisco (1965).

2. Big Load Afloat--U.S. Domestic Water Transportation Resources, The American Waterways Operators, Inc., 1250 Connecticut Avenue, Suite 502, Washington, DC, 20036 (1973), pp. 150-154.

Chapter 6

THE LIMITED MINEMOUTH SCENARIO

- Time span: 1975-2000
- By 2000
  - 58 syncrude plants: 100,000-B/D capacity
  - 85 SNG plants: 250 x 10^6-SCF/day capacity
  - 359 coal-fired electric power plants: 1000-MW capacity
  - 437 million tons/yr of industrial coal demand
- Synfuel plants located both at minemouth and dispersed locations
- Plants allowed at minemouth are the kinds with the least relative impact

The Limited Minemouth Scenario represents a compromise between the Minemouth and Dispersed Scenarios, for, while the Minemouth Scenario would result in lower fuel costs than the Dispersed Scenario, it would also result in very large social costs being borne by the coal producing and converting regions experiencing rapid boom and bust cycles--especially Wyoming, Montana, and North Dakota.

A. Motivation for the Scenario

The Limited Minemouth Scenario is an outgrowth of the insights gained from the coal depletion model results obtained for the Minemouth and Dispersed Scenarios. In particular, as Figure 5-9 showed very clearly, the largest fractional improvement in the production cost of a synthetic fuel is obtained when SNG plants are allowed to produce at the minemouth instead of at dispersed locations. Moreover, as Figure 4-8 showed, the relative work force (and, hence, population influx) is smaller with SNG than for syncrude plants. It is also smaller for electric power plants. In addition, the water demand of an SNG plant is less than for a syncrude plant, (29,000 AF/yr) compared to (8000 AF/yr). The conversion of coal into SNG which takes place partially below ground in the in-situ extraction process gives rise to plants causing the least population influx of any synfuel plant (of the sizes considered in this study).

Consequently, the objective of the Limited Minemouth Scenario was to realize as much as possible the lower product costs of the Minemouth Scenario while mitigating as much as possible the adverse regional socio-economic impacts. Accordingly, synfuel plants--especially SNG--were selectively allowed to move back to minemouth locations. A schedule of such plants was prepared along with a schedule of plants that were to remain at the same locations they occupied in the Dispersed Scenario. The Limited Minemouth Scenario was extended, however, only to the year 2000 because beyond that the compounded uncertainties stemming from the assumptions became untenably large.

B. Scenario

1. Rules for Preparation

The Limited Minemouth Scenario was prepared from the Dispersed Scenario by moving synfuel plants from their dispersed locations in the East and Midwest to specified counties in the western states. The rules applied in selecting plants and sites for this transfer follow:

- The population of the receiving counties should increase no faster than an average annual rate of 5 percent based on the population in 1975, except that the first plant to be constructed in a county was allowed to increase the population temporarily during construction up to 100 percent of the previously resident population.

- Coal resources of the type required by the plants must exist within the county sufficient for a plant's lifetime.

- No more than two plants could begin construction in any county within any five-year time period.

- Minemouth electricity plants and coal mining for export from the region required by the Dispersed Scenario should be located before any synfuel plants are transferred.

- In-situ extraction is the preferred extraction technology for any transferred synfuel plant, strip mining is next in preference, and underground mining is last.

- The order of choosing synfuel plants to transfer is:
  - SNG plants in the Midwest with uncertain water availability (see Appendix K)--for example, the SNG plants located along the Platte River in the Dispersed Scenario.
  - SNG plants to be moved are those that have long distances between their conversion site and their coal supply regions in the Dispersed Scenario.
  - Syncrude plants to be moved are those that have long distances between the source of coal and the site of conversion in the Dispersed Scenario.

2. Plant Relocation

The resulting Limited Minemouth Scenario is shown graphically in Figure 6-1 where it is compared with the Dispersed Scenario in the same year (2000). The Limited Minemouth Scenario affects 26 counties in the six western coal regions and, in all, 70 synthetic fuel plants were located in those 26 counties. Table 6-1 classifies the plants that were transferred back to the minemouth. Appendix L gives a detailed listing of plant sites and start-up dates for the scenario. Approximately three-quarters of the SNG plants (66 out of 85) and one-tenth of the syncrude plants (4 out of 58) in operation in the year 2000 were relocated to the minemouth.

Table 6-1

SYNTHETIC FUEL PLANTS RELOCATED FOR THE LIMITED MINEMOUTH SCENARIO

Region	No. of Counties	SNG In-Situ	SNG Strip	SNG Underground	Syncrude Strip	Total
Wyoming	7	18	0	0	2	20
Montana	7	14	0	1	0	15
North Dakota	3	4	5	0	0	9
Colorado	6	7	0	3	0	10
Utah	1	0	0	2	0	2
New Mexico	2	4	8	0	2	14
Total	26	47	13	6	4	70

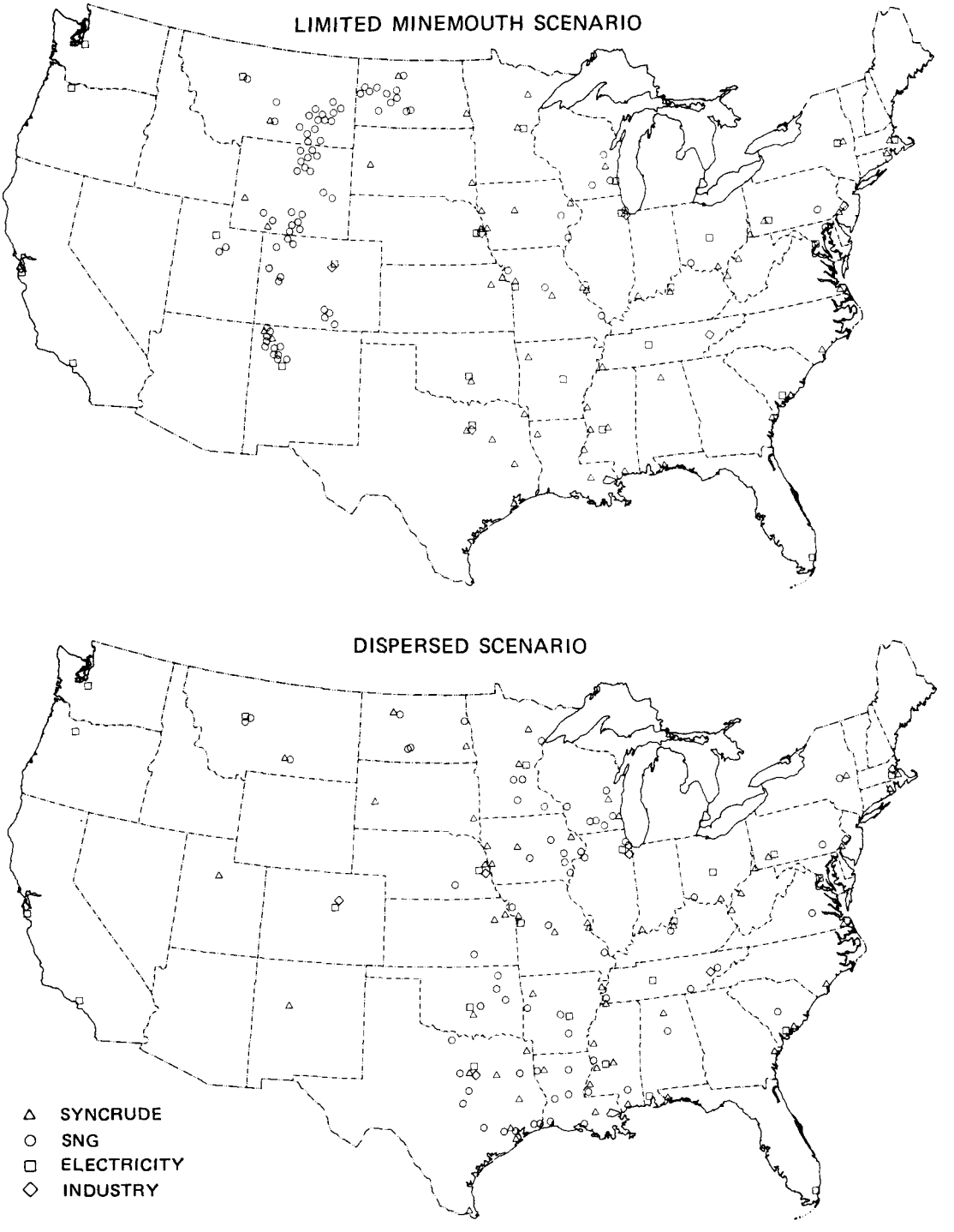

FIGURE 6-1. LIMITED MINEMOUTH SCENARIO COMPARED TO DISPERSED SCENARIO PLANT LOCATIONS; 1975 - 2000

3. Effects on Population Growth

As an example, the result of applying the above rules to Sweetwater County, Wyoming, is shown in Figure 6-2. The base population of that county in 1975 is shown as about 19,000. In 1977, a strip mine producing coal to export to other regions is shown to begin construction and then to be in production by 1979. In 1978, an electric power plant using in-situ extraction starts construction and it is in production seven years later, in 1985. Subsequently, four electric power plants, two SNG plants using in-situ extraction, and a syncrude plant are scheduled for construction and operation, as well as some additional strip mines for shipment of coal out of the region. The total population influx resulting from these energy development activities is shown in Figure 6-2 to remain near the 5 percent annual growth rate. Figure 6-2 was prepared by an extension of the impact prediction model formulated for a small hand-held calculator described in Appendix J.

C. Coal Production

The coal production in each region derived by the Coal Depletion Model for the Limited Minemouth Scenario in the year 2000 is shown in Figure 6-3, where it is compared with the coal production for the same year for the Minemouth and Dispersed Scenarios. As one would expect from the plant location assumptions in the three scenarios, the Limited Minemouth Scenario results in production in the Appalachia and Illinois coal regions intermediate between the other two scenarios. In Wyoming, the Limited Minemouth Scenario coal production is nearly the same as that for the Dispersed Scenario but the production in most western regions (except Utah) is larger than for either the Minemouth or Dispersed Scenarios.

Thus, relocating synfuel plants to minemouths in the West in the cautious, carefully planned manner described above can result in coal production that is much more evenly distributed throughout the West than would occur for either of the extreme scenarios. Moreover, the Limited Minemouth Scenario avoids the boom and bust cycle phenomenon to a much greater extent than does the Minemouth Scenario.

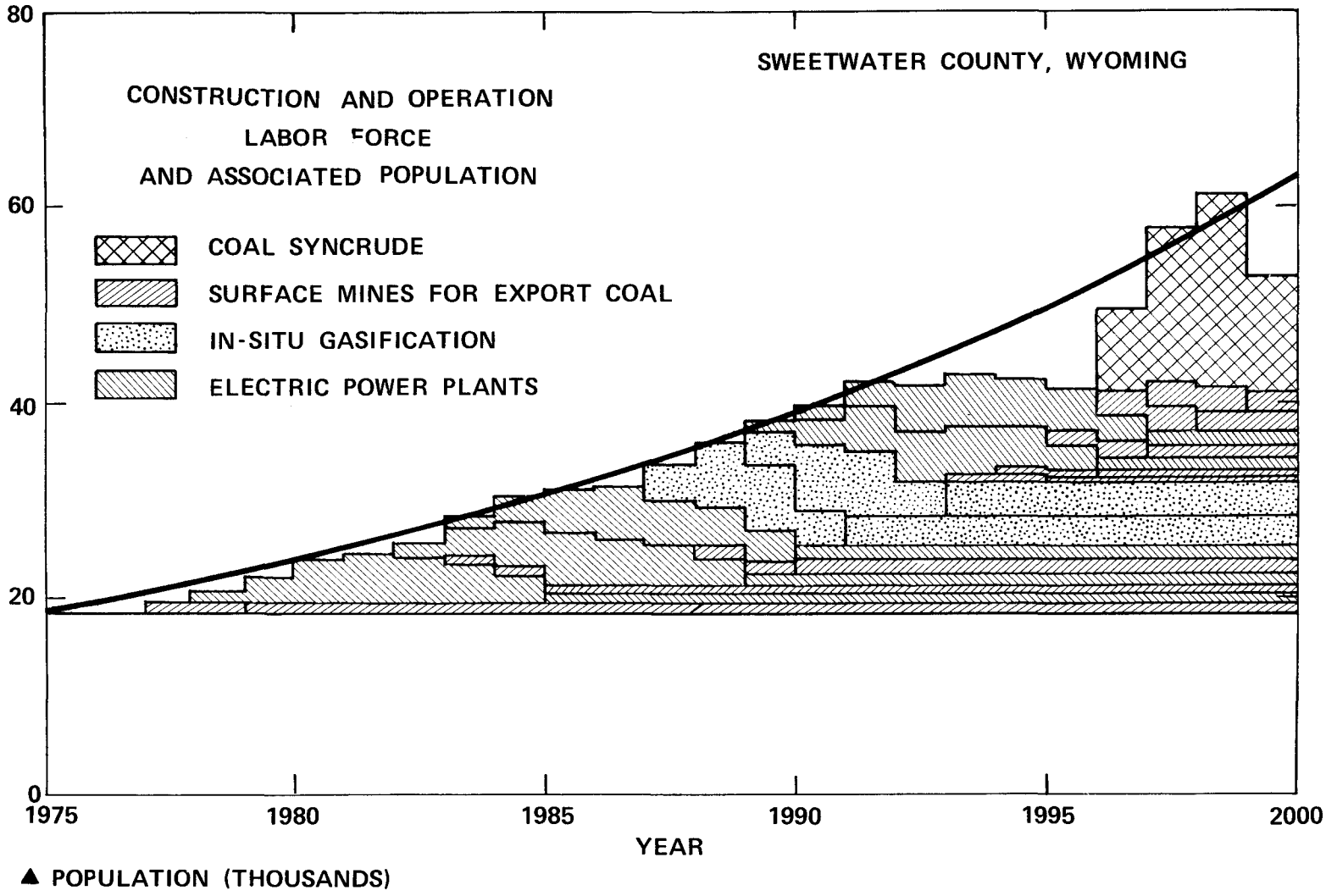

FIGURE 6-2. LIMITED MINEMOUTH SCENARIO IN SWEETWATER COUNTY, WYOMING

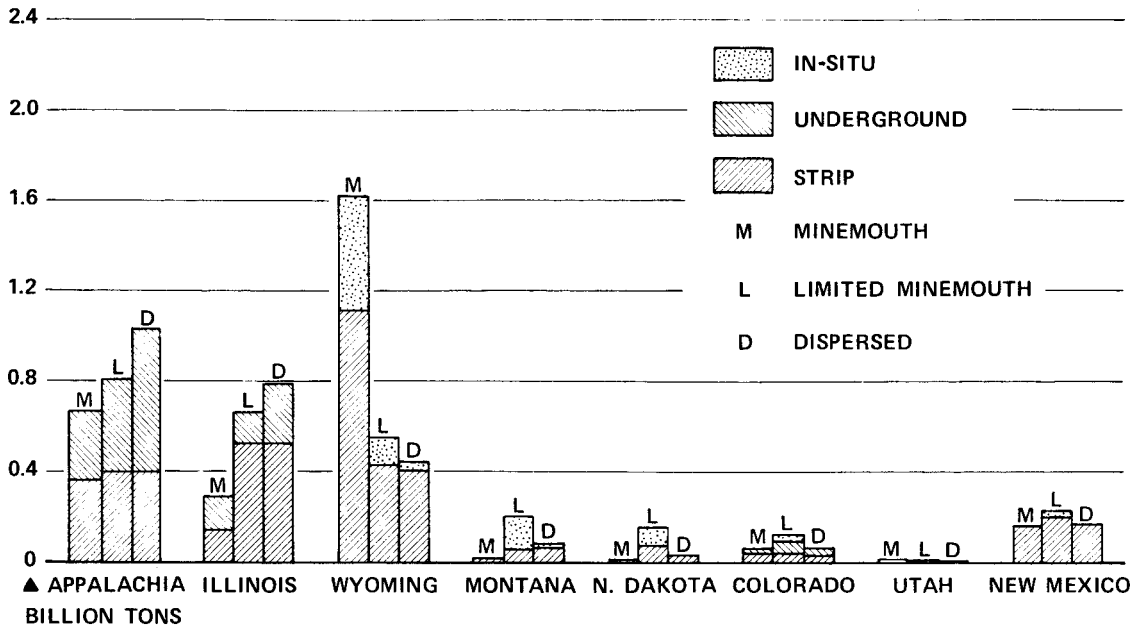

FIGURE 6-3. REGIONAL COAL PRODUCTION -- COMPARISON OF SCENARIOS

The average annual production cost per plant in the year 2000 is shown in Table 6-2 for all three scenarios. As can be seen, the annual per plant cost of SNG is increased much less by the Limited Minemouth Scenario than by the fully Dispersed Scenario. However, the annual syncrude cost per plant is nearly the same in the Limited Minemouth and Dispersed Scenario because very few syncrude plants are located differently.

Table 6-2

YEAR 2000 COMPARISON OF AVERAGE ANNUAL
SYNFUEL PRODUCTION COST PER PLANT
($ million)

Scenario	Syncrude	SNG
Minemouth	565	107
Dispersed	651	214
Limited Minemouth	636	151

D. Lessons of the Limited Minemouth Scenario

The results of the Limited Minemouth Scenario described above show the potential beneficial effects of cautiously and carefully planned development of the synfuel industry in contrast to a development program governed by industry economics as in the Minemouth Scenario, or to a complete denial of western locations because of water and social capacity limitations as in the Dispersed Scenario. The major benefits are

- A relatively even rate of development of the synfuel and coal industry in each western region.
- An extended period of production in each region that avoids early depletion of inexpensively mined coal.
- A relatively even sharing of coal production throughout the western coal regions.
- Intermediate production levels in Appalachia and Illinois.
- A synfuel production cost between the high cost of complete dispersal and the minimum cost of only minemouth locations.*

*Costs not quantitatively assessed in this study include the possible need to move water by aqueduct to western synfuel plants.

Chapter 7

POLICY IMPLICATIONS

A. Policy Questions

Three major areas of policy concern emerge from the analysis of a projected coal-based synthetic fuels industry:

- The longevity of the U.S. coal resource in a future featuring a high level of coal use.
- Strategies to mitigate the worst effects of rapid industrialization and the consequent urbanization coordinated with strategies to avoid potentially severe water shortages in the West.
- The role that energy demand reduction could play in lessening the need to engage in corrective or ameliorative impact mitigation efforts.

B. Coal Depletion

If coal becomes the dominant energy source--directly or indirectly--in the future, then the U.S. coal resource in the measured, indicated, and inferred reliability categories would be depleted at a rapid rate. By the year 2050, half of the coal in those reliability categories would have either been mined and used, or promised to plants then in operation (Figure 7-1). This foretells a much more rapid depletion of the "almost inexhaustible" U.S. coal resource than is generally appreciated.

More coal is likely to be discovered beyond the three reliability categories considered in the Coal Depletion Model.* How much more coal will be found, of course, is unknowable. However, to reach a better understanding of the longevity of the U.S. coal resource under more optimistic assumptions about the size of the coal resource, the Dispersed

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*Alaska was not included in the model although it has coal resources.

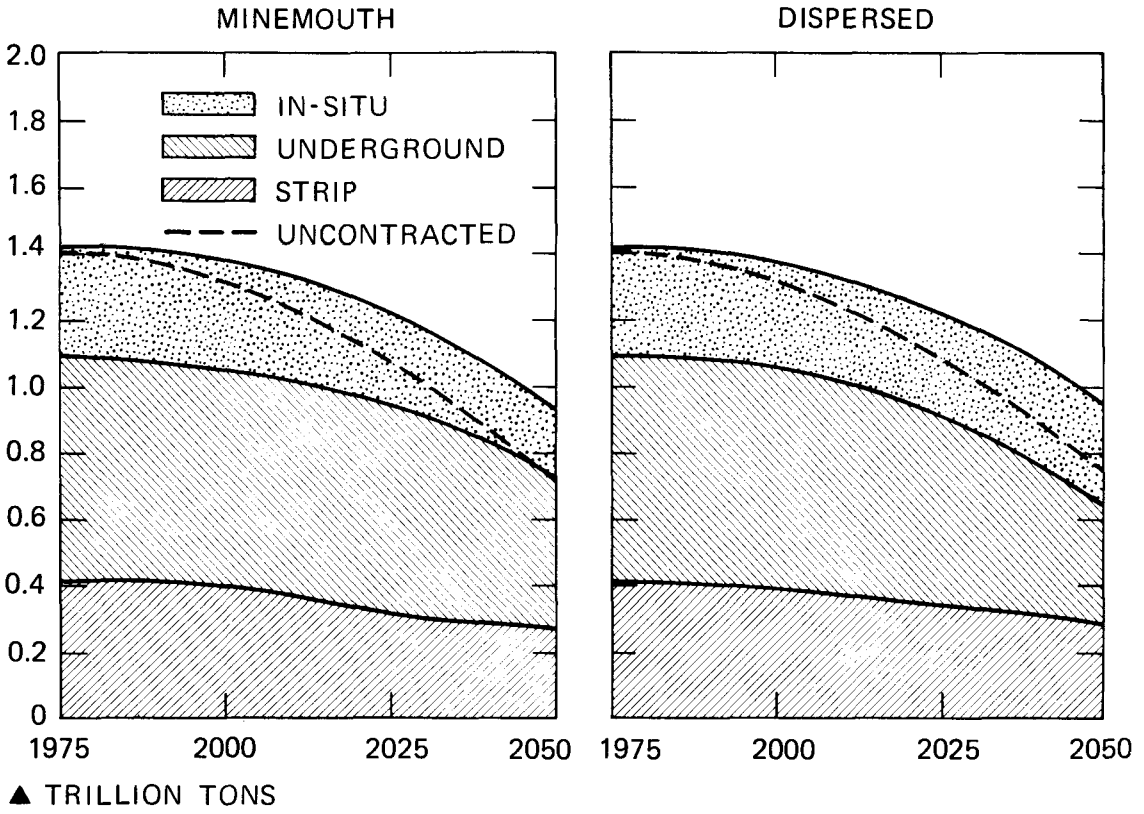

FIGURE 7-1. COMPARISON OF NATIONAL COAL DEPLETION FOR MINEMOUTH AND DISPERSED SCENARIOS
SOLID LINES INDICATE COAL MINED, DASHED LINES INDICATE COAL UNCONTRACTED

Scenario was reexamined with all the coal in the "hypothetical" reliability category included in the extraction cost curves. The results of this sensitivity test are shown in Figure 7-2.*

As one would expect, including coal in the hypothetical category in the total resource slows the depletion of U.S. coal. At the same time, it stretches out the boom/bust cycle in those regions that have large amounts of coal in the hypothetical reliability category. For example, if the hypothetical Wyoming resources were to be proved, the state could then expect that the "bust" portion of the boom/bust cycle would be delayed for many years. This would allow the region to stabilize in population and to bring its public services into accord with their demand.

*This sensitivity test is described in more detail in Appendix M.

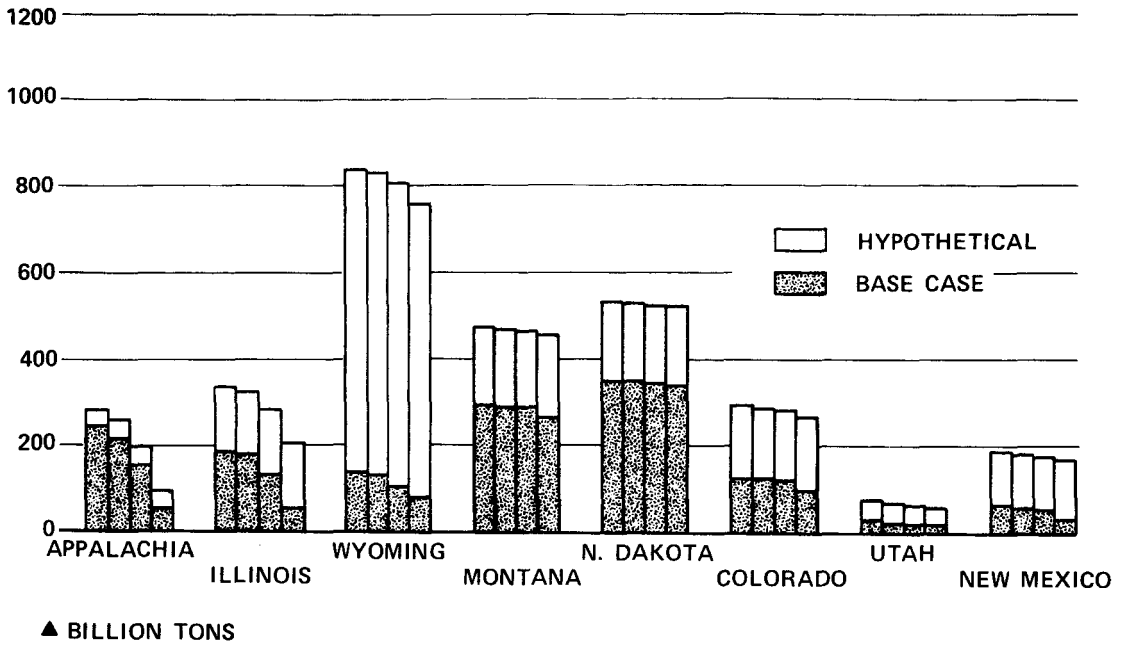

FIGURE 7-2. SENSITIVITY TEST: RESOURCES REMAINING WHEN HYPOTHETICAL RESOURCES ARE INCLUDED

Since the longevity of the coal resource is of vital interest not only to the nation but to the producing regions, it would seem prudent to mount a substantial effort to improve the knowledge of the U.S. coal resource as a part of our national energy policy. This requires a stepped-up exploration and inventory program that can yield information soon enough to affect the long-lasting energy policy decisions that will be made in the next several years.

C. Approaches to Plant Siting

The Minemouth Scenario demonstrated that in a coal-based energy future without constraints on plant locations, sparsely populated, but resource-rich, portions of the West would experience rapid increases in mining activity followed by rapid declines as the best, cheapest, and most-easily extracted coal was depleted. These boom and bust cycles are anticipated with dread by local communities and states.

In reality, of course, the playing out of the Minemouth Scenario would quickly surface constraints. Prominent constraints would be water availability, ability to accommodate new residents, and bottlenecks in transporting the products of coal conversion to market. The natural industrial response to such constraints would be to begin to site plants more in accord with the pattern of the Dispersed Scenario--but only after the problems of the Minemouth Scenario had become constraining.

The combined result, then, of a minemouth approach followed by a dispersed approach would seem to be similar to the Limited Minemouth Scenario when viewed from a distance. Close scrutiny of the Limited Minemouth Scenario, however, reveals an essential difference. The Limited Minemouth Scenario is an attempt to anticipate adverse impacts and real world constraints and to plan to avoid them as much as possible rather than to accommodate reactively to problems after they have occurred. Thus, the Minemouth Scenario is intended to show what could be achieved by a coal conversion plant siting policy national in scope.

From the vantage point of the freedom of industry to make its own decisions and the minimization of national energy costs, the Minemouth Scenario may seem like an optimum future. From the vantage point of western communities and states already bracing for large impacts, the Dispersed Scenario may seem like an optimum approach. However, from both vantage points, when the options are viewed realistically, the Limited Minemouth Scenario may appear to be a decent compromise between the best one could hope for and the best one could expect to get.

At present no entities--public nor private--have the authority to formulate and enforce a coal extraction and conversion siting strategy that is national in scope. Therefore, there is not in place a mechanism through which to realize anything resembling the Limited Minemouth Scenario.

D. Existing Planning Mechanisms

Although there is no national siting strategy for a synthetic fuel industry, some attempts have been and are being made by both industry and governments to avoid the problems brought on by rapid industrial growth through the use of existing mechanisms.

1. Community Development by Industry

Companies planning to move into rural areas with an activity that requires a large work force have become increasingly conscious of the adverse effects boom-town types of conditions have on their operations. Adverse living conditions have been shown to lower employee productivity, increase absenteeism, and increase the turnover of skilled employees. All three factors have important effect on a corporation's production costs and its image among prospective employees and the local community. Accordingly, several companies have planned both residential and entire community developments. Examples are ARCO's plans for building a community called Reno Junction in southern Campbell County, Wyoming,* to serve several new ARCO coal mines, and a town near Grand Valley, Colorado, to serve Colony Development Operation's previously planned oil shale venture.† However, except for such efforts made by companies through joint-venture consortia in oil shale, community planning of this kind appears to have remained uncoordinated.

2. Regulation of Basic Economic Development

Government regulation as an indirect means of controlling the location, size, or rate of growth of the industry can be used to moderate population growth and the secondary community impacts that result from this growth. Figure 7-3 illustrates the involvement of different levels of government in this type of regulation.

a. Federal Government

Primary power for controlling industries related to mineral extraction resides with the federal government, through its ability to grant mineral leases, invest in specific industries, and determine environmental regulations. The federal government is the largest owner

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*Personal communication with Mr. Gary Givens, Programs Coordinator, Community Development Group, Atlantic Richfield Co., Denver, Colorado.

†ARCO was slated to be the operator of Colony (originally a consortium of four oil companies).

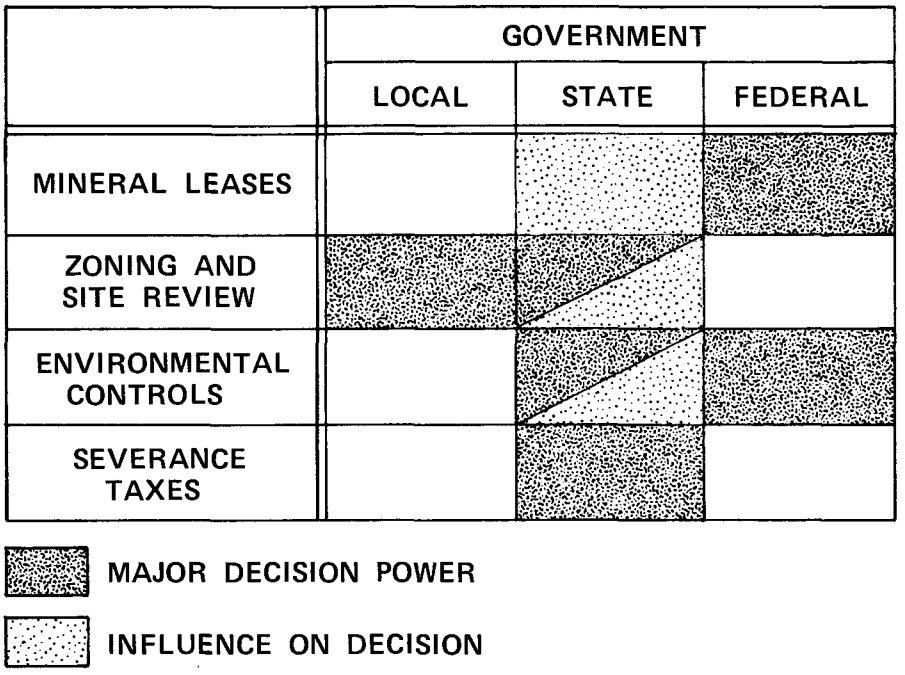

FIGURE 7-3. GOVERNMENT ROLE IN THE REGULATION OF BASIC ECONOMIC DEVELOPMENT

of mineral rights in the West.* Through granting leases for mineral extraction, federal agencies may determine both the location of future industrial development and the speed of this development. The federal government can thus use national interests to determine the degree and rate of regional development.

Environmental regulations provide an indirect but often potent influence on industrial growth. Such regulations may influence industrial location directly, or they may determine how much of the external environmental costs of industrialization are paid for by the industry. If these costs are high, investment in the industry may be

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*In the Decker-Birney region of Montana, for example, the federal government controls 88 percent of the mineral rights (Reference 1).

See Reference 2, Chapter 7, "Legal Mechanisms for Access to Coal and Oil Shale."

reduced, and the growth rate of the industry will be slower than in the nonregulated situations or its locational choices may be altered.

Present federal air pollution emissions regulations have increased the attractiveness of western coal compared to eastern coal because of its comparatively low sulfur content. Strip-mining legislation (which has not been signed into law) might act to reduce coal development in the West by the imposition of high reclamation costs.

Many government agencies are now reconsidering their leasing policies. Both the Department of Interior (U.S. Geological Survey and the Bureau of Land Management) and the Department of Agriculture (primarily the Forest Service) are looking at techniques for considering social concerns in their resource management decisions.[1] At present, these concerns are not formally incorporated in lease allocation decisions. Even if leasing policies are changed to consider social impacts, the cognizant agencies seem unlikely to allow social impacts to hold back the rate of coal development significantly.

b. State Government

State governments share some of the powers of industrial development control held by the federal government, but these powers tend to be weaker in the control of natural resource development. Most states have less influence over mineral leases than the federal government because they control fewer of the mineral rights for coal. Some states have attempted to use environmental laws to control the rate, location, and cost of mineral development.

State governments have other mechanisms for limiting the rates of industrial development. Two powerful ones are the severance tax and plant-siting restrictions. The severance tax is currently used in Montana as in indirect deterrent to mining in the state. The imposition of a 30 percent severance tax did not stop mining activity that had already begun but it appears to have discouraged new mining activity in the state.

The Coal Depletion Model was used to examine the effects of severance taxes on coal mining for the following cases:*

Increase (to 30 percent) on Colorado underground coal

Increase (to 30 percent) on Colorado and Illinois underground coal

Increase (to 100 percent) on Montana strip coal

Decrease (to 5 percent) on Montana strip coal

Increase (to 30 percent) on Wyoming strip coal.

A definite pattern became apparent in the results: When a state acts alone to impose a severance tax on coal, production in the state is decreased and its peak is shifted to a later time. Moreover, the boom cycle is spread over a longer period of time. When several states impose a severance tax the effect of an individual state's severance tax is weakened. If all states were to impose identical severance taxes, the effects would cancel out as long as total demand for coal remained unchanged.†

Although states can influence basic economic development through the use of severance taxes, this form of control is rather imprecise. A more precise mechanism is siting regulation.

Wyoming has recently adopted an "Industrial Development Information and Siting Act," ‡ which gives the state control over the location of large energy production facilities. The act sets up and funds a board to review all plans for large energy production facilities and all other industrial facilities (costing at least $50 million to construct). The board presides over public hearings to assure that the facility planned adheres to existing regulations and to consider the impacts of the facility on local inhabitants. Permits may be refused on

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*See Appendix M for a detailed presentation.

†One would expect, however, that such an across-the-board increase in coal cost would engender a reduction in coal demand.

‡House of Representatives Enrolled Act No. 108, 43rd Legislature of the State of Wyoming, 1975 Session.

the grounds of adverse social impacts. Permits granted under this procedure may include restrictions or requirements related to community impacts. While this is not a direct control on the levels of resource extraction, it is often effective in controlling both initial location and secondary impacts.

c. Local Level (City and County) Government

Local communities rely on state governments for their powers to control land use. Although each of the states involved in coal production permits some form of land use control to be exercised by the local government, this power does not extend to state or federally managed resources. Since the majority of the coal resources of these states are controlled by higher government levels, local governments have very little control over the basic location and rate of development of energy production industries and must depend on other measures, such as those that control secondary development.

