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Analysis of U.S. Underground Thin Seam Mining Potential

Volume 1 - Text

Final Technical Report

December 1978

Published June 1979

Prepared For

U.S. Department of Energy

Assistant Secretary for Energy Technology

Division of Solid Fuels Mining and Preparation

Under Contract No. HCP/T77-C-01-8915-01(5)

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Prepared By

~~E.~~ Robert A. Pimental, Deborah Barell,
Rita J. Fine and William J. Douglas, Ph.D.
Ketron, Inc.

Valley Forge Executive Mall
530 East Swedesford Road
Wayne, Pennsylvania 19087

Prepared For

U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Solid Fuels Mining and Preparation
Washington, D.C. 20585

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	vii
EXECUTIVE SUMMARY	viii
ACKNOWLEDGEMENTS	xii
 1.0 INTRODUCTION	 1
1.1 Background	1
1.2 Basis for Study	1
1.3 Objective	1
1.4 Scope	2
1.5 Approach	3
 2.0 CURRENT LOW SEAM MINING	 4
2.1 Typical Size and Type of Mines	4
2.2 Production and Productivity	9
2.2.1 U. S. Production Per Seam Height Range	9
2.2.2 Daily Production	9
2.2.3 Production Per Shift and Per Man Shift	10
2.3 Mine Plans	12
2.3.1 The Room-and-Pillar System	13
2.4 Accident Statistics	15
2.5 Identification of Problems in Thin Seam Mining	21
2.5.1 Man-Mobility	21
2.5.2 Development of Remote Controlled and Auto- matic Equipment	21
2.5.3 Surface Based Underground Mining Methods	22
2.5.4 Underground Based Mining Methods	23
2.5.5 Health and Safety	23
2.5.6 Haulage	24
2.6 Mine Expansion Plans	24
 3.0 COAL RESOURCES	 27
3.1 Data Sources	27
3.2 Methodology	28
3.3 Resource Data Base	31
3.4 Resource Characteristics	32
3.5 Reserve Ownership	34

TABLE OF CONTENTS (Continued)

	<u>Page</u>
4.0 THE PRESENT AND FUTURE COAL MARKET	36
4.1 Present Demand	36
4.2 Demand Forecasts	39
4.2.1 Electric Utility Demand Forecast	43
4.2.2 Coking and Industrial Coal Demand	50
4.2.3 Demand Forecasts - Exports	56
4.3 Production Forecasts	59
4.4 Price Forecasts	63
5.0 ESTIMATED LIFE OF SEAMS HIGHER THAN 28"	66
6.0 CONCLUSIONS, RECOMMENDATIONS	69
MAIN REFERENCE BIBLIOGRAPHY.....	71
BACKGROUND BIBLIOGRAPHY	75

VOLUME II

APPENDIX A	--	Current Mining Practices in Seams Lower Than 60 Inches
APPENDIX B	--	Coal Resources
APPENDIX C	--	Definition of Producing Districts
APPENDIX D	--	Definition of Census Regions
APPENDIX E	--	The Present and Future Coal Market
APPENDIX F	--	Definition of Classification of Resource Terms

VOLUME III -- Data Base

PART I	--	Identified Underground Mineable Bituminous Coal Resources
PART II	--	Quantity and Quality of Coal in the Most Important Thin Seam Counties

LIST OF TABLES

<u>Table #</u>	<u>Title</u>	<u>Page</u>
I-I	Coal Seam Thickness Categories	3
II-I	Estimated 1975 U. S. Underground Production per Seam Height Range	10
III-I	Demonstrated Bituminous Coal Reserve Base of the Thin Seam States, January 1, 1974, by Method of Mining	29
III-II	Dates of Estimates of the USGS Resource Data Base	30
III-III	Underground Mineable Thin Seam Resources	31
IV-I	Coal Shipment by End Consumer Use	37
IV-II	1977 Coal Shipments from Thin Seam Districts ...	37
IV-III	Coal Demand Forecasts	39
IV-IV	Coal Use Projections	40
IV-V	Theoretical National Aggregates for Demand	41
IV-VI	Demand Forecast	42
IV-VII	National Coal Consumption Forecasts; Utility Sector	45
IV-VIII	Eastern Utility Sector Annual Growth Rate	49
IV-IX	Coking/Industrial Coal Demand Projections	54
IV-X	Comparison of Coal Export Forecasts	57
IV-XI	Comparison of National Predictions	59
IV-XII	Comparison of Eastern Production Predictions	60
IV-XIII	Deep and Surface Production Forecast of Thin Seam Districts	62
V-I	Underground Bituminous Coal Resources	66
V-II	Estimated Life of Underground Mineable Coal in Seams Higher than 28 Inches	67
V-III	Coking Coal in Thin Seam States	68

LIST OF FIGURES

<u>Figure #</u>	<u>Title</u>	<u>Page</u>
1-1	Continental U. S. Coal Resources	2
2-1	Median Annual Tonnage as a Function of Seam Height Range	6
2-2	Percentage and Frequency of Various Mining Systems for each Seam Height Range	6
2-3	Frequency of Various Mining Methods per State ..	7
2-4	Typical Underground Mine Lower than 60 Inches by State	8
2-5	Daily Production as a Function of Seam Height Range	11
2-6	Borehole Mining Potential Operating Conditions ..	23
4-1	Electric Utility Demand for Coal from Thin Seam Districts in 1977	44
4-2	Status of Nuclear Power Plants, December 31, 1977	47
4-3	Coke and Gas Plant Demand for Coal from Thin Seam Districts in 1977	51
4-4	All Other Industrial Demand for Coal from Thin Seam Districts in 1977	53

ABSTRACT

An analysis of the potential for U.S. underground thin seam (<28") coal mining is undertaken to provide basic information for use in making a decision on further thin seam mining equipment development. The characteristics of the present low seam mines and their mining methods are determined, in order to establish baseline data against which changes in mine characteristics can be monitored as a function of time. A detailed data base of thin seam coal resources is developed through a quantitative and qualitative analysis at the bed, county and state level. By establishing present and future coal demand and relating demand to production and resources, the market for thin seam coal has been identified. No thin seam coal demand of significance is forecasted before the year 2000. Current uncertainty as to coal's future does not permit market forecasts beyond the year 2000 with a sufficient level of reliability.

EXECUTIVE SUMMARY

In recent years, an hypothesis has been formulated that the mining of thin seam bituminous coal deposits in the 14 to 28 inch range will become economically viable in the near term as a result of depletion of thicker seam reserves. This report summarizes the collection of relevant data and the analysis of the factors which will determine when thin seam mining will become economically feasible on a broad basis. The results and forecasts contained herein provide a basis for Department of Energy planning efforts, and define lead time requirements for the development of new equipment and technologies suited to the mining of thin seams.

Current Underground Mining Practices in Seams Lower than 60 Inches

Both the extent and technology of current underground mining practices are reviewed and analyzed in order to establish baseline data against which changes in mine characteristics can be monitored as a function of time. Nearly all mines working in seams less than 60 inches are found in seven states: Alabama, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. Seventy-nine percent (79%) of these mines are located in West Virginia and Kentucky.

A strong correlation has been found between seam height range and mine median tonnage class. Most of the mines in seams lower than 60" (44%) are mining in the 40-49" seam height range and produce between 200,000 and 499,999 tons annually. Of these mines, 40% employ continuous mining, with conventional mining ranking second at 24%. The remaining mines (36%) use a variety of combinations in their mining practices. The typical mine in seams less than 60" is in the 40-49" seam height range, employs a continuous mining system and produces between 200,000 and 500,000 tons annually.

In 1975, 60% of the total U.S. production came from seams below 60" in thickness. Mines working in the 40-49" range produced 25% of the total U.S. production, closely followed by those in the 50-60" range producing 24% of the total.

Daily and annual production have been found to be strongly correlated to seam height. A linear extrapolation into the thin seam range (14-28") reduces the expected daily production to zero under current conditions. This indicates that for thin seam coal mining, it will be necessary to develop innovative technologies to solve many of the problems inherent in mining this coal with today's technology.

In order to investigate the suggested trend towards thinner seam mining in the near term, underground mine expansion plans were analyzed. Except for Alabama and some minor states, a trend towards the opening of thinner seam mines in major coal producing states was not evident.

Coal Resources

The resource characteristics for states having significant underground thin seam coal resources are listed below:

	Millions of Short Tons	Percentage of U. S. Identified Thin Seam Resources (14-28")	Percentage of Total Identified Resources in State
Alabama	5,491	6	41
Indiana	2,021	2	6
Iowa	2,160	2	30
Kentucky (East)	9,275	11	41
Missouri	13,516	15	67
Ohio	11,976	14	35
Pennsylvania	13,030	15	21
Virginia	4,133	5	52
West Virginia	15,485	18	16
TOTAL	77,087	88	--

These nine (9) states are referred to as the thin seam states.

From an analysis of the quality of coal resources it is concluded that, at this time, depletion has not created conditions in which thin seam deposits are of considerably higher quality than thicker seam resources. It does not appear that this situation will change significantly in the foreseeable future. However, an increased need for coal and higher transportation costs may increase the demand for local coal in states such as Alabama and Tennessee. This would accelerate the trend towards thin seam mining in these states.

Coal Market Development

Currently, 62% of the production from the thin seam districts is shipped to utilities and 19% is shipped to coke and gas plants. It is expected that the utility sector will account for an increasing share of the consumption in the future.

The issue of air pollution is likely to influence the short-term market development. The limitations on flue gas sulfur content will boost the demand for low sulfur coal. Some present consumers of coal from thin seam states may switch to other producers to buy compliance coal. Present legislation requires new utility plants to be equipped with flue gas desulfurization units. Technologies are also under development to lower the sulfur content of high sulfur coal before it is burned. It is predicted that these developments will revitalize the demand for high sulfur coal by 1985.

The increase in the demand for steam coal from thin seam states seems to be dependent on the total base load of new coal-fired plants on the eastern seaboard and, to a lesser extent, in the East Central states. Future decisions on the use of nuclear energy in these regions are, therefore, crucial for the mid- and long-term demand for this coal.

The abundance of coal coupled with technological improvements in mining, are likely to have a stabilizing effect on coal prices. Coal prices are more sensitive to extraction and preparation costs than to demand. As in the past, reserves will be developed in order of increasing cost of production. The life of the higher seam resources is, therefore, a decisive factor for the feasibility of thin seam mining. The estimated life of the higher seam resources does not indicate a demand for thin seam coal in the short- or mid-term future (approximately 45 years).

Conclusions, Recommendations

Although there is no immediate demand for thin seam coal, some states are currently mining in seams lower than 42 inches. There appears to be a slight trend to continue mining these thin seams, but it is local. The Department of Energy must weigh the latitude within which it wishes to work to develop a new technology. With a minimum of 45 years of coal resources remaining in seams greater than 28 inches, perhaps there should be a re-evaluation of the potential for mining thin seam coal. The issues that must be addressed are health and safety, man-mobility, remote and automatic controlled equipment, haulage, current low seam mining practices, and the coal market.

In view of the projected lead time which is envisioned for broad based mining of thin seams, significant technology development is not warranted at this time. Instead, a re-assessment of thin seam mining should be conducted at regular intervals, perhaps every five years, to ascertain whether market conditions and better information on geological conditions would warrant escalation of thin seam technology.

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Ir. Robert A. Pimentel
Project Manager

1.0 INTRODUCTION

1.1 Background

As a result of United States Government policies aimed at achieving energy independence, coal has been placed in the forefront as a primary replacement for petroleum and natural gas in the near and intermediate term. The U.S. bituminous coal industry is faced with the challenge of achieving the necessary production increase while minimizing the price of coal if energy independence is to be practically and economically feasible.

The U.S. Department of Energy (DOE), Division of Solid Fuels Mining and Preparation must identify research needs in the development of advanced mining systems which can increase coal production efficiency and minimize the associated production costs. These advanced systems may also be required to mine coal deposits which are not technically or economically mineable with the current technology.

1.2 Basis for Study

In recent years, various research efforts have suggested the economic importance of thin seam deposits of bituminous coal. It has been indicated that the thin seam resources represent a large portion of the total measured and indicated resources. As depletion of the higher seam deposits continue at an increasing rate, it is possible that resources of higher quality will be found in the thinner seams. New equipment changes and production statistics suggest that there is a slight trend toward mining of thinner seams. NASA's Jet Propulsion Laboratory (JPL) estimates that the average geological setting for a marginal (low sulfur coal) mine in central Appalachia will change from a 43 inch seam at present to a 28 inch seam in the year 2000.¹ Given a 10- to 20-year development time for new technology and 2 to 8 years to bring a new mine to full production, it is reasonable to assess the potential of underground thin seam mining at this time.

