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PNL-2420

UC-71

Energy Material Transport, Now Through 2000, System Characteristics and Potential Problems

Task 2 Final Report - Coal Transportation

June 1978

**Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by**

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PNL-2420

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BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
Under Contract EY-76-C-06-1830

Printed in the United States of America
Available from
Technical Information Center
U.S. Department of Energy
P.O. Box 62
Oak Ridge, TN 37830

Price: Printed Copy _____; Microfiche \$3.00

Pages	Selling Price	Pages	Selling Price
001-025	\$ 4.00	326-350	\$12.00
026-050	4.50	351-375	12.50
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ENERGY MATERIAL TRANSPORT, NOW THROUGH
2000, SYSTEM CHARACTERISTICS
AND POTENTIAL PROBLEMS
TASK 2 FINAL REPORT - COAL TRANSPORTATION

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June 1978

Prepared for
the U.S. Department of Energy
under Contract EY-76-C-06-1830

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Seattle, Washington

FOREWORD

This report is an account of effort in Task 2 - Coal Transportation, of the project "Energy Material Transport, Now through 2000, System Characteristics and Potential Problems". The project is sponsored by the Department of Energy, Division of Environmental Control Technology, Transportation Branch.

The overall project objectives are:

- To provide an assessment of potential problems which may hinder the safe, environmentally acceptable, and cost-effective development of fossil and nuclear energy material transportation systems in the United States from now until the year 2000,
- to recommend research, development and other necessary action to mitigate the potentially adverse impact of these problems on transportation system development.

The results of effort addressing other tasks in this project are reported as follows:

Task 1 - Nuclear Materials Transportation (BNWL-2066 and BNWL-2248)

Task 3 - Petroleum Transportation (PNL-2421)

Task 4 - Natural Gas Transportation (PNL-2422)

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ENERGY MATERIAL TRANSPORT, NOW THROUGH
YEAR 2000, SYSTEM CHARACTERISTICS
AND POTENTIAL PROBLEMS

TASK 2 - FINAL REPORT - COAL TRANSPORTATION

1.0 SUMMARY

This report contains a summary characterization of the existing domestic coal transportation system and an assessment of some potential problems which may impact coal transportation in the United States during the balance of the century. A primary purpose of this task is to provide information and perspective that contributes to the evaluation of research and development needs and priorities in future programs.

Specific concerns are identified which warrant additional programmatic effort to fill apparent gaps in the coverage of other relevant programs. Recommendations are made for new programs to address these concerns according to their apparent importance under conditions known or anticipated in early 1978. These recommendations are intended to encourage new research initiatives by the coal transportation industry, the Department of Energy (DOE) and other cognizant agencies. The specific involvement of the sponsor of this study^(a) in new project activity is recommended where this is considered to be appropriate.

Concerns were identified by the analysis of problem issues associated with currently-projected growth scenarios for domestic coal consumption. The assessment of potential problem effects on the adequacy of future coal transportation assumes domestic coal production levels of approximately one billion tons in 1985 and two billion tons by the year 2000. The relative priorities of potential problems were judged on the basis of their overall impact on the system and the immediacy of this potential impact.

(a) DOE, Division of Environmental Control Technology (DECT).

Three classes of concern priority were distinguished:

1. Potentially serious concerns requiring immediate action to minimize their possible impact in the next decade.
2. Moderate concerns that may require relatively swift action to minimize their potential impact later in the century.
3. Latent concerns which may increase or decrease in priority or entirely change in nature as they develop. While the trend of these concerns should be monitored, new program action does not appear necessary at this time.

A fourth category relates to other controversial issues that are judged to be inconsequential in their present perspective and, therefore, are not priority concerns. Similarly many problem issues currently discussed in the literature appear to involve desirable improvements in system performance and management that should evolve in the normal course of system development. These issues are not considered to represent concerns within the scope of this study.

1.1 POTENTIALLY SERIOUS CONCERNS IN THE NEXT DECADE

The most important potential problems have consequences which may lead to inadequate domestic coal transportation in the next decade. These highest priority concerns are summarized below together with recommended effort that should be considered in FY 1979 program activities.

1.1.1 Public Acceptance of Coal Transportation

The transportation of coal generates many effects that could conceivably cause a deterioration in public acceptance of the system. Reduced public acceptance could lead to new and tighter regulations which might escalate the cost and hinder the development of adequate coal transportation systems. Because increasing levels of public reaction can be anticipated as the volume of transported coal increases, a new program is warranted to evaluate the future consequences of this concern and to establish guidelines for action to solve the potential problem.

The recommended effort should provide a basis for involving public opinion and knowledge of public psychology in system planning and engineering . It should be established which nuisance effects of coal traffic aggregate into major environmental disturbances as perceived by the public. A priority list should be prepared identifying effects that are tolerable and effects that are not. The future potential impact of coal traffic on community life along specific routes should be evaluated as part of the study of alternative solutions. This study should rank solutions and financing mechanisms based on cost/benefit assessments of the alternatives. Effort at a two man-year level in FY-1979 and FY-1980 and DECT involvement are recommended.