3. Regulation of Secondary Development

Regulation of secondary development may include environmental controls (reclamation and emissions) and a wide variety of measures to ease the population impacts. The distribution of these regulatory powers is illustrated in Figure 7-4. Local governments have much more power to regulate secondary development than basic development; however, they must often rely on state and federal support to be able to wield this power effectively.

a. Federal Level

The federal role in environmental regulation is relevant to community impacts only as it affects the physical setting of the community. Federal input into community impacts is primarily through the funding of planning and community development programs. These programs are effective only to the extent that they are used by state and local governments. Some general programs exist to support planning and community

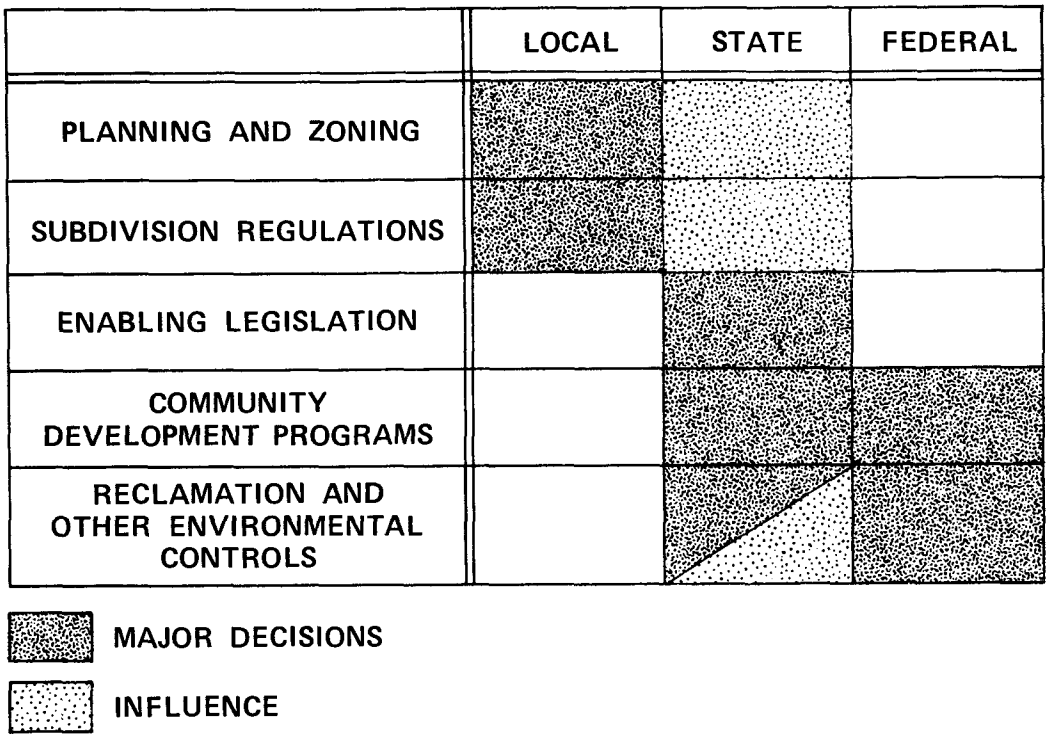

FIGURE 7-4. GOVERNMENT ROLE IN THE REGULATION OF SECONDARY DEVELOPMENT

development efforts.* Other programs have been considered specifically for energy-impacted regions.

b. State Level

Besides the use of plant siting reviews to establish conditional use permits, state governments also have an important role in supporting local development control activities. States prominent in energy development are currently producing a broad range of legislation directed at facilitating community regulatory and development programs. The Wyoming legislature has passed more than a dozen acts toward this end.† These include financial assistance acts, reduction of barriers to

*For example, HUD 701 grants and EPA 208 funds.

†Detailed presentation of the Wyoming acts is available in Part VII of Reference 3.

local funding efforts, subdivision and land use planning acts, and programs that encourage cooperation between different local governments.

c. Local Level

Local governments have been rapidly expanding their regulatory efforts in western boom-towns. Where development was once allowed to proceed without limit, now zoning ordinances and subdivision regulations prevail. In addition, local communities are voting to fund many of the public expenditures that are needed to cope with new growth.

Most of this action is ameliorative. Communities like Rock Springs and Gillette, Wyoming, began to cope with problems after the growth process was well advanced. If coping mechanisms are begun after the community experiences secondary impacts, then overcoming development barriers and service lags generally takes a long time.

4. Investment in Critical Services and Development Promotion

An obvious means of mitigating industrial growth impacts in rural areas is to invest in community development in anticipation of population growth. However, advanced investment is not common in energy development for reasons mentioned in Chapter 4. First, long-time residents in a community are unlikely to vote to pay for facilities that are only required if further growth occurs. Second, state and federal governments face many other pressing social problems that need funding more immediately than does a future community. Third, private investors are reluctant to accept the risks of early investment when industrial development is still uncertain.

An effective early investment program requires organized participation by several levels of government and private investors (Figure 7-5). For example, investment in housing through federal subsidy programs without support for increased sewage capacity often increases cost burdens on a local government. Similarly, new town development without road improvements or provision of social services often has adverse spillover effects on nearby small towns.

At present, some regional agencies are attempting to promote cooperation by increasing the flows of information between different levels of government. However, further coordination will be needed before timely responses to energy development plans are feasible.

E. Prospect

An energy future in which coal plays a major role is predictably near. The lack of guidelines addressed to industrial startup and long-term operation risks the repetition of past situations that are now recognized to cause economic, environmental, and social disruption. The basic question related to policy is "Does the U.S. want to avoid the repetition of past situations that have been so costly in the expenditure of national resources--human, monetary, and natural?" If the answer is "Yes," then it would seem that at the very least it would be worthwhile to stimulate

	SOURCES			
	LOCAL	STATE	FEDERAL	INDUSTRY
FEES	■	■		
TAXES	■	■	■	
BONDS	■	■		
INTER-AGENCY LOANS		■	■	
GRANTS		■	■	
PRIVATE INVESTMENT AND GRANTS				■

FIGURE 7-5. SOURCES OF FUNDS FOR EARLY INVESTMENT IN CRITICAL SERVICES

representatives of stakeholder groups--government, corporate, community, and public interest--to sound out strategies aimed at a thoughful transition to that coal-based energy future. An ideal transition with no adverse effects is probably impossible. But some of the strategies examined in this volume point the way to reducing such effects. If nothing else, a look at strategies will go a long way toward removing the element of surprise, and indicating where compromise may be necessary. This, in itself, should facilitate planning. In considering various strategies, it is likely that combinations of mechanisms will be discovered to have a beneficial effect far beyond the benefit of a single mechanism. Conversely, it may be that combinations of certain other mechanisms will be found to be mutually disadvantageous. Such increased understanding could be valuable to all stakeholders.

Finally, it must be recognized that efficient and effective impact mitigation is embodied in any energy conservation strategy that lessens the demand for coal. Without question, from the vantage point of those in line to experience the most adverse environmental and social impacts, avoidance or reduction in the causative agents is more effective than application of after-the-fact corrective actions.

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Appendix A

COAL RESOURCE INVENTORY

The coal regions used in the model were shown in Figure 2-2 and include all or part of the states shown in Table A-1. Coal resource was defined to the level of specifying each seam in terms of applicable extraction technology (strip, underground, or in-situ); thickness, quantity, quality (bituminous, subbituminous, or lignite) and reliability (reserve base, inferred or hypothetical). In addition, a depth distribution was assigned to each seam. Since data were not available to compile these characteristics directly, many assumptions were made based on judgmental extrapolation from available data. For the most part, these judgments have been checked with coal resource experts, primarily with the United States Geological Survey,[1] to verify their reasonableness.

Table A-1

COAL REGION DEFINITIONS

Coal Region	Included States (all or part)
Appalachia	Pennsylvania, West Virginia, Eastern Kentucky, Ohio, Virginia
Illinois	Illinois, Indiana, Western Kentucky
Wyoming	Wyoming
Montana	Montana
North Dakota	North Dakota
Colorado	Colorado
Utah	Utah
New Mexico	New Mexico

The approach first was to assemble data on the quantity of coal in each region in each quality, reliability, and mining technology category. Then, each category was separated into individual seams. Finally, the average energy and sulfur content were compiled for each region.

1. Quantity of Coal in Each Region and Category

The procedure for describing the quantity of coal in each category can be understood most easily by reference to Table A-2. The quantities in each reserve base category were extracted directly from appropriate Bureau of Mines Information circulars.[2-6] Although these circulars do not refer to in-situ coal, extraction of all coal with a seam thickness of greater than 10 ft and classified in the circulars as underground minable was assumed to be suitable for in-situ extraction and was transferred from the underground to the in-situ category.

To obtain the quantity of inferred resources in each category, the total amount of inferred resources was first obtained by subtracting the total reserve base for each region and quality category from the "identified resources" for that region and quality category shown in U.S. Geological Survey (USGS) Bulletin 1412.[7] These quantities were further disaggregated according to mining technology by means of the following assumptions:

> Half of the quantity of inferred resources are distributed among mining technologies in the same proportion as in the reserve base of the same region and quality category.
>
> The other half of the inferred resources are distributed between only the underground and in-situ categories in the same proportion as in the reserve base of the same region and quality category.

The rationale behind these two assumptions is that in the absence of actual data it is reasonable to assume that while it is likely that most of the strippable resources have been measured and are thus already accounted for in the reserve base, the distribution of inferred resources between underground and in-situ extraction are the same as in the reserve

Table A-2

U.S. COAL RESOURCES
(100 million tons)*

Region	Quality	Reliability Category: Reserve Base UG†	Reserve Base SM	Reserve Base IS	Reserve Base Total	Inferred UG	Inferred SM	Inferred IS	Inferred Total	Hypothetical UG	Hypothetical SM	Hypothetical IS	Hypothetical Total	Totals UG	Totals SM	Totals IS	Totals Total
Appalachia	Bituminous	869	141		1010	1318	99		1417	383	8		391	2570	248		2818
Illinois	Bituminous	711	178		889	897	100		997	1455	45		1500	3063	323		3386
Wyoming	Bituminous	45			45	82			82	560			560	687			687
	Subbituminous	106	238	144	488	244	166	334	744	2523	472	3445	6440	2873	876	3923	7672
Montana	Bituminous	14			14	9			9	18			18	41			41
	Subbituminous	383	355	262	1000	375	136	257	768	931	88	637	1656	1689	579	1156	3424
	Lignite		71		71		527	527	1054		19	107	126		617	634	1251
North Dakota	Lignite		160		160		1673	1673	3346		270	1530	1800		2103	3203	5306
Colorado	Bituminous	92	9		101	947	43		990	1083	14		1097	2122	66		2188
	Subbituminous	24		24	48	75		75	150	258		258	516	357		357	714
Utah	Bituminous	38	3		41	185	6		191	449	4		453	672	13		685
New Mexico	Bituminous	15	3		18	83	6		89	503	11		514	601	20		621
	Subbituminous	6	20		26	281	184	15	480	635	87	34	756	922	291	49	1262
Total		2303	1178	430	3911	4496	2940	2881	10317	8798	1018	6011	15827	15597	5136	9322	30055

*Data have been rounded.
†UG underground mining.
SM strip mining
IS In-situ extraction.

base. Thus, the inferred resources are likely to have a lesser proportion of strippable resources than the reserve base.

The hypothetical resources in each region and quality category were obtained from USGS Bulletin 1412.[7] Only those with less than 3000 ft of overburden were included. To distribute each hypothetical resource category among mining technologies, the same approach was used as for inferred resources (above), except that 85 percent of the hypothetical resources lie deeper than 1000 ft.[7] As a result, only 15 percent of the hypothetical resources in each extraction category were distributed in the same proportions as in the reserve base while 85 percent were distributed in the same proportions as the nonstrippable portion of the reserve base.

2. Disaggregation into Individual Seams

Seam characteristics were based on the information available on seams of the reserve base given in the Bureau of Mines circulars[2-6] (primarily seam thickness and quantity data). Coal in the inferred and hypothetical categories was assumed to have the same relative distribution of seam thicknesses as in the reserve base, but the thickness of each seam was reduced to half that of the corresponding reserve seam.* Also, the inferred resource category includes seams that have been measured but that are thinner than the minimum of 28 inches which comprises the reserve base defined by the Bureau of Mines. Bureau of Mines IC 8531[6] was used to obtain seam thicknesses for strippable coal, and the quantities listed under "recoverable strippable resources" were used to describe the distribution of thicknesses. This source was also used to describe the thickness distribution of in-situ coal. Thus, it was assumed that in-situ coal consists of seams with the same thickness distribution as the measured distribution in the portion of the strippable reserve base that is thicker than 10 ft. Bureau of Mines IC 8655[2] and 8678[3] were used for thickness distribution of underground coal seams. These sources give seam thickness

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*This half-thickness assumption attempts to account for the effect of the generally deeper location of these seams and the possibility that the greater geological pressure has resulted in thinner seams.

in ranges. For example, bituminous coal is classified into amounts having thicknesses between 28 and 42 inches and greater than 42 inches. These ranges were summarized by assuming that they were 34 and 54 inches thick. Likewise, the range shown for subbituminous coal is 60 to 120 inches; this range was represented by assuming a 72-inch value because thicknesses greater than that are assumed to result in no savings in underground mining costs. In effect, then, any thickness of 72 inches or above could have been used to represent that category.

Once the quantity of coal in each region was assigned to an extraction category and disaggregated into seam thickness categories, a depth was associated with each set of seams. Since little information was available on depth of seams, a range of depths was assumed for each category and the quantity of coal was taken to be distributed evenly in five discrete seams located at constant successive increments of depth over the depth range. For example, the depth range used for underground reserve coal was 120 to 1000 ft. The total quantity associated with a particular seam thickness was assumed to be distributed evenly in seams at depths of 120, 340, 560, 780, and 1000 ft, respectively. The depth ranges for each category of coal are shown in Table A-3. These ranges were chosen to incorporate the statistical information on depth of each type of coal shown in USGS Bulletin 1421.[7] Although hypothetical resources include seams down to 3000 ft in depth, nearly 90 percent are less than 2000 ft in depth. Similarly, over 90 percent of the inferred resources are less than 1000 ft in depth. For this reason, the depth range used to distribute the seams does not cover the complete range of possible values but emphasizes the most likely depths.

A maximum strip ratio* was used for the strippable reserve base, which overrides the depth assumption whenever there is a conflict. This

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*The term "strip ratio" is defined in this report as the thickness of the overburden divided by the thickness of the coal seam. This is nearly equivalent to the definition sometimes used in which it is the volume of overburden in cubic yards per ton of coal.

ratio was obtained from Bureau of Mines IC 8531[6] and varies from 8 in Utah to 18 in Illinois.

Table A-3

ASSUMPTION OF COAL SEAM DEPTH (ft)

Mining Technology	Quality		
	Reserve Base	Inferred	Hypothetical
Strip	25 - 125 (strip ratios max. 8-18)	60- 300	60- 300
Underground	120-1000	300-1200	800-2200
In-situ	120-1000	300-1200	800-2200

The procedures outlined above result in a highly disaggregated data base. In particular, there are 877 categories of seam thickness, quality, and regions, and each of these is further disaggregated into three reliability categories (reserve base, inferred, and hypothetical) and five depth categories. Thus, the total number of seams described in the model is 13,155.*

3. Heating Value and Sulfur Content

The heating value and sulfur content for each seam was obtained from the Bureau of Mines circulars.[2-5] The values shown for each state in these circulars are an average of the samples taken rather than an average of seam values weighted by the quantity in the seam. Therefore, to derive representative values of the average heating value and sulfur content of the coal in each model region, a weighted average was calculated for all seams in a county containing over 1 million tons. The derived average heating value and sulfur percentage is shown in Table A-4. In

*13,155 = 877 x 3 x 5.

the last column of Table A-4, those regions in which coal has an average sulfur content greater than 0.6 pound per million Btu are rated as "high sulfur" regions. The value of 0.6 pound per million Btu relates to the Environmental Protection Agency's source performance standard for emissions from large power plants in that if all of the sulfur content of high-sulfur coal were emitted to the air, the EPA standard would be exceeded.

Table A-4

AVERAGE COAL HEATING VALUE AND SULFUR CONTENT

Region	Heating Value (Btu/lb)	Sulfur Content (%)	Sulfur Rating
Appalachia	13,051	>1.0	High
Illinois	11,311	>1.0	High
Wyoming	8,730	0.48	Low
Montana	8,138	0.48	Low
North Dakota	6,821	0.87	High
Colorado	11,669	0.56	Low
Utah	10,506	0.80	High
New Mexico	11,468	0.65	Low

Industry generally has more stringent requirements on coal quality than other users.* To represent this, the model requires coal used for industry to have a heating value of at least 11,000 Btu/pound. As a result of this requirement, industrial coal was chosen in the model from only four of the eight regions: Appalachia, Illinois, Colorado, and New Mexico.

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*Much of the coal used in this category is "metallurgical" coal for steelmaking.

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Appendix B

COAL SEAM EXTRACTION COSTS

A generalized econometric-type cost equation was used for each type of mining technology to obtain the extraction cost per ton for each of the seams described in the previous section. These cost equations relate the extraction cost per ton to seam width, depth, and quantity. These equations are described below.

1. Underground Mining

The equation derived for underground mining cost is:

$$C = 13.57\ (Q/35)^{-0.14}\ (T/6)^{-0.1}\ (D/500)^{0.84}$$

where

C = cost in 1975 dollars/ton extracted

Q = quantity of coal in the seam in millions of tons to a maximum of 175 million tons.

T = seam thickness in feet to a maximum of 6 ft

D = seam depth in feet.

The constant in the equation (13.57) is the cost per ton of a 1 million ton/year underground mine working a seam at 500 ft deep and 6 ft thick. This figure was obtained directly from a recent Bureau of Mines analysis of capital investment and operating costs of underground coal mines.[1] In the Bureau of Mines analysis, the technology is continuous mining, the effect of the Bituminous Wage Agreement of 1974 on wages and union welfare rates is reflected, a 15 percent discounted cash flow rate of return on investment after federal income taxes is used, and a depletion allowance is included.

The second factor in the equation represents economies of scale achievable by large mines. It was assumed that the largest suitably sized mine (up to a maximum of 5 million tons/year) will be used to mine the coal. A 20-year mine lifetime and 57 percent recovery factor were also assumed. For example, a 1-million ton/year mine will exhaust a seam containing 35 million tons of coal in 20 years (i.e., 1 million tons/year times the 20-year lifetime divided by the 0.57 recovery factor to translate coal extracted to coal in the ground). The exponent, -0.14, is obtained from comparison of the extraction cost of mines of different sizes between 1 and 5 million tons/year contained in the same Bureau of Mines study.[1]

The third factor represents the cost variation with seam thickness. Two previous studies of the Bureau of Mines[2,3] were used to derive the exponent for this term. These studies analyzed the cost of two sets of underground mines, one mining 6-foot seams and the other mining 4-foot seams.

The fourth factor is the variation in cost with depth. The exponent for this term is obtained from a fit to a relative cost factor curve produced by SRI.[4] These relative depth cost factors are based on information from a number of sources including the opinions of specialists in various federal and state governmental agencies, subjective judgments of coal mine operating personnel, and SRI data.

2. Strip Mining

The equation derived for strip mining cost is:

$$C = 10.19\ (Q/25)^{-0.3}\ (SR/18)^{0.6}$$

for coal in the Appalachian and Illinois regions, and

$$C = 3.62\ (Q/105)^{-0.25}\ (SR/3)^{0.5}$$

for coal in the western regions, where C and Q are as defined for underground mining and SR is the strip ratio.

The first term in each equation is the capital investment and operating cost of a 1-million ton/year mine at a strip ratio of 18 for the first equation, and a 5-million ton/year mine at a strip ratio of 3 for the second equation. These figures are derived from analyses published by the Bureau of Mines[5] in 1972 using 1969 prices. The costs are translated into 1975 dollars using the wholesale price index for construction and a 15 percent (instead of 12 percent) discounted cash flow to convert the capital investment costs, and the Bituminous Wage Agreement of 1974 to translate labor and welfare costs. In addition, since the very large draglines are a major component of cost for the western 5-million ton/year mines, and since the cost of these machines has increased faster than general construction costs, a separate wholesale price index for draglines was used for the western mining cost translation.

The second factor in the equations represents economies of scale achievable by large mines derived in the same manner as was described for the underground mining cost equation . For eastern and midwestern mines shown in the first equation, the denominator of 25 is derived from the assumption that the largest sized mine would be a 1-million ton/year mine operating for 20 years with a recovery factor of 0.8 (requiring 25 million tons of coal in the ground).

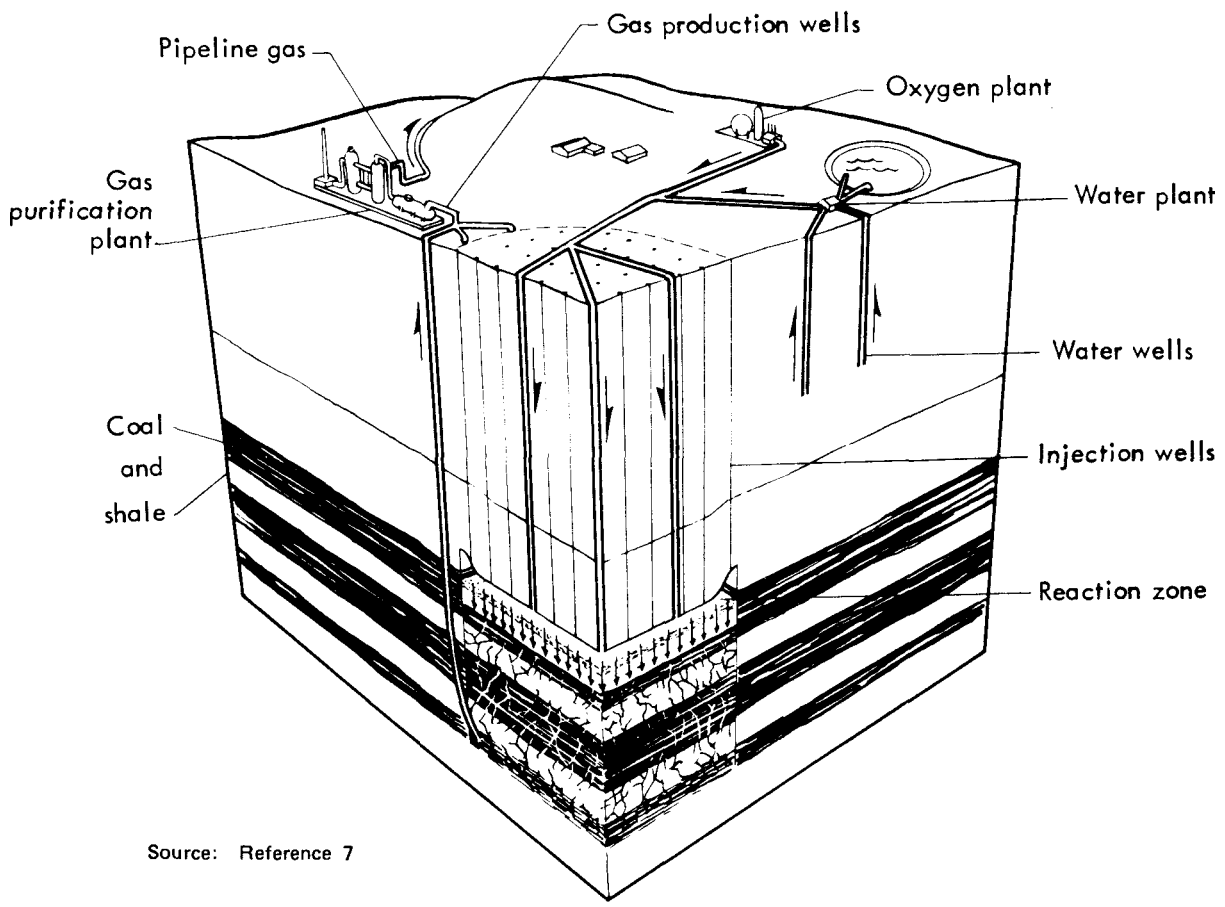
The analyses of the Bureau of Mines show examples of strip mines of up to 3 million tons/year in the east and midwest.[5] Thus, seam quantities greater than 75 million tons (3 x 25) are assumed to allow no greater economies of scale; that is, 3 million tons/year is taken to be the largest practical strip mine size in the east and midwest. Likewise, 5 million tons/year is the maximum size assumed for the west. The exponent of the second factor for each equation is obtained by fitting the several examples shown by the Bureau of Mines for different mine sizes in each region.

The third factor in the equations represents the variation of extraction cost with strip ratio. Since the smallest strip ratio shown

in the Bureau of Mines analyses is 3, that figure was taken as the minimum below which cost would not decrease further. The exponents were derived by fitting the examples shown.

3. In-Situ Extraction

Two methods of in-situ extraction of coal are represented in the model. The first is called vertical combustion and is described in reports by Lawrence Livermore Laboratories (LLL).[6,7] Vertical combustion is applicable to seams greater than 50 ft thick. Figure B-1 shows the LLL proposed method of in-situ extraction. The second method is called the horizontal combustion method; it is being developed by the Laramie Energy Research Center (LERC) of ERDA.[8] It is applicable to seams between



Source: Reference 7

FIGURE B-1. THE LLL IN-SITU COAL-GASIFICATION CONCEPT

10 and 50 ft thick. Each of these methods gasifies the coal in place and collects and purifies the resulting syngas at the surface.

The cost equations derived for in-situ mining of thick and thin seams are:

$$C = \$[0.47 + 0.27 \cdot (D/1500)^{1.8} \cdot (100/T)](0.89\ HV)$$

for seams >50 ft thick.

$$C = \$[0.51 + 0.14 \cdot (D/1500) \cdot (30/T)^{0.69}](0.63\ HV)$$

for seams between 10 and 50 ft thick,

where D is seam depth (ft), T is seam thickness (ft), and HV is heating value (million Btu/ton).

These cost estimates are for 1975; they assume utility financing.

Constants 0.47 and 0.51 represent the cost per million Btu of syngas, which is independent of seam thickness and depth. These costs consist primarily of the capital and operating costs of the surface equipment. The costs given in the LLL report include the cost of converting syngas to SNG. An EPA study on the conversion of coal to SNG[9] was used to estimate the fraction of costs given in the LLL report that correspond to the syngas-SNG conversion. These costs were then subtracted from the LLL costs along with drilling and fracturing costs to give the fixed cost shown.

The second and third factors of each equation show the scaling for depth and seam thickness. These terms are derived directly from curves and examples given in the LLL[6,7] and LERC[8] studies cited above. The capital cost for the surface facilities in the LERC estimate seemed rather low. This figure amounted to only $\$0.075/10^6$ Btu of syngas compared to the LLL figure of $\$0.29/10^6$ Btu. To reconcile this difference, $\$0.21/10^6$ Btu was added to the LERC cost estimate. This added cost is justified on two grounds: (1) the LERC cost estimate assumes air gasification to produce a low heating value utility fuel. The addition of an oxygen plant so that a medium heating value synthesis gas can be produced adds about

$0.10/10^6 Btu to the production cost (based on LLL data); (2) the LERC estimate was based on 1974 costs, which do not take into account the large escalation in plant construction costs that occurred in the 1974-75 period.

The second to last factor of each equation represents the efficiency of conversion of energy in the form of coal to energy in the form of syngas. Vertical combustion has a higher estimated efficiency, 0.89, than horizontal combustion, which has an estimated efficiency of 0.63. Finally, the heating value (HV) in units of millions Btu/ton of coal is included as the final factor to convert the cost into dollars/ton of coal.

A 15 percent penalty was added to the above cost estimates since in-situ processes are still in the engineering development phase and no full-scale operational experience has been obtained to date. This penalty was an attempt to represent the uncertainty in the actual costs and the innate optimism associated with early engineering estimates of final costs of a new technology.

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Appendix C

DERIVATION OF THE EXTRACTION COST CURVES

To obtain the extraction cost curves shown in Figures 2-3 to 2-5, we used the data of Appendices A and B. The appropriate cost equation from Appendix B was applied to each seam described in Appendix A, and then the seams were sorted and listed in order in each region, for each mining technology, according to their extraction cost. The total quantity of coal, Q_t, in each region and mining technology category was then calculated and divided by 20 because the extraction cost curves were approximated (for later use) by means of 20 straight-line segments. Starting at the lowest cost end, the computer then summed the quantity of coal available until $Q_t/20$ was reached. The extraction cost of the seam that causes $Q_t/20$ to be reached was then noted as C_1. The first coordinate of the 20 straight-line segment approximation was then $(C_1, Q_t/20)$. The procedure was repeated until $2\ Q_t/20$ was reached defining C_2, and so on until all 20 defining coordinates were obtained.

Appendix D

TRANSPORTATION COSTS AND DISTANCES

1. Costs

Transportation costs for coal and the electricity transmission costs were obtained from a recently published study by Bechtel Corporation.[1] In that study, equations were derived relating the transportation cost per ton-mile of coal by unit train, slurry pipeline, and barge to the transportation distance. These costs were inflated to 1975 dollars and the units of the equations were transformed into dollars per ton for the study reported here. The resulting expressions used for these three modes of coal transportation follow:

Unit train:

$$C = 0.136\ D^{0.609}$$

C = transportation cost in 1975 dollars per ton

D = distance transported in miles

Slurry pipeline:

$$C = [1.3 + 3.3/Q + (0.0026 + 0.046/Q) \cdot D]\ 1.15$$

where

Q = pipeline capacity in million tons of coal per year

Barge:

$$C = 0.0278 \cdot D^{0.715} + 0.88.$$

These costs are plotted in Figure 2-6 (Chapter 2).

The final factor of the slurry pipeline cost equation is a cost penalty of 15 percent, which represents the engineering and operating cost uncertainty of constructing and operating large, long-distance slurry pipelines.*

The final term of the barge cost equation represents the cost of a rail-to-barge transfer followed by a barge-to-rail transfer. Although not all barge transportation of coal involves a transfer to and from rail transport, the double transfer was charged for all barge transportation of coal.

The electricity transmission cost used in the model was 1.635 mills/million Btu of electricity per mile. This is expressed in dollars per ton of coal used by multiplying by the coal to electricity conversion efficiency and the energy content of one ton of coal.

2. Distances

Distance measurements used for slurry pipeline and rail transportation between a coal region and a conversion plant are highway distances since this information is readily available from standard highway atlases.[2] Highway distances were used directly to approximate slurry pipeline distances. Comparing rail and highway distances (when both were available) showed that the rail distances are about 7 percent longer; thus a 7 percent correction was applied to highway distances to approximate railway distances. Barge distances were obtained directly from an atlas of

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*To date, only two relatively short and low capacity coal slurry pipelines have been built in the United States. One in Ohio was 108 miles long and 10 inches in diameter (1.5 million tons/year capacity). This Ohio pipeline was later abandoned for coal use when rail rates were lowered to be competitive. The other slurry pipeline is the 273 mile and 18-inch diameter Black Mesa pipeline in Arizona (5 million tons/year capacity). Slurry pipelines that are competitive with unit train costs have a capacity of up to 10 million tons/year (25-inch diameter pipeline) and are generally much longer than the Black Mesa pipeline. Thus there is no direct operating experience on which to base firm cost estimates of large capacity and long pipelines for transporting coal slurry.

waterways.[3] In general, the barge transportation alternative involved unit train transportation for part of the total distance and barge travel on a waterway for the remainder. Distance data were stored in the computer for each coal region and plant location combination for calculating the cost of three transportation alternatives: (1) unit train, (2) slurry pipeline, (3) unit train/barge combinations.

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Appendix E

COAL CONVERSION PROCESSES COSTS

When working with the costs of converting various types of coal into gas, liquids, or electricity, it is convenient to express the conversion costs in dollars/ton of coal converted (exclusive of the cost of the coal itself). This requires knowledge of product cost, the efficiency of the conversion process, and the heating value of the coal used. Such parameters are typically specified in engineering cost analyses of various coal conversion processes.

The conversion cost is expressed by the following general equations:

$$C_{conv} = C_{prod}\ (Eff)\ (HV) - C_{coal}$$

$$= \left[C_{prod} - \frac{C_{coal}}{(Eff)(HV)}\right]\ (Eff)(HV)$$

where C_{conv} is the coal conversion cost in dollars per ton; C_{prod} is the cost of the product in dollars/10^6 Btu; C_{coal} is the cost of coal in dollars/ton; Eff is the energy efficiency of the process; and HV is the heating value of the coal in 10^6 Btu/ton.

Once the coefficient in brackets has been determined, using some specific data. this cost equation can be used as an approximation to scale the cost of conversion for various coal types having different heating values. In general, the energy conversion efficiency is not specifically determined for each coal type; however, assumptions are made based on engineering process analyses.

1. Coal Liquefaction

Recent cost estimates (1975) for coal liquefaction place the cost of producing syncrude at \$18-20/barrel[1] (\$3.10-3.50/10^6 Btu) assuming 100 percent equity financing and a 15 percent DCF (discounted cash flow) return on investment. Generally, the cost of syncrude from western subbituminous coal is at the lower end of the range, while syncrude from eastern bituminous coal is at the upper end of the range. The largest part of the differences arises from the higher costs of eastern coal, but smaller differences occur, which arise from varying assumptions about plant facilities investment, by-product credits, and so on.

There are various estimates of the conversion efficiency of coal liquefaction in the range of 50-70 percent.[1-3] However, an advanced single-stage liquefaction process such as the H-Coal process optimized for the production of liquid products and producing no gaseous by-products can achieve an overall energy efficiency of about 68 percent with bituminous coal and 63 percent with subbituminous coal.[3] The efficiency difference is largely due to the more favorable chemical composition of bituminous coal (relatively easier to convert to a liquid product), which contains more hydrogen and less oxygen than subbituminous coal.

Using the general conversion cost equation to estimate the conversion cost of the two coal types, assuming product costs of \$18/B and \$20/B and coal costs of \$5/ton and \$15/ton for western subbituminous and eastern bituminous coal, respectively:

Subbituminous coal:

$$C_{conv} = \left[3.10 - \frac{5}{(0.63)(17)}\right] (Eff)(HV)$$

$$= \$2.6 \ (Eff) \ (HV)$$

Bituminous coal:

$$C_{conv} = \left[3.50 - \frac{15}{(0.68)(24)}\right] (Eff)(HV)$$

$$= \$2.6\ (Eff)(HV)$$

Thus, the product cost exclusive of coal cost is effectively the same for the two coal types; this result provides some justification for using the approximate form of the cost equation. The conversion cost per ton will differ, however, due to the different efficiency factors, as well as differences in heating values.

2. Coal Gasification

Various discussions in the literature have placed the production cost for SNG, using commercial gasification technology and utility financing, roughly in the range of $\$2.00$-$\$2.50/10^6$ Btu (1975 dollars).* This cost range assumes minemouth conversion of western subbituminous coal costing about $5/ton. A typical heating value for this type of coal is 17×10^6 Btu/ton. The coal-to-gas efficiency of energy conversion for

*A recent application by Western Gasification Company (WESCO) to the Federal Power Commission for permission to construct and operate a coal gasification plant in northwestern New Mexico indicated a product cost of $\$2.38/10^6$ Btu.[5] An analysis by Gulf Research and Development Co. gave a somewhat lower figure, $\$1.89/10^6$ Btu.[6,7] The Institute of Gas Technology has also estimated the cost of SNG production using western coal.[8,9] Their results are based on mid-1973 costs. Updating these costs to 1975 results in a product cost of about $\$1.95/10^6$ Btu. These costs are sensitive to a number of assumptions; for example, by-product credits can decrease the product cost by up to 30¢ per 10^6 Btu.

gasification followed by methanation is about 56 percent.[4,5] * This figure includes the coal consumed as plant fuel, as well as that fed to the gasifiers.