1.3 Objective

This report describes the collection and analysis of data and provides an assessment of currently available information that is indicative of the

¹ Draft input to the MOPPS Interagency Task Force, prepared by The Jet Propulsion Laboratory and Energy and Environmental Analysis, Inc. for the United States Bureau of Mines, June 1977.

thin seam mining potential. The objective of the study was to determine the present conditions and constraints of mining thin seam coal; to assess the demand for thin seam coal, and to determine the economic extraction cost limit.

1.4 Scope

The U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS) have defined a method of classification for coal resources. This system classifies coal beds in terms of their degree of geological identification and economic or technological feasibility of recovery. The system is depicted in Figure 1-1.¹

FIGURE 1-1
CONTINENTAL U.S. COAL RESOURCES

¹ See Appendix F for definition of classification of resource terms.

For the purpose of this study, only identified resources are considered. Estimates of undiscovered resources are too unreliable to justify inclusion in this study. Inferred resources are also included. Since thin seam resources are considered to be subeconomic at this time, it is expected that relatively large amounts of thin seam resources have to be classified as inferred.

The USGS has defined seam categories by seam height as given in Tabel I-I.

TABLE I-I
COAL SEAM THICKNESS CATEGORIES

Seam Category	Bituminous and Anthracite (inches)
Thin	14 to 28
Intermediate	28 to 42
Thick	42

SOURCE: USGS Bulletin 1412

If there is a trend towards thin seam mining, then the research should focus on those states having considerable thin seam deposits. Hereafter they are referred to as "thin seam" states and include: Alabama; Indiana; Kentucky (east); Ohio; Pennsylvania; Virginia; West Virginia; Iowa; and Missouri. These states each have thin seam resources over 1 billion short tons and represent 88% of all U.S. identified thin seam resources. Missouri and Iowa represent 43% of the identified thin seam resources in the Western states.

1.5 Approach

An extensive literature search was conducted and a wide variety of data sources was used to complete the study. The state of current mining in seams lower than 60" was reviewed and analyzed in order to establish baseline data against which the change of mine characteristics could be monitored as a function of time (Section 2). Facts pertaining to coal resources (Section 3) and the present and future coal market (Section 4) were gathered in order to assess the lifetime of the thicker seams (Section 5). Conclusions and recommendations are contained in Section 6.

2.0 CURRENT MINING PRACTICES IN SEAMS LOWER THAN 60 INCHES

The purpose of this section is to provide the baseline data against which changes in mine characteristics over time can be monitored. In addition, it provides an identification of the specific problems in low seam mining. In this section only, "lower than 60 inches" was used as the definition of a low seam. This definition does not correspond with the accepted one for the lowest seams currently mined, which puts the low seam range between 28 and 42 inches. This range has been extended up to 60 inches, in order to include most of the mines in the thin seam states.¹

2.1 Typical Size and Type of Mines

The material in this section was compiled from the 1977 Keystone Coal Industry Manual. The mines listed by the Keystone Manual produce 95% of the U.S. coal tonnage. Small, economically unstable mines with relative short life times were excluded from the list.

Mines with a seam height of 60 inches or less were identified. In cases where the seam height was presented as a range, the midpoint was used. Only states with more than five (5) mines in seams less than 60 inches were included in this study. These states were: Alabama; Kentucky; Ohio; Pennsylvania; Tennessee; Virginia and West Virginia.² All the Eastern thin seam states, except Indiana, were represented. Tennessee is not considered a thin seam state because it has no resources in seams 14-28" thick. Tennessee, although it only has three mines lower than 60", was included because mine expansion plans (Section 2.6) show a slight trend towards thinner seam mining.

1

- o 86% of the underground mines in West Virginia and Kentucky mine seams of 60 inches or less. These mines comprise 79% of the U.S. underground mines in this seam height range, listed in the 1977 Keystone Coal Industry Manual.
- o 77% of the underground mines in Pennsylvania, Virginia, and Ohio mine seams of 60 inches or less. These mines comprise 17% of the U.S. underground mines in this seam height range, listed in the Keystone Manual.

2

States with less than five (5) mines in seams lower than 60 inches are: Arkansas, Illinois, Iowa, and Maryland.

The final data base consisted of 800 mines. As the result of incomplete data, some of the mines were excluded from the data base, depending on the type of analysis. For twenty (20) mines, no tonnage class was reported. Of the remaining 780 mines, only 407 reported a mining method.¹

By segregating the mines into a matrix of tonnage by seam height range, the following information is derived: the largest number of mines is in the 40-49" x 200-499,999 category. The states of Pennsylvania and Virginia have their largest number in this category. Kentucky's greatest number of mines per category occurs in 40-49" x 10-49,999 while, for Ohio, it is in the 50-60 x $\geq 500,000$ category. Alabama has an equal number of mines in the 30-39 x $\geq 500,000$ and 40-49" x $\geq 500,000$ categories. The largest number of mines in Tennessee is in the 30-39" x 50-99,999 group. Lastly, the largest number of mines in West Virginia occurs in the 40-49" x 100-199,999 category.

There is an interesting aspect to the reported annual tonnage and seam height range. Assuming uniform distributions within the tonnage classes, the median for each seam height range can be expressed as a function of the seam height as shown in Figure 2-1.

The most commonly employed mining method across state seam height ranges, and tonnage classes is continuous (214 of 407 mines); the second is conventional (96); the third a combination of continuous and conventional (Ct-Cv) at 59; and the fourth is a continuous-longwall (Ct-Lg) combination at 30.²

Examination of seam height ranges reveals the current popularity of a particular mining method. A percentage analysis of the mining methods used in each seam height range is presented in Figure 2-2.

¹ See Appendix A -- Number of Mines per Seam Height Range and Tonnage Class Across States.

² See Appendix A -- Frequency of Use of Various Mining Methods by Seam Height Range and Tonnage Class Across States.

FIGURE 2-1

Median Annual Tonnage as a Function of Seam Height Range

Mining Method Seam Height Range	Ct	Cv	Ct/Cv	Ct/Lg	Lg/Sh	Ct/Sh	Lg	Ct/Cv/Lg	Ct/Lg/Sh
20-29"	100 f=3								
30-39"	63.4 f=58	21.5 f=20	11.8 f=11	3.2 f=3					1.0 f=1
40-49"	47.6 f=88	25.9 f=48	15.7 f=29	7.6 f=13	0.3 f=1	0.5 f=1		1.6 f=3	
50-60"	51.6 f=65	19.8 f=25	15.9 f=20	11.1 f=14			1.6 f=2		

Ct - Continuous

Cv - Conventional

Lg - Longwall

Sh - Shortwall

FIGURE 2-2

Percentage and Frequency of Various Mining Systems for
Each Seam Height Range

Evidently, continuous mining systems are used frequently in each seam height. A tendency can be seen towards an increased use of continuous miners at lower seam heights. This does not necessarily mean that the continuous mining method is the best one for low seams. Another explanation is that mining of the low seams has only recently become economical. One can assume that the low seam mines are relatively new. It is possible that across seam heights, all new mines use continuous miners. Figure 2-2 reflects then the general current popularity of continuous mining. The figure shows a more frequent use of longwall and shortwall systems in the higher seams.

Figure 2-3 describes the various mining methods used by each state. Ohio, Pennsylvania, Virginia, and West Virginia basically use a continuous mining method while Kentucky predominantly employs the conventional method.

Mining Method States	Ct	Cv	Ct-Cv	Ct-Lg	Lg	Lg-Sh	Ct-Sh	Ct-Cv-Lg	Ct-Lg-Sh
Alabama		2	5	1					
Kentucky	32	44	15	3	1		1		
Ohio	13	1	5						
Pennsylvania	43	3	3	10					
Tennessee	1		1	1					
Virginia	15	7	2	5					1
West Virginia	110	39	29	10	1	1		3	
TOTALS	214	96	59	30	2	1	1	3	1

Ct - Continuous
Cv - Conventional

Lg - Longwall
Sh - Shortwall

FIGURE 2-3

Frequency of Use of Various Mining Methods per State

According to the 1977 Keystone Manual, the mine working in seam heights lower than 60", is characteristically 40-49" in seam height producing between 200,000-499,999 tons annually and uses a continuous mining system most often. Figure 2-4 describes what the typical mines lower than 60" are by state.

State	Seam Height x Tonnage Class	Mining Method
Alabama	30-39" x $\geq 500,000$ 40-49" x $\geq 500,000$	Ct/Cv
Kentucky	40-49" x 10-49,999	*
Ohio	50-60" x $\geq 500,000$	Ct
Pennsylvania	40-49" x 200-499,999	Ct
Tennessee	30-39" x 50-99,999	Continuous Combinations
Virginia	40-49" x 200-499,999	Ct
W. Virginia	40-49" x 100-199,999	Ct

Ct - Continuous
Cv - Conventional

FIGURE 2-4

Typical Underground Mine Lower than 60" by State

*

In this Seam Height x Tonnage Class category, there is a high incidence of mines which report unknown mining methods. Generally, Kentucky uses 46% conventional, 33% continuous and 16% continuous-conventional combination methods.

2.2 Production and Productivity

Production and productivity in deep mines depend on a multitude of factors such as: natural conditions (roof, floor, grades, water, methane, seam height, coal characteristics); mining system (room-and-pillar, long-wall); mining equipment (conventional, continuous, shearer, plow); equipment conditions; crew size; crew experience; crew attitude; mine plan; labor/management relations; organizational factors; etc. In order to study the production and productivities in low seam mines, data must be drawn from a large sample in order to reduce the influence of all independent variables except seam height.

The extensive data base provided in the 1977 Keystone Coal Industry Manual is used to estimate the 1975 U.S. production per seam height range for mines in seams lower than 60" and to study the daily production as a function of seam height. Average shift production and production per man-shift has been calculated for various mining systems using KETRON's in-house data base and published literature.

2.2.1 U. S. Production Per Seam Height Range

The 1975 U.S. production per seam height range for mines lower than 60" was estimated from the data provided in the 1977 Keystone Manual. The number of mines per tonnage class in each seam height range was multiplied by the midpoint production in each respective tonnage class.¹ The results for each seam height range are summarized in Table II-I. The mines in seams thinner than 60 inches produced 60% of the total U.S. underground production in 1975. Of these seams, the largest production came from the mines in the 40-49 and 50-60 inch seam height ranges. These ranges contributed equally to 81% of the coal production from seams thinner than 60 inches. The production from seams less than 30 inches is below 1%.

2.2.2 Daily Production

The 1977 Keystone Manual reports the daily production (Tons per Day = TPD) for a large number of mines. The data show a near perfect correlation between seam height and TPD. Figure 2-5 shows this relationship.

¹ As midpoint for the < 10,000 tonnage class, 10,000 tons has been used. The midpoint for the > 500,000 class has been estimated at 750,000 tons.

TABLE II-I
Estimated 1975 U.S. Underground Production per
Seam Height Range

Seam Height (Inches)	Production (thousand short tons)
20-29	1,610
30-39	29,915
40-49	72,510
50-60	<u>70,770</u>
Total	174,805
All seam heights, Total ¹	292,825

Through extrapolation, the data suggest that in seams of 17 inches and lower, production is not possible with current extraction technologies. One can argue that the relationship between seam height and TPD loses its linear character at the thin seam end, and that the lower limit for this equipment is actually higher than 17 inches. This serves to emphasize how strongly the feasibility of thin seam mining depends on the development of innovative extraction technologies.

2.2.3 Production Per Shift and Per Man Shift

The 1977 Keystone Manual reports the number of shifts only for a limited number of mines. The number of working sections is not reported. Consequently, to complete the analysis of shift production, it was necessary to use other data sources.²

¹ Source: 1977 Keystone Coal Industry Manual.

² Longwall Mining Man Mobility Study, prepared for the U.S. Bureau of Mines by KETRON, INC., Final Report, 1977.

FIGURE 2-5
Daily Production as a Function of
Seam Height Range

Production and productivity information was acquired from recent studies addressing the issue of productivity in conventional,¹ continuous,² and longwall³ mining systems. The information is drawn from a small sample of working sections and may not be representative in the statistical sense. However, the examples presented are interesting in their own right.

¹ Industrial Engineering Evaluation of Underground Conventional Mining Equipment, prepared for the U.S. Bureau of Mines by KETRON, INC., Final Report 1976.

² Industrial Engineering Study of Continuous Mining Systems, prepared for the U.S. Bureau of Mines by J.J. Davis Associates, Inc., 1976.

³ Longwall Conveyor System Study, prepared for the Department of Energy by KETRON, INC., Final Report, 1978.

Detailed section descriptions and production and productivity information for five (5) conventional low seam sections can be found in Appendix A.¹ The average seam height for these sections was 40.8". Average production was 264.2 raw tons/shift and the average productivity was 24 raw tons per manshift.² The respectable productivity in the lowest seam (Section 1) could be attributable to the very high average crew seniority.