Using an average conversion cost of $\$2.25/10^6$ Btu and the other figures discussed above, the cost per ton of coal gasified is:

$$C_{conv} = \left[\$2.25 - \frac{5}{(0.56)(17)}\right] (Eff)(HV)$$

$$= \$1.70\ (Eff)(HV)$$

3. Electricity

The costs (1975) of producing electricity in a coal-fired power plant were based on a capital requirement of $360/kW for a plant using low-sulfur coal and $430/kW for one using high-sulfur coal (including the cost of stack gas scrubbing).[11] A yearly average load factor of 60 percent, a conversion efficiency of 35 percent, and conventional utility financing were assumed.

With these assumptions, the cost of electricity was taken to be about 1.5¢/kWh from low-sulfur western coal costing $5/ton and about 2.1¢/kWh for high-sulfur eastern coal costing $15/ton. Using the general conversion equation:

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*The efficiency of the gasification process varies somewhat from one coal type to the next, although the variation is not large. For example, Hittman Associates report that for the Synthane process (similar to, but more advanced than the Lurgi process) the efficiency varies from 53.5 percent to 58.4 percent for different coal types.[2,10] Variations in efficiency estimates can stem, in part, from different assumptions about the way plant fuel is supplied, whether or not by-product tars and oils are regasified, etc. An average value of 56 percent appears to adequately represent the capability of present or near-term technology, with expected variations due to different coal types of no more than ±2 percent.

Low-sulfur coal: $C_{conv} = \$3.5\ (Eff)(HV)$

High-sulfur coal: $C_{conv} = \$4.5\ (Eff)(HV)$

4. Conversion of In-Situ Syngas

Once syngas has been produced by in-situ processes, brought to the surface and cleaned, it can then be converted to methane or burned to produce electricity.

About 25 percent of the capital cost and 17 percent of the operating costs can be attributed to the methane synthesis step, based on a detailed cost breakdown for the production of SNG from coal.[12] Applying these factors to the costs of SNG production previous presented, the cost of converting syngas to SNG is $\$0.48/10^6$ Btu of syngas. Since the thermal efficiency of conversion is 85 percent,[12] the cost per million Btu of SNG is $\$0.56/10^6$ Btu of SNG.

The costs of burning low-heating-value gas in a power plant to produce electricity were based on the capital and operating costs for a gas-fired power plant, exclusive of fuel costs. The combined capital charges and operating and maintenance costs were estimated at $50 million/year,[13] about 20 percent less than those for a coal-fired plant. At a load factor of 60 percent, and a conversion efficiency of 35 percent, the cost of generating electricity is about $\$0.98/10^6$ Btu of low-heating-value gas. However, since the power plant can burn low-heating-value gas resulting from using air as the gasifying medium in in-situ extraction instead of oxygen, an adjustment in the cost of gas production can be made to reflect the savings derived from eliminating the oxygen production plant. This savings amounts to about 9-10¢ per 10^6 Btu of gas. This savings was incorporated into the power plant cost. Thus, the net conversion cost became:

$$C_{elec} = \$0.90/10^6 \text{ Btu of syngas}$$

or

$$C_{elec} = \$2.57/10^6 \text{ Btu of electricity.}$$

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Appendix F

COAL DEMAND SCENARIO

1. Coal Demand

The starting point for the coal demand scenario was the per capita fuel demand for 1975-2100 shown in Figure 2-7 (Chapter 2) and the 1975 levels of use in each category. The demand of Figure 2-7 was then multiplied year-by-year with the population projection shown in Figure 2-8 (Chapter 2) to derive a scenario disaggregated with respect to energy form--liquid fuels (oil), gas, electricity, and industrial coal. To derive the coal demand curves shown in Figure 2-9 (Chapter 2) future consumption of each energy form was then further partitioned in the following manner:

Coal-Fired Electricity--Half of all electricity production was assumed to be generated in coal-fired plants. A 35 percent coal-to-electricity energy conversion efficiency was used.

Industrial Coal--No partitioning was required. Coal exports are included in this category.

Syncrude--U.S. oil consumption was partitioned into domestic oil, synthetic crude derived from oil shale, imports, and coal syncrude by subtracting projections of the supply derived from the first three categories from the total demand of Figure 2-9. This process is shown in Figure F-1. Domestic oil production was projected by assuming that cumulative production after 1975 will be limited to 250×10^9 barrels of oil.[1] Plausible production rates consistent with this limit include a production peak between 1990 and 1995 and declining production after 2000 at a rate of about 3 percent per year. Production from oil shale was assumed to rise to 2×10^6 B/D in 2000 and remain constant thereafter. Imports were assumed to remain constant between 1990 and 2050.

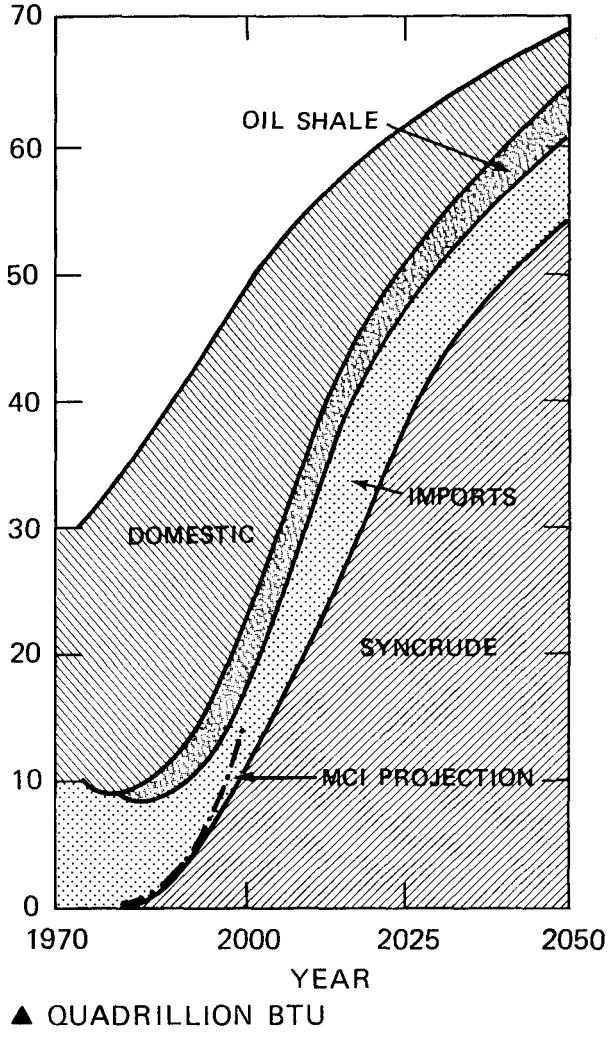

FIGURE F-1. ASSUMED COMPONENTS OF U.S. OIL SUPPLY FOR COAL DEMAND SCENARIO

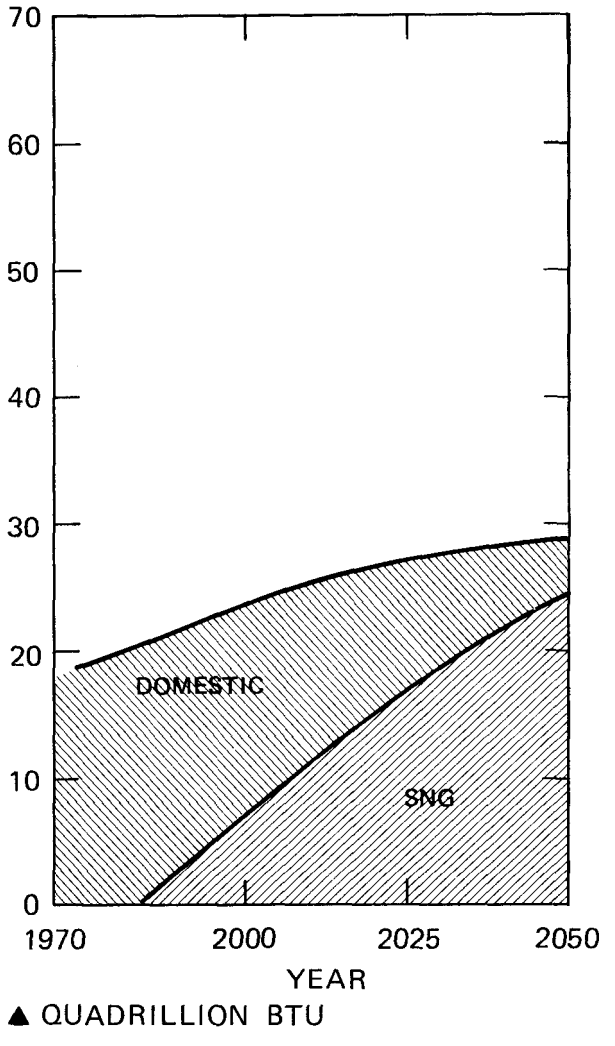

FIGURE F-2. ASSUMED COMPONENTS OF U.S. GAS SUPPLY FOR COAL DEMAND SCENARIO

Figure F-1 also shows the Maximum Credible Implementation scenario of synthetic liquids production used in Volumes I and II of SRI's previous study, entitled "Synthetic Liquid Fuels Development--Assessment of Critical Factors," for comparison with the syncrude production schedule used for the coal depletion model. The model's schedule for the production of synthetic liquids is below that of the MCI, because the previous study concluded that a high level of methanol production is unlikely and undesirable and because the MCI growth in the last decade of the century has been called "excessive" by numerous readers.

Substitute Natural Gas--The scenario's gas consumption was partitioned into domestic natural gas and SNG as in Figure F-2. No imports of natural gas were assumed. Natural gas production from conventional desposits was projected by assuming that cumulative production after 1975 will be limited to 900×10^{12} cu ft[1] and that production will decline exponentially (at approximately 2.5 percent per year) from 1975 onward.

2. 1975 Regional Coal Production

Coal production in 1975 by region and mining technology was derived by using the Bureau of Mines Mineral Industry Survey[2] for coal for the first six months of 1975 to estimate the production of coal in each region for electric utility and industrial uses. The Federal Power Commission Annual Summary for 1974[3] was used to obtain the fraction of utility coal that was strip-mined (this was the only recent survey available when the data were needed). Since data on the fraction of industrial coal strip-mined in each region were not available, and since a very large fraction is known to be mined underground, all industrial coal was assumed to be underground-mined from 1975 to 2050.

The resulting estimate for 1975 coal production is shown in Table F-1. The production for 1975 and for the remainder of the period for each contract active in 1975 was subtracted from the initial coal resource available before any new contracts are processed.

Table F-1

ESTIMATED 1975 COAL PRODUCTION
(Million tons)

Coal Region	Electric Utility		Industrial
	Underground	Strip	Underground
Appalachia	127	72	177
Illinois	52	79	18
Wyoming	1	19	0
Montana	0	23	0
North Dakota	0	6	0
Colorado	2	1	5
Utah	3	0	4
New Mexico	1	11	0
Total	191	211	204

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Appendix G

CONVERSION PLANT AND DEMAND GATEWAY LOCATIONS

The coal demand for syncrude, SNG, electricity, and industry, was disaggregated into the number of plants and their locations as described below.

1. Syncrude

The syncrude production was divided into an integral number of 191 trillion Btu/year plants (equivalent to 100,000 B/D) beginning operation at five-year intervals. Each plant was assumed to have a lifetime of 25 years and to continue in production for succeeding 25-year lifetimes after receiving appropriate repairs or rebuilding. Thus, although a new contract for coal would be negotiated at the end of each 25 years, in the Dispersed Scenario the plant would continue at its same location; these can be considered as plant restarts. In the Minemouth Scenario, plants would be free to choose a new location each 25 years to allow for the abondonment of plants when their minemouth coal supply was depleted. The number of new (additional) plants beginning operation at each five-year interval is the difference between the total scheduled production of syncrude and the number of plants still in operation.

For the Dispersed Scenario, new plants were located in cities east of the 100th meridian that have a population of at least 30,000 in 1970. Locations were chosen at a railroad or waterway terminus and within a few miles of a surface water resource. However, the first few plants were located in northwestern and midwestern states to satisfy the anticipated demand arising from a cutoff of Canadian oil and gas imports. The list of syncrude plant locations with their date of production start is shown in Table G-1.

Table G-1

DISPERSED SCENARIO--LOCATION AND PRODUCTION START YEAR OF SYNCRUDE PLANTS

			1980		
Billings, MT					
			1985		
Billings, MT	Sioux Falls, SD	Sioux City, IA	Council Bluffs, IA		
			1990		
Galveston, TX	Vicksburg, MS	Topeka, KS	Greenville, MS	Tyler, TX	Minneapolis, MN
Fargo, ND	Memphis, TN	Dubuque, IA	Pasadena, TX	Hibbing, MN	
			1995		
Huntington, WV	Fond Du Lac, WI	Dallas, TX	Omaha, NB	Pensacola, FL	Savannah, GA
Norman, OK	Providence, RI	Pittsburgh, PA	Kansas City, MO	Evansville, IN	Fayetteville, AR
Portsmouth, OH	St Charles, MO	Decatur, AL	Beaumont, TX	Rapid City, MO	Boston, MA
Jackson, MS					
			2000		
Philadelphia, PA	Charleston, SC	Wheeling, WV	Minot, ND	Harlingen, TX	Leavenworth, KS
Shreveport, LA	Natchez, MS	Gulfport, MS	Houston, TX	Baton Rouge, LA	Ft Dodge, IA
Norfolk, VA	Lufkin, TX	Louisville, KY	St Louis, MO	Texarkana, TX	Wilmington, NC
New York, NY	Parkersburg, WV	Albany, NY	Blytheville, AR	Jefferson City, MO	Tampa, FL
			2005		
New Port, RI	Crestview, FL	Hot Springs, AR	Bowling Green, KY	Ft Worth, TX	Norfolk, VA
Sandusky, OH	Springfield, IL	Milwaukee, WI	Albert Lee, MN	Anniston, AL	Syracuse, NY
Tallahassee, FL	Cheyenne, WY	Bryan, TX	Manhattan, KS	Clarksdale, MS	Corpus Christi, TX
Hutchinson, KS	St Joseph, MI	Toledo, OH	New Haven, CT	Trenton, NJ	Laredo, TX
Casper, WY	Columbus, IN				
			2010		
Fort Myers, FL	New Haven, CT	Chattanooga, TN	Dover, DE	Miami, FL	Victoria, TX
Winston-Salem, NC	Ithaca, NY	Davenport, IA	Racine, WI	Birmingham, AL	Charleston, WV
Gadsden, AL	Galveston, TX	Mc Alester, OK	Ottumwa, IA	Terre Haute, IN	Zanesville, OH
Poughkeepsie, NY	Hartford, CT	Edinburg, TX	West Palm Beach, FL	Elizabeth, NC	Columbus, GA
Florence, AL	Brownsville, TX	Sherman, TX	Brunswick, GA		

Table G-1 (continued)

2015

Wilmington, DE	Sarasota, FL	Lawrence, KN	Dotham, AL	Toledo, OH	Grand Rapids, MI
Wheeling, WV	Grand Forks, ND	Leavenworth, KS	Vicksburg, MS	Brownsville, TX	Cicinnati, OH
Janesville, WI	Ottumwa, IA	Schenectady, NY	Victoria, TX	Columbia, SC	Baltimore, MD
Ft Smith, AR	Mismark, ND	St Louis, MO	Little Rock, AR	Pasadena, TX	Savannah, GA
Richmond, VA	Louisville, KY	Kansas City, MO	Quincy, IL	Burlington, IA	

2020

Corpus Christi, TX	Port Arthur, TX	Pittsburgh, PA	Wilmington, NC	Jackson, MS	Quincy, IL
Rockford, IL	Gary, IN	Flint, MI	Columbus, OH	Wilmington, DE	Hot Springs, AR
Elizabeth, NC	Houma, LA	Asheville, NC	Bryan, TX	El Dorado, AR	Winston-Salem, NC
Cheyenne, WY	Cumberland, MD	Dover, DE	Columbus, IN	Lafayette, IN	Detroit, MI
Marquette, MI	Toledo, OH	Zanesville, OH	Decatur, IL	Evansville, IN	Albany, NY

2025

Harrisburg, PA	Iowa City, IA	Pensacola, FL	Little Rock, AR	Beaumont, TX	Houston, TX
Niagara Falls, NY	Buffalo, NY	Poughkeepsie, NY	West Palm Beach, FL	Tallahassee, FL	Leesville, LA
Columbus, GA	Rome, GA	Macon, GA	Florence, SC	Chillicothe, OH	Bowling Green, KY
Columbia, TN	Paducah, KY	Owensboro, KY	Erie, PA	Miami, FL	Newark, NJ
Hartford, CT	Buffalo, NY	Dotham, AL	Terre Haute, IN	Columbus, OH	

2030

Lincoln, NB	Salina, KS	Ottumwa, IA	McAlester, OK	Danville, IL	Michigan City, IN
Sandusky, OH	Lansing, MI	Schenectady, NY	Newark, NJ	New Brunswick, NJ	New London, CT
New Haven, CT	Washington, DC	Houma, LA	Sherman, TX	San Antonio, TX	Asheville, NC
Waycross, GA	Brunswick, GA	Montgomery, AL	Tuscaloosa, AL	Morgantown, WV	Franklin, PA
Casper, WY					

2035

Gulfport, MS	Lake Sharles, LA	Sioux City, IA	Sioux Falls, SD	Lawrence, KS	Poplar Bluff, MD
Crestview, FL	Anniston, AL	Valparaiso, IN	Gary, IN	Wilmington, NC	Salina, KS
Augusta, GA	Atlanta, GA	Gadsden, AL	Tuscaloosa, AL	Huntsville, AL	Morgantown, WV
Williamsport, PA					

2040

New Orleans, LA	Providence, RI	La Crosse, WI	Fargo, ND	Shawnee, OK	Orange, TX
Houston, TX	Topeka, KS	Boston, MA	Chicago, IL	Charleston, WV	Morgantown, WV
Wilkes-Barre, PA	Reading, PA	Bowling Green, KY	Owensboro, KY		

Table G-1 (concluded)

2045

Paducah, KY	Dyersburg, TN	Columbus, MS	Miami, FL	Richmond, VA	Wichita, KS
Cape Girardeau, MD	Memphis, TN	Mankato, MN	Pascagoola, MS	Ithaca, NY	Fort Myers, FL

2050

Waco, TX	St Cloud, MN	Manhattan, KS	Leesville, LA	Montgomery, AL	Erie, PA
Scranton, PA	Reading, PA	Valdosta, GA	Birmingham, AL	Syracuse, NY	Decatur, IL
Peoria, IL					

2. Substitute Natural Gas

SNG production was disaggregated in the same manner and with the same rules for plant location as for syncrude except that the standard plant size chosen was 80 trillion Btu/year (equivalent to 250 x 10^6 SCF/day). The resulting start dates are shown in Table G-2.

3. Electricity

Coal-fired electricity plants were located on the basis of the following assumptions:

> Coal-fired electricity plants are of unit size of 20 trillion Btu/year (equivalent to 1000 MW_e).
>
> The total coal-fired electricity production is distributed among the nine major regions of the United States defined by the Bureau of the Census. The relative distribution used is derived from a forecast published by the Federal Energy Administration for 1985.* This FEA projection postulates that most of the anticipated changeover of oil- and gas-fired boilers to coal-fired boilers will have been accomplished by 1985 and is thus represented in the projected distribution of production.† The fraction of energy production in each region used in the model is shown in Table G-3 and is held constant throughout the 75-year period.
>
> Within each census region, a number of distribution centers are chosen to reflect the regional population distribution. New electricity plants in a census region are assigned to cities designated as distribution centers in approximate proportion to the population represented by that city. Table G-4 shows the cities used and their relative populations. Within each region, their order of contract negotiation within the model was randomized.
>
> A fraction of the new electricity production in each census region and in each five-year period is located at the minemouth in a nearby coal region. The electricity is sent over transmission lines to the designated distribution center within the census region. The coal region where each minemouth electricity plant is located is determined in the model by calculating which region would yield the least expensive electricity (including transmission costs) to the designated city of distribution. The

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*"National Energy Outlook, February 1976," FEA-N-75/713, Federal Energy Administration, Government Printing Office, Washington, DC (1976).

†The FEA figures were adjusted downward in the regions that include Texas, Oklahoma, Alabama, and Missouri to account for the exclusion of the coal in those states in the model's data base.

Table G-2

DISPERSED SCENARIO--LOCATION AND PRODUCTION START YEAR OF SNG PLANTS

			1980		
Bismark, ND	Great Falls, MT	Grand Forks, ND	Des Moines, IA		
			1985		
Ponca, OK	Longview, TX	St Joseph, MO	Pascagoola, MS	Chicago, IL	Austin, TX
Monroe, LA	Janesville, WI	Ft Worth, TX	Corpus Christi, TX	Port Arthur, TX	
			1990		
Pine Bluff, AR	Columbia, MO	Tulsa, OK	Waco, TX	Knoxville, TN	Clinton, IA
Mobile, AL	Bismark, ND	Cape Girardeau, MO	Cincinnati, OH	Cedar Rapids, IA	Lake Charles, LA
Brownsville, TX	Wichita Falls, TX	Birmingham, AL	Orange, TX	Wichita, KS	Muskogee, OK
Waterloo, IA	Little Rock, AR				
			1995		
Grand Island, NB	Bartlesville, OK	Shawnee, OK	Rochester, MN	Hattiesburg, MS	La Crosse, WI
New Orleans, LA	Alexandria, LA	Waukesha, WI	Lafayette, LA	St Cloud, MN	Ft Smith, AR
Columbia,, SC	Baltimore, MD	Harrisburg, PA	Madison, WI	Richmond, VA	Appleton, WI
Chattanooga, TN	Minneapolis, MN	Des Moines, IA	Pascagoola, MS	Minot, ND	Madison, WI
			2000		
Vicksburg, MS	Mankato, MN	Moline, IL	Temple, TX	Great Falls, MT	New Orleans, LA
Iowa City, IA	Charleston, SC	Chicago, IL	Port Huron, MI	Shreveport, LA	Duluth, MN
Brunswick, GA	Pasadena, TX	Corpus Christi, TX	Billings, MT	Cumberland, MD	Leesville, LA
New York, NY	Louisville, KY	Houston, TX	Memphis, TN	Davenport, IA	Jefferson City, MO
Natchez, MS	Galveston, TX				
			2005		
Chillicothe, OH	Alexandria, LA	Omaha, NB	Hattiesburg, MS	Dallas, TX	Columbus, MI
Franklin, PA	Philadelphia, PA	Waukegan, IL	Pittsburgh, PA	Sarasota, FL	Poplar Bluff, MO
Cumberland, MD	Saginaw, MI	Milwaukee, WI	Detroit, MI	Elizabeth, NC	Williamsport, PA
Augusta, GA	Dotham, AL	Evansville, IN	Marshalltown, IA	El Dorado, AR	Sherman, TX
Macon, GA	Charlotte, NC	Topeka, KS	Mobile, AL		

Table G-2 (continued)

2010

San Antonio, TX	Florence, SC	Buffalo, NY	Washington, DC	Kalamazoo, MI	Danville, IL
Marquette, MI	Indianapolis, IN	Cleveland, OH	Birmingham, AL	New London, CT	Schenectady, NY
Stamford, CT	Pensacola, FL	Huntington, WV	Norfolk, VA	Portsmouth, OH	Gary, IN
Columbus, OH	Flint, MI	Niagara Falls, NY	Rochester, NY	Asheville, NC	Reading, PA
Charleston, WV	Rome, GA	Huntsville, AL	Jacksonville, FL	Lawton, OK	

2015

Kearney, NB	Scranton, PA	Council Bluffs, IA	Boston, MA	Stamford, CT	Lafayette, IN
Duluth, MN	Enid, OK	Columbus, NB	Kansas City, MO	Hutchinson, KS	Dubuque, IA
Texarkana, TX	Austen, MN	Lincoln, NB	Rockford, IL	Michigan City, IN	Terre Haute, IN
Valparaiso, IN	Wilmington, NC	Houston, TX	Fort Wayne, IN	Saginaw, MI	Blytheville, AR
New Brunswick, NJ	Newark, NJ	Houma, LA	Tulsa, OK		

2020

Peoria, IL	Bay City, MI	Columbus, IN	Cleveland, OH	Hattiesburg, MS	Sheboygan, WI
Newport, RI	Trenton, NJ	Ithaca, NY	Laredo, TX	Houma, LA	Edinburg, TX
Crestview, FL	Anniston, AL	Albert Lee, MN	Decatur, AL	Clinton, IA	Ft Dodge, IA
Washington, DC	Fort Myers, FL	Dover, DE	Huntington, WV	Port Arthur, TX	Beaumont, TX
Wheeling, WV	Knoxville, TN	Leavenworth, KS			

2025

Wheeling, WV	Grand Rapids, MI	Bay City, MI	Toledo, OH	Saginaw, MI	Milwaukee, WI
Portsmouth, OH	Appleton, WI	Dubuque, IA	Texarkana, TX	Mawkesha, WI	Harrisburg, PA
Lufkin, TX	Norfolk, VA	Louisville, KY	Orange, TX	Pine Bluff, AR	Cedar Rapids, IA
Greenville, MS	Tulsa, OK	Waterloo, IA	Gulfport, MS	Lake Charles, LA	St Cloud, MN

2030

Cumberland, MD	Rochester, NY	Schenectady, NY	New Port, TI	Fort Wayne, IN	Detroit, MI
Joliet, IL	Rockford, IL	Kankakee, IL	Peoria, IL	Hutchinson, KS	Chicago, IL
Parkersburg, WV	Blytheville, AR	Minneapolis, MN	Pine Bluff, AR	Wichita, Falls, TX	Hibbing, MN
New Orleans, LA	Bismark, ND	Rochester, MN	St Joseph, MO		

2035

Scranton, PA	Wilkes-Barre, PA	Bowling Green, KY	Columbia, TN	Clarksdale, MS	Charlotte, NC
Waycross, GA	Montgomery, AL	Popular Bluff, MO	Lufkin, TX	Chattanooga, TN	Lafayette, LA
Columbus, NB	Marshalltown, IA	Davenport, IA	Austen, MN	Indianapolis, IN	Port Huron, MI
Kalamazoo, MI					

Table G-2 (concluded)

2040

Macon, GA	Augusta, GA	Columbia, TN	Chillicothe, OH	Florence, AL	Huntsville, AL
Victoria, TX	Austin, TX	Jacksonville, FL	Birmingham, AL	Muskogee, OK	Ponca, OK
St Louis, MO	Rapid City, SD	Grand Island, NB	Baton Rouge, LA	Temple, TX	Natchez, MS

2045

Waterloo, IA	Des Moines, IA	Muskogee, OK	Longview, TX	Fond Du Lac, WI	St Charles, MO
Moline, IL	Columbia, MO	Monroe, LA	Enid, OK	Kankakee, IL	South Bend, IN
Cleveland, OH	Green Bay, WI	Lafayette, IN	Fayetteville, AR	New York, NY	

2050

Mobile, AL	Sarasota, FL	Billings, MT	Norman, OK	Sioux City, IA	Knoxville, TN
Harlingen, TX	Stamford, CT	Waycross, GA	Florence, AL	Franklin, PA	Clarksdale, MS
Omaha, NB	Chicago, IL	Longview, TX			

Table G-3

ASSUMED DISTRIBUTION OF COAL-FIRED ELECTRICITY PRODUCTION AND INDUSTRIAL COAL DEMAND

Census Region	Fraction of Coal-Fired Electricity Production	Fraction of Industrial Demand
Northeast	0.022	0
Middle Atlantic	0.154	0.213
South Atlantic	0.200	0.357
East North Central	0.285	0.316
East South Central	0.097	0.035
West North Central	0.122	0.033
West South Central	0.037	0.001
Mountain	0.068	0.026
Pacific	0.015	0.019

Table G-4

ASSUMED ELECTRICITY PRODUCTION
AND DISTRIBUTION CENTERS

Census Region	City	Assigned Relative Fraction Within Region
Northeast	Boston, MA	1/1
Mid Atlantic	Albany, NY	1/5
	Pittsburgh, PA	4/5
South Atlantic	Charleston, SC	1/12
	Miami, FL	4/12
	Washington, DC	7/12
East North Central	Chicago, IL	10/12
	Columbus, OH	1/12
	Milwaukee, WI	1/12
East South Central	Jackson, MS	1/6
	Louisville, KY	2/6
	Nashville, TN	3/6
West North Central	Kansas City, MO	2/5
	Minneapolis, MN	2/5
	Omaha, NB	1/5
West South Central	Dallas, TX	5/9
	Little Rock, AR	1/9
	Oklahoma City, OK	3/9
Mountain	Albuquerque, NM	3/12
	Great Falls, MT	1/12
	Denver, CO	6/12
	Salt Lake City, UT	2/12
Pacific	Los Angeles, CA	6/12
	Portland, OR	1/12
	San Francisco, CA	3/12
	Seattle, WA	2/12

fraction of new electric power plants assumed to be located at the minemouth decreases linearly with time from 18 percent (the fraction corresponding to recent years) in 1980 to 4 percent in 2050. This decrease in minemouth locations was assumed because resource areas seem to be decreasingly willing to accept the pollution associated with electricity generation destined for distant markets.

In the model, electric power plants have a useful lifetime of 30 years. If the plant location is not at the minemouth it is continued in the same location after being refurbished and negotiating a new contract for coal for each successive period of 30 years. If the plant is minemouth, a new least-cost minemouth location is chosen for each successive 30-year period.

The 1975 production of coal-fired electricity is based on a set of long-term contracts for coal--similar to those negotiated in the model--which have a relatively even distribution of years remaining in the contracts. The fraction of coal contracts existing in 1975 and the assumed remaining terms are shown in Table G-5. When these existing contracts expire, new plants are started in each census region in conformity with the assumed distribution described in Table G-3. The application of these assumptions results in the list of new electricity plants and their locations as shown in Table G-6.

Table G-5

ASSUMED REMAINING TERMS OF 1975
ELECTRICITY GENERATION AND
INDUSTRIAL COAL CONTRACTS

Remaining Time (years)	Fraction of Existing Contracts	
	Electricity	Industry
5	0.14	0.20
10	0.15	0.23
15	0.16	0.27
20	0.17	0.30
25	0.18	--
30	0.20	--

Table G-6

ELECTRIC POWER PLANTS--LOCATION, DISTRIBUTION CENTER AND YEAR OF START-UP

Distribution Center	Year of Production Start														
	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Boston, MA	1 0*	1-1	1 0	1-1	1 0	2 0	1 0	0 0	1 0	1 0	1 0	1 0	0-1	0 0	1 0
Albany, NY	2 0	2 0	2 0	2 0	2 0	2 0	2 0	1 0	1 0	1 0	1 0	1 0	1-1	1 0	1 0
Pittsburgh, PA	6-1	6-2	6-2	7-1	7-2	8-1	4 0	4-1	4-1	4-1	4 0	5 0	4 0	4 0	5 0
Charleston, SC	1 0	1 0	1 0	1 0	1-1	1 0	0-1	0 0	1 0	0 0	1 0	1 0	0 0	1 0	0 0
Miami, FL	3-1	3-1	4 0	4-1	4 0	5 0	3 0	2-1	2 0	2-1	2 0	2 0	3 0	2 0	3 0
Washington, DC	6-1	6-1	6-2	7-1	7-1	7-2	4 0	4 0	4 0	5 0	4 0	4-1	4 0	4-1	4 0
Chicago, IL	12-2	12-3	13-2	13-3	15-1	16-2	8-2	8 0	9-1	8 0	8-1	8-1	8 0	9 0	9 0
Columbus, OH	1-1	1 0	1-1	1 0	2 0	2 0	1 0	0-1	0 0	1 0	1 0	1 0	1 0	1 0	1 0
Milwaukee, WI	1 0	2 0	1 0	2 0	1-1	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	0-1	0 0
Jackson, MS	1 0	1 0	1 0	1 0	1 0	1 0	1 0	1 0	0 0	1 0	0 0	1 0	1 0	0 0	1 0
Louisville, KY	2 0	2 0	2 0	2 0	2 0	3 0	1 0	1 0	1-1	1 0	1 0	1 0	1 0	2 0	1 0
Nashville, TN	2-1	2-1	2-1	3-1	3 0	3-1	1 0	2 0	2 0	1 0	3 0	1 0	2 0	2 0	1 0
Kansas City, MO	3 0	3 0	3 0	3-1	2-1	3-1	1 0	2 0	2 0	2 0	2 0	2 0	1-1	1 0	2 0
Minneapolis, MN	2-1	2-1	2-1	3 0	3-1	3 0	2 0	2 0	2 0	2 0	1-1	1 0	2 0	2 0	1-1
Omaha, NB	1 0	2 0	1-1	1 0	2 0	1-1	1 0	0-1	0 0	1 0	1 0	1 0	1 0	1 0	1 0
Dallas, TX	1 0	1 0	1-1	1 0	2 0	0-1	1 0	0-1	1 0	0 0	1 0	0 0	1 0	1 0	1 0
Little Rock, AR	0 0	1 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0
Oklahoma City, OK	1 0	0-1	0 0	1 0	1 0	1 0	0 0	1 0	0 0	1 0	0 0	1 0	0 0	1 0	0 0
Albuquerque, NM	1 0	1 0	1 0	1 0	1-1	1 0	0 0	1 0	1 0	0 0	1 0	0 0	1 0	1 0	1 0
Great Falls, MT	0 0	1 0	0 0	1 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0
Denver, CO	1-1	1 0	3-1	1 0	2 0	3 0	1-1	0 0	2 0	2 0	1 0	1 0	1 0	1 0	2 0
Salt Lake City, UT	1 0	1 0	0 0	1 0	1 0	0-1	0 0	1 0	0 0	0 0	1 0	0 0	1 0	0 0	0 0
Los Angeles, CA	1 0	0 0	1 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0	1 0
Portland, OR	0 0	0 0	0 0	0 0	0 0	0 0	0-1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
San Francisco, CA	0 0	1 0	0 0	0 0	1 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	0 0
Seattle, WA	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0	0 0

*a-b: a = number of 1000 MW_e plants located at the distribution center.
b = number of 1000 MW_e plants located at minemouth and transmitting their electricity to the distribution center.

4. Industry

A single demand center for industrial coal was identified in each census region. The 1975 distribution of industrial coal demand among the census regions was assumed to remain valid from 1975 to 2050. This distribution is shown in Table G-3. Contracts for coal delivery to the industrial demand centers were assumed to be 20 years long. The assumed remaining terms of existing contracts is shown in Table G-5; the resulting industrial coal demands and locations are shown in Table G-7.