Information on three continuous sections is provided in Appendix A.³ The average seam height was found to be 49.3". The average production was 240 tons per shift, and the average productivity was 30.9 tons per manshift.⁴

An analysis of production/productivity data on the longwall shearer sections reveals that the average seam height is 49.3", the average production is 444.9 and the average productivity is 36.8 tons per manshift.^{4,5}

2.3 Mine Plans

Currently, most mines in coal seams lower than 60" employ the room-and-pillar method. A large variety of mine plans based on the same room-and-pillar theme are used, with the variations depending on geological and other factors. Only the seam height is discussed here as one of the many factors governing the mine plan selection.

To date, there are perhaps 80 longwall faces installed in the United States, but the number of units is growing. Among the current longwall faces, seam height differences have not resulted in major differences in mine plans.⁶ Since room-and-pillar development work for longwall is

¹ See Appendix A -- Production per Shift and per Man Shift-Conventional.

² This productivity may seem high compared to other published figures. The productivity presented here is based on raw tonnage and face crews only. Belt line maintenance crews, maintenance shift crews, and other above ground support personnel are excluded. A nominal multiplier of 2.3 is used to account for non-face personnel, reducing the productivity to about 10.TPMS.

³ See Appendix A -- Production per Shift and per Man Shift-Continuous.

⁴ See footnote 2.

⁵ See Appendix A -- Production per Shift and per Man Shift-Longwall.

⁶ Seam height can be a factor in equipment and mining system selection:

effected in much the same way as room-and-pillar mining in general, only the relationship between seam height and room-and-pillar mine plans are discussed.

2.3.1 The Room-and-Pillar System

As a coal seam gets thinner, the pillar strength increases, if all other conditions are constant. This fact is generally realized, yet little work has been done to discover the relationship between pillar strength and size in the United States.

Bieniawski¹ performed extensive in-situ strength studies of South African coal. He found two factors to be of importance:

1. Pillar Width
2. Pillar Slenderness

For a square cross-section, width greater than 5 feet, and width-to-height ratio greater than or equal to one, the pillar strength (C) is:

$$C_{psi} = 400 + 220 W/H \quad (1)$$

This linear relationship holds only for the specific coal tested, and the coefficients will depend on the coal characteristics. It can be seen from equation (1) that C increases with decreasing seam height. Furthermore, at the same depth (equal pillar stresses), the thinner seam will be stable with smaller pillars.

Although a mining system in thin seams can have smaller pillars, the entry widths in a thicker seam will not change, given equal conditions. The entry width depends on immediate roof conditions and the seam depth, and pillar dimensions are not a factor.

The extraction ratio of a room-and-pillar system will increase in thin seam mines, since it is a function of the cross-section size of the pillars and the room width. The effect of smaller pillars on the extraction ratio (R) is illustrated below:

¹ Bieniawski, Z.T., The Effect of Specimen Size on Compressive Strength of Coal, International Journal of Rock Mechanics and Mining Sciences, Vol. 5, No. 5, July 1968.

$$R = \frac{\text{Area Mined}}{\text{Original Area}} = \frac{(W+L)^2 - (W)^2}{(W+L)^2}$$

$$= \frac{L (2W+L)}{(W+L)^2}$$

If $W_1 = 60'$ and $W_2 = 30'$ and $L = 20'$;

$$R_1 = \frac{(60 + 20)^2 - (60)^2}{(60 + 20)^2} = 44\%$$

$$R_2 = \frac{(30 + 20)^2 - (30)^2}{(30 + 20)^2} = 64\%$$

This 20% increase in extraction ratio is an extreme example but is illustrative of the effect.

Place widths are designed as wide as possible in order to increase the output per cut, and consequently per place change thus increasing productive time. The limit on width depends on the ability to maintain roof stability with practical and economical artificial support reinforcement. Additional restrictions are imposed by the law.

Bolting plans should be designed to permit the installation of the shortest bolt possible, and a tradeoff exists between bolt length and bolt center distance. The roof must be safely supported, the bolts must be installed without too much effort, and the roofbolting operation must not become a bottleneck. Additional support, such as header blocks, cross-

beams, posts, and cribs should be avoided due to the obvious impact on man and machine movement.

Ventilation of working sections in thin seam coal poses a problem. To conform with the law, a certain quantity of air must reach the face. In a thinner seam, this means increasing velocity, due to the decrease in cross-sectional area. If the air velocity becomes too high, excessive problems will result. In a thin seam mining system the cross-sectional area may be increased by adding more intake entries. Lower velocities will also result in a lower air pressure, and thus reduced leakage through stoppings.

If it becomes necessary to increase the number of intakes in thin seams, tramming distances will be increased during development. Also, more time will be spent in development work due to the addition of entries. Driving mains and submains is generally less productive than panel work, due to longer tramming distances and the necessity of providing better roof support in the mains, among other factors.

2.4 Accident Statistics

The Code of Federal Regulations (30 CFR, Part 80) requires coal mine operators to report accidents and injuries. Reporting is standardized through the use of special forms collected by MSHA's Health and Safety Analysis Center, Denver, Colorado. MSHA maintains a computerized file of all reported accidents and performs statistical analyses on accident data.

Until 1978, the reporting forms did not require the identification of the seam height in which the accidents occurred. In 1978, MSHA introduced new forms requiring that it be reported. At the time of this analysis, the available data base was too small for significant statistical analyses.

Recently, MSHA performed a comparative study on the injury hazards in different coal seam heights.¹ The study was based on injuries reported in underground coal mines between January 1, 1974 and June 30, 1976. The three (3) seam heights studied were "low" coal (L) with a seam height less than 36 inches, "medium" coal (M) with a seam height from 36 through 72 inches, and "high" coal (H) with a seam height over 72 inches. Since the original accident reports did not contain seam height information, the average seam height of the mine was used, where such information was available.

¹ Hudson, S., Comparison of Injury Hazards in Different Coal Seam Heights, MSHA Health and Safety Analysis Center, Denver.

An analysis was performed for each of 20 accident types to determine if the injury rates for the three (3) seam height groups were significantly different. The research indicated that the risk of fatal injury for all 20 types of accidents was not demonstrably different in the three (3) seam height categories.¹ Conclusive comparisons between seam heights were more difficult for fatal than for disabling injuries because fatality rates were based on 100 times fewer injuries than disabling injury rates. Comparing levels of fatality hazard for low coal with those for either medium or high coal was especially difficult due to the less precise estimates resulting from relatively little exposure time in low coal. Conclusive comparisons of the fatality rates could only be made if the rates were extremely different or if they were based on considerably more exposure time than that available.

The research also demonstrated that the disabling injury hazard for high coal was never significantly greater than the disabling injury hazard for low coal. The findings showed that, generally, there was an increase in the disabling injury hazard with a lowering of seam height.

If there is a trend toward thinner seam mining, the results of this MSHA study indicate that unless safer mining methods for low seams are implemented, an increase in the number of disabling injuries can be expected. The MSHA report gives the following comprehensive list of explanation for the increase in the level of hazard as the seam height decreases. These explanations identify many potential safety problems in thin seam mining.

1. Poorer lighting and/or decreased visibility with lower coal.
2. Hazards may be greater in low coal due to the cramped or uncomfortable positions these workers must assume.
3. Low clearance in lower coal contribute to disabling injuries.
4. Roof fall hazards are greater in low coal partly because the miners cannot get away as easily as in higher coal, due to the confined space, when they see or hear signs of an imminent roof fall.

¹

See Appendix A -- Accident Statistics.

5. Lack of cabs and canopies on face equipment in low coal are partly responsible for low coals' high level of roof fall injury hazard.
6. Low coal mines tend to be smaller than medium and high coal mines. If the smaller mines have less developed safety programs, this might tend to increase the disabling injury hazard at low coal mines for all accident types.
7. If the geology of low, medium and high coal mines is different, then this probably affects the hazard of roof falls and possibly of other accident types.
8. Most low coal mines are in West Virginia, Virginia, and Kentucky, and these states had the highest disabling injury rates in the United States during the study time period. There may be a factor unrelated to seam height whereby these states tend to experience higher disabling injury rates than other states. If this is true, then the apparent increase in hazard for low coal may partially derive from most low coal mines being in these states.
9. If mining low coal is a less desirable job than mining higher coal, then low coal miners would probably tend to be younger, less skilled, and less experienced.

In comparing disabling with non-disabling hazards for each accident type, researchers found that for most accident types the rate of hazard for disabling injuries is greatest for low coal, while the rate of hazard for non-disabling injuries is greatest for high coal. The MSHA report gives the following possible explanations:

1. Low coal accidents are more likely to be serious once they occur, since it is harder to get away from or to correct a potential accident situation due to the confined space.
2. Reporting differences between low, medium, and high coal mines. Perhaps low coal mines report non-disabling and non-injury accidents less clearly than higher coal mines.

If the extent of non-reporting by size of mine is approximately the same for coal as for metal and non-metal underground mines, then reporting quality should deteriorate as the seam height decreases. If this is true, and if reporting of non-disabling injuries is less complete than for disabling injuries, this could explain the trend reversal observed between the hazard for disabling and non-disabling injuries. This reversal is possibly the result of reporting differences.

The greatest number of injuries were found to be the result of Falls of Roof and Haulage, which were subdivided into accident subtypes. For Falls of Roof, the accident subtypes are the activity of the miner at the time he was injured. The four subtypes found to have a statistically significant difference between seam heights were "while timbering", "while roofbolting", "while operating a longwall miner", and "while operating a continuous miner". The trend displayed for timbering is $L > M > H$ and for roofbolting is $M > L$ (and almost $H > L$). The most likely explanation for these trends is the greater use of timbers and lesser use of roofbolts in low coal. The trends for operating a continuous miner ($L > M$) and a longwall miner ($M > H$) are not so easily explained. Perhaps the use of cabs and canopies on face equipment in higher coal is responsible for the lower level of hazard for disabling injuries in higher coal.

A recent MESA study¹ found that "75 percent of all equipment affected by the cab and canopy standards in mining heights of 36 inches or more was found to comply with standards, and about 27 percent of equipment affected in mining heights of 30 to 36 inches was found to comply. However, compliance was found to be negligible in mines with mining heights below 30 inches."

Another factor is the variable use of longwall and continuous miners in different seam heights. Longwall mining is often used in medium seam heights, somewhat less in high coal seams, and rarely in low coal. Continuous miners are used in all seam heights; however, the model of miner is specific to a seam height. The varying usage across seam height coupled with the greater use of cabs and canopies in higher coal may explain the significant differences.

22

1

"Deadline Suspended for Low Coal Cabs and Canopies," MESA Magazine, 1977, Vol. 10, page 16.

For haulage, the accident subtypes which were significantly different across seam heights were: five subtypes involving mining cars--derailing, rerailing, collisions, runaway, and falling or jumping in or from; two subtypes involving shuttle cars--squeezed by shuttle car and all other shuttle car accidents; and one subtype involving belt haulage--persons riding the belt.

The trend across seam height for "collisions of mining cars" ($H > M > L$) is representative of the accident subtypes involving mining cars. This can probably be explained by greater use of mining cars in higher coal.

The relation across seam heights for "squeezed by shuttle car injuries" is $L > M > H$. The subtype "all other shuttle car injuries" has a slightly different relation, in that L and M have approximately equal rates and both have significantly higher rates than H. This greater rate of hazard in lower coal seams may be due, at least partially, to the greater use of shuttle cars in lower coal.

The other haulage category with a statistically significant pattern was "persons riding the belt", which displays the trend $L > M > H$. This relation is probably due to the greater use of belt haulage in low coal. A worker also has more incentive to ride a belt in a mine where walking is difficult or impossible.

The explanations given for the higher accident rates in low coal for the operation of face equipment and for shuttle cars are amplified by the findings of a study, in which scoops and tractor related fatalities were analyzed.¹

"Scoops and tractors are two of the three types of mining equipment which were most frequently involved in haulage fatalities that occurred from 1971 through 1973 in underground bituminous coal mines. [Most of these accidents occurred] in coal seams ranging from 27 to 48 inches in thickness.

Most frequent causes identified in the investigation reports include: (1) failure to follow established operating practices, (2) poorly maintained equipment, (3) failure to be alert to the hazards of the job, (4) unsafe mining practices,

¹

McHellan, R.R., and R.A. Speirer, Analysis of Fatalities Related to Scoops and Tractors in Underground Bituminous Coal Mines, 1971-1973, MESA Information Report IR 1016, 1975.

and (5) poorly trained operators. Analysis of the accidents indicates that both labor and management are negligent in recognizing and eliminating the more obvious hazards associated with the operation of this equipment. Mines utilizing scoops and tractors should be the target of efforts to emphasize recognition of the particular operating hazards of this equipment and appropriate training of the equipment operators. The best way to reduce fatal accidents of this kind is to design workable and acceptable canopies which would greatly reduce the number of injuries to the head, neck, and chest."¹

Some relevant information is also provided in a report by Theodore Barry and Associates.² As part of this study, compliance with Federal regulations was investigated. It was concluded that from 1966 through 1970, on a year-by-year basis, the compliance in small mines with less than 15 employees, is considerably worse than in mines with 16 or more employees. Mines with less than 15 employees are probably low seam mines.

Theodore Barry also investigated the relationship between roof fall accidents and seam height. "Roof fall size seems to decrease as a function of increased seam height. Larger roof falls in lower seams may be related to the wider entry widths and greater areas of unsupported roof typically found in smaller mines with lower seams.

"In addition, . . . the 0-3 foot coal seams experience a disproportionate percentage of roof fall accidents." Some of the contributing factors seem to be: lack of support; a greater degree of roof control plan violations; inadequate temporary roof control plans in relation to other seams.³

¹ McHellan, R.R. and R.A. Speirer, Analysis of Fatalities Related to Scoops and Tractors in Underground Bituminous Coal Mines, 1971-1973, MESA Information Report, IR 1016, 1975.

^{2 & 3} Industrial Engineering Study of Hazards Associated with Underground Coal Mine Production, Theodore Barry and Associates, U.S. Bureau of Mines, 1971.

2.5 Identification of Problems in Thin Seam Mining

Problems in mining in seams lower than 60" have been discussed in the previous subsections. It is clear that in the thinnest seam heights, these problems will be amplified. Some additional topics of concern for the mining of seams in the 14 to 28 inch range are discussed in this subsection.

2.5.1 Man-Mobility

It is obvious that man-mobility in seam heights from 14-28 inches will be practically reduced to zero.¹ Integrated operator cabins that would relieve operators from following their equipment are not feasible, due to extreme visibility and operator protection problems. The reduced man-mobility would also create problems in supervision. The obvious conclusion is that remote or automatic controlled extraction systems or surface based underground mining systems must be developed.

Whatever system is used, the underground hardware must have better reliability and maintainability characteristics than the current state-of-the-art. The mobility of the maintenance crew is highly restricted and it will be extremely difficult to transport spare parts and tools. Remote controlled or automatic controlled equipment requires sensors and control equipment. The reliability of these instruments is comparatively low especially in the harsh mining environment, and improvements would be necessary. Removal and installation of underground hardware will be difficult, and the tonnage that can be mined between equipment moves will be an important factor in system design.

2.5.2 Development of Remote Controlled and Automatic Equipment

Development of remote controlled and automatic equipment will be a difficult task. The requirement for extremely high reliability and ease of maintenance characteristics has previously been discussed. This problem may be easier to solve than those of identifying and isolating signals that describe the state of the system. Research being conducted to identify signals for use in higher seams may yield valuable information for use in the development of special thin seam equipment.

¹

Longwall Mining Man Mobility Study, prepared for the U.S. Bureau of Mines by KETRON, INC., Final Report, 1977.

2.5.3 Surface Based Underground Mining Methods

Surface Based Underground Mining (SBUM) methods such as Underground Coal Conversion (UCC), in-situ gasification and combustion, and borehole hydraulic mining are currently under development. SBUM would be extremely attractive for the extraction of thin seam resources, since the need for personnel underground would be reduced or eliminated.

The literature indicates that UCC methods are not applicable to thin seam coal mining:

"Data from Soviet UCC operations indicate that coal seam thickness has a significant effect on the product gas heating value. The reason most often cited is heat loss to the surrounding rock. In thick seams, only a small portion of the heat of combustion of coal char is lost to overlying (cap) rock and underlying (base) rock; in thin seams a much larger portion of the heat is said to be conducted out of the coal into the surrounding rock. Heat loss to cap and base rock subtracts from the amount of heat energy available to drive the highly endothermic gasification reaction and causes a decline in gas heating value. In addition, the gasifier passages in thin seams rapidly become so wide that air can by-pass the reaction fronts and burn the gas that is being formed. Soviet data indicate that a minimum seam thickness of 1.5 m (5 ft.) is desirable for UCC. Thicker seams are also desirable because they contain larger tonnage per unit area. This minimizes the amount of drilling required to gasify a given volume of coal."¹

Of course, the above restrictions are equally valid for in-situ gasification and in-situ combustion.

Borehole mining appears equally invalid for thin seam coal mining. Figure 2-6 shows the potential operating zone for Borehole mining. The lower limit for underground mineable resources is at a 35 foot seam height.

¹

"Underground Coal Conversion Programs", Volume II Resources. DOE/ET-0008/3, February 1978.

FIGURE 2-6

Borehole Mining Potential Operation Conditions

SOURCE: Borehole Hydraulic Coal Mining System Analysis, Jet Propulsion Laboratory Publication 77-18, 1977.

2.5.4 Underground Based Mining Methods

Underground-based technologies are hard to visualize. The only possibility may be a new design for a longwall system utilizing boring machines to drive single entry, higher than seam height, gates. The longwall face would be automated and of an exotic design. Also, changes in the current health and safety law would be necessary to allow single entry longwall design to accommodate this system.

2.5.5 Health and Safety

The development of mining systems for thin seams will involve many health and safety problems. Health problems of psychological and physical nature must be addressed. Limited head clearance in the mine will have negative psychological effects on the miners, especially when

water and/or bad top is encountered. The position in which a miner must work in thin seam coal will likely cause back, neck and knee problems.

The limited visibility of equipment operators will have a negative effect on safety. In addition, it will be difficult to move out of the way of moving equipment and to move out of potentially dangerous areas.

2.5.6 Haulage

Low clearance will necessitate the use of low capacity shuttle cars or continuous haulage. Continuous haulage has been recommended for use with auger miners. While continuous haulage eliminates "wait on shuttle car" delays, all continuous haulage systems in existence today have experienced reliability and flexibility problems.

2.6 Mine Expansion Plans

In order to investigate the suggested trend toward thinner seam mining in the short term, underground mine expansion plans in states east of the Mississippi were surveyed. Bureau of Mines Information Circular 8765¹ served as a data source for this information. The data base for this circular was compiled from a variety of sources, and was the most recent and comprehensive source for such data.

Only those states which have underground mine expansion plans in seams lower than 60 inches were analyzed. This selection criterion was the same as the one used in the analysis of current mines in seams lower than 60" (Section 2.1). This made it possible to compare the characteristics of the current mines and those in the expansion plans. An initial comparison revealed that expansion plans in seams lower than 60 inches were restricted to those states which already have mines in that seam height range. These states were: Alabama, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.

1

Projects to Expand Fuel Sources in Eastern States -- An Update of Information Circular 8725, Bureau of Mines Information Circular 8765, 1978.

An analysis reveals the following information:¹

Alabama	--	mine expansion will be in an annual tonnage class of 200,000 or greater and eight (8) of the twelve (12) mines with known seam heights will be in the 50-60 inch range. There appears to be a slight trend toward the lower ranges of 30-39".
Kentucky	--	mine expansion will be in an annual tonnage class of 200,000 or greater and four (4) of the (6) mines with known seam heights will be in the 50-60 inch range.
Ohio	--	mine expansion will be in an annual tonnage class of greater than 500,000 and seven (7) of the nine (9) mines with known seam heights will be in the 50-60 inch range.
Pennsylvania	--	mine expansion will be in an annual tonnage class of 200,000 or greater, and thirteen (13) of the eighteen (18) mines with known seam heights will be in the 40-60 inch range.
Tennessee	--	mine expansion will be in an annual tonnage class of greater than 500,000 and both mines will be in the 30-39 inch range. There appears to be a slight trend toward the thinner seams.
Virginia	--	mine expansion will be in an annual tonnage class of 200,000 or greater and four (4) of the seven (7) mines with known seam heights will be in the 70-79 inch range.
West Virginia	--	mine expansion will be essentially in the annual tonnage class of 200,000 or greater and eighteen (18) of the twenty three (23) mines with known seam height range will be in the 40-60 inch range. There appears to be a slight trend toward thinner seam mining.

1

See Appendix A -- Underground Mine Expansion Plans in States East of the Mississippi.

Mine expansion plans for all seven (7) states show that with known seam heights, 99% will be in an annual tonnage class of 200,000 or greater and 56 of the 75 mines will be in the 40-60 inch range.

Comparing this information with the data provided in Section 2.1, the overall tendency is not to expand mines into thinner seams in the near-term. The seemingly large annual tonnage class may be explained by the fact that some of the expansion plans are extensions of existing mine operations. In these cases, total planned capacities, rather than the incremental ones, are reported. Overall, the data confirms the analysis of the typical mine in the thin seam states (see Section 2.1).

3.0 COAL RESOURCES

KETRON has compiled a resource data base containing both quantity and quality data for those states with considerable thin seam coal (14-28"). Alabama, Indiana, Iowa, eastern Kentucky, Ohio, Pennsylvania, Virginia, West Virginia and Missouri each have thin seam resources greater than 1 billion short tons and together represent 88% of all identified U. S. thin seam resources. Missouri and Iowa, the only Western states, represent 43% of all identified western thin seam coal. These nine states form the basis for the thin seam analysis and are referred to as the thin seam states.

The data base consists of a series of tables with resource estimates at a coal bed level of detail for each county. The tables are further disaggregated by overburden and seam height range for two reliability categories:

- o Measured and indicated;
- o Measured, indicated and inferred.

The mean, high and low of sulfur content and BTU values are supplied for each bed where information was available. These tables have been used to identify:

- o Beds and counties with the most thin seam resources relative to the total U. S. thin seam resources;
- o The relative importance (in % of total resources) of thin seam resources for each of the counties and states;
- o The depth of the thin seam resources relative to the depth of thicker seams; and
- o The quality (% sulfur and BTU) of the thin seam deposits relative to the quality of coal in thicker seams.

3.1 Data Sources

The National Coal Resources Data System of the U. S. Geological Survey is the primary source for the resource estimates used in this study. This system is both comprehensive and detailed in its reporting of thin seam deposits. As the main source for coal quality data, the McGraw Hill publication, U. S. Coal Mine Production by Seam, 1976, was used.

3.2 Methodology

In order to use the USGS tonnage estimates in the analysis of thin seam resources, it has been necessary to adjust the figures for three (3) factors:

- o Unclassified resources
- o Strippable resources
- o Out-of-date resource estimates

Unclassified resources, where tonnage estimates have not been disaggregated into seam thickness categories, occur because of the variety of data sources used by USGS. Only a few of the states considered in this study contain unclassified resources: West Virginia; Pennsylvania; and Ohio. They represent about 40% of the total tonnage under investigation. West Virginia accounts for 24%, Pennsylvania for 14%, and Ohio for 2% of these resources.

For those counties having classified resources, the unclassified resources have been distributed over seam thickness ranges in the ratio given by the classified resources. The remainder of unclassified resources has been distributed over seam thickness ranges at the state level only.

A certain amount of coal recorded in the 0-1000, 0-2000, and 0-3000 foot overburden categories is strippable under the current economic and political situation. Since only coal which can be mined by deep-mining methods was of interest, it has been necessary to subtract a certain percentage from the tonnage estimates. The percentage of strippable reserves was calculated from the information provided in Table III-I.

Table III-I contains information for measured and indicated resources only. It has been assumed that these percentages also apply to inferred resources. Assuming that these percentages are also valid at the county level, they have been subtracted from 0-1000, 0-2000, and 0-3000 foot overburden categories. Bed figures have also been adjusted in the same manner as the county figures. This estimation technique was applied to every state except Indiana, where strippable resources were reported directly.

TABLE III-I

Demonstrated Bituminous Coal Reserve Base of the
Thin Seam States, January 1, 1974, by Method of Mining¹

	(Millions of Short Tons)			
	Potential Mining Method			
	Underground	Surface	Total	% Strippable Reserves
Alabama	1,798	157	1,955	8
East Kentucky	9,467	3,450	12,917	27
Indiana	8,948	1,674	10,623	16
Iowa	2,885	0	2,885	0
Missouri	6,074	3,414	9,487	36
Ohio	17,423	3,654	21,077	17
Pennsylvania	22,789	1,091	23,880	5
Virginia	2,833	679	3,512	19
West Virginia	34,378	5,212	39,590	13
TOTAL	106,595	19,331	125,921	15

¹

Coal Facts 1974-1975, National Coal Association (U. S. Bureau of
Mines data)

For many states, the information provided by USGS is not current. Table III-II provides the dates of the estimates for the "thin seam states".

TABLE III-II
Dates of Estimates of the USGS Resource Data Base

State	Date of Estimate
Alabama	1958
Indiana	1958
Iowa	1965
Kentucky (East)	original
Missouri	1970
Pennsylvania	10% original 55% 1928 35% 1948-1954
Ohio	98% original 2% 1951
Virginia	1951
West Virginia	74% original 26% 1949-1955

Tonnage estimates in Kentucky, Pennsylvania, Ohio, Virginia and West Virginia have been updated, accounting for the production and loss-in-mining from seams greater than 28 inches for measured and indicated resources.¹ Alabama, Indiana, Iowa and Missouri were not updated since the USGS estimates for these states are fairly recent.