Table G-7

CONTRACTS FOR DELIVERY OF INDUSTRIAL COAL TO DEMAND CENTERS
(trillion Btu/yr)

Year of Contract Start	Demand Center							
	Philadelphia	Chicago	Knoxville	Charleston	Omaha	Dallas	Denver	San Francisco
1980	456	676	71	764	75	2	56	41
1985	489	725	76	819	80	2	60	44
1990	533	790	83	893	88	3	65	48
1995	566	839	88	948	93	3	69	50
2000	692	1026	107	1160	114	3	84	62
2005	725	1075	112	1215	119	3	88	65
2010	769	1140	119	1288	126	4	94	69
2015	802	1189	124	1344	132	4	98	72
2020	928	1376	144	1555	152	4	113	83
2025	961	1425	149	1610	158	5	117	86
2030	1005	1491	156	1684	165	5	123	90
2035	1038	1540	161	1739	171	5	127	93
2040	1164	1727	180	1951	191	5	142	104
2045	1197	1775	185	2006	197	6	204	107
2050	1241	1841	192	2080	204	6	151	111

Appendix H

PREDICTING IMPACTS

Controversy over the level of and importance of impacts comes from several sources: (1) differences among prediction techniques, (2) uncertainties inherent in all attempts to describe the future, and (3) differing interpretations of predictions (e.g., different attitudes towards the importance of a particular growth rate in producing community problems). This appendix reviews some methods of prediction that are used to describe impacts of industrial development.

Several general questions are of concern to all levels of government and industry in analyzing how the location and timing of an industry and management of its impacts will affect a region. These questions include:

- What magnitude of change in population and economic activity will the growth in industry induce at the local and regional level?
- What changes are required in the existing community structure to accommodate this change?
- What are the costs of changing the community structure?
- How are the benefits and costs of the development distributed?
- How will public attitudes either ease or inhibit this change?
- What is the potential for long-term stability? How easily could the community cope with post-boom downward adjustments.

Answers to these questions require projections of the real world, which rely on many future societal actions about which there is very little knowledge. Government policy, administrative setups, and closely related public attitudes can have a major influence on the direction of change, yet these are difficult to predict. However, some of the possible elements of change can be identified and be considered in government policy administrative activities and public influence.

1. Population and Employment Change

The first indication that a change in community structure will occur comes when a company indicates its intentions to locate in the region. A prediction of employment and population growth will be at least as uncertain as the employers projection of employment figures.

Given an initial announced change in employment levels, several different kinds of projections can be made--the amount of regional employment generated by the new industry, the amount of regional population growth that will accompany the employment increases, and how the population and employment growth may be distributed within the region.

a. Employment Generation in Local Communities

Several different studies have mentioned the amount of employment generated by primary jobs from a major resource-related industry in the western coal region.* The employment multipliers found have varied, depending on particular communities investigated, the type of industry investigated, and the definition of basic and service (or secondary) sectors. Numbers have ranged from 1.4† for a temporary construction work force to 2.5 for the operating work force of a gasification plant.‡ In Reference 1, using a simple comparison of basic to secondary employment, multipliers between 3 and 3.6 were computed for both Sheridan and Natrona Counties in Wyoming. However, these high figures probably represent more than the influence of basic county jobs on secondary employment since both counties have a high number of people who hold jobs in contiguous counties; moreover these people patronize local shops.

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*See References 1-4.
†Reference 4, p. 77.
‡Reference 2, p. 6.

These studies and others* have recommended (a) development of specific employment multipliers for each case studied, and (b) the use of simple computational devices rather than complex models, because of the high degree of uncertainty inherent in most of the data available. This is a reasonable strategy to follow, at least to the extent that numbers generated by these methods concur reasonably with accepted theories of community growth. Further investigation may be needed where multipliers seem surprisingly high or low.

What is "reasonable" in the size of an employment multiplier? Several factors seem to influence secondary employment generation.† Factors tending to increase local multipliers include: (1) distance from larger service centers (if a population must make most day-to-day purchases locally, then more retail trade and services will build up in the area); (2) higher wage rates in the new industry (the new population will have more to spend and thus can support more secondary economic activity); (3) industry use of related industrial support services (e.g., machine repair shops, transportation and communication). Factors tending to decrease local multiplier effects include, in addition to the inverses of the factors previously mentioned: (1) impermanence of an employment boom (services and trade may not expand to meet the needs of a temporary construction work force), and (2) transiency among workers even in the long-term operating employment sector (people who plan to leave the area after a short time often have a high level of savings).

For long-term rapid development in a fairly isolated county, an employment multiplier of 2 or slightly higher seems reasonable. Smaller employment multipliers in a local area often only indicate that some of the

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*See Reference 5, for example.

†The factors mentioned here do not correspond exactly to the technical factors often described in theoretical studies of multipliers (e.g., local spending, local employment, leakages in taxes, savings, nonlocal purchases). Instead, we identify industry and community characteristics likely to affect these technical factors.

growth problems (or benefits) are being passed on to the nearest, slightly larger service and residential center.

b. Population Growth

Total population growth induced by a new industry can be approximated by use of a population multiplier that is based on the number of new primary jobs brought to a community by the industry. The concept of a population multiplier is depicted in Figure H-1. It can be expressed mathematically as

$$\Delta P = pE$$

where ΔP is the change in the total population, E is the new primary employment, and p is the population multiplier. Further decomposition of

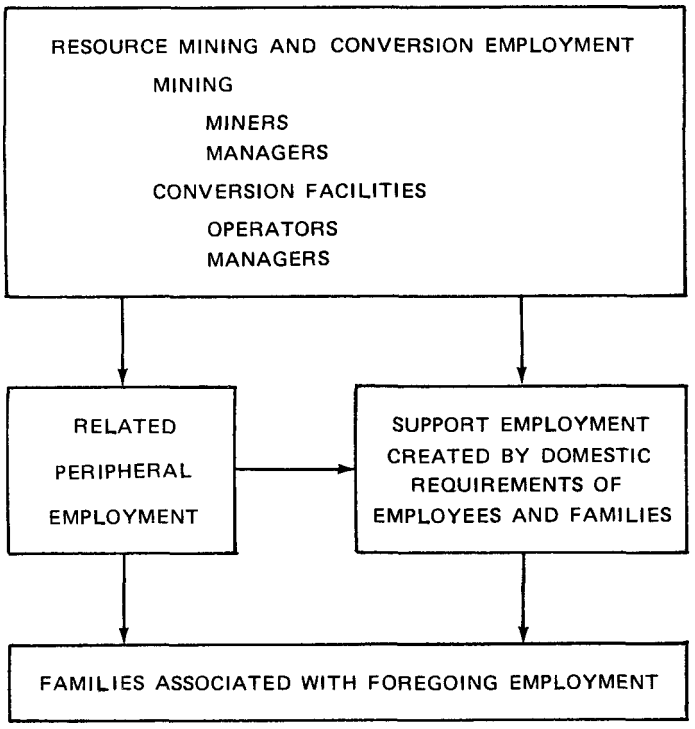

FIGURE H-1. BASIS FOR THE POPULATION MULTIPLIER CONCEPT

of this formula can be made

$$p = eqf$$

where e is the employment multiplier discussed above, q is the fraction of jobs filled by in-migrants, and f is the average family size of job holders (both primary and secondary).

This type of estimate is useful as a first-cut attempt. However, it may be an inaccurate picture of what will occur in the community. Average family size will change over time and with different kinds of workers (as it has in Gillette). In addition, the total population increase may be affected by a high degree of participation in the work force by the adults and teenage children in a family who are not the primary wage earners.

The size of the population multiplier also depends on factors similar to those mentioned for the employment multiplier. Population multipliers for local areas will be reduced if many people live in larger towns and cities within commuting distance from jobs or if workers staying in the area a short time do not bring their families. Low multipliers in these instances, as with employment multipliers, may only indicate a transfer of benefits or problems to another locality. Population multipliers will be increased when families are present and when the average worker family size is high compared with previous family sizes in the community or compared with the U.S. average.

c. Computerized Population Growth Scenarios

Despite the insensitivities of gross population growth estimates, these estimates can still be useful as a basis for beginning analyses. We have developed some computerized techniques that can quickly generate county growth rates based on given levels of industrial development, a specified population multiplier, and a base population for the county. The technique and an example are presented in Appendix J. The advantage

of this technique is that estimates of population growth incorporate variations that may occur in the size and growth rate of the population over time, as employment levels vary.* The computerized growth scenario techniques can be modified to allow for variations in multipliers and to estimate changing demands for housing and some other infrastructures and social service needs.

2. Population Structure

The structure of the incoming population will have a great influence on the needs of the community--from the size of houses required to the types of recreational activities demanded. Unfortunately, this is one of many factors that is extremely hard to predict with any accuracy. A survey of new employees by the industry would be a helpful input into understanding this factor, but it still would not provide all of the information needed about other inmigrants to the community (such as those responding to secondary employment opportunities).

A second alternative for estimating these changes is to examine existing trends in boom-towns and existing migration trends in the United States. One can obtain some idea of changes in age structure from these sources. Both sources indicate that new workers in a community are likely to be young (between 18 and 30) and to bring families with young children with them. This is consistent both with experience in Gillette (see Chapter 4) and with long-term U.S. migration trends.† This tendency is likely to be sensitive to the type of employment available in the community. For example, fewer construction workers may bring their families for a temporary job in a region than would permanent workers. However, recent studies for the Old West Regional Commission have shown that

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*However, an alternative interpretation to fluctuations in population levels may be that the unemployment rate will fluctuate and at times be very high in the local regions.
†Reference 6, p. 175.

construction workers families participate in moves more often than researchers had previously assumed.*

Projections about new populations imply that the growth of a new industry may cause a more than proportional increase in the number of young families in the community. More detailed predictions of changes in the age distribution of the population require other sources of information, which are often unavailable. Many other changes in the population structure, such as education levels or racial distribution, are even more difficult to predict when information is limited.

3. Structural Changes in the Community

Structural changes in the community as discussed here refer to infrastructure changes, changes in the housing stock, changes in social and private services, and changes in the cultural climate of the community. The extent to which industrial development causes structural changes in a local community or region depends largely on the relative amount of change in population and employment imposed on the community. An addition of 1000 people to a community is more easily absorbed by the existing infrastructure and social structure in a city of 100,000 than in a town of 5000. However, to predict structural changes in the community, we need to know more about the local community and the new population than relative population size.

a. Demand and Supply of Housing

A numerical prediction of the changes in demand for housing is fairly straightforward, given a projection of the number of new families in the community and the distribution of family size and family composition. It is more difficult to measure the type of housing demanded, or even to define "demand" for particular housing types (such as single family, apartment, or mobile homes). Recent surveys in Wyoming have

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*Reference 7, p. 6.

shown that the type of housing people say they would like to live in may differ from the type of housing they say they would purchase, if it were available.* (These discrepancies may be due to uncertainties over future incomes, housing prices, family size, or other factors).

It is also difficult to predict the expansion of the housing supply. However, observation of rapid growth communities indicates that supply is likely to lag behind demand and lead to a tight housing market. Impact on the local housing supply, then, will be related in part to existing housing stock and vacancy rates. Inflationary spirals in the housing market are most likely to occur when the incoming population requires more housing than is presently available on the housing market.

b. Social Services

Increasing demands for social services cannot be related to the rate of population growth by standard multipliers. Social service and welfare needs do not necessarily increase in proportion with the size of population. The size of planning staffs, for example, has increased much faster than the total population size in many boom communities. To look at another example, requests for mental health services increased eight times as quickly as the population increased in Sweetwater County, Wyoming, with the rapid growth of the late 1960s and early 1970s.†

As with housing, however, one can get some indication of the impact of new populations on social service delivery by looking at present service capacities. Such measures could include (without being limited to) physicians in the region, hospital beds and occupancy rates, recreational facilities (location and capacity), and number and capacities of schools. Heavy strains on present capacity will occur when the

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*Reference 8.

†John Gilmore, Denver Research Institute, Talk to the American Society of Planning Officials, Vancouver, April 1975.

change in population is large. "Catch up" costs will be high when the basic community is small, because initial service capacity is likely to be low on a per capita basis.

c. Cultural Impacts

Cultural changes in the community may cause significant changes in social structure. Services that were once provided by neighbors may no longer be available through informal networks. While these changes are not quantifiable or measurable, in many cases it is a straightforward process to make general predictions of whether growth will produce these effects. Local cultures become seriously threatened when newcomers to the community form a significant portion of the population and bring with them new backgrounds, new interests, and new lifestyles. There is little understanding of the long-term implications of these changes. Further research is needed in this area, and we make no attempt here to discuss this dimension of the problem.

The impacts described under community structure are primarily negative--housing shortages, service shortages, changes in cultural identity. These are impacts that are closely related to the beginning of the growth period. These problems may last for many years, but they may also eventually be overcome. In the long run, then, some communities gain in structural advantages as a result of growth. However, the eventual emergence of beneficial solutions to growth problems depends a great deal on long-term growth trends, and community, state, and federal policy. No simple predictions of long-term impacts can be made in this area in general, in rapid growth situations.

4. Financing*

The fiscal impacts of growth may be conceptualized in two ways: (1) by projecting future demands for services compared with current

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*Some of the most thorough work in this area appears in Reference 9 and 10.

capacities and assessing the costs of expansion, or (2) by a cost-revenue approach, which compares projected costs for incoming populations with projected additions to community income from energy development. The first approach allows us to consider whether a community is presently ready to accommodate new growth. The second approach takes a longer time frame, assessing the community's ability to pay for its needs in the future. In either case, quantitative projections must be done on a case by case basis, to achieve any level of accuracy.

As with other impacts, severity is related to the nature of the community, the nature of the industry, public attitudes, and community policy. The location of the industry with respect to the community is a critical factor in determining whether the community can afford to meet the demands for growth. If the industry is within the taxing jurisdiction of the community, then cost burdens on the local population may even be reduced as services improve. However, there are many cases where cities receive the growth and counties receive the taxes (as in Campbell County) or where one county receives the industrial growth and another county suffers the major population impacts (as with Sheridan County, Wyoming, and mining activity in the Decker-Birney region of Montana). In these cases, cost burdens may remain high over a long period of time, in the residential areas, unless intergovernmental transfers of funds are negotiated.

Fiscal impacts also depend on the community's perception of needs and priorities. Some communities may demand higher levels of services than others. Furthermore:

> "Whether such a burden occurred depended as much upon the financial policy adopted by the community in regard to use of local property and sales tax and its willingness to assume long term debt as it did on the type and level of service it may or may not have chosen to fund."*

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*Reference 9, p. 2.

5. Distributional Impacts

As a community assesses the impacts of growth, it may be as interested to determine who will pay for growth (the distribution of costs) as it is to determine how much growth will cost in total. Very little research exists on this subject. We suggest an approach to this problem, but at this stage we do not provide methods for assessing impacts.

As a first cut, it seems that there would be two levels of cost distribution that would interest a community: (a) the distribution of costs (tax burdens) between the industry and the local community, and (2) the distribution of costs (tax burdens) between residents working for the industry and those continuing in the older social and economic activities of the community. Distribution of costs at the first level will depend on boundaries of taxing jurisdictions and any differential taxing policies that may be offered to industry in the region. The second level of cost distribution will depend on the type of taxes imposed (property, sales, or income), the use of other pricing mechanisms for services, assessment practices with respect to the type and age of housing, and reactions by older residents and newcomers to potential high cost situations (e.g., whether a long-term resident chooses to sell a business or property and move out of the area).

REFERENCES FOR APPENDIX H

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2. "Rapid Growth from Energy Projects: Ideas for State and Local Action," Department of Housing and Urban Development, Office of Community Planning and Development, Washington, DC (1976).

3. "Factors Influencing an Area's Ability to Absorb a Large Scale Commercial Coal-Processing Complex--A Case Study of the Fort Union Lignite Region," University of Denver Research Institute, Energy Research and Development Administration, FE-1526-2 (June 1975).

4. R. K. Doran, M. K. Duff, J. S. Gilmore, "Socio-Economic Impacts of Proposed Burlington Northern and Chicago North Western Rail Line in Campbell-Converse Counties," Wyoming, University of Denver Research Institute (May 1974).

5. "A Procedures Manual For Assessing the Impact of the Construction and Operation of Coal Utilization Facilities in the Old West Region," prepared by Booz, Allen, and Hamilton, Inc., for the Old West Regional Commission, Washington, DC (no date).

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9. "Excess Cost Burden in Three Communities Affected by Energy Development in the West," prepared by Real Estate Research Corporation, for Office of Minerals Policy Development, Department of the Interior, Washington, DC (September 1975).

10. "A Discussion of Problems and Future Development in the West: Supporting Documentation, prepared by Real Estate Research Corporation, for Office of Minerals Policy Development, Department of the Interior, Washington, DC (September 1975).

Appendix J

USERS' MANUAL FOR COMPUTERIZED GENERATION OF SCENARIO IMPACTS

1. Purpose and Equipment

This appendix is a guide to the use of a series of computer programs designed to examine the growth effects resulting from the buildup of a synthetic fuels industry. These programs facilitate rapid exploration of many community and environmental consequences at the local or regional level.

The programs are designed for the readily available Texas Instruments SR-52 hand-held programmable calculator (January 1977 list price, $295). This calculator can use programs stored on small magnetic cards. Potential users can obtain a set of programmed cards by mailing 13 blank cards to the authors of this report. Since each calculator is capable of duplicating cards, any user who possesses a programmed set of cards can prepare a set for other prospective users. Alternatively, a user can program the calculator and prepare a set of magnetic cards himself using information provided in this guide. The calculator can be used with an optional printer, the Texas Instruments PC-100 (January 1977 list price, $295); the program descriptions indicate the output of the printer if it is used.

This calculator was chosen for several reasons. First, it is widely available and moderately priced. Second, it is one of the few that can be programmed and that can also store program instructions and data on small magnetic cards. This feature makes detailed and repetitive calculations easy to perform. Third, the calculator has enough data memory (20 normal addressable locations) and program memory (224 program steps) to allow detailed calculations. Fourth, the availability of the printing unit can minimize the amount of handwritten record-keeping. The programs

can be written more efficiently for use on large digital computers, but many potential users are not skilled in computer programming and do not have ready access to a computer terminal.

Experience in the use of computers is not necessary. Although the SR-52 calculator is sophisticated, the user need not understand all of its operations and capabilities. Along with reading of some portions of the manufacturer's owner's manual, indicated below, this guide should enable any user to prepare his own impact scenarios. In later sections, a step-by-step guide is given along with an example on which the user can practice to gain confidence in his use of the machine and its programs.

2. SR-52 Calculator Owner's Instructions

For users unfamiliar with the operation of the SR-52 and its optional printer, the PC-100, a reading of the following sections of the manufacturer's owner's manuals will prove valuable:

a. All Users

- SR-52 Owner's Manual

Section I--Introduces the calculator.

Appendix A--Describes the care and use of the calculator, battery pack, ac/charger, and care and use of the magnetic cards. Please read this appendix before using the calculator.

Section II--Describes how to enter and display results. Page 23 describes how to clear an incorrect number entry. Note that you may only clear an incorrect entry with the clear entry key, CE, before executing the program. Do not use the clear key, CLR, to clear incorrect entries while using any of the programs in this guide because it may result in incorrect calculations.

Section XIII--Describes the control of the PC-100 printer functions. Each of the programs listed in this SRI user's guide has been written for use with or without the printer attached to the calculator. The printer will simplify the use of these programs, will greatly reduce the use of hand-written records, and reduce the frequency of incorrectly written results.

- PC-100 Owner's Manual--Describes the printing unit. Do not attempt to execute any of the programs described in this SRI guide while the printing unit is in the TRACE MODE because some of the programs would then require several hours for execution and many, many feet of paper to print the results.

b. Users Wishing to Perform Other Calculations While Using These Programs

- Section III--Describes the arithmetic functions. Adding, subtracting, multiplying, and dividing for unrelated purposes may be performed while programs are loaded into the calculators, provided certain restrictions are observed. In particular, clearing the memories or storing new data in the memories while using the programs described here will generally result in incorrect calculations during program execution. It is safest to begin the program sequences again from scratch if the user suspects that data stored in the memories has been altered by any of his arithmetic calculations.

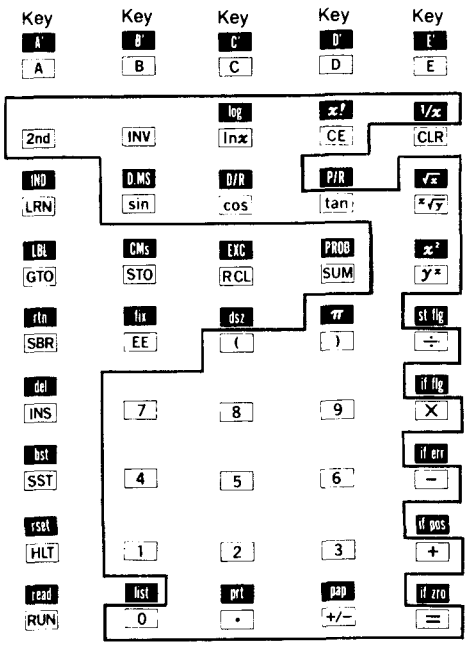

FIGURE J-1. CALCULATOR KEYS

The user may use any of the keys within the boundary in Figure J-1 for intermediate calculations. He should always complete an intermediate calculation with the "=" key. The use of any of the other keys (except as instructed in the program directions) while using the programs described in this SRI guide may result in incorrect program calculations or may alter the program sequence. If any of the keys outside the boundary shown in Figure J-1 is used accidentally, including the clear key (CLR), the only foolproof method of recovery or correction is to begin all over with the first card in the series.

c. Users Desiring to Make Their Own Program Cards

- Section VII--Entering Programs, pages 76-77: Describes keying a program into the calculator. Each program described in this SRI user's guide is accompanied by the ordered key sequence so that the user can enter the programs into the calculator. Figures 1a and 1b on pages 79 and 80 of the owner's manual display the "key codes" corresponding to each calculator key. For example, the A' key, code 16, is entered by pressing the second function key, 2nd, and then the A key.

  Editing Programs, pages 78-81: Describes how to recover from mistakes made while entering the program sequence.

  Recording on a Magnetic Card, pages 77-78: Describes how to read a program onto the magnetic cards for permanent program storage. Use a pen or pencil designed for writing on plastic or glass to label each card appropriately.

d. General Comment

While programs are running, the display will be blank except for two flashing minus signs. Keys may not be depressed during this time. After the program finishes, the displayed minus signs will stop flashing. Then further keyboard entries may be made.

3. Capabilities and Uses

Several programs have been written to generate a year-by-year population forecast for a region based on any user-specified schedule (within reasonable bounds) for the development of synthetic fuel plants in the region. Oil shale plants, coal syncrude plants, methanol-from-coal plants, choice of coal mining type (surface or underground) and type of coal (eastern or western), and other choices are all available through a selection of appropriate programs. Other programs generate impact data that scale (are proportional) to the population of a region--such as municipal water demand, municipal waste generation, and school, police, and fire service demands.

Some programs generate impact descriptions that are proportional not to the number of people present in a community but instead to the amount of synthetic fuel produced by the plants. Such impacts include industrial water demand and industrial air pollutant emissions.

4. Scenarios of Synthetic Liquid Fuel Development

Several different scenarios for development have been presented in the main body of this chapter and also in Chapter 22 of SRI's previous report, "Synthetic Liquid Fuels Development: Assessment of Critical Factors," (ERDA 76-129/1 and 129/2). Those scenarios, of course, do not exhaust all the possibilities of location, plant timing, and impact mitigation strategy that local or regional planners may wish to explore. This guide enables anyone to explore other scenarios with small cost. Variations well worth exploring are:

- The effects of a given scenario of plant startups on communities of different size.
- The comparative effects of small versus large plant size units on the growth in a community.
- The effect on growth rate of establishing alternative plant startup date schedules.

For a scenario of synthetic liquid fuel plant deployment the calculator models can provide

- Population growth data
  - construction force
  - operation force.
- Fuel output of the plants.
- Water requirements for the plants.
- Data for any effect that is proportional either to the population or fuel production.

5. Programs

a. General Description

The programs have been named to designate their purpose. The various programs are listed below:

S--Oil shale development effects

C--Coal development effects

P--Population-related effects of coal development

F--Fuel output and plant operation effects of coal development.

These programs are described generally below and in more detail in later sections. The S series is accompanied by an example. It is recommended that all users practice using this example. No examples are given for the other series because they are similar in operation to the S series.

The S series consists of two magnetic cards. Results are calculated for one year at a time for a single synfuel technology. The scaling factors built into the S program are appropriate for the oil shale technology described in Volume II, Chapter 4. The scaling factors can be changed either to accommodate newer data or to investigate another technology.* The running time of the program is relatively short.

The C series consists of three magnetic cards. Again, results are calculated one year at a time, but two synfuels technologies--syncrude and methanol--are accommodated. Alternative sets of scaling factors are provided to represent either eastern or western coal and either surface or underground mining. These scaling factors can be changed to accommodate other technologies.* The running time is again relatively short.

The P series consists of four magnetic cards, accommodates two synfuels technologies, and can give results over a 30-year span. The scaling factors built into the P series are appropriate for the same two coal conversion technologies and the mining options cited above for the C series. Again, the impact scaling factors can be changed.* The total population and any impact effect that is proportional to total population can be calculated readily. The running time for this series is relatively long for large numbers of plants.

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*The authors should be consulted for instruction on making these changes, which require program editing.

The F series is similar to the P series, except that the synfuel production level or any impact effect that is proportional to that level can be calculated readily. Production employees (and associated population) and water demand scaling factors are built in. The capabilities and limitations of all four series of programs are summarized in Table J-1. The following section describing the oil shale programs contains the sample problem that should be used for practice.

b. Oil Shale Development Programs--S1 and S-2

(1) Objectives

The population growth, plant operation water demand, and syncrude production level for any selected future year are calculated from a user-defined scenario of startup dates for oil shale plants. At the option of the user the calculated population can include construction employees with their families and supporting population. Up to 20 of each of the following sizes of syncrude plant can be accommodated:

- Small--50,000 B/D
- Large--100,000 B/D.

(2) Required Input

Data that must be entered directly by the user are the following:

- Initial population of the region of interest.
- Year of production startup for each small syncrude plant (20 or fewer).
- Year of production startup for each large syncrude plant (20 or fewer).
- Population multiplier--6.5 is suggested as a starting point.
- Scaling factor for any effect proportional to population (optional).

Program card S1 enters the number of employees engaged in plant and mine construction and production. Per 100,000 B/D of capacity, these employees number 900, 1800, 1800, 900, and 1700, starting with the first year of

Table J-1

SUMMARY OF PROGRAM CAPABILITIES

Capability	Program Series S Oil Shale	C Coal	P Coal	F Coal
Number of resource types[1]	1	3	3	3
Maximum number of plants allowed				
Small syncrude	20	6	--	--
Large syncrude	20	6	--	--
Syncrude (either size)[2]	--	--	10	12
Small methanol	--	6	--	--
Large methanol	--	6	--	--
Methanol (either size)	--	--	10	12
Effects calculated				
Total population	X	X	X	--
Population excluding construction-related	X	X	--	X
Synfuel production level	X	--	--	X
Water demand	X	--	--	X
Other effects proportional to the effects above	X	X	X	X
Number of magnetic cards	2	3	4	4
Maximum running time[3] (minutes)	2.5	1	19	2
Years of data generated per run	1	1	16[4]	24[5]

Notes:
(1) Western surface mining is an example of a resource type.
(2) Other constraints on plant size exist, and are noted later.
(3) Running times vary with the number of plants considered. The time shown is for the longest running card with the maximum number of plants.
(4) Data are generated for alternate years over a 30-year span.
(5) Data are generated for each distinct startup year; 24 is the maximum number.

construction through the first year of operation. The water demand factor--160 AF/Y for each 1000 B/D of synfuel production--is also automatically entered. These data may be altered.*

(3) Calculated Output

The user must specify the years for which the impact effects are to be calculated; these must be entered into the calculator. For each year of interest entered, the following are calculated:

- Total population, including the synfuel production and construction employees, their families, and associated support population.
- Population excluding construction employees, their families, and associated support population (optional).
- Total synfuel production level in units of 1000 B/D.
- Plant water demand in AF/Y.
- Optionally, any effect proportional to the population choices above (if the user has provided a scaling factor).

The user must repeat the calculation for each year of interest, and to obtain both the total population and the population excluding construction-related persons.

(4) Specific User Instructions

To use the S series, the user must first prepare a schedule of plant startup dates denoted by the last two digits of the year. For example, the year 1980 is denoted by 80, and the year 2013 is denoted by 13. The program can accept years in the range of 1975 through 2073. Plant capacity must be specified in 50,000 B/D (small) and 100,000 B/D (large) increments. Larger capacity, such as 150,000 B/D, is handled by starting small and large plants in the same year. It is

*The authors should be consulted for instruction on making these changes, which require program editing.

convenient to list large and small plants separately (no more than 20 of either type).

If the user enters the present population in the area of interest, then the total population (or, optionally, population excluding construction-related persons) will be calculated. If the user is interested only in the incremental population caused by the development, he can obtain this simply by entering "0" for the present population.

We suggest a population multiplier of 6.5 be used at first. Later the user can enter his own choice of a multiplier to test the sensitivity of the calculated results to small changes in this assumed multiplier.

To calculate (optional) an effect proportional to the total population, the user must specify a scaling factor equal to the per capita demand for the service. For example, if one hospital bed is required on the average for each 100 persons, then the hospital demand scaling factor is 1/100 or 0.01. For each year the population is calculated, the program then also quickly calculates the number of hopsital beds.

Once the user has assembled the necessary input data and has reviewed the indicated sections of the calculator and printing unit operating manuals supplied by the manufacturer, the instructions in Table J-2 should be followed.

(5) Sample Problem

An example set of data for input to the S series program is given in Table J-3, and the results obtained by using this data and the instructions of Table J-2 are shown in Table J-4 for selected years and Figure J-2 for all years (population only). We suggest that all users practice with this example before attempting other scenarios.

(6) Program Listing

The complete program listings for programs S1 and S2 are given in Tables J-5 and J-6. To use the programs, it is not necessary

Table J-2

INSTRUCTIONS FOR OIL SHALE SERIES--S1, S2

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
1	Enter program card S1	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
2	Enter initial population	Population	A	Population	Population
3	Enter startup year of a small plant[1,2,3]	2-digit year	B	2-digit year	2-digit year
4	Repeat Step 3 as needed until all small plants are entered				
5	Find total number of small plants[4]	-	C	No. of plants	No. of plants
6	Prepare to enter large plant start-up dates	-	2nd, st flg, 0	No change	-
7	Enter startup year of a large plant	2-digit year	B	2-digit year	2-digit year

[1]The number of plants of each size is limited to 20; if exceeded, the number -1 is displayed.
[2]The year 2000, entered 00, is a special case. The calculator and the printer will display only 0.
[3]The acceptable year range is 75 to 73 (1975-2073); a 74 entered will cause 0 to be displayed and no plant startup will be recorded.
[4]This step may be performed any time during entry of plants, to verify the number entered (in the absence of a printer).

Table J-2 (continued)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
8	Repeat Step 7, as needed, until all large plants are entered				
9	Find total number of large plants[4]	-	C	No. of plants	No. of plants
10	Enter population multiplier[5,6]	650	D	17.	See Note 6
11	Enter program card S2	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
12	Enter optional scaling factor (this step can be omitted)	Factor	2nd, C'	Factor[7]	Factor[7]
13	Execute this step if construction employee related population is to be excluded. Omit this step if total population is desired[8,9]	-	2nd, st flg, 1	No change	-

[5]To enter population multipliers other than 6.5, enter the alternative multiplier times 100.
[6]If a printer is used, Step 10 causes all the scaling factors to be printed out: population multiplier times 100, water demand factor, and the number of construction and production employees, divided by 100, from the first year of plant construction through to the first year of production.
[7]The scaling factor will be displayed and printed rounded to the nearest integer. The calculator will, however, use the unrounded value in the calculation.
[3]If Step 13 was omitted, it may be executed later to find the production employee related population only.
[9]If Step 13 was originally executed, it may be later nullified by pressing "INV, 2nd, st flg, 1" to find the total population including construction related persons.

Table J-2 (concluded)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
14	Find population for year desired[10]	2-digit year	B	Population	Year Population
15	Find optional scaled result[11] (this step can be omitted)	-	C	Result	Result
16	Find total synfuel production in units of 1000 B/D[12]	-	D	Fuel	Fuel
17	Find water demand in units of AF/Y[12]	-	E	Water	Water
18	Repeat Steps 14 to 17 for additional years				

[10]The acceptable year range is 75 to 73 (1975 to 2073); a 74 entered will cause "0" to be displayed and Step 14 must be repeated with a proper entry.
[11]The scaled result will be displayed and printed rounded to the nearest integer.
[12]Step 17, or Step 16 and 17, may be omitted. Step 16 must be performed if Step 17 results are desired.

Table J-3

EXAMPLE DATA INPUT FOR S SERIES PROGRAMS

Plant Startup Data		Year For Which Output is Desired
Year of Plant Startups	Plant Size (B/D)	
1980	50,000	1976-2000 at one year intervals
1985	100,000	
1990	50,000 100,000	
1995	100,000 100,000	
2000	100,000 100,000 100,000	

Initial population	23,500 (Garfield and Rio Blanco Counties, Colorado)
Population multiplier	6.5 (enter 650)
Optional scaling factor	0.48 (for illustration purposes; the national average number of automobiles is 0.48 per capita).