The various adjustments made to update the USGS estimates, did not produce exact tonnage figures. They did provide the best tonnage estimates possible.

¹ See Appendix B -- Resource Adjustments for the methods used in each state.

3.3 Resource Data Base

The thin seam resource data base used in the study is contained in Volume III. The data base represents 88% of the total identified thin seam resources. These resources are located in Alabama, Indiana, Iowa, Kentucky (East), Missouri, Ohio, Pennsylvania, Virginia, and West Virginia (which are the thin seam states). For each of these states, the data base contains resource estimates at both the state and county levels (Volume III).

Table III-III defines the contribution of each thin seam state to the total of thin seam resources, and the importance of the state's thin seam resources relative to its total resources.

TABLE III-III
Underground Mineable Thin Seam Resources

	Millions of Short Tons	Percentage of U. S. Identified Thin Seam Resources (14-28")	Percentage of Total Identified Resources in State
Alabama	5,491	6	41
Indiana	2,021	2	6
Iowa	2,160	2	30
Kentucky (East)	9,275	11	41
Missouri	13,516	15	67
Ohio	11,976	14	35
Pennsylvania	13,030	15	21
Virginia	4,133	5	52
West Virginia	15,485	18	16
TOTAL	77,087	88	--

Coal bed data has been compiled for the most important thin seam counties (over 200 million short tons) in these states. In most states, approximately 90% of the thin seam coal is represented. This information is contained in Volume III. The threshold of 200 million short tons is chosen to exclude from the data base the beds with insufficient thin seam resources to guarantee a reasonable mine life.

In Indiana, 94% of the underground coal is in seams >28". Since thin seam resources are relatively unimportant, no bed level data has been compiled for this state.

Seventy-three percent (73%) of the total identified resources in West Virginia is unclassified by seam height range. Of the counties with classified resources, the following are considered important: Logan, McDowell, Mingo, Raleigh, and Wyoming. These counties represent about 3 billion short tons or 20% of the state's thin seam resources and are included in the data base.

Thin seam resources in several other states deserve mention. Arkansas, Oklahoma and Maryland each have thin seam resources less than 1 billion short tons. However, these resources constitute one-third (1/3) to one-half (1/2) of the total coal in each state. If a demand for local coal in these states becomes evident in the future, these thin seam resources could become important.

Two other areas, Kansas and western Kentucky, have considerable coal resources, but they are unclassified by seam height range. However, a few general statements can be made about each. The state of Kansas contains approximately 19 billion short tons of bituminous coal. Of this, only about 3 billion is strippable. According to the Kansas Geological Survey, most of the remaining 16 billion short tons exist in seams which are too thin or irregular to mine at present. A study is currently being conducted by the Kansas Geological Survey to provide more information. Western Kentucky has an estimated 28 billion short tons of coal. The Kentucky Geological Survey has indicated that over 50% of these resources are in seams greater than 42" and that there are also considerable resources in seams 28-42". Though there are resources in seams less than 28" thick, they should be of little importance.

3.4. Resource Characteristics

If it is assumed that the "best" reserves are developed first, it is possible that currently the "better" resources are found in the thin seams. "Better", in this context, refers to the depth and the quality of the deposits. In order to test this hypothesis, a number of analyses were conducted.

To analyze differences in ash, sulfur and BTU values among seam height ranges, KETRON's tonnage estimates are combined with quality data from the Bureau of Mines.¹ This data source provides average ash and sulfur content and average BTU value for each county.

Three charts were constructed for each "thin seam" state, one for each seam height range. Ranges for the % of ash and sulfur, and BTU values were determined, and tonnage estimates for each seam height were entered in the appropriate category, based on county average values. The tonnage estimates in each category were then totaled to provide the range of quality and corresponding tonnage estimates at a state level for each seam height range. Graphical representations were then constructed to enhance the visibility of the results.

A separate analysis was performed for each thin seam state. Ranges for the % of ash and sulfur, and for the BTU values were determined to rate the quality of the coal in each county. Resource estimates for the county in three seam height ranges were then combined with the quality data. This approach provided the tonnage distribution in each seam height range for each of the coal quality measures.²

The data indicated that in Alabama most of the low sulfur and high BTU coal in the highest seams has been depleted. Indiana still has extensive resources in the highest seams; some relatively high BTU coal can be found in the thin seams. In Iowa, the quality does not vary much between seam heights. In Kentucky, as in the previous states, the distributions are fairly similar. The thin seams contain some low sulfur coal (<.5%) that is not found in the higher seams. The data show that the quality of the thin seam coal is comparable to the quality of the higher seams.

In Missouri, the thin seam resources are of better quality than the higher seam resources. Underground production of this coal, however, is not forecast at this time, due to the vast amounts of strippable coal in this state. The analysis shows little difference between the qualities of thin and higher seam coal in Pennsylvania and Ohio.

¹ Bureau of Mines Information Circular #8655 -- The Reserve Base of Bituminous Coal and Anthracite for Underground Mining in the Eastern United States, 1974.

² See Appendix B -- Coal Quality in the Thin Seam States.

Relative to its higher seams, Virginia has fair amounts of low ash and high BTU coal. Low sulfur (< .5%) coal is found predominantly in the intermediate seam heights. In West Virginia, a relatively large amount of high quality coal is still available in the higher seams.

From the above observations, it is concluded that, at this time, depletion has not created a situation in which thin seam deposits are of considerably better quality than higher seam resources. From the distributions, it appears that this situation will not significantly change in the foreseeable future.

KETRON has not analyzed the relative depth of the resources in the various seam height ranges. Practically all coal in the thin seam states falls in the 0-1000 feet overburden range. Data providing more detail was not available.

3.5 Reserve Ownership

Existing data on reserve ownership are fragmentary and of limited accuracy. Ownership information is normally based on reserves that do not include the thin seam resources. A few general statements, however, can be made with regard to the ownership of coal properties in the east, where all thin seam resources of potential economic importance are located.

"Energy Alternatives: A Comparative Analysis"¹ states: "The federal government owns approximately 48 percent of all coal lands located in Alaska, Colorado, Montana, North Dakota, Oklahoma, Utah, and Wyoming (BLM, 1974: Vol. 1, p. V-208). Federal ownership in these states ranges from four percent in Oklahoma to 97 percent in Alaska (BLM, 1974: Vol. 1, p. V-208). Although overall data are not available, apparently the federal government does not own as much as four percent of the coal lands in any other state. In any case, the major coal lands in the eastern and midwestern U.S. are privately owned."

"Ownership of coal reserves by private companies is widely dispersed. The 20 firms with the largest reserve holdings listed in the Keystone News Bulletin have 21 percent of the 1975 reserve base. Consolidation Coal, the largest owner, has only 3 percent of the total.

¹ "Energy Alternatives: A Comparative Analysis," University of Oklahoma, 1975.

Although it is reasonable to infer that the ownership of the highest quality reserves is somewhat more concentrated, there is enough information to indicate that reserve concentration is sufficiently low to forestall high market concentration levels in the future."¹

It should be emphasized that the information provided here refers to the ownership of coal reserves. Reserves do not include thin seam resources. It is highly unlikely that the ownership of thin seam resources is more concentrated than the ownership of those lands that are currently interesting from an economical standpoint. It is also reasonable to conclude that most thin seam resources are privately owned.

¹

Coal Price Formation EPRI-EA 497

4.0 THE PRESENT AND FUTURE COAL MARKET

4.1 Present Demand

In order to determine the need for thin seam coal, it is necessary to examine the present market dependency on those USBM supply districts which have a large supply of this coal.¹ This information can be gleaned from the "Bituminous Coal and Lignite Distribution," January through September and October through December, 1977.

To ascertain total shipments for 1977, the two reports were summed.² In doing so, we were able to determine the major consumer use of coal shipped from these supply districts.³ Henceforth, they will be termed the thin seam districts or states.

An analysis demonstrated that, in 1977, domestic and export consumption of domestic coal was about 678 million short tons.

¹ These districts are 1,2,3 and 6,4,7,8,11,12 and 13 (See Appendix C -- Definition of Producing Districts).

² In a conversation with Ms. Mary B. McNair of the Office of Energy Data and Interpretation, we discovered that the net change in mine inventory for the first nine months suppressed actual shipping numbers. We were instructed to add in double the negative quantity to obtain total shipments. Ms. McNair indicated that the change in inventory was equated with consumption.

³ In a conversation, Ms. McNair stated that shipments are equated with consumption in order to arrive at the table figures.

From Table IV-I we can see how this coal was used:

TABLE IV-I
Coal Shipments by End Consumer Use

Consumer Use	Electric Utility	Coke & Gas Plants	Retail Dealer	All Other Industrial	Exports (Excl. Canada)	Other
Shipments from All Districts (Thousand Short Tons)	489,668	84,959	3,084	59,699	35,650	4,786
Shipments from Thin Seam Districts (Thousand Short Tons)	253,068	76,337	2,244	39,030	35,367	3,428
% Thin Seam Districts Contribution	51.7	89.8	72.8	65.4	99.2	71.6

The data can be disaggregated on the basis of major end consumer use for each of the thin seam districts. The data are illustrated in Table IV-II.

TABLE IV-II
1977 Coal Shipments from Thin Seam Districts
(Thousand Short Tons/Percentage Shipped From District)

District	Electric Utility	Coke and Gas Plants	Retail Dealers	All Other Industrial	Exports (Excl. Canada)	Other	Total
1	40,500 70.3	7,437 12.9	74 0.1	4,618 8.0	4,515 7.8	489 0.8	54,633 100.0
2	11,960 36.8	17,832 54.9	74 0.2	2,341 7.2	5 0.0	256 0.8	32,408 100.0
3 & 6	31,852 80.3	2,903 7.3	50 0.1	2,554 6.4	2,068 5.2	250 0.6	39,677 100.0
4	41,313 86.4	--	477 1.0	5,218 10.9	--	807 1.7	47,815 100.0
7	595 2.6	11,321 48.8	58 0.2	961 4.1	9,417 40.6	831 3.6	23,183 100.0
8	90,218 56.7	32,567 20.5	1,456 0.9	18,091 11.4	16,104 10.1	690 0.4	159,126 100.0
11	22,482 86.2	4 0.0	42 0.2	3,485 13.4	0 0.0	68 0.2	20,081 100.0
12	484 96.4	--	--	18 3.6	--	--	502 100.0
13	13,664 59.4	4,273 18.6	13 0.0	1,744 7.6	3,258 14.2	37 0.2	22,989 100.0

The data display that Districts 1, 3 & 6, 4, 8, 11, 12 and 13 ship more than 50% of their bituminous coal for electric utility purposes. Districts 2 and 7 ship mostly metallurgical and coking coals. In addition, a considerable percentage of the coal from district 7 is exported.¹

Present demand for coal from the thin seam districts appears to be variable. Upon closer examination, we find that the nearest competitor is District 9, western Kentucky.

An investigation of the relative market shares held by Districts 8 and 9 reveals that they compete for Tennessee and Georgia steam coal markets.² When eastern Kentucky (District 8) depletes its higher seam coal, it is highly probable that western Kentucky (District 9) will capture District 8's share of Tennessee's and Georgia's bituminous coal purchases. District 9 also commands a major market share of eastern Kentucky and Alabama's coal purchases. It is equally possible that these states will shift ostensibly to District 9 when District 8 exhausts its higher seam coal. These same possibilities exist for the thin seam districts' market share of Minnesota, Wisconsin, Missouri, Illinois, Indiana, Michigan and Ohio where western Kentucky presently retains a minor market share. This group of states could become major consumers of western Kentucky coal rather than eastern when it no longer produces higher seam coal.³ The competition between Districts 8 and 9 represents a small portion of the possible demand shift from the thin seam districts. To assess this trend, it is necessary to evaluate the total demand for all domestic coal. This is accomplished by a review of the demand forecasts.

1 See Appendix C -- Definition of Producing Districts.

2 "Bituminous Coal and Lignite Distribution, January-September 1977" and "Bituminous Coal and Lignite Distribution, October-December 1977".

3 See Appendix E -- Comparative Market Shares of Districts 8 and 9 for a detailed analysis of the competition between eastern and western Kentucky for a share of the 1977 coal market.

4.2 Demand Forecasts

There are numerous published forecasts about the total demand for U. S. coal until 1990. A comparison of those used for this investigation is shown below in Table IV-III.