Table J-4

SAMPLE DATA FROM S SERIES PROGRAMS

Printout		Notes
Input	23500.	INITIAL POPULATION
	80.	FIRST SMALL PLANT--1980
	90.	SECOND SMALL PLANT--1990
	2.	TOTAL NUMBER OF SMALL PLANTS
	85.	FIRST LARGE PLANT--1985
	90.	SECOND LARGE PLANT--1990
	95.	THIRD LARGE PLANT--1995
	95.	FOURTH LARGE PLANT--1995
	0.	FIFTH LARGE PLANT--2000
	0.	SIXTH LARGE PLANT--2000
	0.	SEVENTH LARGE PLANT--2000
	7.	NUMBER OF LARGE PLANTS
	650.	POPULATION MULTIPLIER (6.5) TIMES 100
	160.	PLANT WATER USE (160 AF/Y per 1000 B/D)
	9.	EMPLOYMENT DURING 1st YEAR OF CONSTRUCTION (in 100's)
	18.	EMPLOYMENT DURING 2nd YEAR OF CONSTRUCTION (in 100's)
	18.	EMPLOYMENT DURING 3rd YEAR OF CONSTRUCTION (in 100's)
	9.	EMPLOYMENT DURING 4th YEAR OF CONSTRUCTION (in 100's)
	17.	EMPLOYMENT DURING PLANT OPERATION (in 100's)
	0.	MULTIPLIER (0.48 AUTOS/CAPITA) (See Note 7, Table J-2)
Output	83.	1983
	40725.	TOTAL POPULATION
	19548	TOTAL NUMBER OF AUTOMOBILES
	50.	SYNFUEL PRODUCTION--50,000 B/D
	8000.	WATER DEMAND FOR SYNFUEL--8000 AF/Y
	97.	1997
	113850.	TOTAL POPULATION
	54648	TOTAL NUMBER OF AUTOMOBILES
	500.	SYNFUEL PRODUCTION--500,000 B/D
	80000.	WATER DEMAND FOR SYNFUEL--80,000 AF/Y
	0.	2000
	111900.	TOTAL POPULATION
	53712.	TOTAL NUMBER OF AUTOMOBILES
	800.	SYNFUEL PRODUCTION--800,000 B/D
	128000.	WATER DEMAND FOR SYNFUEL--128,000 AF/Y
	83.	1983
	29025.	POPULATION, EXCLUDING CONSTRUCTION RELATED
	97.	1997
	78750.	POPULATION, EXCLUDING CONSTRUCTION RELATED

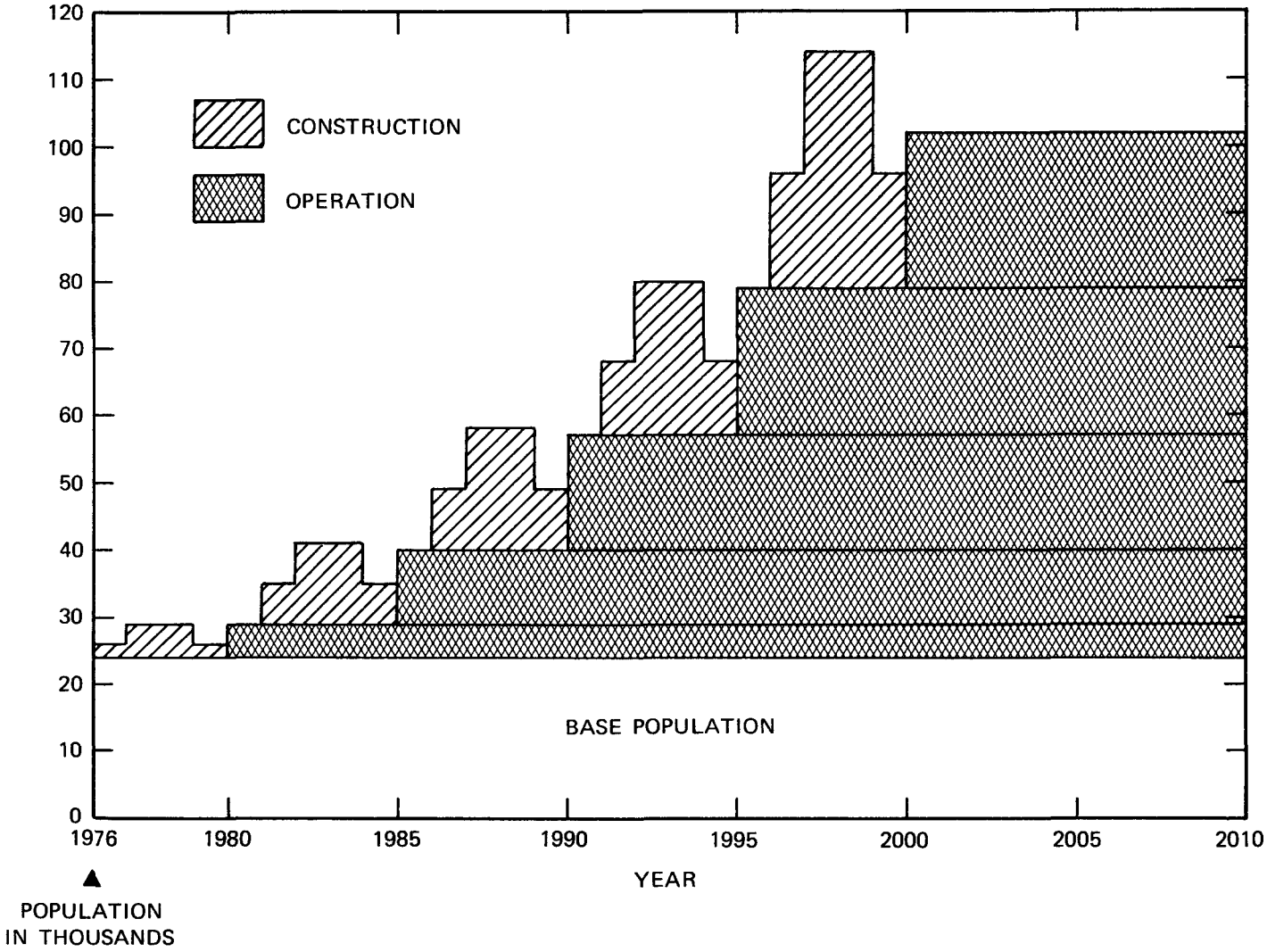

FIGURE J-2. POPULATION GROWTH OBTAINED BY RUNNING THE EXAMPLE PROBLEM

Table J-5
Program Listing for S1
(Step Number - Key Code)

000	81	045	00	090	60	135	37	180	98
001	46	046	00	091	00	136	65	181	99
002	11	047	05	092	00	137	43	182	81
003	47	048	06	093	09	138	01	183	46
004	57	049	01	094	07	139	04	184	14
005	00	050	09	095	75	140	95	185	42
006	42	051	75	096	04	141	36	186	09
007	01	052	43	097	95	142	44	187	08
008	06	053	01	098	42	143	01	188	99
009	98	054	08	099	01	144	05	189	98
010	99	055	95	100	05	145	01	190	01
011	86	056	22	101	43	146	60	191	06
012	46	057	80	102	01	147	00	192	00
013	12	058	00	103	07	148	01	193	42
014	42	059	00	104	75	149	05	194	09
015	00	060	00	105	43	150	08	195	09
016	00	061	43	106	01	151	44	196	98
017	75	062	01	107	09	152	01	197	09
018	07	063	09	108	60	153	08	198	42
019	04	064	60	109	00	154	41	199	00
020	95	065	00	110	01	155	01	200	01
021	90	066	00	111	01	156	06	201	98
022	00	067	07	112	06	157	01	202	01
023	00	068	02	113	43	158	44	203	08
024	00	069	43	114	01	159	01	204	42
025	80	070	01	115	08	160	09	205	00
026	00	071	08	116	55	161	43	206	02
027	03	072	55	117	05	162	00	207	98
028	04	073	05	118	95	163	00	208	42
029	85	074	75	119	65	164	98	209	00
030	01	075	93	120	01	165	81	210	03
031	00	076	05	121	00	166	46	211	98
032	00	077	95	122	85	167	13	212	09
033	95	078	37	123	08	168	43	213	42
034	42	079	80	124	95	169	01	214	00
035	01	080	00	125	42	170	09	215	04
036	04	081	08	126	01	171	60	216	98
037	01	082	04	127	07	172	00	217	01
038	09	083	00	128	01	173	01	218	07
039	75	084	42	129	00	174	07	219	42
040	43	085	01	130	45	175	09	220	00
041	01	086	07	131	43	176	43	221	05
042	09	087	85	132	01	177	01	222	98
043	95	088	01	133	07	178	08	223	86
044	60	089	00	134	95	179	99		

Table J-6
Program Listing for S2
(Step Number - Key Code)

000	46	045	42	090	01	135	95	180	65
001	12	046	01	091	00	136	44	181	43
002	99	047	08	092	04	137	01	182	09
003	98	048	22	093	08	138	05	183	08
004	75	049	50	094	85	139	22	184	85
005	07	050	02	095	04	140	60	185	43
006	04	051	22	096	95	141	02	186	01
007	95	052	50	097	22	142	00	187	06
008	90	053	03	098	80	143	04	188	95
009	02	054	01	099	00	144	08	189	98
010	02	055	00	100	04	145	05	190	81
011	02	056	00	101	08	146	00	191	46
012	80	057	49	102	85	147	44	192	13
013	00	058	01	103	01	148	01	193	65
014	02	059	08	104	95	149	04	194	43
015	01	060	43	105	41	150	60	195	06
016	85	061	01	106	01	151	03	196	09
017	01	062	08	107	01	152	00	197	95
018	00	063	75	108	02	153	04	198	98
019	00	064	93	109	50	154	08	199	81
020	95	065	05	110	02	155	44	200	46
021	42	066	95	111	05	156	01	201	14
022	00	067	22	112	42	157	04	202	43
023	00	068	52	113	01	158	41	203	01
024	06	069	37	114	09	159	00	204	04
025	42	070	22	115	43	160	04	205	98
026	01	071	80	116	01	161	08	206	81
027	07	072	01	117	07	162	01	207	46
028	00	073	06	118	75	163	44	208	15
029	42	074	02	119	01	164	01	209	65
030	01	075	22	120	00	165	07	210	43
031	04	076	44	121	95	166	01	211	09
032	42	077	01	122	80	167	03	212	09
033	01	078	08	123	01	168	75	213	95
034	05	079	75	124	03	169	43	214	98
035	36	080	43	125	01	170	01	215	81
036	43	081	00	126	50	171	07	216	46
037	01	082	00	127	03	172	95	217	18
038	07	083	95	128	93	173	80	218	42
039	55	084	94	129	05	174	00	219	06
040	01	085	80	130	65	175	03	220	09
041	52	086	01	131	36	176	05	221	98
042	01	087	00	132	43	177	43	222	81
043	00	088	09	133	01	178	01	223	00
044	95	089	60	134	09	179	05		

for the user to read or understand these listings. However, users who wish to enter programs directly into the SR-52 calculator and to record them on blank magnetic cards for subsequent use can use these listings. Users who intend to modify the programs for their own special needs will find these listings convenient.

c. Coal Development Programs--C1, C2, and C3

(1) Objectives

The population in an area for any selected future year is calculated from a user-defined scenario of syncrude and methanol plant startup dates. The population calculated can include production employees plus construction employees with their families and supporting population, or the construction-related popalation can be excluded. Both cases include the population associated with the coal mines needed to supply the plants. Small and large plants may be considered in the following sizes:

- Syncrude
  - Small (30,000 B/D)
  - Large (100,000 B/D)
- Methanol
  - Small (25,000 OEB*/D)
  - Large (50,000 OEB/D)

(2) Required Input

Data that must be entered directly by the user are the following:

- Initial population of the region of interest.
- Year of initial production startup for each small syncrude plant (6 or fewer).
- Year of initial production startup for each large syncrude plant (6 or fewer).
- Year of initial production startup for each small methanol plant (6 or fewer).

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*OEB = oil equivalent barrel.

- Year of initial production startup for each large methanol plant (6 or fewer).
- Population multiplier--6.5 is suggested as a starting point.
- Scaling factor for any effect proportional to population (optional).

Program card C2 enters other necessary data when the user selects western or eastern coal and surface or underground mining. These data are summarized in Table J-7. The program can be modified to stretch the methanol plant construction cycle from three to four or five years, or to alter the other data.*

(3) Calculated Output

The user must specify the years for which the impact effects are to be calculated; these must be entered into the calculator. For each year of interest entered, the following are calculated:

- Total population, including the synfuel and mines production and construction employees, their families and associated support population.
- Population excluding construction employees, their families and associated support population (optional).
- Optionally, any effect proportional to the population choices above (if the user has provided a scaling factor).

The user must repeat the calculation for each year of interest, and to obtain both the total population and the population excluding construction related persons.

(4) Specific User Instructions

To use the C series, the user must first prepare a schedule of plant startup dates denoted by the last two digits of the year. For example, the year 1980 is denoted by 80, and the year 2013 is denoted 13.

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*The authors should be consulted for instructions on making these changes, which require program editing.

Table J-7

NUMBER OF CONSTRUCTION AND PRODUCTION EMPLOYEES FOR
LARGE SYNCRUDE AND METHANOL PLANTS AND ASSOCIATES MINES

		Employees					
		Western Surface		Eastern Surface		Eastern Underground	
		Syncrude	Methanol	Syncrude	Methanol	Syncrude	Methanol
Production	(year 0)	2000	1200	2200	1300	4900	3400
Construction	(year -1)	1700	2300	1600	2100	2000	2500
	(year -2)	2900	4100	2800	4000	3200	4400
	(year -3)	2400	1900	2400	1900	2400	1900
	(year -4)	1200	0	1200	0	1200	0

The program can accept years in the range 1975 through 2073. Syncrude plant capacity must be specified in 30,000 B/D (small) and 100,000 B/D (large) increments. Methanol plant capacity is similarly specified in increments of 25,000 OEB/D (small) and 50,000 OEB/D (large). For both fuels, larger capacity such as 130,000 B/D is handled by starting small and large plants in the same year. It is convenient to list small and large plants separately (no more than six of any type and size).

If the user enters the present population of the area of interest, then total population (or optionally the population excluding construction related persons) will be calculated. If the user is interested only in the incremental population caused by the development, this can be obtained simply by entering "0" for the present population.

The user must next determine whether the "western" or "eastern" coal characteristic is the resource of interest. If desired, with eastern coal, underground mines may be selected for one type of plant and surface mines for the other type of plant.

We suggest a population multiplier of 6.5 be used at first. Later, the user can enter his own choice of multiplier to test the sensitivity of the calculated results to small changes in this assumed multiplier.

To calculate (optional) an effect proportional to the total population, the user must specify a scaling factor equal to the per capita demand for the service. For example, if one hospital bed is required on the average for each 100 persons, then the hospital demand scaling factor is 1/100 or 0.01. For each year the population is calculated, the program then also quickly calculates the number of hospital beds.

Once the user has assembled the necessary input data and has practiced with the example given with the S series, the instructions given in Table J-8 should be followed.

Table J-8

INSTRUCTIONS FOR COAL SERIES--C1, C2, C3

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
1	Enter program card C1	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
2	Enter initial population	Population	A	Population	Population
3	Enter startup year of a small syncrude plant[2,3]	2-digit year	B	2-digit year	2-digit year
4	Repeat Step 3, as needed, until all small syncrude plants are entered[1]				
5	Enter startup year of a large syncrude plant[2,3]	2-digit year	C	2-digit year	2-digit year
6	Repeat Step 5, as needed, until all large syncrude plants are entered[1]				
7	Enter startup year of a small methanol plant[2,3]	2-digit year	D	2-digit year	2-digit year
8	Repeat Step 7, as needed, until all small methanol plants are entered[1]				

[1] The number of plants of each type and size is limited to 6.
[2] The year 2000, entered 00, is a special case. The calculator and the printer will display only 0.
[3] The acceptable year range is 75 to 73 (1975-2073); a 74 entered will cause 0 to be displayed and no plant startup will be recorded.

Table J-8 (continued)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
9	Enter startup year of a large methanol plant[2,3]	2-digit year	E	2-digit year	2-digit year
10	Repeat Step 9, as needed, until all large methanol plants are entered[1]				
11	Enter program card C2[7]	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
12	Choose resource type for syncrude plants[4]	-	A or B or C	12	(See Note 5)
13	Choose resource type for methanol plants[4]	-	2nd, A' or 2nd, B' or 2nd, C'	19	(See Note 5)
14	Enter population multiplier[6]	650	D	650	650
15	Enter (optional) scaling factor[8]	Factor	2nd, D'	Factor	Factor

[4]Western surface mining is selected with "A" and "2nd, A'"; eastern surface mining is selected with "B" and "2nd, B'"; eastern underground mining is selected with "C" and "2nd, C'."
[5]The corresponding column from Table J-7 (see text) is printed out in hundreds.
[6]To enter population multipliers other than 6.5, enter the alternative multiplier times 100.
[7]This C2 portion of the C series may be repeated after running the program C3 if the user wishes to examine the effects of choosing different resource types, population multipliers, or scaling necessary to repeat program C1 unless a new plant scenario (or population) is entered. But if C1 is repeated, the C2 must be repeated as well.
[8]The scaling factor will be displayed and printed rounded to the nearest integer. The calculator will, however, use the unrounded value in the calculation.

Table J-8 (concluded)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
16	Enter program card C3	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
17	Execute this step if construction employee related population is to be excluded. Omit this step if total population is desired.[9,10]	-	2nd, st flg, 0	-	-
18	Find population for the year desired[11]	2-digit year	B	Population	Year Population
19	Find optional scaled result[12] (This step can be omitted)	-	C	Result	Result
20	Repeat Steps 18 and 19, as needed				

[9]If Step 17 was originally omitted, it may be executed later to exclude construction employee related population.

[10]If Step 17 was originally executed, it may be nullified later by pressing the keys "INV, 2nd, st flg, 0" to find the population including the construction-employee-related population.

[11]The acceptable year range is 75 to 73 (1975-2073); a 74 entered will cause "0" to be displayed and Step 18 must be repeated with a proper entry.

[12]The scaled result will be displayed and printed rounded to the nearest integer.

(5) Program Listing

The complete program listings for programs C1, C2, and C3 are given in Tables J-9 through J-11. To use the programs, it is not necessary for the user to read or understand these listings. However, those who wish to enter programs directly into the SR-52 calculator and to record them on blank magnetic cards for subsequent use can use these listings. Users who intend to modify the programs for their own special needs will find these listings convenient.

d. Coal Development Population Programs--P1, P2, P3, and P4

(1) Objectives

Population growth over a selected 30-year span is calculated from a user-defined scenario of syncrude and methanol plant production startup dates. From a selected initial year, the population is calculated at two-year intervals. The population calculated includes construction and production employees along with their families and supporting population; the population associated with the coal mines needed to supply the plants is included. Syncrude and methanol plants may be considered in the following sizes:

- Syncrude
  - Small--30,000 B/D
  - Large--100,000 B/D
- Methanol
  - Small--25,000 OEB/D
  - Large--50,000 OEB/D

(2) Required Input

Data that must be entered directly by the user are the following:

- Year of production startup of syncrude plants (5 or fewer of each size or, alternatively, 10 plants or fewer of the same size).
- Year of production startup of methanol plants (5 or fewer of each size, or alternatively, 10 or fewer of the same size).

Table J-9
Program Listing for C1
(Step Number - Key Code)

000	81	045	43	090	99	135	01	180	00
001	46	046	01	091	50	136	05	181	00
002	11	047	09	092	03	137	46	182	00
003	47	048	55	093	46	138	88	183	00
004	57	049	43	094	78	139	43	184	00
005	00	050	00	095	16	140	00	185	00
006	42	051	01	096	49	141	00	186	00
007	01	052	95	097	00	142	98	187	00
008	06	053	44	098	03	143	81	188	00
009	01	054	01	099	43	144	46	189	00
010	42	055	02	100	01	145	16	190	00
011	00	056	41	101	09	146	42	191	00
012	01	057	88	102	55	147	00	192	00
013	42	058	46	103	43	148	00	193	00
014	00	059	13	104	00	149	75	194	00
015	02	060	60	105	03	150	07	195	00
016	42	061	02	106	95	151	04	196	00
017	00	062	77	107	44	152	95	197	00
018	03	063	99	108	01	153	90	198	00
019	42	064	50	109	04	154	87	199	00
020	00	065	02	110	41	155	80	200	00
021	04	066	46	111	88	156	85	201	00
022	43	067	77	112	46	157	85	202	00
023	01	068	16	113	15	158	01	203	00
024	06	069	49	114	60	159	00	204	00
025	22	070	00	115	04	160	00	205	00
026	52	071	02	116	79	161	95	206	00
027	46	072	43	117	99	162	46	207	00
028	87	073	01	118	50	163	85	208	00
029	98	074	09	119	04	164	42	209	00
030	86	075	55	120	46	165	01	210	00
031	46	076	43	121	79	166	09	211	00
032	12	077	00	122	16	167	01	212	00
033	60	078	02	123	49	168	00	213	00
034	01	079	95	124	00	169	00	214	00
035	89	080	44	125	04	170	56	215	00
036	99	081	01	126	43	171	00	216	00
037	50	082	03	127	01	172	00	217	00
038	01	083	41	128	09	173	00	218	00
039	46	084	88	129	55	174	00	219	00
040	89	085	46	130	43	175	00	220	00
041	16	086	14	131	00	176	00	221	00
042	49	087	60	132	04	177	00	222	00
043	00	088	03	133	95	178	00	223	00
044	01	089	78	134	44	179	00		

Table J-10
Program Listing for C2
(Step Number - Key Code)

000 46	045 10	090 02	135 00	180 00
001 11	046 04	091 01	136 56	181 00
002 06	047 09	092 15	137 46	182 00
003 10	048 15	093 04	138 14	183 00
004 02	049 02	094 00	139 42	184 00
005 00	050 00	095 15	140 09	185 00
006 15	051 15	096 01	141 09	186 00
007 01	052 03	097 09	142 22	187 00
008 07	053 02	098 15	143 52	188 00
009 15	054 15	099 99	144 98	189 00
010 02	055 02	100 81	145 46	190 00
011 09	056 04	101 46	146 87	191 00
012 15	057 15	102 18	147 99	192 00
013 02	058 01	103 01	148 81	193 00
014 04	059 02	104 02	149 46	194 00
015 15	060 15	105 10	150 19	195 00
016 01	061 99	106 03	151 42	196 00
017 02	062 81	107 04	152 09	197 00
018 15	063 46	108 15	153 08	198 00
019 99	064 16	109 02	154 22	199 00
020 81	065 01	110 05	155 52	200 00
021 46	066 02	111 15	156 98	201 00
022 12	067 10	112 04	157 99	202 00
023 06	068 01	113 04	158 81	203 00
024 10	069 02	114 15	159 00	204 00
025 02	070 15	115 01	160 00	205 00
026 02	071 02	116 09	161 00	206 00
027 15	072 03	117 15	162 00	207 00
028 01	073 15	118 99	163 00	208 00
029 06	074 04	119 81	164 00	209 00
030 15	075 01	120 46	165 00	210 00
031 02	076 15	121 15	166 00	211 00
032 08	077 01	122 22	167 00	212 00
033 15	078 09	123 58	168 00	213 00
034 02	079 15	124 87	169 00	214 00
035 04	080 99	125 36	170 00	215 00
036 15	081 81	126 42	171 00	216 00
037 01	082 46	127 00	172 00	217 00
038 02	083 17	128 00	173 00	218 00
039 15	084 01	129 98	174 00	219 00
040 99	085 02	130 56	175 00	220 00
041 81	086 10	131 46	176 00	221 00
042 46	087 01	132 10	177 00	222 00
043 13	088 03	133 42	178 00	223 00
044 06	089 15	134 00	179 00	

Table J-11
Program Listing for C3
(Step Number - Key Code)

000	46	045	80	090	00	135	01	180	44
001	17	046	00	091	95	136	02	181	01
002	65	047	06	092	42	137	08	182	09
003	36	048	06	093	00	138	01	183	01
004	43	049	60	094	00	139	17	184	17
005	01	050	00	095	00	140	41	185	41
006	09	051	00	096	42	141	01	186	01
007	95	052	01	097	01	142	02	187	07
008	44	053	04	098	07	143	08	188	03
009	01	054	85	099	43	144	43	189	43
010	07	055	05	100	01	145	01	190	01
011	56	056	95	101	02	146	04	191	06
012	46	057	22	102	42	147	42	192	85
013	16	058	80	103	01	148	01	193	43
014	01	059	00	104	08	149	08	194	09
015	00	060	01	105	16	150	16	195	09
016	00	061	04	106	22	151	22	196	65
017	49	062	42	107	80	152	80	197	43
018	01	063	01	108	01	153	01	198	01
019	08	064	09	109	02	154	06	199	07
020	43	065	56	110	02	155	07	200	95
021	01	066	05	111	90	156	06	201	98
022	08	067	42	112	01	157	44	202	81
023	75	068	01	113	00	158	01	203	46
024	93	069	09	114	05	159	09	204	13
025	05	070	56	115	93	160	93	205	65
026	95	071	46	116	03	161	05	206	43
027	22	072	12	117	17	162	17	207	09
028	52	073	99	118	41	163	41	208	08
029	37	074	98	119	01	164	01	209	95
030	22	075	75	120	00	165	05	210	98
031	80	076	07	121	05	166	00	211	81
032	00	077	04	122	43	167	43	212	00
033	06	078	95	123	01	168	01	213	00
034	05	079	90	124	03	169	05	214	00
035	22	080	02	125	42	170	42	215	00
036	44	081	00	126	01	171	01	216	00
037	01	082	01	127	08	172	08	217	00
038	08	083	80	128	16	173	16	218	00
039	75	084	00	129	22	174	22	219	00
040	43	085	09	130	80	175	80	220	00
041	00	086	02	131	01	176	01	221	00
042	00	087	85	132	04	177	08	222	00
043	95	088	01	133	04	178	09	223	00
044	94	089	00	134	90	179	06		

- The initial year of a 30-year span of interest.
- Initial population of the region of interest.
- Population multiplier--6.5 is suggested as a starting point.
- Scaling factor for any effect proportional to population (optional).

Other data are entered by the program when the user selects western or eastern coal and surface or underground mining. These data, stored in Program Card P2, are summarized in Table J-7, and can be modified by the user to stretch the methanol plant construction cycle from three to four or five years, or to alter the other data.*

(3) Calculated Output

The following data are calculated at two-year intervals over a specified 30-year span.

- Total population, including the synfuel and mines construction and production employees, along with their families, and associated support population.
- Optionally, any effect proportional to the population above (if user has supplied a scaling factor).

If the user desires results at one-year intervals, he should repeat the calculation with the time span starting one year later. This will give the results in the years skipped initially. For a given time span, the user may provide other scaling factors to calculate other effects.

(4) Specific User Instructions

To use the P series, the user must first prepare a schedule of plant startup dates. The initial year of synfuel production for each plant is denoted by the last two digits. For example, the year 1980 is denoted by 80, and the year 2013 is denoted by 13. The program accepts dates in the range 19<u>75</u> through 20<u>73</u>. Syncrude plant capacity must be

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*The authors should be consulted for instructions on making these changes, which require program editing.

specified in increments of 30,000 B/D (small) and 100,000 B/D (large). Larger capacity such as 130,000 B/D is handled by starting large and small plants in the same year. It is convenient to list small and large plants separately. For each type of plant no more than 5 plant startups are allowed, or no more than 10 plant startups if only one size is selected.

Next, the user must select "western" or "eastern" coal. For eastern coal, underground mines may be selected for one plant type, and surface mines for the other plant type.

If the user enters the present population in the area of interest, then the total future population will be calculated, but if the user is interested only in the incremental population caused by the development, he should simply enter "0" for the present population.

We suggest that 6.5 be used initially as a population multiplier. The user can test the sensitivity of the calculated result to changes in this assumed multiplier by repeating the calculations with other values for the multiplier.

To calculate (optional) an effect proportional to the population, the user must specify a scaling factor equal to the per capita demand for the service. For example, if one hospital bed is required on the average for each 100 persons, then the hospital demand scaling factor is 1/100 or 0.01. For each year the population is calculated in the 30-year span, the program will then calculate the required number of hospital beds.

Once the user has assembled the necessary input data and has practiced with the example given with the S series, the instructions given in Table J-12 should be followed.

(5) Program Listing

The complete program listings for programs P1, P2, P3, and P4 are given in Tables J-13 through J-16. To use the programs, it is not necessary for the user to read or understand these listings.

Table J-12

INSTRUCTIONS FOR COAL POPULATION SERIES--P1, P2, P3, P4

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
1	Enter program card P1	Side A Side B	CLR, 2nd READ 2nd, READ	0 0	- -
2	Initialize the program		A	1.	-
3	Prepare to enter small syncrude plants, if none of the plants is small omit this step[1]	-	2nd, st flg, 0	No change	-
4	Enter startup year of syncrude plant[2]	2-digit year	B	2-digit year	2-digit year
5	Repeat Step 4, as needed, to maximum of 5 plants, all the same size				
6	Repeat Step 3 if more syncrude plants are to be entered[1]				
7	Enter startup year of syncrude plant[2] (if any)	2-digit year	C	2-digit year	2-digit year
8	Repeat Step 7, as needed, to a maximum of 5 plants, all the same size				

[1]All plants to be entered with a given B, C, D or E key must be entered successively before proceeding to the next key. If the "st flg" key is pressed immediately before a B, C, D or E key is initially used, all plants then entered by that key will be small; otherwise, all entered by that key will be large.
[2]The acceptable year range is 75 to 73 (1975-2073), a 75 entered will cause "0" to be displayed and no plant startup will be recorded; moreover, Step 3 must be repeated if 74 was the first entry fo[illegible] key.

Table J-12 (continued)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
9	Repeat Steps 3-8 for methanol plants, except use keys D and E to enter up to 5 plants each[1,2]				
10	Enter program card P2[3]	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
11	Choose resource type for syncrude plants[4]	-	A or B or C	(See Note 5)	(See Note 5)
12	Choose resource type for methanol plants[4]	-	2nd, A' or 2nd, B' or 2nd, C'	(see Note 5)	(See Note 5)
13	Enter the first year of a 30-year span of interest[6]	2-digit year	E	2-digit year	2-digit year

[3]This P2 portion of the P series may be repeated after running program P4, so that different resource types or starting years of the 30-year span may be selected. Steps 11 and 12 are repeated only when the resource type is changed (press "INV, 2nd, fix" before repeating Steps 11 or 12, to see the display), but Step 13 must be repeated even if the same start year is used. It is not necessary to repeat program P1 unless a different plant scenario is selected. However, if P1 is repeated, P2 and successive programs must also be repeated.

[4]Western surface mining is selected with "A" and "2nd, A'"; eastern surface mining is selected with "B" and "2nd, B'"; eastern underground mining is selected with "C" and "2nd, C'."

[5]The number displayed or printed is composed of the corresponding employee data from Table J-7 (see text).

[6]The acceptable range for the initial year of the 30-year span is 75 to 43 (1975-2043).

Table J-12 (continued)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
14	Enter program card P3	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
15	Process data[7]	-	RUN	0	(See Note 8)
16	Enter program card P4[9]	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
17	Enter initial population	Population	E	Population	Population
18	Enter population multiplier[10]	650	2nd, E'	650	650
19	Enter scaling factor (optional)[11]	Factor	2nd, D'	Factor	Factor

[7] This program is relatively long running. Approximately 19 minutes is required for a full load of 20 plants, proportionately less for fewer plants.

[8] Progress of the program is monitored on the printer. As data for each of the sixteen years (alternate years over the 30-year span) are processed, the resulting employee population (in hundreds) is printed for that year. Family and supporting population factors are not yet included.

[9] This program may be repeated any number of times with alternative values entered in Steps 17, 18, or 19. (It is not necessary to reenter the magnetic card.)

[10] To enter population multipliers other than 6.5, enter the alternative multiplier times 100.

[11] The scaling factor will be displayed and printed rounded to the nearest integer. The calculator will, however, use the unrounded value in the calculation.

Table J-12 (concluded)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
20	Display first year data[12]		A	Year--data	Year--data
21	Display next year data		RUN	Year--data	Year-data
22	Repeat Step 21 twice, successively				
23	Repeat Steps 20 through 22 except using keys B, then C, then D[12]				
24	Prepare to calculate data scaled to population (optional)		2nd, st flg, 0	No change	
25	Repeat Steps 20 to 23 to obtain scaled data (optional)[13]				

[12]Each of the keys A, B, C, D, processes one quarter (4 years) of the 16 years of data (covering the 30-year time span with alternate years), and displays the year associated with the data together with the calculated result in compressed form. For example, the display "7800012140" indicates the calculated result 12,140 for the year 1978. Then, pressing the RUN key three times will successively display the next three years of that quarter. The quarters may be displayed in any order, any number of times.

[13]The value of the scaled effect is limited to less than 100,000,000 and to more than 1. An adjustment may be made to get values into this range. For example, if the factor 1000 is needed to get values into this range, multiply the scaling factor entered in Step 19 by 1000. Then the results obtained in Step 25 are adjusted by moving the decimal point three places to the left (divide by 1000).

Table J-13
Program Listing for P1
(Step Number - Key Code)

000	81	045	18	090	68	135	78	180	01
001	46	046	99	091	46	136	02	181	00
002	11	047	60	092	13	137	05	182	00
003	47	048	00	093	10	138	18	183	49
004	01	049	88	094	43	139	42	184	00
005	42	050	05	095	00	140	00	185	03
006	00	051	00	096	07	141	08	186	43
007	00	052	46	097	22	142	46	187	01
008	42	053	88	098	90	143	78	188	02
009	00	054	56	099	77	144	01	189	55
010	01	055	46	100	01	145	00	190	43
011	42	056	12	101	05	146	00	191	00
012	00	057	10	102	18	147	49	192	03
013	02	058	43	103	42	148	00	193	95
014	42	059	00	104	00	149	02	194	44
015	00	060	06	105	07	150	43	195	00
016	03	061	22	106	46	151	01	196	09
017	46	062	90	107	77	152	02	197	46
018	67	063	89	108	01	153	55	198	68
019	86	064	01	109	00	154	43	199	43
020	46	065	05	110	00	155	00	200	01
021	10	066	18	111	49	156	02	201	01
022	42	067	42	112	00	157	95	202	98
023	01	068	00	113	01	158	44	203	86
024	01	069	06	114	43	159	00	204	00
025	75	070	46	115	01	160	08	205	00
026	07	071	89	116	02	161	41	206	00
027	04	072	01	117	55	162	68	207	00
028	95	073	00	118	43	163	46	208	00
029	90	074	00	119	00	164	15	209	00
030	67	075	49	120	01	165	10	210	00
031	80	076	00	121	95	166	43	211	00
032	87	077	00	122	44	167	00	212	00
033	85	078	43	123	00	168	09	213	00
034	01	079	01	124	07	169	22	214	00
035	00	080	02	125	41	170	90	215	00
036	00	081	55	126	68	171	79	216	00
037	95	082	43	127	46	172	02	217	00
038	46	083	00	128	14	173	05	218	00
039	87	084	00	129	10	174	18	219	00
040	42	085	95	130	43	175	42	220	00
041	01	086	44	131	00	176	00	221	00
042	02	087	00	132	08	177	09	222	00
043	56	088	06	133	22	178	46	223	00
044	46	089	41	134	90	179	79		

Table J-14
Program Listing for P2
(Step Number - Key Code)

000 81	045 01	090 93	135 46	180 00
001 46	046 08	091 04	136 18	181 00
002 15	047 01	092 09	137 93	182 00
003 57	048 05	093 02	138 03	183 00
004 00	049 42	094 00	139 04	184 00
005 42	050 01	095 03	140 02	185 00
006 01	051 09	096 02	141 05	186 00
007 01	052 43	097 02	142 04	187 00
008 75	053 01	098 04	143 04	188 00
009 07	054 01	099 01	144 01	189 00
010 04	055 99	100 02	145 09	190 00
011 95	056 98	101 46	146 46	191 00
012 90	057 86	102 88	147 89	192 00
013 00	058 46	103 42	148 42	193 00
014 00	059 11	104 00	149 00	194 00
015 00	060 93	105 02	150 03	195 00
016 80	061 02	106 99	151 99	196 00
017 87	062 00	107 98	152 98	197 00
018 85	063 01	108 86	153 86	198 00
019 01	064 07	109 46	154 00	199 00
020 00	065 02	110 16	155 00	200 00
021 00	066 09	111 93	156 00	201 00
022 46	067 02	112 01	157 00	202 00
023 87	068 04	113 02	158 00	203 00
024 75	069 01	114 02	159 00	204 00
025 02	070 02	115 03	160 00	205 00
026 95	071 41	116 04	161 00	206 00
027 42	072 88	117 01	162 00	207 00
028 00	073 46	118 01	163 00	208 00
029 04	074 12	119 09	164 00	209 00
030 03	075 93	120 41	165 00	210 00
031 42	076 02	121 89	166 00	211 00
032 01	077 02	122 46	167 00	212 00
033 04	078 01	123 17	168 00	213 00
034 00	079 06	124 93	169 00	214 00
035 42	080 02	125 01	170 00	215 00
036 01	081 08	126 03	171 00	216 00
037 05	082 02	127 02	172 00	217 00
038 42	083 04	128 01	173 00	218 00
039 01	084 01	129 04	174 00	219 00
040 06	085 02	130 00	175 00	220 00
041 42	086 41	131 01	176 00	221 00
042 01	087 88	132 09	177 00	222 00
043 07	088 46	133 41	178 00	223 00
044 42	089 13	134 89	179 00	

Table J-15
Program Listing for P3
(Step Number - Key Code)

000 43	045 01	090 01	135 01	180 03
001 01	046 00	091 75	136 04	181 41
002 04	047 90	092 43	137 01	182 00
003 80	048 01	093 00	138 43	183 06
004 00	049 08	094 04	139 00	184 09
005 02	050 05	095 75	140 03	185 01
006 06	051 75	096 01	141 42	186 44
007 04	052 93	097 95	142 00	187 01
008 44	053 05	098 22	143 01	188 00
009 01	054 95	099 80	144 01	189 09
010 04	055 37	100 01	145 00	190 75
011 01	056 42	101 01	146 00	191 43
012 44	057 01	102 07	147 49	192 01
013 01	058 02	103 75	148 00	193 00
014 09	059 94	104 05	149 01	194 95
015 01	060 85	105 95	150 43	195 80
016 09	061 36	106 80	151 00	196 00
017 75	062 43	107 00	152 01	197 04
018 43	063 01	108 06	153 90	198 03
019 01	064 00	109 09	154 01	199 43
020 09	065 95	110 85	155 07	200 01
021 95	066 42	111 07	156 00	201 03
022 90	067 01	112 95	157 75	202 37
023 02	068 01	113 41	158 93	203 98
024 02	069 01	114 01	159 05	204 55
025 00	070 00	115 01	160 95	205 01
026 01	071 00	116 08	161 37	206 00
027 22	072 49	117 01	162 22	207 00
028 44	073 01	118 42	163 44	208 00
029 01	074 01	119 00	164 00	209 36
030 04	075 43	120 00	165 01	210 22
031 02	076 01	121 43	166 58	211 49
032 44	077 01	122 01	167 01	212 01
033 00	078 90	123 00	168 04	213 09
034 04	079 01	124 75	169 04	214 95
035 00	080 08	125 08	170 65	215 36
036 42	081 05	126 95	171 43	216 44
037 01	082 75	127 80	172 01	217 01
038 03	083 93	128 01	173 02	218 09
039 06	084 05	129 03	174 55	219 86
040 42	085 95	130 08	175 05	220 81
041 01	086 37	131 43	176 00	221 00
042 00	087 22	132 00	177 95	222 00
043 36	088 44	133 02	178 44	223 00
044 43	089 01	134 41	179 01	

Table J-16
Program Listing for P4
(Step Number - Key Code)

000	46	045	01	090	01	135	01	180	36
001	11	046	04	091	01	136	00	181	42
002	43	047	42	092	42	137	00	182	01
003	01	048	00	093	01	138	00	183	09
004	05	049	00	094	09	139	49	184	01
005	16	050	46	095	99	140	01	185	22
006	03	051	87	096	46	141	00	186	44
007	00	052	01	097	88	142	43	187	01
008	41	053	44	098	36	143	01	188	09
009	79	054	01	099	43	144	00	189	58
010	46	055	09	100	01	145	90	190	89
011	12	056	43	101	09	146	77	191	43
012	43	057	00	102	98	147	75	192	00
013	01	058	01	103	81	148	93	193	04
014	06	059	75	104	01	149	05	194	75
015	16	060	01	105	44	150	95	195	56
016	02	061	00	106	01	151	22	196	46
017	02	062	00	107	09	152	52	197	15
018	41	063	95	108	43	153	37	198	42
019	79	064	80	109	01	154	46	199	00
020	46	065	78	110	09	155	77	200	05
021	13	066	85	111	75	156	22	201	98
022	43	067	01	112	01	157	44	202	99
023	01	068	00	113	05	158	01	203	81
024	07	069	00	114	95	159	00	204	46
025	16	070	95	115	22	160	65	205	10
026	01	071	46	116	90	161	43	206	42
027	04	072	78	117	88	162	09	207	09
028	41	073	65	118	81	163	09	208	09
029	79	074	01	119	46	164	85	209	98
030	46	075	52	120	16	165	43	210	99
031	14	076	08	121	42	166	00	211	81
032	43	077	95	122	01	167	05	212	46
033	01	078	36	123	00	168	95	213	19
034	08	079	44	124	04	169	22	214	42
035	16	080	01	125	42	170	60	215	09
036	06	081	09	126	00	171	00	216	08
037	46	082	02	127	00	172	67	217	98
038	79	083	44	128	01	173	65	218	99
039	85	084	00	129	04	174	43	219	81
040	07	085	01	130	42	175	09	220	00
041	04	086	58	131	01	176	08	221	00
042	95	087	87	132	09	177	95	222	00
043	42	088	22	133	46	178	46	223	00
044	00	089	52	134	89	179	67		

However, those who wish to enter programs directly into the SR-52 calculator and to record them on blank magnetic cards for subsequent use can use these listings. Users who intend to modify the programs for their own special needs will find these listings convenient.

e. Coal Development Fuel Programs--F1, F2, F3, and F4

(1) Objectives

The level of synfuel production and related effects are calculated from a user-defined scenario of plant production startup dates for syncrude and methanol. The population (excluding construction workers with their families and supporting population) and water demand are calculated for each year in which production capacity increases. Both calculations of effects include the contributions from the coal mines needed to supply the plants. Plants may be considered in the following sizes:

- Syncrude
  - Small--30,000 B/D
  - Large--100,000 B/D
- Methanol
  - Small--25,000 OEB/D
  - Large--50,000 OEB/D

(2) Required Input

Data that must be entered directly by the user are the following:

- Year of production startup of syncrude plants (12 or fewer of which no more than 9 may be large).
- Year of production startup of methanol plants (12 or fewer in any mixture of sizes).
- The initial population in the region of interest, or the initial water demand, or (optionally) the initial value of any other quantity that is proportional to the synfuel production level.
- Scaling factors for any effect proportional to the production levels of the synfuels (optional).

Program card F3 enters other necessary data when the user selects western or eastern coal and surface or underground mining. These data are summarized in Table J-7 for production employees. The water demand data are given in Table J-17. These inputs can be modified to satisfy other data requirements.*

Table J-17

WATER DEMAND FOR SYNFUELS PRODUCTION

Resource Type	Water Demand (Acre ft/year [AF/Y]) Large Syncrude Plant	Large Methanol Plant
Western surface mined coal	29,600	15,450
Eastern surface mined coal	29,450	15,300
Eastern underground mined coal	29,000	15,000

(3) Calculated Output

For each year in which the production level of synfuels increases, the following are calculated:

- Population (excluding construction employees and their families and supporting population).
- Total water demand in AF/Y.
- Total synfuel production level in units of 1000 OEB/D.
- Optionally, any effect proportional to the synfuels production levels (if the user has provided a scaling factor).

On the first time through the series, one of the listed effects is calculated for the user-specified scenario of plant startup dates. Subsequently, a portion of the F series (contained on the last two program

*The authors should be consulted for instructions on making these changes, which require program editing.

cards) is repeated for each additional impact effect of interest to the user.

(4) Specific User Instructions

To use the F series, the user must first prepare a schedule of plant startup dates. The initial year of synfuel production for each plant is denoted by the last two digits. For example, the year 1980 is denoted by 80, and the year 2013 is denoted by 13. The program accepts dates in the range 1975 through 2072. Syncrude plant capacity must be specified in increments of 30,000 B/D (small) and 100,000 B/D (large). Methanol plant capacity is similarly specified in increments of 25,000 OEB/D (small) and 50,000 OEB/D (large). Larger capacity such as 130,000 B/D must be handled by starting large and small plants in the same year. It is convenient to place all the plants in one list in chronological order. The program will not handle more than 12 plants of any one type, but the limit on the number of large syncrude plants is 9.

The user must decide whether the effect to be calculated on the first time through the series is population, water demand, synfuel production, or another effect proportional to synfuel production. On subsequent passes through part of the series the other effects can be calculated.

If either population or water demand is chosen, the user must decide whether the "western" or "eastern" coal is the resource of interest. For eastern coal, underground mines may be selected for one plant type and surface mines for the other plant type.

If the user chooses to calculate an effect proportional to the synfuel production level, the magnitude of the effect for one large syncrude plant and for one large methanol plant must be determined. These are the scaling factors for the effect and can be entered to find the effect of the entire scenario. If the synfuel production level itself is desired, scaling factors 100 and 50 are entered for syncrude and methanol, respectively, to calculate synfuels output in units of 1000 OEB/D.

For any effect an initial value must be entered so that the calculated effect will include both the initial value and the increment caused by plant and mine operation. However, if the user is interested only in the incremental effect of the scenario, "0" should be entered for the initial value.

Once the user has assembled the necessary input data and has practiced with the example given for the S series, the instructions given in Table J-18 should be followed.

(5) Program Listing

The complete program listings for programs F1, F2, F3, and F4 are given in Tables J-19 through J-22. To use the program, it is not necessary for the user to read or understand these listings. However, those who wish to enter programs directly into the SR-52 calculator and to record them on blank magnetic cards for subsequent use can use these listings. Users who intend to modify the programs for their own special needs will find these listings convenient.

Table J-18

INSTRUCTIONS FOR COAL FUEL SERIES--F1, F2, F3, F4

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
1	Enter program card F1	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
2	Initialize the program		E	0	-
3	Enter a syncrude plant[1]	2-digit year	A or B	2-digit year	2-digit year
4	Repeat Step 3 until all syncrude plants are entered[2]				
5	Enter a methanol plant[1]	2-digit year	C or D	2-digit year	2-digit year
6	Repeat Step 5 until all methanol plants are entered[2]				
7	Finalize the program		2nd, E'	0	-
8	Enter program card F2	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -

[1]Plants must be entered in chronological order. Two or more plants may be the same year. Small plants are entered with keys A or C, large plants with keys B or D. The acceptable year range is 75 to 72 (1975-2072); a 74 entered will cause "0" to be displayed and no plant startup will be recorded; a 73 entered will cause that plant and succeeding ones of the same type to be ignored.

[2]The maximum number of each type of plant is 12, regardless of size; however, the maximum number of large syncrude plants is 9.

Table J-18 (continued)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
9	Process data[3]	-	A	0	(See Note 4)
10	Enter program card F3[5]	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -
11	Enter initial value of effect[6]	Initial value	D or E or 2nd, D'	Initial value	Initial value
12	Enter resource type for syncrude plants (omit this step if 2nd, D' option is chosen in Step 11)[7]	-	A or B or C	(See Note 8)	(See Note 8)

[3] This program runs approximately 15 s plus 6 s per plant entered.

[4] Progress of the program is monitored on the printer. One number, a coded composite, is printed for each distinct startup year for each plant type. These data are further processed and interpreted in succeeding programs. The 4-digit code includes a date and output level for one synfuel. The first two digits are the coded year, with 1975 as 01, 1976 as 02, and so on. The second 2 digits are the coded output level, 10 units for each large syncrude plant and 2 units for each large methanol plant. The syncrude data are printed first, followed by the methanol data.

[5] This program may be repeated after running program F4 to calculate alternative effects; programs F1 and F2 need be repeated only for alternative plant startup scenarios.

[6] Select one option: D (for population), E (for water), or 2nd, D' (for synfuel production or production related effects). If D or E is selected, do Steps 12 and 13. If 2nd, D' is selected, do Steps 14 and 15. Omit any millions digits or higher in the initial value of the selected effect; also see Note 9. Units for water are AF/Y, and for synfuel production are 1000 OEB/D. Population multipliers other than 6.5 (built into the D option) may be handled with the "2nd, D'" option, using Table J-7. Select the production employee number from the pertinent resource type, multiply by the selected population multiplier, and enter this as a scaling factor in Step 14 or 15. (Further adjustment by the factors 1/10 and 1/2 for syncrude and methanol, respectively, is automatic).

[7] Western surface mining is selected with "A" and "2nd, A'," eastern surface mining with "B" and "2nd, B'," eastern underground mining with "C" and 2nd, C'."

Table J-18 (continued)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
13	Enter resource type for methanol plants (omit this step if 2nd, D' option is chosen in Step 11)[7]	-	2nd, A' or 2nd, B' or 2nd, C'	(see Note 8)	(See Note 8)
14	Enter syncrude scaling factor (omit this step if D or E option is chosen in Step 11)[9]	Factor	RUN	Factor/10	Factor/10
15	Enter methanol scaling factor (omit this step if D or E option is chosen in Step 11)[9]	Factor	RUN	Factor/2	Factor/2
16	Enter program card F4	Side A Side B	CLR, 2nd, READ 2nd, READ	0 0	- -

[8]Data from Tables J-7 or J-17 are displayed, with adjustment. A population multiplier of 6.5 is applied to Table J-7 data, and data from both tables are divided by 10 for syncrude plants and are divided by 2 for methanol plants to accommodate the program coding.

Table J-18 (concluded)

Step	Procedure	Enter	Press SR-52 Keys	Result Displayed on Calculator	Result Displayed on Printer
17	Display data for first year[9]	-	A	Year--data[10]	Year--data[10]
18	Display data for next year	-	RUN	Year--data[10]	Year--data[10]
19	Repeat Step 18 until the last startup year entered appears				

[9]The value of the effect is limited to less than 10,000,000 and to more than 1. This is adequate for the effects built into program F3 if the Note 6 is observed. For the scaled effects calculated from scaling factors derived by the user, some limitations should be observed. It is convenient to limit the scaling factors to numbers between 1 and 1,000. An adjustment may be made to get scaling factors into this range, then a compensating adjustment is made to the calculated result. For example, if the factor 1000 is needed to get both scaling factors into the acceptable range, multiply the initial value entered by 1000 also, then multiply the calculated result by 1/1000, and so on. Any result (or adjusted scaling factor) displayed is rounded to the nearest whole number.

[10]The display "890095800" indicates the result 95,800 for the year 1989. Years in the next century are coded 1YY; that is, the year 2017 would appear as 117.

Table J-19
Program Listing for F1
(Step Number - Key Code)

000	81	045	19	090	42	135	01	180	46
001	46	046	41	091	00	136	52	181	87
002	15	047	88	092	01	137	01	182	65
003	47	048	46	093	01	138	05	183	01
004	57	049	12	094	44	139	95	184	00
005	00	050	19	095	01	140	22	185	95
006	01	051	01	096	02	141	90	186	42
007	52	052	44	097	41	142	77	187	00
008	04	053	00	098	77	143	01	188	03
009	42	054	03	099	46	144	52	189	56
010	00	055	46	100	13	145	03	190	46
011	00	056	88	101	19	146	42	191	10
012	01	057	43	102	41	147	00	192	00
013	52	058	00	103	89	148	02	193	42
014	03	059	03	104	46	149	01	194	00
015	42	060	55	105	14	150	44	195	01
016	00	061	43	106	19	151	01	196	42
017	01	062	00	107	01	152	03	197	00
018	42	063	01	108	44	153	46	198	02
019	00	064	95	109	00	154	77	199	42
020	02	065	36	110	03	155	22	200	01
021	04	066	44	111	46	156	52	201	01
022	42	067	01	112	89	157	43	202	42
023	01	068	02	113	43	158	01	203	01
024	00	069	01	114	00	159	01	204	02
025	42	070	52	115	03	160	98	205	42
026	01	071	03	116	55	161	86	206	01
027	02	072	49	117	43	162	46	207	03
028	07	073	00	118	00	163	19	208	86
029	42	074	01	119	02	164	42	209	00
030	01	075	43	120	95	165	01	210	00
031	03	076	00	121	36	166	01	211	00
032	01	077	01	122	44	167	75	212	00
033	01	078	75	123	01	168	07	213	00
034	42	079	01	124	03	169	04	214	00
035	01	080	52	125	01	170	95	215	00
036	09	081	01	126	52	171	90	216	00
037	00	082	05	127	03	172	78	217	00
038	46	083	95	128	49	173	80	218	00
039	78	084	22	129	00	174	87	219	00
040	22	085	90	130	02	175	85	220	00
041	52	086	77	131	43	176	01	221	00
042	86	087	01	132	00	177	00	222	00
043	46	088	52	133	02	178	00	223	00
044	11	089	03	134	75	179	95		

Table J-20
Program Listing for F2
(Step Number - Key Code)

000	46	045	52	090	00	135	01	180	41
001	13	046	01	091	01	136	04	181	00
002	75	047	06	092	95	137	07	182	06
003	93	048	95	093	90	138	65	183	07
004	05	049	90	094	01	139	07	184	50
005	95	050	00	095	00	140	85	185	01
006	22	051	05	096	05	141	03	186	14
007	52	052	04	097	43	142	95	187	01
008	37	053	56	098	00	143	41	188	52
009	56	054	01	099	01	144	01	189	04
010	46	055	52	100	90	145	05	190	42
011	14	056	04	101	01	146	02	191	00
012	43	057	42	102	00	147	65	192	00
013	00	058	00	103	05	148	01	193	00
014	01	059	00	104	14	149	85	194	42
015	65	060	01	105	43	150	01	195	00
016	01	061	44	106	00	151	95	196	01
017	00	062	01	107	03	152	44	197	42
018	00	063	09	108	13	153	00	198	00
019	85	064	56	109	22	154	02	199	02
020	43	065	46	110	44	155	41	200	01
021	00	066	11	111	00	156	00	201	05
022	02	067	36	112	03	157	07	202	42
023	95	068	43	113	42	158	04	203	01
024	98	069	01	114	00	159	01	204	09
025	55	070	00	115	01	160	44	205	41
026	43	071	42	116	01	161	01	206	00
027	00	072	00	117	00	162	00	207	06
028	00	073	03	118	49	163	43	208	07
029	95	074	01	119	00	164	01	209	14
030	36	075	00	120	03	165	00	210	25
031	44	076	00	121	43	166	75	211	81
032	01	077	49	122	00	167	07	212	00
033	09	078	00	123	03	168	95	213	00
034	01	079	03	124	90	169	90	214	00
035	52	080	43	125	01	170	01	215	00
036	04	081	00	126	02	171	08	216	00
037	49	082	03	127	09	172	04	217	00
038	00	083	90	128	13	173	75	218	00
039	00	084	01	129	22	174	03	219	00
040	43	085	05	130	44	175	95	220	00
041	00	086	09	131	00	176	90	221	00
042	00	087	13	132	03	177	02	222	00
043	75	088	75	133	60	178	00	223	00
044	01	089	43	134	01	179	09		

Table J-21
Program Listing for F3
(Step Number - Key Code)

000 46	045 00	090 09	135 98	180 79
001 14	046 00	091 46	136 81	181 03
002 46	047 95	092 77	137 55	182 09
003 19	048 42	093 42	138 02	183 00
004 42	049 00	094 00	139 95	184 00
005 00	050 08	095 07	140 41	185 46
006 03	051 10	096 43	141 79	186 79
007 22	052 22	097 00	142 46	187 42
008 50	053 44	098 03	143 12	188 00
009 01	054 00	099 98	144 02	189 05
010 41	055 08	100 81	145 09	190 98
011 67	056 41	101 55	146 04	191 81
012 46	057 88	102 01	147 05	192 46
013 15	058 46	103 00	148 60	193 17
014 42	059 87	104 95	149 01	194 07
015 00	060 09	105 41	150 78	195 06
016 03	061 09	106 78	151 01	196 05
017 50	062 46	107 46	152 04	197 00
018 01	063 88	108 10	153 03	198 60
019 46	064 42	109 75	154 00	199 01
020 67	065 00	110 93	155 41	200 79
021 00	066 06	111 05	156 78	201 04
022 42	067 43	112 95	157 46	202 02
023 00	068 01	113 22	158 13	203 02
024 01	069 05	114 52	159 02	204 05
025 42	070 90	115 37	160 09	205 41
026 00	071 89	116 56	161 00	206 79
027 02	072 65	117 46	162 00	207 46
028 01	073 01	118 11	163 60	208 18
029 01	074 00	119 02	164 01	209 07
030 42	075 00	120 09	165 78	210 05
031 01	076 95	121 06	166 03	211 00
032 00	077 42	122 00	167 01	212 00
033 01	078 00	123 60	168 08	213 60
034 05	079 09	124 01	169 05	214 01
035 42	080 10	125 78	170 41	215 79
036 01	081 22	126 01	171 78	216 01
037 09	082 44	127 03	172 46	217 01
038 43	083 00	128 00	173 16	218 00
039 01	084 09	129 00	174 07	219 05
040 01	085 41	130 46	175 07	220 00
041 90	086 77	131 78	176 02	221 41
042 87	087 46	132 42	177 05	222 79
043 65	088 89	133 00	178 60	223 00
044 01	089 09	134 04	179 01	

Table J-22
Program Listing for F4
(Step Number - Key Code)

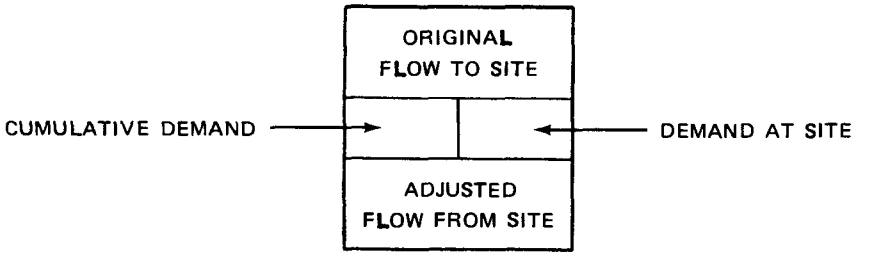
000	46	045	87	090	60	135	16	180	00
001	11	046	46	091	00	136	22	181	09
002	22	047	77	092	87	137	44	182	56
003	50	048	18	093	86	138	00	183	46
004	00	049	65	094	46	139	08	184	68
005	43	050	43	095	12	140	56	185	01
006	00	051	00	096	36	141	46	186	44
007	06	052	05	097	43	142	79	187	01
008	75	053	85	098	01	143	01	188	09
009	43	054	42	099	00	144	44	189	43
010	00	055	00	100	42	145	01	190	01
011	07	056	02	101	00	146	00	191	09
012	95	057	19	102	08	147	43	192	75
013	90	058	43	103	56	148	01	193	01
014	89	059	00	104	46	149	00	194	09
015	80	060	07	105	13	150	75	195	95
016	77	061	54	106	36	151	01	196	90
017	46	062	85	107	43	152	05	197	69
018	78	063	43	108	01	153	95	198	13
019	17	064	00	109	09	154	90	199	41
020	65	065	01	110	42	155	67	200	18
021	43	066	95	111	00	156	12	201	46
022	00	067	98	112	09	157	41	202	69
023	04	068	81	113	56	158	17	203	09
024	95	069	41	114	46	159	46	204	09
025	42	070	88	115	16	160	67	205	56
026	00	071	46	116	75	161	09	206	46
027	01	072	89	117	93	162	09	207	19
028	60	073	50	118	05	163	56	208	43
029	00	074	00	119	95	164	46	209	00
030	77	075	41	120	37	165	18	210	03
031	85	076	78	121	56	166	01	211	85
032	19	077	46	122	46	167	00	212	01
033	43	078	87	123	17	168	00	213	52
034	00	079	17	124	01	169	49	214	07
035	06	080	42	125	00	170	00	215	65
036	54	081	00	126	00	171	09	216	53
037	85	082	06	127	49	172	43	217	07
038	43	083	86	128	00	173	00	218	04
039	00	084	46	129	08	174	09	219	85
040	02	085	88	130	43	175	90	220	22
041	95	086	18	131	00	176	68	221	52
042	98	087	42	132	08	177	16	222	56
043	81	088	00	133	90	178	22	223	00
044	41	089	07	134	79	179	44		

Appendix K

WATER REQUIREMENTS FOR THE DISPERSED SCENARIO

The plant sites chosen for the Dispersed Scenario have been examined to verify that an adequate water supply exists in the area of the plant. This examination is detailed in Figures K-1 to K-7.

Figure K-1 shows the river systems involved. Figures K-2 to K-6 show the flows of water that would reach each plant if there had been no synfuel plants using upstream water, the water demand of synfuel plants at the site, the cumulative upstream synfuel demand, and the flow of water from the site (accounting for all synfuel use to that point on the river). The following convention is used



The flow data has been taken from U.S. Geological Survey data* on the flows of surface water. Data are in cubic ft/sec. (cfs).

With few exceptions, the assumed adequacy of supply has indeed been validated. The exceptions are itemized in Table K-1 and indicated in Figures K-1 to K-7 by a double asterisk.

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*"Surface Water Supply of the United States, 1966-1970," U.S. Geological Survey Water Supply Papers (various volumes) (1975).

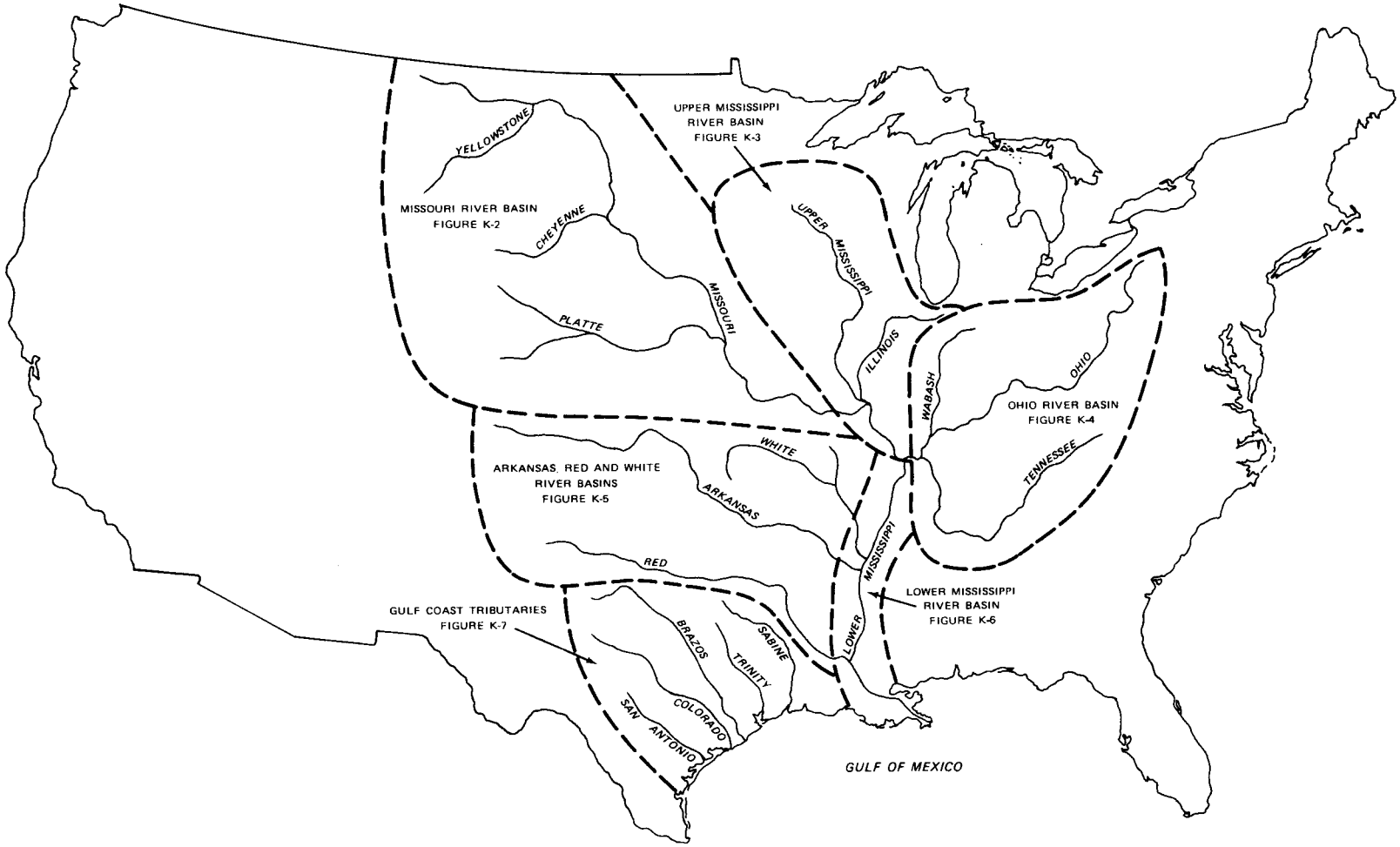


FIGURE K-1. RIVER BASIN INDEX

SYNFUEL WATER USE IS DETAILED IN FIGURES INDICATED

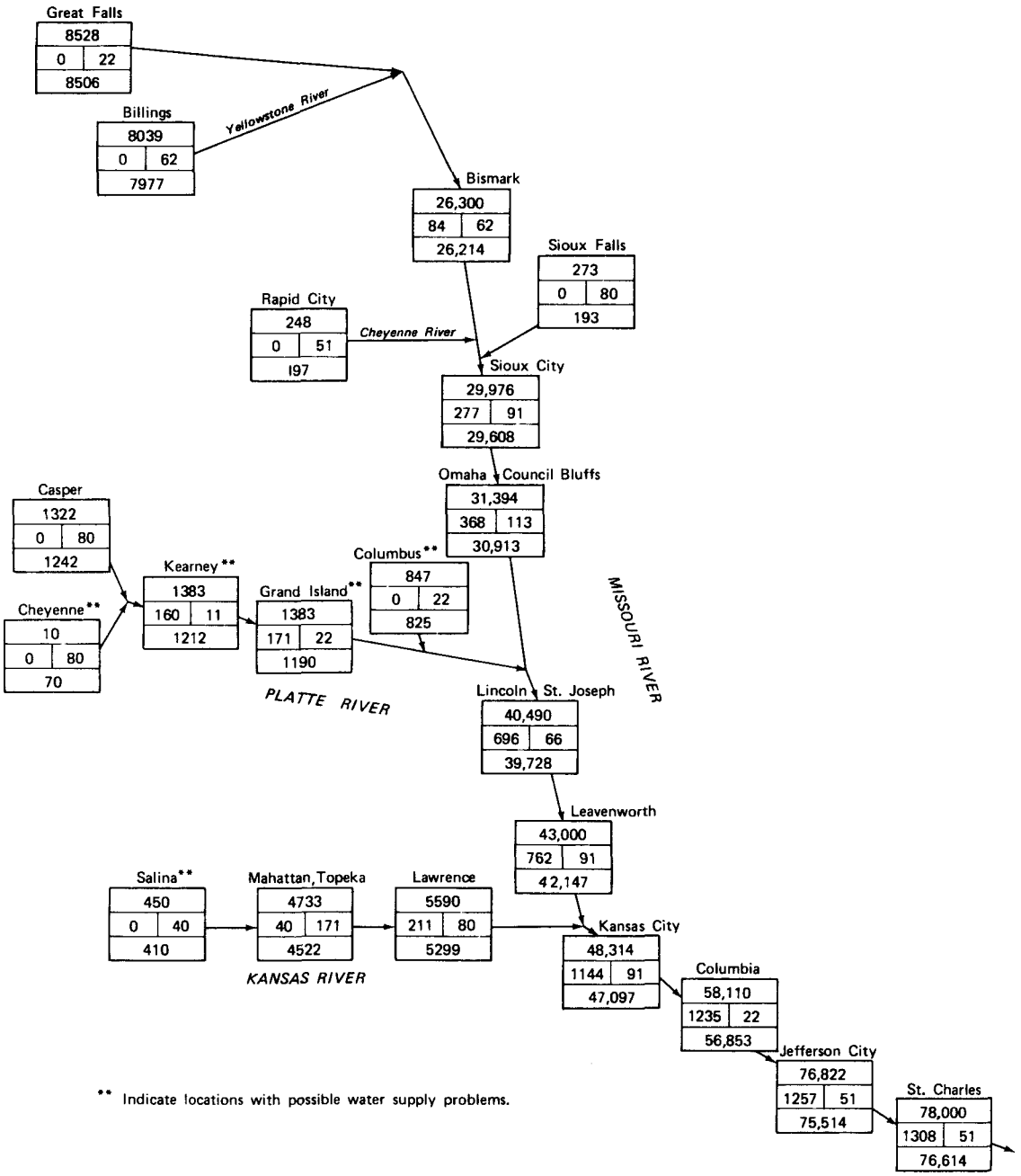
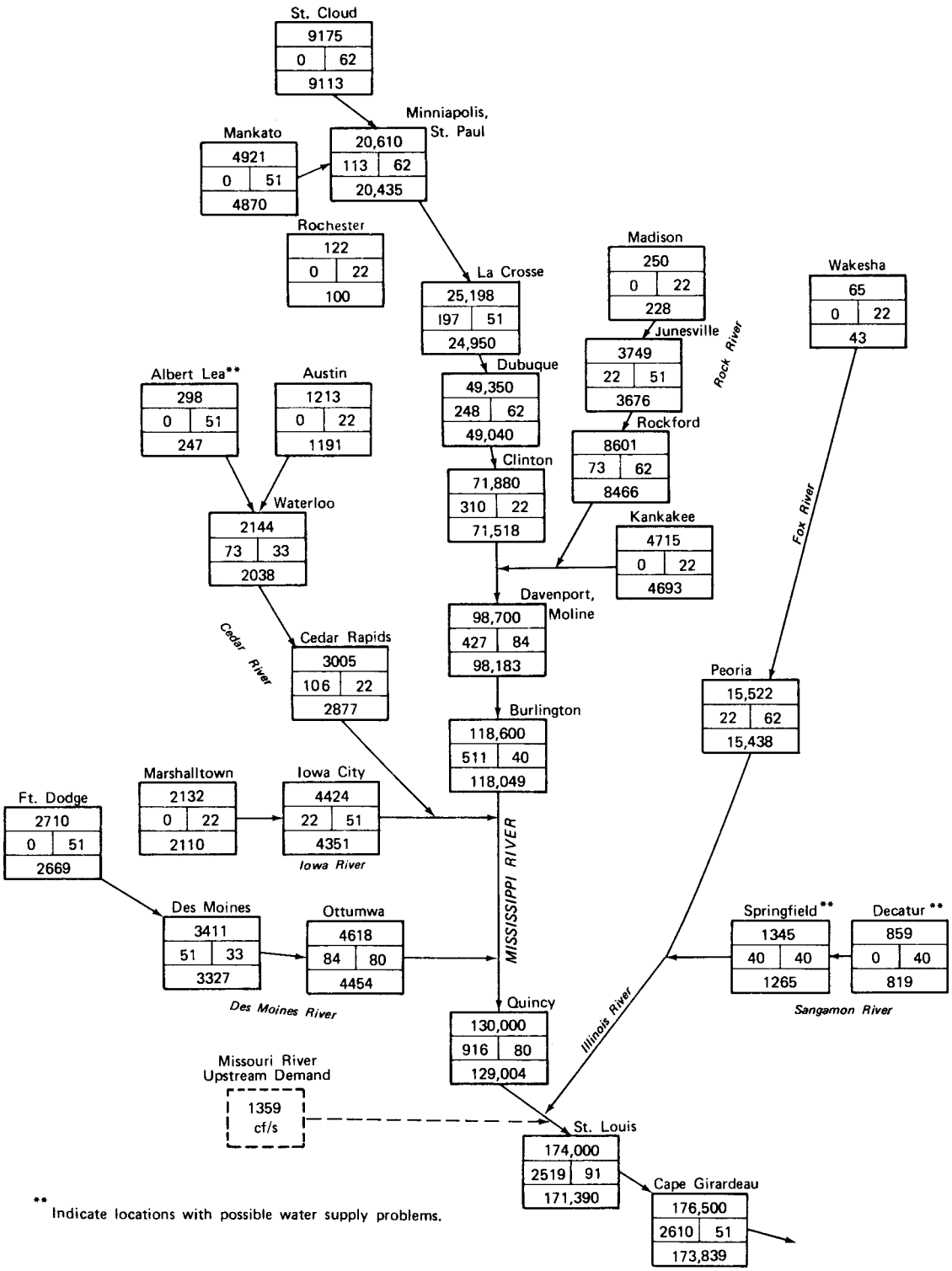