TABLE IV-III
Coal Demand Forecasts

Forecast	Demand (Million Short Tons)	
	1985	1990
Project Independence ¹		
Unconstrained	1,092	1,247
Constrained	992	1,247
Data Resources, Inc. ²		
Series C	920-990 (Domestic)	1,065-1,225 (Domestic)
Energy Supply And Demand Situation ³	812	864
Analyst ⁴	NA	NA
Joel Price ⁵	1,114	NA

-
- 1 National Energy Outlook, 1976, p. 173.
 - 2 Projections of Energy Supply and Demand and Their Impacts, Annual Report to Congress, Vol. II, 1978, p. 184.
 - 3 Energy Supply and Demand Situation in North America to 1990, Vol. 6: Coal, 1974, p. 43.
 - 4 Charles J. Elia, "Earnings Estimates for Coal Producers Are Cut By Analyst for '78 and '79," Wall Street Journal, May 8, 1978, p. 30.
 - 5 Joel Price, "Coal-Carrying the Unignited Torch," General Electric Energy Symposium, August 1, 1978, Table 7.

Projections of Energy Supply and Demand and Their Impacts
revealed the following predictions as seen in Table IV-IV.

TABLE IV-IV

Coal Use Projections (PESD, Mid-Range Projection Series C) ¹ (Millions of Tons Per Year)			
	Actual 1976	Projected	
		1985	1990
<i>Uses</i>			
Electric Utilities.....	449	745	912
Metallurgical	85	97	101
Industrial ²	56	106	130
Synthetics.....	—	13	34
Total	590	961	1,177
Exports	59	74	81
¹ Includes Central West and Gulf. ² Includes Rockies, Southwest, Northwest, and Alaska. ³ Includes residential and commercial. Note: Totals may not add because of rounding and stock increases in 1976. (Stock changes are not projected for 1985 or 1990.)			

Joel Price, coal industry financial specialist and writer of The Coal Observer, delivered a prepared speech at the General Electric Energy Symposium on August 1, 1978. He presented the demand forecast shown in Table IV-V.

¹ Projections of Energy Supply and Demand, p. xlv.

TABLE IV-V

Theoretical National Aggregates For Demand¹
(Millions of Tons)

<u>Demand</u>	<u>1985</u>
Utilities	806.6
Metallurgical	96.0
Industrial and Retail	130.0
Export	72.0
Synthetics	<u>9.0</u>
TOTAL	1,113.6

He noted that the 806.6 million tons for utilities in 1985, a composite of utility plans, was probably too high.

¹

Joel Price, "Coal-Carrying the Unignited Torch," address given at the General Electric Energy Symposium, Sheraton Airport Inn, Newark, N.J., August 1, 1978, Table 7.

Project Independence forecasts the demand by sector to be:

TABLE IV-VI

Demand Forecast

(PI, Reference Scenario, \$13 Oil Imports)¹

(Million Tons)

Sector	1974	1985	Compound Annual Percent Growth Rate
Electric Utility	388	715	5.7
Household/ Commerical	9	5	-5.5
Industrial	64	124	6.2
Coke and Gas	90	100	1.0
Synthetics	-	16	-
Exports	<u>60</u>	<u>80*</u>	<u>2.6</u>
TOTAL	611	1,040	5.0

* Assumed values

It should be realized that for the purpose of this study, 1985 predictions are considered short-term. To assess the potential for thin seam mining, projections for the year 2000 and beyond would be more meaningful. Most forecasts extend only to 1990 and will have to serve as the framework for a decision to develop the technologies to mine thin seam coal.

¹ The Energy Sourcebook, 1977, p. 197.

4.2.1 Electric Utility Demand Forecast

In 1977, the largest consumer of domestic coal was the electric utility sector, accounting for about 490 million short tons or 72.2% of the coal consumption. The thin seam districts were a major supplier. The data from the "Distribution" was translated into the map of Figure 4-1 which shows the relative demand for steam coal from thin seam districts in 1977.¹

The data demonstrate that historically the eastern seaboard states rely heavily on thin seam districts for their steam coal.

Harvey² offers his analysis of what the coal demand portends for eastern Kentucky. "The East Central and East North Central Regions³ will dominate the demand pattern for coal shipped to electric utilities ... The next largest markets in terms of coal demanded are the South Atlantic and Central regions."⁴

An important concern of this study was to determine how the demand for utility coal from thin seam districts would develop in the mid- and long-term. In order to evaluate demand potential, the various forecasts were analyzed first on a national basis, and second, by highlighting the region east of the Mississippi.

In 1977, electric utilities constituted 72.2% of the total demand for coal. Published forecasts indicate that this percentage of the market share will remain stable to 1990. A review of these forecasts show that they are quite similar. Table IV-VII demonstrates this contention:

¹ See Appendix E -- 1977 Coal Shipments from the Thin Seam Districts to Electric Utilities.

² Harvey, The Economics of Kentucky Coal, Lexington, Kentucky: The University of Kentucky Press, 1977, p. 34.

³ See Appendix D -- Definition of Census Regions.

⁴ Harvey, The Economics of Kentucky Coal, pp. 27 and 33.

FIGURE 4-1
Electric Utility Demand For Coal
From Thin Seam Districts in 1977

TABLE IV-VII

National Coal Consumption Forecasts; Utility Sector

Forecast	National Electric Utility Consumption	
	(Million Short Tons)	
	1985	1990
PESD ¹	720 - 755	810 - 945
Coal Markets ²	700 - 1,200	NA
ICF	760 ³	1,007 ³
NERC ⁴	785	
Joel Price ⁵	807	

-
- 1 Projections of Energy Supply and Demand and Their Impacts, p. 181.
- 2 Coal Markets and Transportation Problems, p. 22.
- 3 Joel Price, The Coal Observer, New York; Dean Witter Reynolds, Inc., July 1978, p. 8.
- 4 National Electric Reliability Council, see Joel Price, "Coal-Carrying the Unignited Torch", August 1978, p. 9.
- 5 Joel Price, "Coal-Carrying the Unignited Torch", August 1978.

The Energy Information Administration (EIA) reports that demand forecasts do "not appear to be significantly sensitive to changes in absolute or relative prices of coal and other fuels in the short term, although this relationship would be pronounced as capital stock adjustments were made. Similarly, coal demand is not particularly sensitive to the weather since its use by utilities is primarily in the base load."¹

The EIA finds that electric utility coal consumption is "sensitive to the capacity at which the coal-fired plants are assumed to be operated. The potential for increasing utility coal demand by using existing capacity more heavily is limited, however, since most coal units already are operated to meet base load generation requirements."² The logical conclusion is that the future of electric utility coal consumption is dependent on the expansion of the total base load with the addition of new coal-fired plants. PI reports that this activity should occur in the following manner: "the trend to oil on the East Coast would be reversed; utilities on the Southwest would be shifting out of natural gas; and utilities on the Pacific Coast would be shifting from both oil and gas to coal. The low growth rates in the central regions reflect high current coal consumption and substantial increases in nuclear capacity."³

The map of Figure 4-2 shows the present and proposed nuclear power plants. Most of these facilities are clustered around large population centers. Despite nuclear power plant prominence, "it appears that coal will continue to be the most cost-effective fossil fuel for base load plants, and will remain competitive with nuclear based electric power upon location and environmental constraints."⁴

1,2 Projections of Energy Supply and Demand, p. 179.

3 National Energy Outlook, p. 178.

4 Projections of Energy Supply and Demand, p. 185.

FIGURE 4-2
Status of Nuclear Power Plants,
December 31, 1977

PI also forecasts that "utilities on a national basis will rely about evenly on low sulfur coal and high sulfur coal with scrubbers to comply with sulfur emission regulations on new plants. However, this mix varies widely by region."¹ "The forecast also indicates that existing plants will burn high sulfur coal where permitted by air pollution regulations, but will switch to low sulfur (rather than install scrubbers) where required to reduce emissions."²

¹ National Energy Outlook, p. 176 and The Energy Source Book, p. 198.

² National Energy Outlook, p. 175 and The Energy Source Book, p. 199.

The issue of air pollution regulations looms prominently in the consumption of high sulfur coal. The Clean Air Act of 1970 (and amendments) takes into consideration, among other items, the amount of emissions of sulfur oxides (SO_x) and particulates (TSP).¹

TSP and SO_x are among the major emission offenders in burning coal. Depending upon State Implementation Plans (SIP's) and Clean Air Act policing, utilities may be forced to buy compliance coal or build scrubbers. Another option may be to rely on nuclear power plants.

Since coal-fired electric utility plants will incur higher costs in order to comply with air pollution regulations, then nuclear power plants may become a viable energy alternative. The issues of safety and radioactive waste material, however, form a restraint on the expansion of nuclear power as an energy source. It is clear that legislators face some difficult decisions. At this time, the eventual long-term policies are difficult to predict. The following situation illuminates this problem.

Since scrubbers are still unreliable,² some electric utilities in the states of Ohio and Illinois are ordering up to two-fifths of their coal from out-of-state in order to comply with Clean Air Act Regulations. Illinois' Governor James R. Thompson "is against Commonwealth's planned out-of-state buy because it could cost 1,000 miners and 400 railroad workers their jobs, (and Ohio's) Governor James A. Rhodes...has asked President Carter to postpone enforcement of sulfur dioxide standards for three years...".

"Indiana and other midwestern states are watching to see what happens.

"The utilities favor low-sulfur coal because using it is often cheaper than building scrubbers to clean a power plant's emissions...

"Commonwealth (Illinois) also claims it cannot be in compliance with standards by next year's deadline if it installs scrubbers, which take at least 40 months to build." The EPA is now studying the problem.³

¹ See Edward H. Pechan, 1985 Air Pollution Emissions for a detailed analysis of this issue.

² The Coal Observer, September 1977, p. 12.

³ "Business Week", May 1, 1978, p. 34.

Although the national growth rate in the electric utility sector is forecast to be between 4.6% and 5.8%, eastern utility growth rate will grow at a lower rate as shown in Table IV-VIII.

TABLE IV-VIII
Eastern Utility Sector Annual Growth Rate¹

Year	Percent Annual Growth Rate
1975-80	2.6
1980-85	2.8
1975-85	2.7

Joel Price comments that these rates "may be surprising, but nuclear power's role will be enlarged in the east."²

Western coal also plays a role in the eastern utility coal burn. In July 1977, The Coal Observer forecast the 1985 eastern electric utility demand for western coal to be about 64 million short tons.³ A year later, the figure was reduced to 54 million tons. Comparing this with an expected demand for eastern coal of 429 million tons,⁴ it must be concluded that, at least until 1985, western coal does not play a major role in the eastern market.

Even though its role may be small, western coal will wrest a portion away from the normal thin seam district markets. This marginal loss might come from Indiana, Michigan, Wisconsin, Illinois and Ohio.

¹ The Coal Observer, New York: Dean Witter Renolds, Inc., July 1977, p. 3.

² Idem. See also Joel Price, "Coal-Carrying the Unignited Torch", August 1978, p. 6.

³ Joel Price, The Coal Observer, New York: Dean Witter Reynolds, Inc. July 1977, p. 4, Table 3.

⁴ See Joel Price, "Coal-Carrying the Unignited Torch", August 1978, Table 4.

Further expansion of western coal into the eastern utility market is unlikely. Some utilities may opt for Appalachian compliance coal over "a western compliance product because their existing boilers are not designed to handle the moisture of subbituminous coal. With compliance coal, the utility can be assured of its performance under boiler."¹

It seems that the "local coal issue has been and will remain a political football. There is no question that western low sulfur coal burned under SIP's... will cost consumers considerably less than indigenous high-sulfur Ohio or Illinois coal with scrubbers."² Ohio, which presently consumes 50-99% of its electric utility coal from thin seam districts, might swap out to western coal.³

In 1977, the three largest consumers of electric utility coal from the thin seam districts were Ohio, Pennsylvania, and Indiana. Would any of these large customers be tempted to swap out their present reliance on the thin seam districts for other districts' coal? Ohio buys most of its own coal, with District 8 marshalling the second largest part of Ohio's coal purchases.⁴ It is possible, however, that Ohio may switch to low sulfur western coal in order to meet its State Implementation Plan, unless prohibitive transportation costs force it to buy nearby thin seam coal. Indiana also purchases a sizeable portion of its coal from District 9. Georgia and Michigan may also opt for western coal. The remaining thin seam district customers, including Pennsylvania, will probably not change their current sources for steam coal.

4.2.2 Coking and Industrial Coal Demand

In 1977, while utilities dominated the demand, coal shipped to all domestic and foreign coke and gas plants totaled about 85 million short tons or 12.5% of the total demand for U. S. coal. The "Distribution" data display those states which are presently the major consumers of coking coal from the thin seam districts. These data have been transferred to the map of Figure 4-3 which displays the current dependency for coking coal from the thin seam districts.⁵

^{1 & 2} Joel Price, The Coal Observer, July 1978, p. 3.

³ See electric utility map of State Dependence on Coal from Thin Seam Districts, Figure 4-1, p.

⁴ See Appendix E -- Comparative Market Shares of Districts 8 and 9.

⁵ See Appendix E -- 1977 Coal Shipments from the Thin Seam Districts to Coke and Gas Plants.

% From Thin Seam Districts

50-99

100

FIGURE 4-3

Coke And Gas Plant Demand For Coal
From Thin Seam Districts In 1977

From the same source, we can obtain information about coal shipments for "Other Industrial"¹ use. In 1977, these shipments totaled about 50 million short tons or 8.8% of the total demand. Of these shipments about 39 million short tons came from the thin seam districts, or 65.3% of all coal shipped from the U. S. to this user sector. Figure 4-4 is derived from the "Distribution".²

Will there be any changes in the demand for industrial and/or coking coal from the thin seam districts? Published forecasts of national and foreign demand and the demands from the east of the Mississippi have been analyzed to evaluate the likelihood of change in demand.

¹ "Bituminous Coal and Lignite Distribution, October-December 1977", p. 5. "All Other Industrial" is defined as "all consumers of bituminous coal and lignite other than electric utilities, coke plants, retail dealers, railroads, coal mines, and mine employees".

² See Appendix E -- 1977 Coal Shipments from the Thin Seam Districts to "All Other Industrial" Users.

FIGURE 4-4

All Other - Industrial Demand For Coal
From Thin Seam Districts In 1977

Table IV-IX shows a comparison of forecasts of the national demand for coking/industrial coal.

TABLE IV-IX
Coking/Industrial
Coal Demand Projections

Projected National Coking/Industrial Coal Demand (Million Tons)			
Forecast		1985	1990
PESD ¹	Met	97	101
	Indus	106	130
PI ²	Met	100	
	Indus	129	
Coal Observer ³	Met	96	100
	Indus	160	139
Joel Price ⁴	Met	96	
	Indus	130	
ICF ⁵	Met		
	Indus		

1 Projections of Energy Supply and Demand, p. 181. PESD defines two categories for coking coal: metallurgical and industrial. Industrial includes residential and commercial uses. This is the series C mid-range projection.

2 The Energy Source Book, 1977, p. 199. PI has separated household and commercial. For the purposes of standardized information, this category which is projected to consume 5 million tons in 1985 was added to the industrial sector.

3 Joel Price, The Coal Observer, July 1978, p. 8. There is a separate category for residential/commercial which accounts for 1.5 million tons in 1985 and 0.7 million tons in 1990. For consistency, these figures were added to the industrial estimates. These numbers represent the medium case.

4 Joel Price, "Coal-Carrying the Unignited Torch," General Electric Energy Symposium, August 1978, Table 7. Industrial and Retail are already combined.

5 Production and Consumption of Coal, 1976-1980, p. 65. Industrial coal includes retail.

The five forecasts are quite comparable. It serves no purpose, therefore, to use a particular forecast as a standard of measurement. The short-term metallurgical market is beset by problems. With a decreasing demand for coal by steel producers,¹ "some metallurgical coal [may find]... its way into the utility market as a compliance product..."² Foreign supplies of metallurgical coal have been displacing domestic ones³ and 1978 exports of coking coal are lagging behind 1977 ones. Technological advancements, such as formcoking, could reduce the demand even more.⁴

"The projected demand for metallurgical coke could be further decrease [sic] by as much as 15 to 20 million tons by 1985 if formcoking proves technologically and economically feasible."⁵

In 1976, domestic consumption of coking coal was 85 million tons or 14% of the total domestic consumption. In 1977, the domestic demand dropped to about 79 million tons or 12% of the total output. With regard to total shipped tonnage, domestic coking coal consumption dropped 7% in a single-year period. PI predicts a 1% growth rate in coke consumption while PESD forecasts a 1.3% growth rate.⁶ This slow increase appears jeopardized with a drop in domestic coke consumption in 1977 and the steep increase in coke imports in spring 1978.⁷ "The supply/demand of coking coal is creating an imbalance which analysts say may become worse before it gets better."⁸ While coking coal constitutes only 12.5% of the total demand in 1977, 89.8% comes from the thin seam districts. Since coking coal commands a higher price, any slackening in the demand could have an immediate and significant socioeconomic impact in the thin seam states.

1 See Joel Price, The Coal Observer, December 1977, p. 6.

2 Joel Price, "Coal-The Unignited Torch," General Electric Energy Symposium, August 1978, p. 8. See also "What Ails the Market for Metallurgical Coal", Business Week, August 21, 1978, p. 27.

3 "Coke Imports Skyrocket," Coal Outlook Thu June 8th, Washington D.C.: Casey Publishing Co., 1978.

4&5 See Paul H. Mutscher, Impact of Changing Technology on the Demand for Metallurgical Coal and Coke Produced in the United States to 1985, Washington, D.C.: U.S. Bureau of Mines, 1975, p. 1.

6 PESD, p. xlv.

7 "Coke Imports Skyrocket."

8 George Getshow, "Coal's Short-Term Outlook is Clouded by Rising Capacity and Leveling Demand," Wall Street Journal, May 8, 1978, p. 30.

Coking coal projections state-by-state are unavailable. No observations about future dependency on thin seam districts can be made on a by-state basis.

Industrial and retail coal predictions show a rapid growth but the reasons are hazy. In part, this might be attributed to the fact that the "possibilities for future industrial coal utilization remain elusive due to inadequate data."¹ It seems, moreover, that "the government has no real idea on industrial coal consumption."²

Joel Price recently presented the demand forecasts displayed in Table IV-X. He predicted an increase of more than 68% in the demand from the industrial and retail sector between 1980 and 1985. It should also be noted that a synthetic fuel demand sector enters the picture by 1985, accounting for about 0.8% of the total demand. Although the synthetic fuel percentage of market demand is negligible, the appearance of this new technology creates difficulties in forecasting its potential growth.

4.2.3 Demand Forecasts - Exports

In 1977, exports commanded 7.5% of the total demand for U. S. coal. The thin seam districts shipped about 51 million short tons, or 99.4% of this total export. A table comparing forecasts is shown below in Table IV-X.

¹ Joel Price, "Coal-Carrying the Unignited Torch", August 1978, p. 14.

² Ibid., p. 13.

TABLE IV-X
Comparison of Coal Exports Forecasts
(In Million Short Tons)

Forecast	1980	1985	1990
Coal Observer ¹	64	80	
Coal Observer ²	70	87	
Coal Observer ³		72-74	76-77
Joel Price ⁴	56	72	
PESD ⁵		74	81
PI ⁶		80	

In 1976, 59 million short tons were exported. In 1977, exports dropped to 51 million short tons.⁷ There are many factors that account for the decrease in the export demand. For example, the foreign steel production scenario appears increasingly unhealthy. Other sources of cheaper foreign coal are displacing American coal. Since most all exports (99.4%) come from the thin seam districts, they are virtually the only ones which could be affected by the export demand forecasts. All the coal that Canada imports from the United States comes from the thin seam districts. Japan, western Europe and some of South America are other major importers of coal from the thin seam districts.⁸ Mexico

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- 1 Joel Price, The Coal Observer, December 1977, p. 6.
 - 2 Joel Price, The Coal Observer, July 1977, p. 6.
 - 3 Joel Price, The Coal Observer, July 1978, p. 8.
 - 4 Joel Price, "Coal-The Unignited Torch," General Electric Energy Symposium, August 1978, Table 6.
 - 5 Projections of Energy Supply and Demand and Their Impacts, pp. 181-182.
 - 6 National Energy Outlook, 1976, p. 173.
 - 7 "Bituminous Coal and Lignite Distribution," January-September, October-December 1977, and Joel Price, The Coal Observer, December 1977, p. 6.
 - 8 "Exports pick Up Steam," Coal Outlook Thu June 8th, 1978

received a negligible portion from District 14¹ which may forecast a possible shift from the thin seam districts.

The Coal Observer reports that Japan's intake "seems headed south [downward] in 1978, [and] any estimate for 1980 must be tentative... Forecasts for European communities' coal receipts from this country in 1980 have become increasingly fragile and almost certainly will slip well below the 13.1 million tons of 1976, which were somewhat inflated. At any rate, total exports, which include steam coal for Canada, are being reduced by 6 million tons for 1980 and 7 million tons in 1985..."²

Of exports, Mr. Price says that they are "primarily metallurgical save for 10.5 million tons of steam coal to Canada, [and] 1980 reflects the slowing world growth rate which obviously impacts steel, restraints on Japanese imports here and in Europe, and mounting coal competition from other countries."³

This amounts to a surplus of coal on the export market. A sluggish export market could back up onto the domestic one creating an increasing imbalance in the supply/demand market. This situation might lengthen the number of years before depletion would create a need to extract thin seam coal.

Published forecasts apparently could not anticipate the present sluggish demand. PI predicted an annual growth rate of 2.6% to 1985 in export demand while PESD forecast one of 2.5%.

1 "Bituminous Coal and Lignite Distribution," January-September and October-December 1977.

2 Joel Price, The Coal Observer, December 1977, p. 6

3 Joel Price, "Coal-The Unignited Torch," General Electric Symposium, August 1978, p. 7.

4.3 Production Forecasts

Published forecasts used for this project stop at 1990. Those used are displayed in Table IV-XI.

TABLE IV-XI
Comparison of National Production Predictions
(In Million Short Tons)

Forecast	1977	1985	1990
PI ¹ BAU	755	1,100	1,300
PIACC	926	2,063	2,803
PESD ² Low		994	1,145
PESD High		1,065	1,348
Energy Supply and Demand ³		866	966
Market Analyst ⁴			
Coal Statistics ⁵	689 ^p		
ICF ⁶	726		
Joel Price ⁷	689	1,143	
Coal Observer ⁸		990-1,188	1,114-1,856

p - Preliminary final production figures for 1977 are 688, 575 thousand short tons.

- 1 PI, Coal, Appendices, Tables 4 and 5.
- 2 PESD, Table 8.5, p. 181, Table 8.6, p. 182.
- 3 Energy Supply and Demand, p. 43.
- 4 Charles J. Elia, "Earnings Estimates," Wall Street Journal, July 13, 1978.
- 5 Conversation with Mr. Leonard Westerstrom, Coal Statistics, Department of Energy, August 10, 1978.
- 6 Coal Production and Consumption, 1976-1980, Table 1-1.
- 7 Joel Price, "Coal-Carrying the Unignited Torch," Table 7.
- 8 The Coal Observer, July 1978, Table 1, p. 8.

Shifting to the eastern production that embodies the thin seam districts, the forecasts take on the following semblance in Table IV-XII.

TABLE IV-XII
Comparison of Eastern Production Forecasts
(In Million Short Tons)

Forecast	1976	1977	1980	1985	1990
Joel Price ¹	431	418	504	537	
Distribution ²		409			
PI ³ BAU		496	558	657	768
PI ACC		588	827	1,120	1,668

Forecasts other than those presented in Table IV-XII, do not present sufficient definition of regional production to provide a thin seam district analysis. The only source that divides the production data into deep and surface mined production⁴ is Project Independence, 1974. Project Independence, and notably its Business As Usual (BAU) scenario, is not significantly different from other recent forecasts, although it may overestimate production.⁵ PI's production forecasts are, therefore, used to estimate the lifetime of the reserve base of high seam coal (Section 5).

¹ Joel Price, "Coal-Carrying the Unignited Torch", August 1978, Table 5. Missouri is not included in either western or eastern coal production figures.

² "Bituminous Coal and Lignite Distribution", January-September and October-December, 1977. Note: the 409 thousand short tons represent shipments which are equated with consumption and does not represent total production.

³ Project Independence, Coal, 1974, Tables 6 and 7.

⁴ Another data source can provide deep and surface production forecasts. The cost of access to this data source is far from being within the scope of this project.

⁵ Project Independence is currently being updated. At the time of this study, the updated information was unavailable.

Using Project Independence BAU scenario as a guideline, we conclude that there is ample underground production to satisfy mid- and long-range demands.¹ As a matter of fact, there have been surpluses. In 1977, there was a national production surplus of about 11-15 million tons, depending on the estimates used. A production surplus of 123 million tons is estimated in 1980, with a surplus of about 30 million tons in 1985.² The reasons for the surge in surplus and the subsequent decrease are described by Joel Price.

- "1. There is too much coal slated for production in the west, both in 1980 and 1985, thus downgrading of plans is in order.
- "2. There was a surplus of eastern coal production in 1977 and based on announced plans, it could swell to 46 million tons in 1980.
- "3. Since utility demand forecasts continue to be lowered, and if mine productivity picks up by use of incentive plans, conceivably an indicated need for 57 million as yet uncommitted tons of coal in 1985, may in reality be totally unnecessary.
- "4. The strip mining bill is pulling tonnage out of circulation with uncertain consequences.
- "5. Compliance coal is the hottest game in town; in 1983-1984, high sulfur will likely come back into vogue unless scrubber rules are relaxed."³

Other explanations can be found in the upswing for industrial coal demand and synthetic fuel use by 1985.