FIGURE K-2. MISSOURI RIVER BASIN: SYNFUEL WATER USE COMPARED WITH AVAILABLE FLOW



** Indicate locations with possible water supply problems.

FIGURE K-3. UPPER MISSISSIPPI RIVER BASIN: SYNFUEL WATER USE COMPARED WITH AVAILABLE FLOW

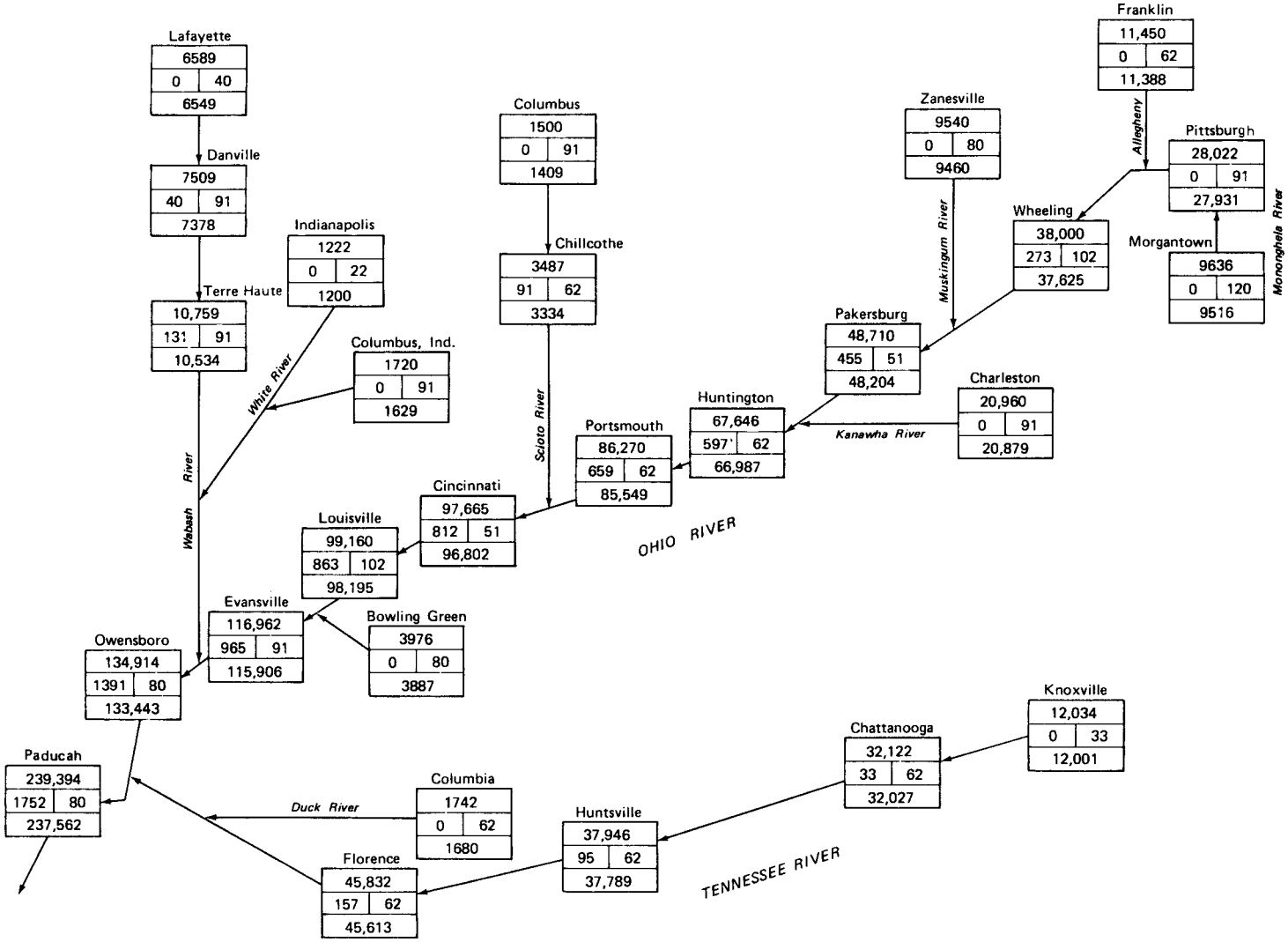


FIGURE K-4. OHIO RIVER BASIN: SYNFUEL WATER USE COMPARED WITH AVAILABLE FLOW

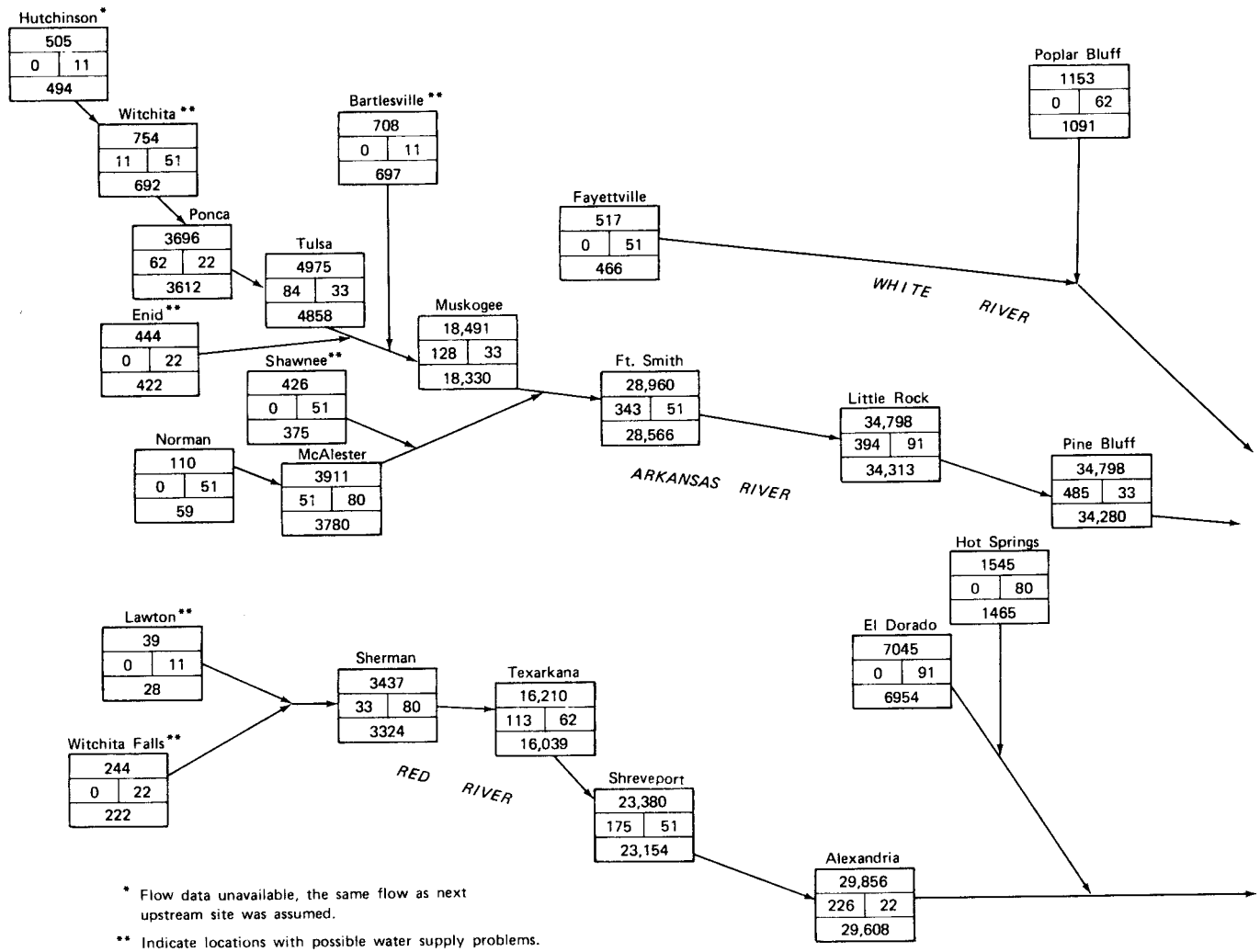


FIGURE K-5. ARKANSAS, RED AND WHITE RIVER BASINS: SYNFUEL WATER USE COMPARED WITH AVAILABLE FLOW

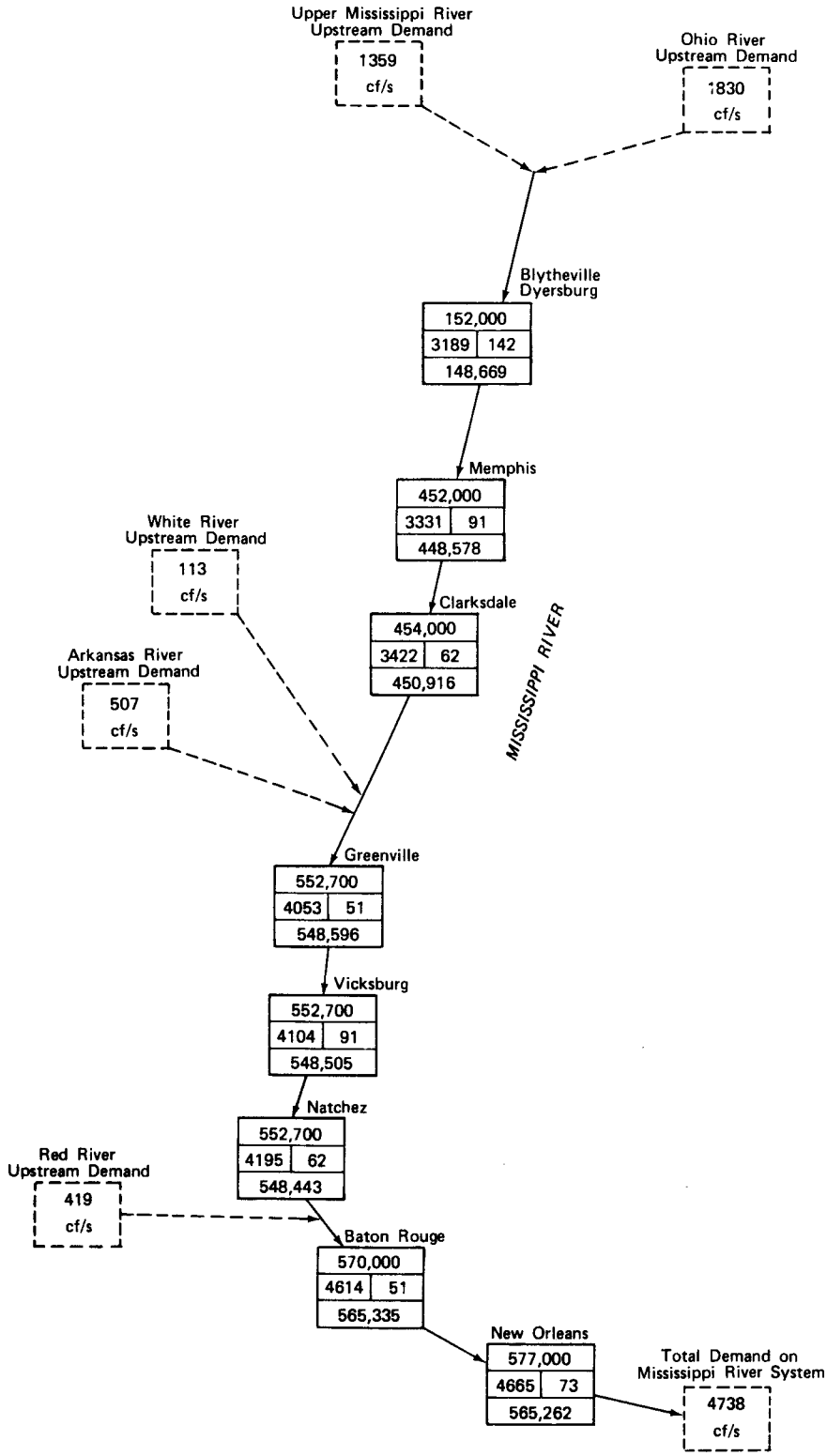
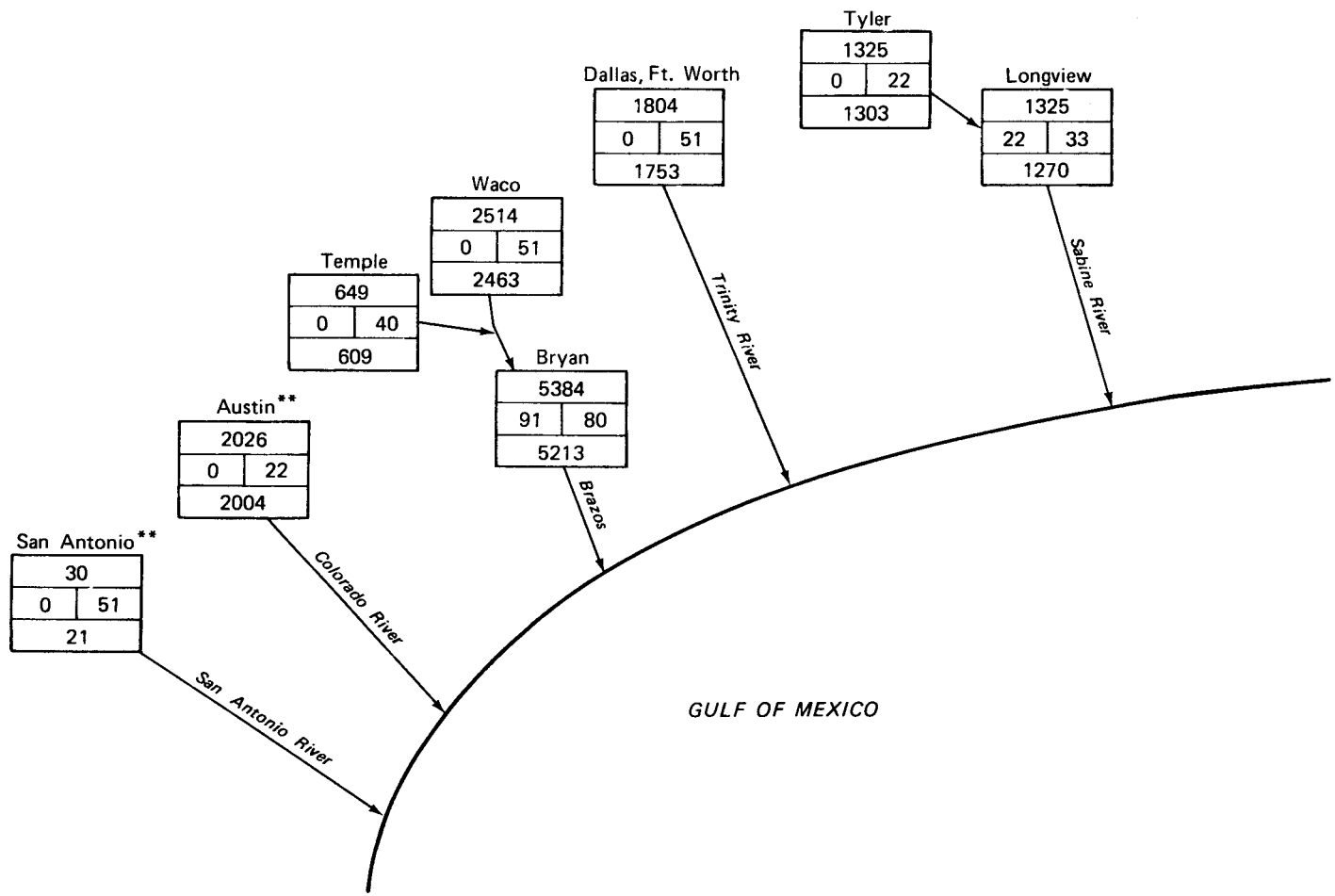


FIGURE K-6. LOWER MISSISSIPPI RIVER BASIN: SYNFUEL WATER USE COMPARED WITH AVAILABLE FLOW



** Indicate locations with possible water supply problems.

FIGURE K-7. GULF COAST TRIBUTARIES: SYNFUEL WATER USE COMPARED WITH AVAILABLE FLOW

Table K-1

SITES WITH WATER PROBLEMS IN THE DISPERSED SCENARIO

River Basin	Plant Site	Synfuel Water Demand at Site or Upstream (cfs)	Stream Flow (cfs)		Possible Problem Areas	
			Average Flow	Low Period Flow	Low Periods	All Year
Missouri						
Big Sioux	Sioux Falls, SD	80	273	3	*	
Crow Creek	Cheyenne, WY	80	10	0		*
Platte	Kearney, NB	171	1383	0	*	
Platte	Grand Island, NB	193	1383	0	*	
Loup	Columbus, NB	22	847	0	*	
Kansas	Salina, KS	40	450	20	*	
Upper Mississippi						
Shellrock	Albert Lea, MN	51	298	24	*	
Sangamon	Decatur, IL	40	859	29	*	
Sangamon	Springfield, IL	80	1345	29	*	
Ohio						
None						
Arkansas, Red, and White						
Arkansas	Hutchinson, KS	11	505	54	*	
Arkansas	Wichita, KS	62	754	73	*	
Cimarron	Enid, OK	22	444	6	*	
Caney	Bartlesville, OK	11	708	9	*	
N. Canadian	Shawnee, OK	51	426	7	*	
Cache Creek	Lawton, OK	11	39	0		*
Wichita	Wichita Falls, TX	22	244	20	*	
Lower Mississippi						
None						
Gulf Coast Tributaries						
Colorado	Austin, TX	22	2026	11	*	
San Antonio	San Antonio, TX	51	30	0		*

Appendix L

LIMITED MINEMOUTH SCENARIO PLANT SITING

The Limited Minemouth Scenario was derived from the Dispersed Scenario by moving selected synfuel plants to minemouth locations in accordance with a rationale described in Chapter 6. Table L-1 lists those location changes.

Table L-1

PLANT SITING CHANGES FROM THE DISPERSED SCENARIO

Production Start Year	Plant Type	Plant Location Moved: From	To: Coal Region	To: County	Extraction Technology
1980	SNG	Des Moines, IA	New Mexico	San Juan	Strip
1980	SNG	Grand Forks, ND	New Mexico	McKinley	Strip
1985	SNG	Ponka, OK	New Mexico	San Juan	Strip
1985	SNG	Longview, TX	New Mexico	McKinley	Strip
1985	SNG	Monroe, LA	North Dakota	Williams	Strip
1985	SNG	Pascagoola, MI	North Dakota	McLean	In-situ
1985	SNG	Fort Worth, TX	Wyoming	Carbon	In-situ
1985	SNG	Austin, TX	Montana	Custer	In-situ
1985	SNG	Port Arthur, TX	Montana	Dawson	In-situ
1985	SNG	Corpus Christi, TX	Utah	Carbon	Underground
1990	SNG	Tulsa, OK	New Mexico	San Juan	Strip
1990	SNG	Little Rock, AK	New Mexico	San Juan	Strip
1990	SNG	Wichita Falls, TX	New Mexico	McKinley	In-situ
1990	SNG	Brownsville, TX	New Mexico	McKinley	In-situ
1990	SNG	Waco, TX	North Dakota	Williams	Strip
1990	SNG	Birmingham, AL	North Dakota	Williams	In-situ
1990	SNG	Wichita, KN	Wyoming	Sheridan	In-situ
1990	SNG	Lake Charles, LA	Wyoming	Johnson	In-situ
1990	SNG	Mobile, AL	Wyoming	Carbon	In-situ
1990	SNG	Pine Bluff, AK	Montana	Rosebud	In-situ
1990	SNG	Waterloo, IA	Montana	Custer	In-situ
1990	SNG	Knoxville, TN	Montana	Dawson	In-situ
1990	SNG	Orange, TX	North Dakota	McLean	In-situ
1990	SNG	Muskogee, OK	North Dakota	McLean	In-situ
1995	SNG	Pascagoola, MI	Wyoming	Sheridan	In-situ
1995	SNG	Hattiesburg, MI	Wyoming	Carbon	In-situ
1995	SNG	Minneapolis, MN	Wyoming	Sweetwater	In-situ

Table L-1 (continued)

Production Start Year	Plant Type	Plant Location Moved From	To Coal Region	To County	Extraction Technology
1995	SNG	Grand Island, NB	Wyoming	Converse	In-situ
1995	SNG	Bartlesville, OH	Wyoming	Johnson	In-situ
1995	SNG	Columbia, SC	Wyoming	Carbon	In-situ
1995	SNG	New Orleans, LA	Wyoming	Sweetwater	In-situ
1995	SNG	Madison, WI	Montana	Custer	In-situ
1995	SNG	Fort Smith, AK	Montana	Dawson	In-situ
1995	SNG	Alexandria, LA	Montana	Rosebud	In-situ
1995	SNG	Shawnee, OK	Colorado	Routt	In-situ
1995	SNG	Chattanooga, TN	Colorado	Huerfano	In-situ
1995	SNG	Richmond, VA	New Mexico	San Juan	Strip
1995	SNG	La Crosse, WI	New Mexico	San Juan	Strip
1995	SNG	Lafayette, LA	New Mexico	McKinley	In-situ
1995	SNG	St. Cloud, MN	New Mexico	McKinley	In-situ
1995	SNG	Rochester, MN	North Dakota	McLean	In-situ
2000	Syncrude	Blytheville, AK	New Mexico	San Juan	Strip
2000	Syncrude	Harlingen, TX	New Mexico	San Juan	Strip
2000	SNG	Great Falls, MO	North Dakota	Stark	Strip
2000	SNG	Port Huron, MI	North Dakota	Williams	Strip
2000	SNG	Brunswick, GA	North Dakota	McLean	In-situ
2000	SNG	New Orleans, LA	North Dakota	McLean	In-situ
2000	Syncrude	Houston, TX	Wyoming	Sheridan	Strip
2000	SNG	Galveston, TX	Wyoming	Carbon	In-situ
2000	SNG	Cumberland, MD	Wyoming	Converse	In-situ
2000	SNG	Natchez, MS	Wyoming	Carbon	In-situ
2000	SNG	Duluth, MN	Wyoming	Johnson	In-situ
2000	SNG	Vicksburg, MS	Wyoming	Sheridan	In-situ
2000	Syncrude	Tampa, FL	Wyoming	Lincoln	Strip
2000	SNG	Memphis, TN	Montana	Custer	In-situ
2000	SNG	Iowa City, IA	Montana	Custer	In-situ
2000	SNG	Corpus Christi, TX	Montana	Bighorn	In-situ

Table L-1 (concluded)

Production Start Year	Plant Type	Plant Location Moved			Extraction Technology
		From	To		
			Coal Region	County	
2000	SNG	Louisville, KY	Montana	Rosebud	In-situ
2000	SNG	Moline, IL	Montana	Custer	In-situ
2000	SNG	Leesville, LA	Montana	Dawson	In-situ
2000	SNG	Houston, TX	Montana	Fergus	Underground
2000	SNG	Davenport, IA	Colorado	Moffat	In-situ
2000	SNG	Shreveport, LA	Colorado	Huerfano	In-situ
2000	SNG	Jefferson City, MO	Colorado	Routt	In-situ
2000	SNG	Mankato, MN	Colorado	Garfield	Underground
2000	SNG	Charleston, SC	Colorado	Gunnison	Underground
2000	SNG	New York, NY	Colorado	Las Animas	Underground
2000	SNG	Pasadena, TX	Utah	Carbon	Underground

Appendix M

COAL DEPLETION MODEL SENSITIVITY TESTS

One effective way to illustrate the influence of particular factors on the results of a model is to alter one variable and then rerun the model. The new results can then be compared with some "base case" to observe the effect of the altered variable. We have taken the Dispersed Scenario as the base case (with one exception noted). Sensitivity of the model results has been examined for the following variables:

- Severance taxes
- Time of initiation of synthetic fuels production
- Cost of sulfur removal in coal-fired electricity generation
- In-situ mining cost
- Inclusion of the "hypothetical" coal resources.

These variables have been chosen for analysis because they are both the most uncertain and potentially the most critical.

In most of the illustrations that follow, the base case coal production is shown for four years--1975, 2000, 2025, 2050--in a heavy outline. When the changed assumption of the sensitivity test results in an increase, the hatched area is shown added to the base case, but when the changed assumption results in a decrease a stipled area is shown subtracted from the base case.

1. Severance Taxes

The severance taxes used in the model were listed previously in Table 2-2. It is difficult to foresee changes in such taxes, but those shown are representative.

a. Reduction of the Montana Tax

The largest tax is Montana's 30 percent tax on strip-mined coal. To observe the effect of this tax, Figure M-1 compares the production in each region in the base case with the results obtained when the model is run with the Montana tax reduced to 5 percent on strip-mined coal. As expected, a reduction in Montana's severance tax results in an increase in Montana coal production. Indeed, with the lower tax, production in 2025 is double that of the base case. Figure M-1 shows that the lower tax initiates the boom in Montana production 5 to 10 years earlier than in the base case, and has also increased the peak production slightly. As might also be expected, in compensation for the increased production in Montana, production in those regions in

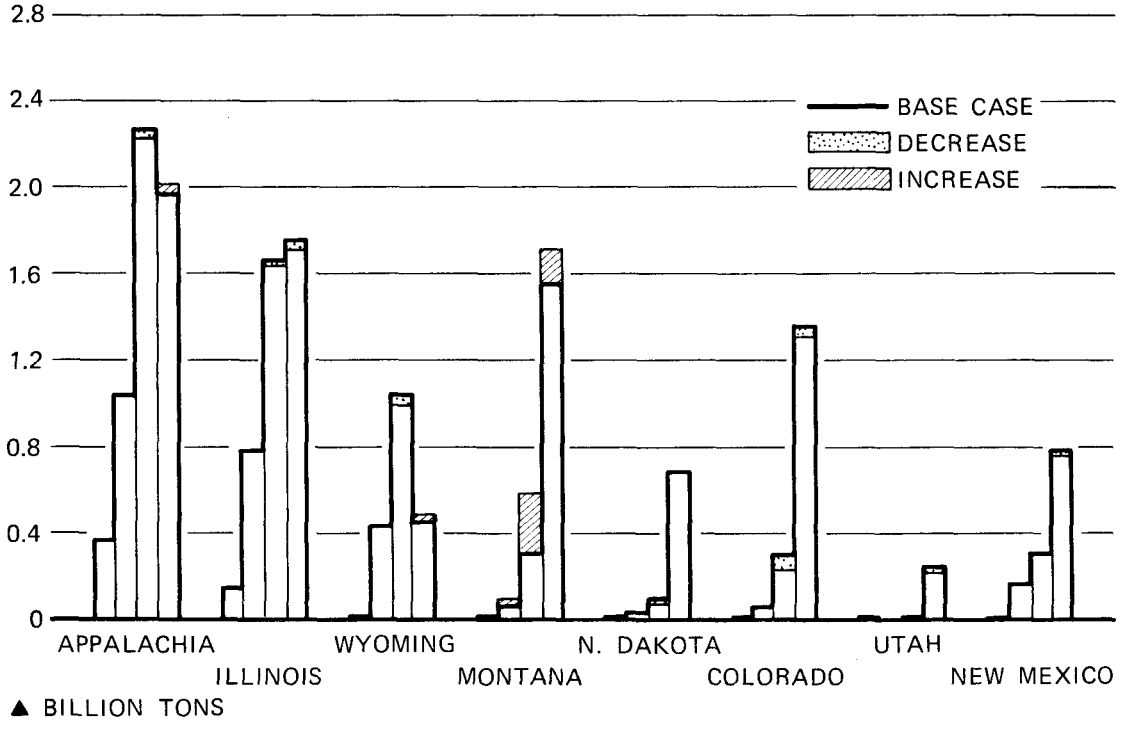


FIGURE M-1. SENSITIVITY TEST: MONTANA SEVERANCE TAX REDUCED TO 5%

competition with Montana decreases. In this case, production is reduced slightly in nearly all of the other regions.

b. Increase in the Montana Tax

Since the effect the high base-case severance tax has been shown to delay initiation of the production cycle, as well as to decrease the peak production, it is interesting to see the effect of a significantly higher tax. Figure M-2 shows the results of an increase in the Montana tax from the 30 percent of the base case to 100 percent on strip-mined coal. Production is reduced by 75 percent in 2025 and by 40 percent in 2050.

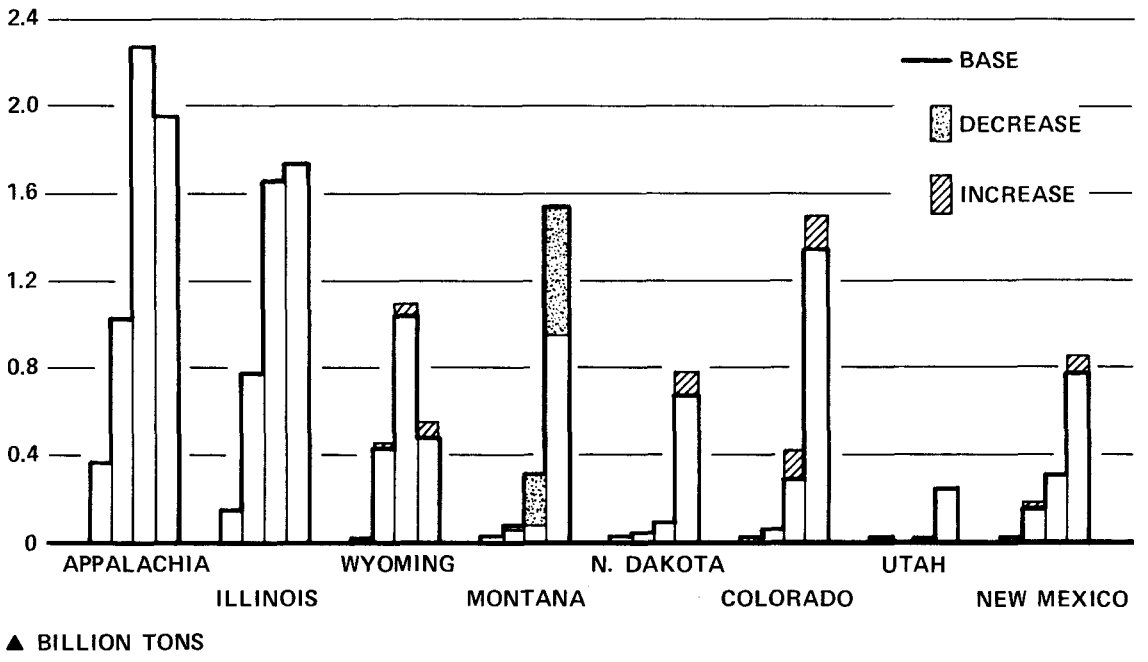


FIGURE M-2. SENSITIVITY TEST: MONTANA SEVERANCE TAX INCREASED TO 100%

The two sensitivity calculations shown in Figures M-1 and M-2 show that the effect of a high regional severance tax on coal is a delay in the extraction of its resources and the distribution of the extraction that does occur over a longer time with lower peak production levels.

c. Increase in the Colorado Tax

To test the degree that the effect of tax changes in Montana are unique to that state, the model was run with the tax on underground Colorado coal increased from approximately 5 percent (50¢/ton) to 30 percent. Underground coal was chosen for the tax because Colorado has very little strip-minable resource. Figure M-3 shows that the effects of

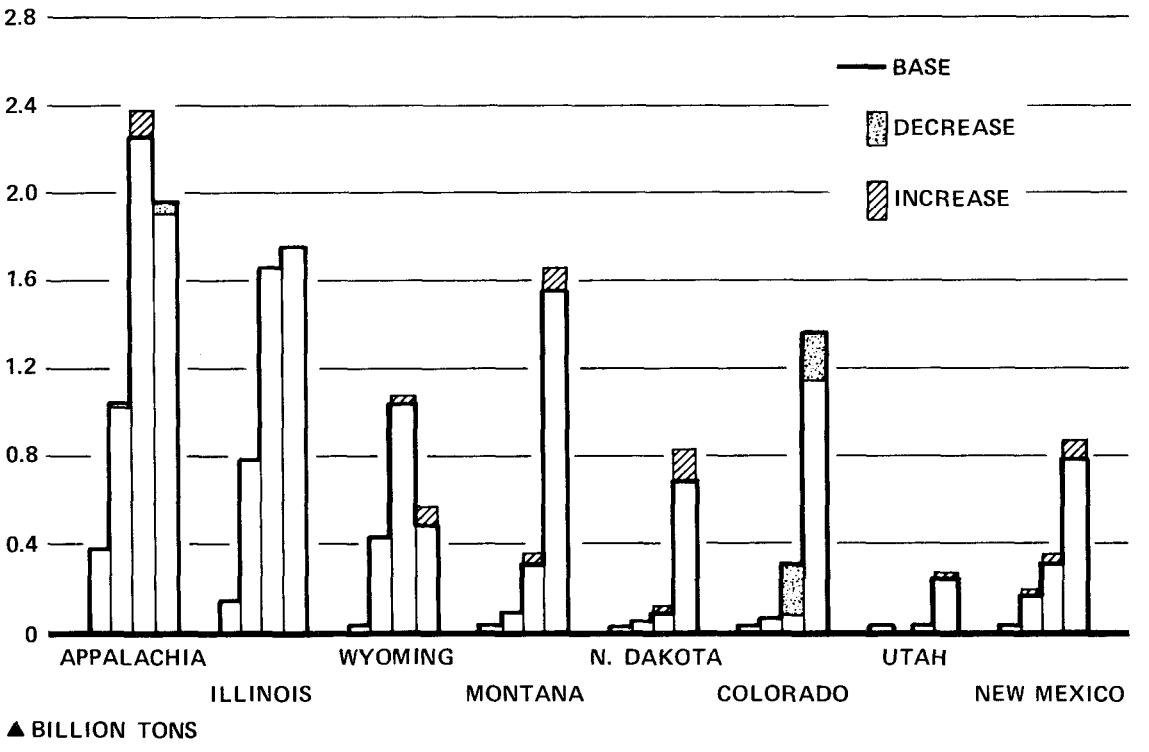


FIGURE M-3. SENSITIVITY TEST: COLORADO SEVERANCE TAX INCREASED TO 30%

this change are similar to those found for Montana--the tax decreases production markedly during the early portion of the production boom period but reduces the magnitude of the ultimate peak production only moderately. Again, as expected, the reduction in Colorado production is offset by an increase in most of the other regions.

d. Increase in the Tax on Both Colorado and Illinois Underground Mined Coal

Finally, the effect of a tax of 30 percent on Illinois underground coal in addition to the tax increase on Colorado underground coal discussed above is shown in Figure M-4. The effects on Colorado production are nearly the same as before, but the effect on Illinois is not

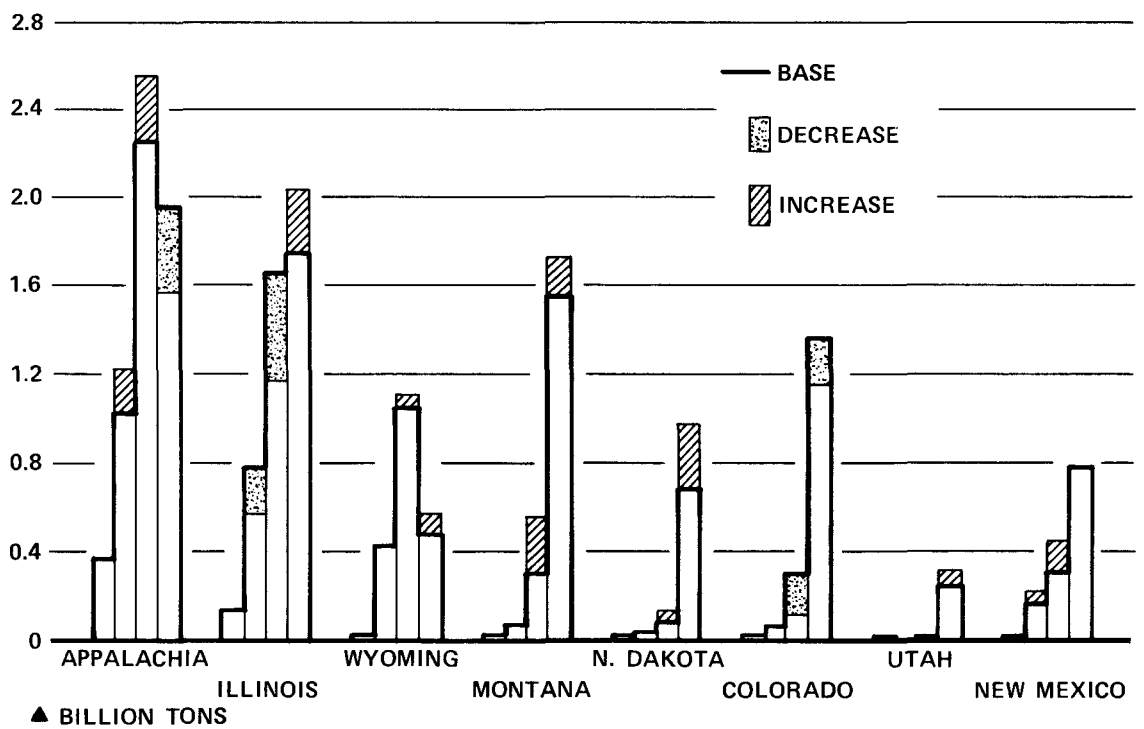


FIGURE M-4. SENSITIVITY TEST: COLORADO AND ILLINOIS SEVERANCE TAX INCREASED TO 30%

wholly expected. In particular, while production in Illinois decreases in the rising part of the boom cycle, later peak production is actually increased by the higher tax. Closer analysis shows that in the high tax case, the model does not choose Illinois for new underground mining contracts until after the year 2000, while in the base case, underground production increases steadily from the present to 2000. After 2000, however, underground production increases more rapidly in the high tax case and surpasses the production of the untaxed base case in the year 2050. Moreover, the model calculations reveal why, in spite of the high severance tax, in later years the Illinois production increases above the level of the base case. In the early years, the tax discourages use of Illinois coal, but later, as the best and cheapest alternative coals are depleted, Illinois coal becomes very competitive and is selected for use frequently even with the high taxes.

e. Increase in the Wyoming Tax

Adding a severance tax of 30 percent in Wyoming to the conditions of the base case produces, as shown in Figure M-5, the expected effect of reducing Wyoming production and, in compensation, the increase of production in other regions. In 2000, Illinois provides most of the compensating increase, but in 2025 Appalachia, Montana, and Colorado provide most of the compensating increase.