What percentage of the total production can the thin seam districts expect to maintain? Table IV-XIII provides these forecasts.

-
- 1 See Appendix E -- BAU Thin Seam Districts Underground Production Forecast.
 - 2 Joel Price, "Coal-Carrying the Unignited Torch," August 1978, Table 7.
 - 3 Joel Price, "Coal-Carrying the Unignited Torch," August 1978, pp. 13-14.

TABLE IV-XIII

Deep and Surface Production Forecast of
Thin Seam Districts

(In Million Short Tons and % of National Production)

Forecast	1977		1980		1985		1990	
Joel Price ¹	418	60.6	504	53.0	537	46.9		
PI ² BAU	496	65.6	558	62.3	657	59.7	768	59.0
ACC	588	63.4	827	60.1	1,120	53.7	1,668	59.6

Joel Price's prediction of the eastern coal market share of production is less optimistic than PI's. In both predictions, however, eastern coal production drops slowly as a percentage of the total estimates. As we have noted, one of the reasons is that western coal production is more responsive to price. Another explanation is the decision by electric utilities to use western coal "in lieu of existing eastern commitments to meet State Implementation Plans, which means pre-1970 Plants. This swells the west and diminishes the east, equally in Btu's, unequally in tons."³

It is plausible then that electric utility utilization of western coal accounts for the decrease in eastern production as a percentage of the U.S. total. A further possible explanation about western coal's slight increase is that its "supply is vast, it is relatively inexpensive to mine and it is low in sulfur and, therefore, less expensive to burn cleanly."⁴

Regardless of the slight drop in projected percentage production, eastern coal should be capable of meeting the predicted demand through 1990.

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- 1 Joel Price, "Coal-Carrying the Unignited Torch," August 1978, Table 5. Note: Missouri is not included.
 - 2 Project Independence, Coal, 1974. Tables 6 and 7. Note: These figures represent both deep and surface production. For underground production estimates, see Appendix E -- BAU Thin Seam Districts Underground Forecast.
 - 3 Joel Price, "Coal-Carrying the Unignited Torch", August 1978, p. 3.
 - 4 Facts About Coal, 1973-1974, NCA, p. 32.

4.4 Price Forecasts

The potential for thin seam mining is partly dependent on the future development of the market price for coal. In this section, both recent and future coal price developments and their relevance to the potential of thin seam mining are discussed.

The demand for coal dropped when oil became a favored energy source by electric utilities, and prices became sluggish. The market brightened in 1973. The "sharp increases in coal prices between September 1973 and November 1974 reflected an abnormal surge in demand for a product whose immediate supply cannot be expanded rapidly. This surge was caused by a quadrupling of the price of imported oil...These sharp increases in price led to sharp increases in coal company profits in 1974 and 1975."¹ Coal prices then receded from their historic highs in those two years. Now profits seem precarious in 1978.

Despite the present overcast outlook, one source states that the "outlook for coal prices in the next decade is favorable...with good prospects for stable prices (1975 dollars), and in some parts of the country, declining prices."² With a demand for thin seam coal, it is unlikely that prices for this coal will decline. This contention is borne out in a study by EPRI. On a national scale, which includes deep and surface mineable coal, EPRI found that:³

- o The longer-term outlook for coal prices is that it will increase to 1985, and then level off and remain stable to 2000.
- o Prices reflect the production costs as opposed to the demand for coal.

¹ A Study of Coal Prices, pp. 86-87.

² Ibid, p. 1.

³ Fuel and Energy Price Forecasts, EPRI, Volumes I & II, 1977.

Other analysts have come to the conclusions:

- o If the demand for coal increased rapidly, the price would reflect demand. If, however, there was adequate lead time to develop a coal supply, the prices would reflect production costs.¹
- o "The evolution of costs over time will depend on factors in addition to depletion. While depletion acts to increase costs, technological progress reduces them. The recent history of productivity in the mining industry is not encouraging in this regard. Nevertheless, over the long run, coal mining costs need not rise if technology can reverse recent trends. In fact, the long sweep of history of mineral supply is one of technology overcoming the cost increase imposed by nature."²

With depletion, how will coal mining be characterized by the year 2000? NASA's Jet Propulsion Laboratory (JPL) and Energy and Environmental Analysis (EEA) provided input to this end.³

The trend towards thin seam mining appears most urgent in the Appalachian area. As such, we will investigate the mining characteristics of this region. This example will provide a preliminary overview of the possible need to develop technology to mine thin seam coal. By the year 2000, the typical northern Appalachian mine will not have changed much from its 1975 characteristics: a shaft mine, 300' deep, with six sections, working in a 60" seam and using a continuous mining method. In central Appalachia, the typical mine will change from four to two sections, and drop from a 43" to a 28" seam height. As in 1975, this will be a drift mine using a continuous mining method. Can development of new mining technology be justified for the thin seams in central Appalachia? The answer is speculative. If there is a demand for local coal, and it is less than 28" in seam in height, then it would have to be cost competitive with exogenous coal. Looking at a specific example, there appears to be a slight trend towards thin seam mining in Alabama, Tennessee and West Virginia. Since Alabama and Tennessee are forecast to mine thinner seams than West Virginia, they

1 & 3 Draft Input to the MOPPS Interagency Task Force, Prepared by The Jet Propulsion Laboratory and Energy and Environmental Analysis, Inc. for the U. S. Bureau of Mines, June 1977, Unpublished.

2 Zimmerman, M. B., Modeling Depletion In A Mineral Industry: The Case of Coal, in The Bell Journal of Economics.

will serve as a benchmark to determine the price competition with coal from states not mining thin seams in 2000. Using JPL and EEA's price determinations for \$/MMBTU, coal cleaning and transportation, we find that northern Appalachian coal delivered to Alabama or Tennessee should be approximately \$1.56/MMBTU in the year 2000. Alabama and Tennessee's use of indigenous thin seam coal should be approximately \$2.02/MMBTU for the same year. Keeping these gross approximations in mind, the Department of Energy will have to debate the latitude within which it wishes to work in order to develop the technology to mine thin seam coal.

Part of the elasticity of this assessment to develop a new technology stems from the life of the resources higher than 28 inches. An investigation of these lifetimes is meaningful at this juncture.

5.0 ESTIMATED LIFE OF SEAMS HIGHER THAN 28"

To estimate the life of the higher seams, the identified coal resources by state, presented in section 3.0, were used. In order to combine this information with production forecasts by district, the resource information was rearranged at the county level to arrive at resource estimates by district. Unclassified resources were divided over seam height ranges by ratio of the classified resources in the district. Table V-I contains a summary of the results.

TABLE V-I
Underground Bituminous Coal Resources
(Million of Short Tons)

District	Year of Estimate	Seam Height		Total
		14-28"	> 28"	
1 + 2 ¹	1970	13,030	49,352	62,382
3 ²	1974	16,782	29,040	45,822
4	1974	11,976	22,647	34,623
6	1974	116	4,078	4,194
7	1974	2,748	4,767	7,515
8	1974	25,198	39,714	64,912
11	1958	2,021	29,468	31,489
12	1958	2,160	5,077	7,237
13 ³	1958	5,491	7,464	12,955
15 ⁴	1971	13,516	6,754	20,270
TOTAL		93,038	198,361	291,399

- 1 For districts 1 and 2 the Pennsylvania resources are given. Small resources in Maryland and West Virginia are not included.
- 2 Resources in district 3 are unclassified. Total resources are divided over the seam height ranges by ratio of the resources in these ranges in districts 6, 7 and 8 combined.
- 3 For district 13 the Alabama resources are given. Some resources in Tennessee are not included.
- 4 For district 15 the Missouri resources are given. Some resources in Kansas, Texas and Oklahoma are not included.

The resource data were combined with actual and estimated production information to update the year of estimate, and with production forecasts to estimate the resource life. The production forecasts published in Project Independence were used, since they are the only forecasts that separate deep and surface production. The Business as Usual (BAU) forecast was used, which appears to be slightly exaggerated and thus has a reducing effect on the estimated resource life. The last year for which a production estimate is available is 1990, after which the production is assumed to be constant at the 1990 level, probably inflating the expected life of the resources. A 50% recovery rate is assumed.

The results are shown in Table V-II.

TABLE V-II

Estimated Life of Underground Mineable Coal
in Seams Higher than 28 Inches

District	Estimated Life (years from 1978)	Thin Seam Resources (million of short tons)
1 + 2	342	13,030
3	376	16,782
4	475	11,976
6	161	116
7	45	2,748
8	96	25,198
11	5767	2,021
12	3168	2,160
13	238	5,491
15	no production forecasted	13,516

From this information, it appears that a need for thin seam coal is not to be expected in the near future. A closer examination, however, is required. Coal for metallurgical use requires special characteristics. In 1977, almost 90% of the coal shipped to coke and gas plants came from the thin seam states. The estimated life of the underground mineable coking coal resources may be significantly shorter than Table V-II indicates.

The Keystone Manual identifies those seams in which coal of coking quality is known to exist. Using the resource data provided in Section 3, these seams represent the following percentages of the respective state's total resources:

TABLE V-III
Coking Coal In Thin Seam States*

State	Coking Coal As % Of Total Resources	% In Seams > 28"
Alabama	55	65
Kentucky	50	70
Ohio	12	65
Pennsylvania	60	84
Virginia	45	13
West Virginia	49	85
* No coking coal identified in Missouri, Indiana or Iowa		

From Table IV-I, it follows that in 1977, 19% of the production from thin seam districts was shipped to coke and gas plants, and that 62% was shipped to utilities. Also in Section 4, it was shown that the demand for steam coal is estimated to grow five times as fast as the demand for coking coal. From the above resource percentages for coking coal and since Ohio does not currently product coking coal¹, it can be concluded that sufficient coking coal resources are present in the higher seams to satisfy the demand far beyond the year 2000.

1

See Appendix E -- 1977 Coal Shipments from the Thin Seam Districts to Coke and Gas Plants.

6.0 CONCLUSIONS, RECOMMENDATIONS

The results of the study indicates that mine expansion plans in Alabama, Tennessee and West Virginia reveal a slight trend towards the thinner seams (42"). USGS reports that Tennessee coal resources of less than 28 inches are negligible. West Virginia's thin seam coal resources (14-28"), as a percentage of the total in the state, are only 16%. In conjunction with the estimated life of its thicker seam resources (>28"), which ranges from 45 (for District 7) to 376 (District 3), thin seam mining in West Virginia does not appear to be an urgent issue.

Although the estimated life of Alabama's underground coal resources in seams thicker than 28 inches is about 238 years, a large percentage (41%) of Alabama's resources have been identified as thin seam. The quality of this coal is better than the thicker seam coal. Thin seam coal mining in Alabama appears to be a local issue, with the cost of transportation possibly providing the impetus for its growth.

If we argue in favor of thin seam coal mining, we must weigh the problems inherent in developing a new mining system. Accident statistics show that as the seam height decreases, the rate of disabling injuries increases. We conclude that safety regulations must be even more stringent in thin seam coal mining than present standards.

Mine plans and methods must be altered for thin seams. For example, the pillars could be reduced in size, roof bolts shortened or flexible bolt and drill technology applied, air velocity increased, and place widths increased.

Man-mobility will be extremely limited in thin seam coal mining. This problem entails the development of remote or automatic controlled extraction systems or surface based underground mining systems (SBUM). New haulage equipment should be developed to compensate for the extremely low clearance and reduced capacity.

In addition to the technical problems of thin seam coal extraction, the demand for this coal must be established. An analysis of the coal market to 1990 does not show a sufficient demand that could precipitate thin seam coal mining throughout the thin seam states.

The estimated life of coal reserves higher than 28" indicates at the minimum, 45 years of reserves remain (this occurs in District 7). Again, the extraction and transportation costs may be the deciding factors in the development of thin seam coal mining technology. The gross overview demonstrated that delivered to the same destination in central Appalachia,

northern Appalachian coal will cost about \$1.60/MMBTU and central Appalachian coal will be about \$2.00/MMBTU in the year 2000. The reason for the difference is the reduction in the average seam height from 43" to 29" in central Appalachia and the maintenance of the 60" seam height in northern Appalachia.

We conclude that, at least until 2000, thin seam coal mining will remain a small and local issue. Politics, environment, and economics, as well as an added demand for coal are factors which provide an increased need for thin seam coal.

The following recommendations are based on the results of the analysis:

- o Due to the estimated life of higher seam resources and an estimated development time for a low seam extraction technology of twenty years, the Department of Energy can afford to postpone the decision to initiate the development of this technology.
- o Due to the high level of uncertainty concerning coal's long-term future, it is strongly recommended, that the issue of thin seam mining not be discarded; but that future developments affecting the coal market be observed and the potential for thin seam mining be re-evaluated on a regular basis, perhaps in five years, when new market conditions and improved geological information can be applied.

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