2. Delayed Synthetic Fuel Development

The timing of the onset of the synthetic fuel industry is one of the major real-world uncertainties in the scenarios. The base case assumes that the first few small gasification plants and the first small liquefaction plant would begin production in 1980, followed by a rapid buildup in production to meet the projected total demand for oil and gas without a major increase in imports. Yet, because there are large uncertainties in the financing of synthetic fuel plants, the future market prices of competing natural oil and gas, as well as environmental constraints, the deployment of a synthetic fuel industry is likely to start later than assumed in the base case. To test the effect of such a delay on coal

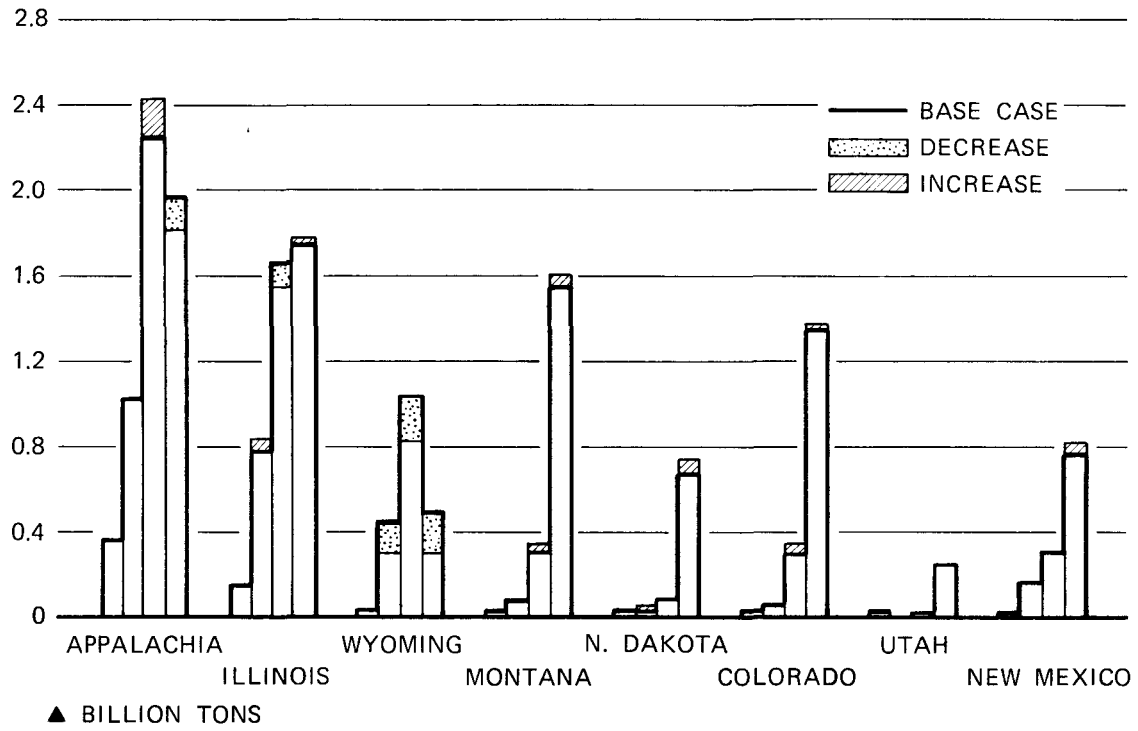


FIGURE M-5. SENSITIVITY TEST: WYOMING SEVERANCE TAX INCREASED TO 30%

depletion we have run the model with a different plant deployment schedule, as shown in Figure M-6. Once deployment begins, the industry growth rate was taken to be exactly the same as in the base case but the onset of the SNG industry was delayed by 10 years and the onset of the syncrude industry by 20 years. Thus, in this sensitivity test the first few SNG plants begin production in 1990 (instead of 1980) and the first syncrude plant begins production in 2000 (instead of 1980).

As shown in Figure M-7, the major effect of the delay in the onset of the synthetic fuels industry is a general reduction in production and a shift in the peak coal production in each region to a later time--except for Wyoming. The Wyoming peak is shifted very little because the (undelayed) electricity industry contracts for a larger portion of its

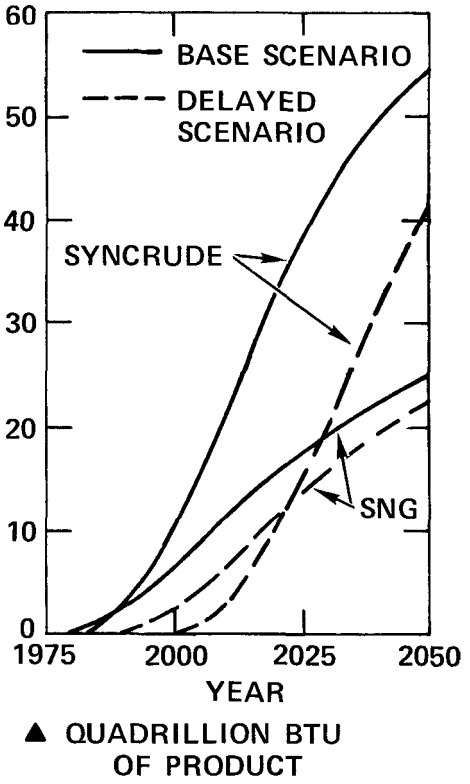


FIGURE M-6. SENSITIVITY TEST: ASSUMED DELAY OF SYNTHETIC FUELS INDUSTRY

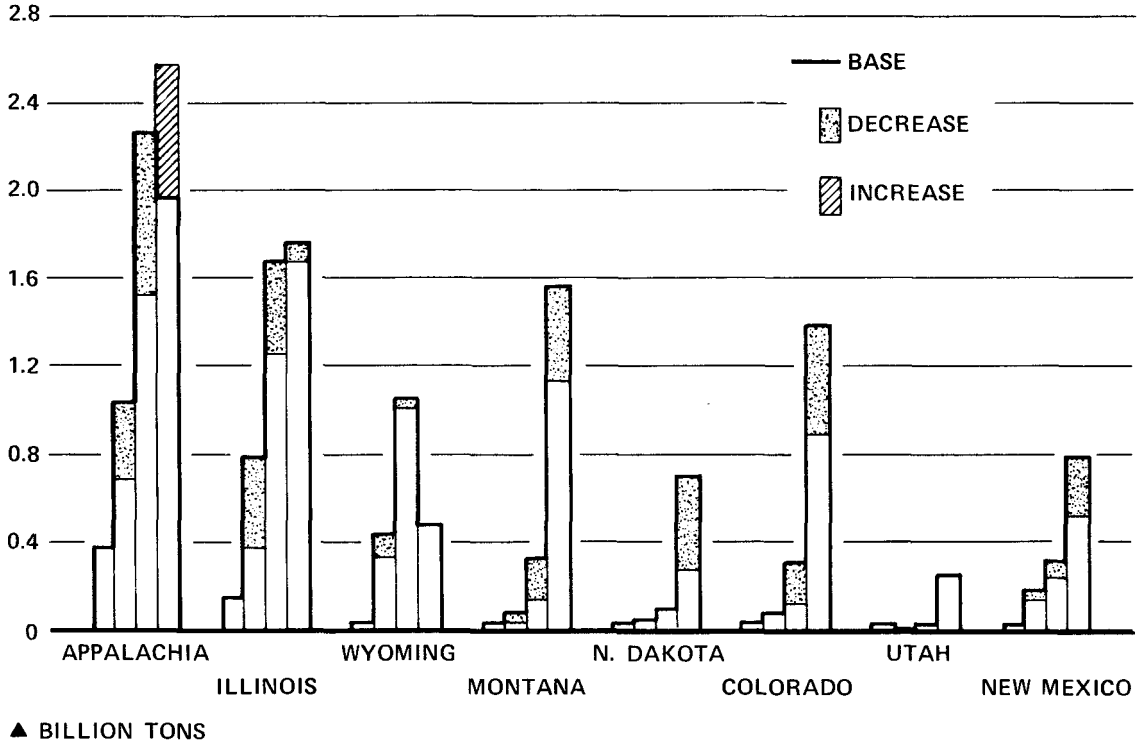


FIGURE M-7. SENSITIVITY TEST: COAL PRODUCTION UNDER ASSUMED DELAY IN SYNTHETIC FUELS INDUSTRY

strip-minable coal from Wyoming. The increase shown in Appalachia in 2050 stems from increased dependence on eastern coal because the Wyoming strip coal has been depleted by the time the synthetic fuel industry's demand for coal becomes large.

3. Sulfur Scrubbing Cost

The cost of stack-gas scrubbing of high sulfur coal is a significant variable in the model because it affects the relative attractiveness of various coals for use in electricity generation. Moreover, this cost is uncertain and the subject of controversy. A conservative (high) estimate of $1.00/million Btu of electricity produced was used in the base case. The effects of using half that estimate, $0.50/million Btu of electricity produced, on the production of coal is shown in Figure M-8. Recall that the regions classified as high-sulfur regions (Table 2-1) are Appalachia, Illinois, North Dakota, and Utah. With this reduced value of stack gas scrubbing costs, the model shows an increase in the use of coal from Appalachia and Illinois through 2000, just as would be expected.

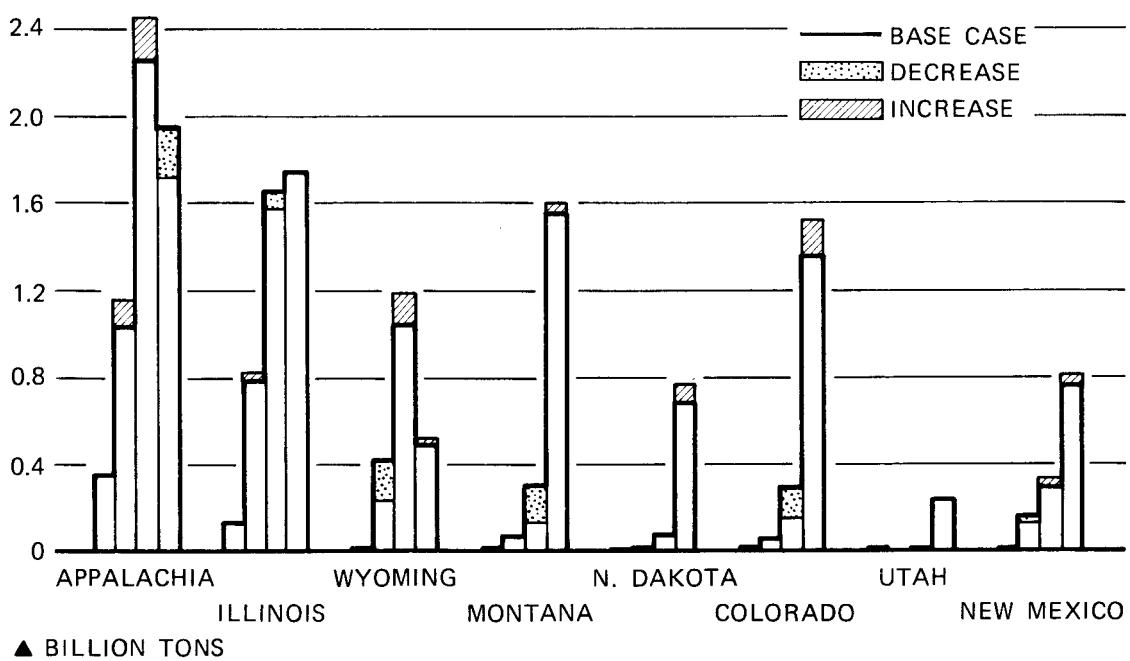


FIGURE M-8. SENSITIVITY TEST: SULFUR SCRUBBING COST REDUCED 50%

Hidden within the effects shown in Figure M-8 is a combined shift of coal production away from synthetic fuels and towards electricity in the East and Midwest, and an opposite shift in the West of coal production away from electricity and to synthetic fuels.

Figure M-9 shows only the portion of total coal production that is associated with electricity production since the cost of this form of energy product is the most sensitive to the costs incurred in sulfur clean-up. Figure M-9 shows clearly that in the base case western coals were heavily chosen for electricity power contracts, but the reduced sulfur scrubbing costs significantly lessens the emphasis on western coal for electricity generation. North Dakota and Utah coal is not chosen in the model for electricity generation in either the base case or this sensitivity case.

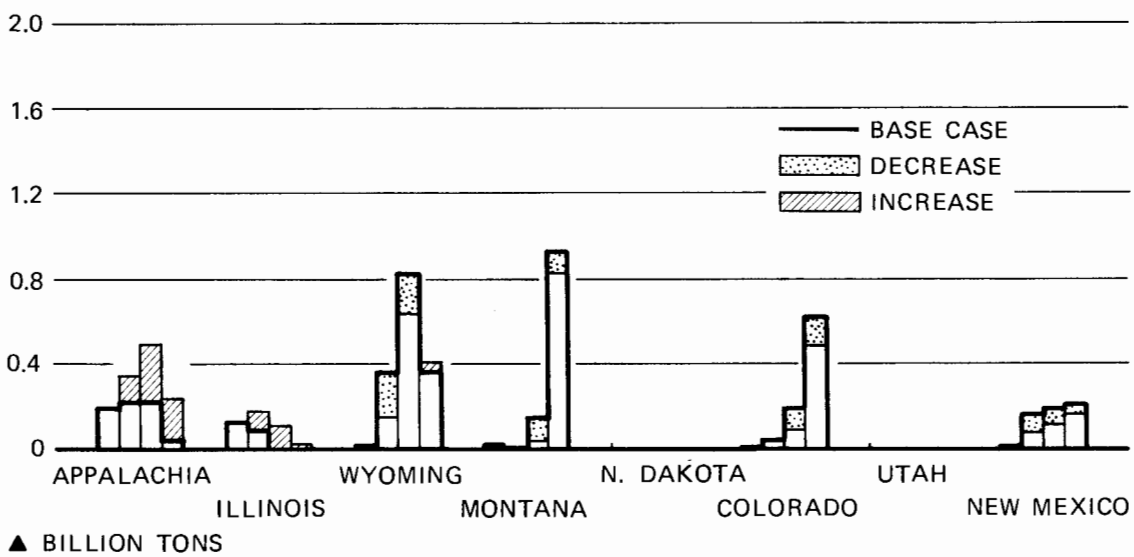


FIGURE M-9. SENSITIVITY TEST: COAL PRODUCTION ALLOCATED TO ELECTRIC POWER GENERATION ASSUMING SULFUR SCRUBBING COST REDUCED 50%

4. In-Situ Extraction Cost

In-situ extraction is presently experimental. The costs for achieving in-situ gasification used in the base case were derived from engineering studies based on experiments. As a result, there is a substantial uncertainty in the ultimate cost and efficiency of in-situ extraction.

Figure M-10 shows the effect of increasing the cost of in-situ extraction by 50 percent in the model. Departing from our previous practice of treating the Dispersed Scenario as the base case, the Minemouth Scenario was used to make this comparison because minemouth fuel conversion is assumed to be necessary with in-situ extraction.

Figures 3-2 to 3-4 showed that the coal regions, which account for nearly all of the in-situ extraction in the (minemouth) base case, are Wyoming, Montana, and North Dakota. Figure M-10 shows that the increased in-situ cost does not change Wyoming production, largely because Wyoming strip and in-situ coal are both cheaper than alternatives. This is true since Wyoming in-situ coal consists mainly of seams greater than 50-ft thick, which would allow use of the efficient vertical combustion method of in-situ extraction. Montana and North Dakota seams, which are suitable for in-situ extraction are thinner, ranging in thickness from 10 to 50 ft. As a result, the less efficient horizontal combustion method must be used.

Because they are cheaper to use, Wyoming strip and in-situ coal are used (or contracted for) almost to the point of depletion before Montana and North Dakota strip or in-situ coal become competitive. Increasing the cost of in-situ coal by 50 percent, as in this sensitivity test, does not change this relationship because Wyoming strip and in-situ remain much cheaper to use than Montana or North Dakota strip or in-situ coal. The primary effect of the increased cost of in-situ extraction is a shift away from in-situ extraction in Montana and in North Dakota to strip mining in North Dakota. The other regions are relatively unaffected.

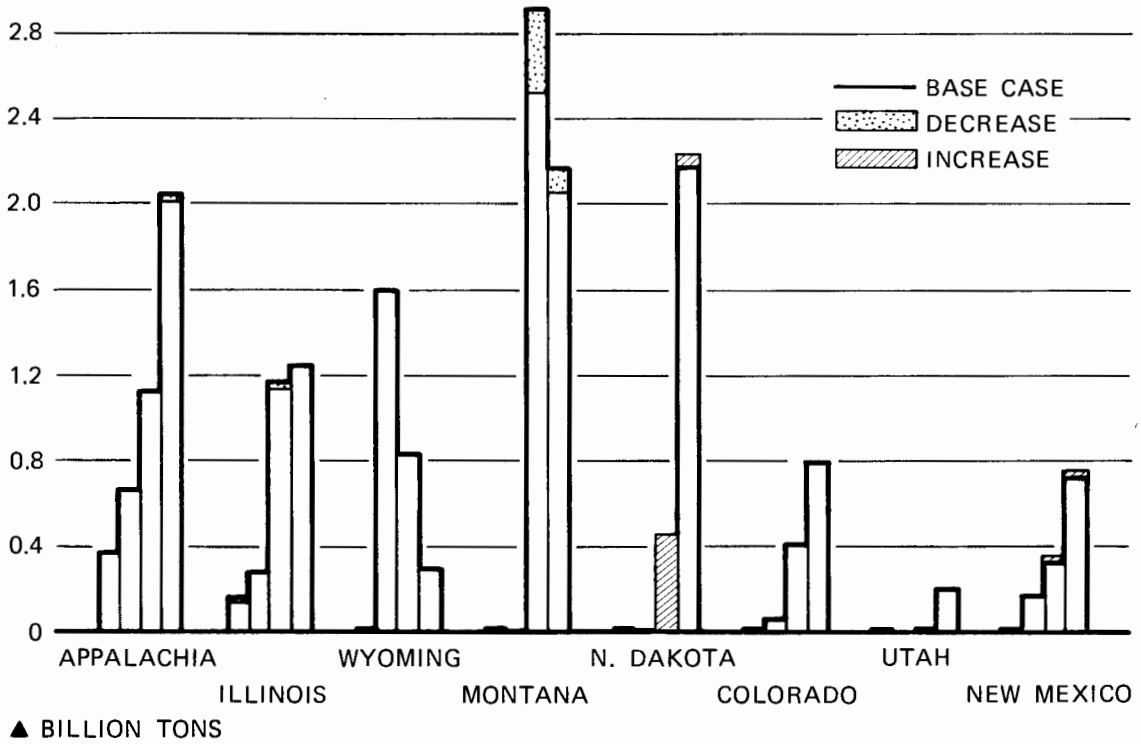


FIGURE M-10. SENSITIVITY TEST: IN-SITU EXTRACTION COST INCREASED 50%

If, however, the cost of in-situ were to be increased by 100 percent, instead of 50 percent, Wyoming in-situ coal would no longer be less expensive to use than North Dakota strip coal. Wyoming production would then be reduced and delayed as shown in Figure M-11. By 2050, the general cost of coal extraction would have risen to the point that Wyoming in-situ, as well as Illinois and Colorado underground coal, become competitive with North Dakota strip coal so that Wyoming, Illinois, and Colorado production would increase while that of North Dakota would decrease.

Thus, a moderate increase in in-situ extraction cost that is not sufficient to make Wyoming in-situ coal more costly than North Dakota strip coal results in a replacement of Montana in-situ production with North Dakota strip production. But a larger increase in the cost of in-situ coal makes Wyoming in-situ coal more costly than North Dakota

strip coal, and Wyoming in-situ extraction is replaced by North Dakota strip coal. When the extraction costs of all mining become high enough to make Wyoming in-situ competitive again with North Dakota strip mining, Illinois and Colorado underground coal become competitive and their production also increases.

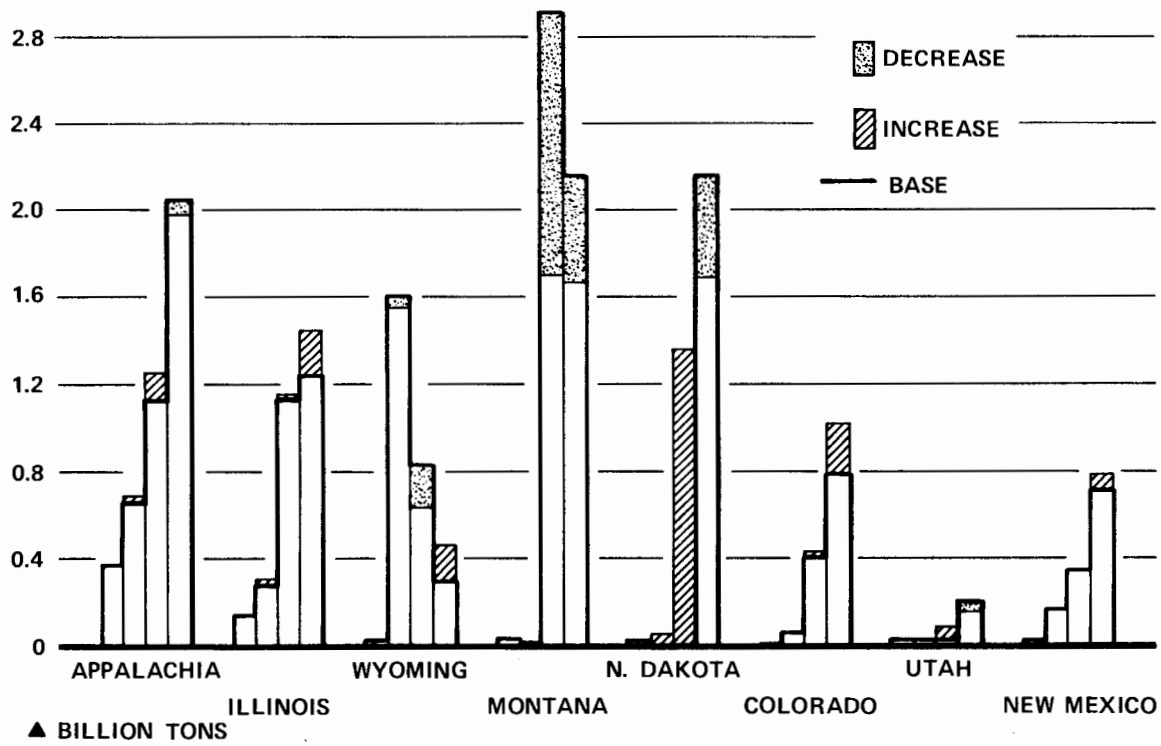


FIGURE M-11. SENSITIVITY TEST: IN-SITU EXTRACTION COST INCREASED 100%

5. Hypothetical Coal Resources

The coal resources used in the model include the "reserve base" and the "inferred" categories. The "hypothetical" category, discussed in Chapter 2 and Appendix A, is relatively uncertain with respect both to its quantity and its characteristics. This category is not based on physical measurements or observations but is only hypothesized from geological theory.

Figure M-12 shows the effect of including coal resources in the hypothetical reliability category. In most regions, inclusion of this category increases the coal resource in a region by 50 percent to 100 percent. Appalachia and Wyoming are exceptions. Appalachia has been explored, mapped, and mined for so long that there is little coal in the hypothetical category because the extent of the Appalachian resource is known more reliably. The extent of the Wyoming coal resource, however, is not known reliably; inclusion of the hypothetical category increases the Wyoming resource sixfold. To appreciate the effect of the realization of the these hypothetical resources, the resource and extraction cost submodels described in Appendices A, B, and C were extended, and then the model was rerun with the base case. The resulting effect on coal depletion is shown in Figure M-12. Although the pattern of depletion is nearly the same, all regions except Appalachia now have significantly more coal resources from which to draw.

The effect of inclusion of hypothetical resources on regional production is shown in Figure M-13. Production is increased in regions and at times where production had previously dropped off because of a sharp increase in costs. Consequently, production is increased primarily in Wyoming in 2025 and 2050, and in Illinois and Appalachia in 2050. Production is decreased correspondingly in other regions.

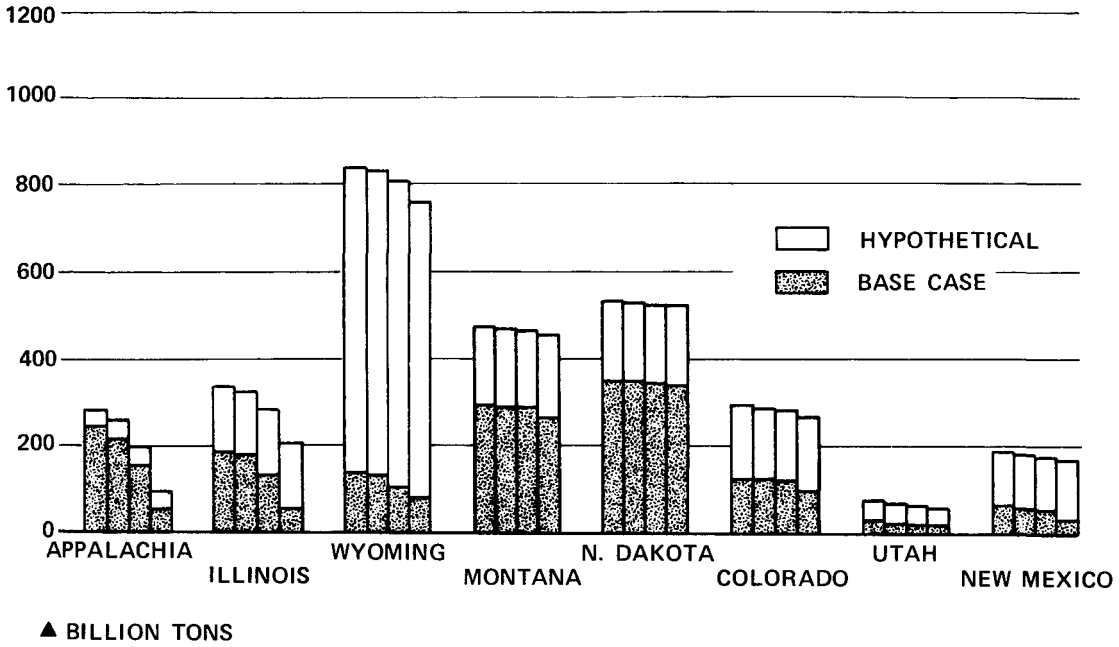


FIGURE M-12. SENSITIVITY TEST: RESOURCES REMAINING WHEN HYPOTHETICAL RESOURCES ARE INCLUDED

6. Summary of Model Sensitivity Tests

Varying the assumptions used in the model reveal the following general kinds of behavior:

Severance Taxes--A high severance tax imposed by a coal producing region delays the peak production period and reduces the peak quantity produced. In compensation, coal production is increased in other regions.

Delay of Synthetic Fuel Production--Delayed initiation of the synthetic fuels industry delays the coal production cycle correspondingly in all regions except Wyoming because its inexpensively-mined coal would be used more for electricity generation. However, this would tend to deplete Wyoming coal, and, later, when the synthetic fuel industry enters

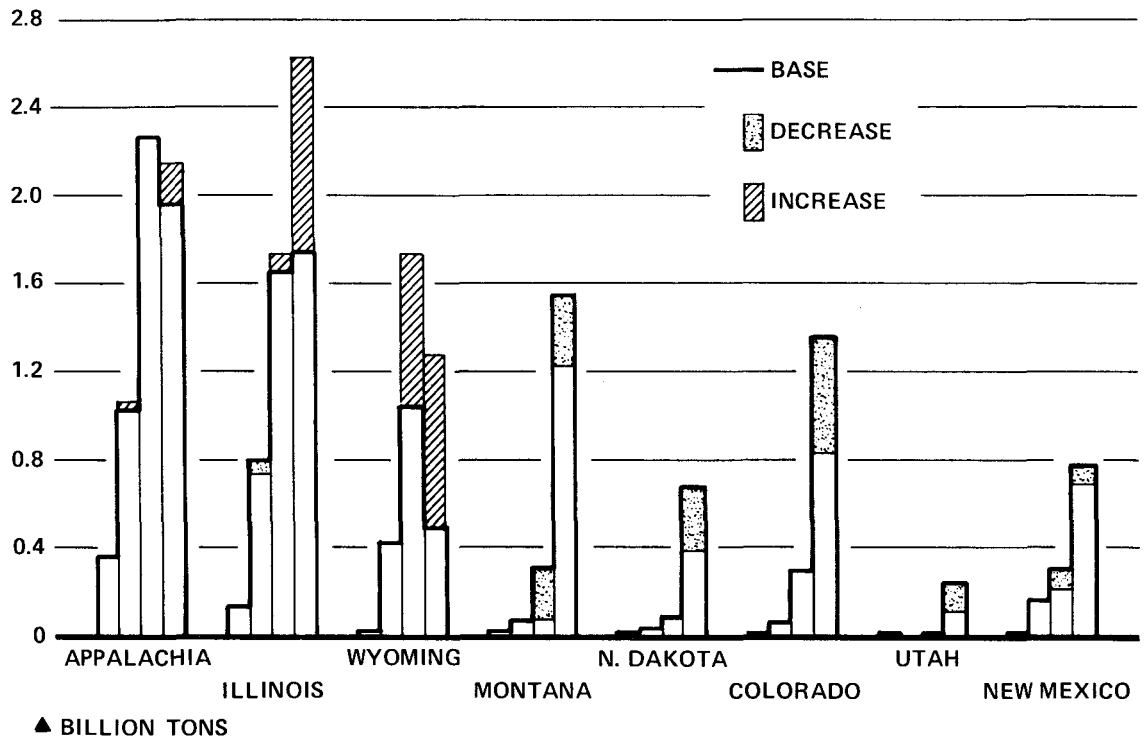


FIGURE M-13. SENSITIVITY TEST: COAL PRODUCTION WHEN HYPOTHETICAL RESOURCES ARE INCLUDED

its high growth phase, the synthetic fuels industry would have to rely more on production in the East and Midwest.

Reduced Cost of Sulfur Scrubbing--Reducing the cost of stack gas scrubbing of high-sulfur coal for electric power generation results in electric utilities shifting to the use of eastern and midwestern high-sulfur coals. This would decrease the use of western low-sulfur coal by eastern-based utilities. As a result, synthetic fuels would shift to an even greater use of western coal than in the base case.

Increased In-Situ Extraction Cost--An increase in the assumed cost of in-situ extraction decreases the in-situ use of coal in Wyoming,

Montana, and North Dakota for SNG and electricity generation and, in compensation, increases the use of North Dakota strippable coal.

Increased Coal Resources--Addition of "hypothetical" resources to "reserve base" and "inferred" resources increases the coal resources in Wyoming by about 600 percent and by about 100 percent in most of the other regions. As a result, production would increase in regions (primarily Wyoming and Illinois) where production had been limited previously by depletion.