1.1.2 Impact of Frozen Coal

In winter, coal freezing in rail cars, barges and stockpiles prevents normal delivery schedules from being met. Under prolonged and severe cold weather conditions, this could create a regional shortage of coal during a period of high demand.

In past winters frozen coal has restricted the output of several industries. Climatic cycles are suggested in which winters tend to become more severe at the end of centuries. Coal transportation plans should be developed with the assumption that recent severe winters may be typical during the balance of the century. A program of innovative research and development (R&D) is needed to establish more effective methods for ensuring that frozen coal is not a future winter problem. The recommended effort should address system-level options and specific cost-effective and environmentally-compatible techniques for preventing coal freezing or thawing frozen coal. An initial one man-year effort is recommended in FY-1979 to identify potentially profitable areas for future research and development activities. The DECT should provide support where environmental issues may be involved.

1.1.3 Impact of Proposed Coal Slurry Pipelines

Important comparative data still need to be developed before it can be decided that coal slurry pipelines are sufficiently attractive on a whole-system basis to warrant government encouragement.

Controversy still exists about the whole-system cost/benefit relationships for coal slurry pipelines and their potential impact on railroad operations and financial stability. Further review is needed to bring order to this situation and add important perspective to the fundamental question of whether government should encourage and/or subsidize coal slurry systems. An in-depth energy assessment of slurry and railroad unit train operations is particularly important and has not been emphasized in related program effort to date. A comprehensive DOE position paper should be prepared on a case-by-case, whole-system comparison of slurries and unit trains. This is needed to provide a broader data base for proceedings such as those relating to the questions of eminent domain and water rights in which an understanding of the merits of the competing systems is important. A three to four man-year effort in FY-1979 is recommended using knowledge from related programs as a starting point. Consideration of environmental and safety issues in this effort would require a substantial contribution from the DECT.

This concern does not strictly meet the criterion of having a potentially direct impact on coal transportation in the next decade. However, regulatory decisions are expected in the next two years which may affect the impact coal slurries have on competing systems during the balance of the century. For this reason the recommended research is a current, high-priority item.

1.1.4 Transportation Preparedness for Sludge Removal

The lack of future preparedness to transport large amounts of sludge and ash may restrict the use of coal in future environmentally-compatible generating stations and plants.

The Clean Air Act and its amendments contain New Source Performance Standards (NSPS) and the concept of Best Available Control Technology (BACT). A current interpretation of the BACT provision, which has yet to be enforced, requires the SO₂ removal systems not only to meet the NSPS but also be the best system existing at the time of installation. Limestone scrubbers, presently the most accepted SO₂ removal system, generate large amounts of sludge. When combined with the ash collected and depending on the sulfur content, the quantity of waste requiring disposal may approach one half ton

for every ton of coal consumed. Large increases in coal consumption may accelerate the depletion of present disposal sites and force the expansion of waste disposal systems. This expansion may require increased shipping distances and therefore an increased dependence on transportation.

To date, inadequate attention has been applied to these problems. A review of current disposal site capacities should be made and compared with projected disposal requirements in the 1980s. This should be used to identify areas where sludge may be a future transportation problem. If sludge transportation development is shown to be needed, a systems approach to planning should be undertaken to assure environmentally acceptable and cost-effective transportation of the sludge. Guidelines should be developed that consider alternative solutions for sludge disposal or subsequent use. This should have a high priority because of the lead time required to assess the possible magnitude of the problem and to implement solutions. An initial half man year effort should be applied in FY-1979 to quantify the magnitude of this potential problem.

1.2 CURRENTLY MODERATE CONCERNS WITH LONGER-TERM POTENTIAL IMPACT

This category includes concerns that may impact coal transportation between the 1980s and the end of the century. These concerns are currently a moderate priority because their potential impact may occur later and more time is available to address solutions than is apparent in the above cases.

1.2.1 Unit Train Rates

If value of service is not considered as a factor in rate prescription by the ICC, the revenue generated by coal carriage may be reduced to the point that railroad management loses the incentive to expand coal-carrying capacity. This could lead to an inadequate coal transportation system which may not be sufficient to serve the anticipated increases in coal demand.

Regulation of rail rates for unit coal trains traditionally has been based primarily upon three factors: cost of service, comparative rates, and

value of service. The San Antonio Rate Case is a matter of concern to the railroad industry because the ICC indicated a possible departure from its policy of allowing a value-of-service factor in ratemaking procedures by the railroads.

An evaluation should be initiated to determine the impact of the San Antonio case precedent on both the railroads and consumers of rail-transported coal. While the San Antonio case does not represent any consistent ICC policy, cases now pending before the ICC may be decided similarly to it. The recommended action warrants early consideration to avoid increasing the potential impacts of the case on the development of the coal transportation system and on the future cost of energy. Further analysis may be needed to provide the ICC with a basis for determining allowable revenue factors which would offer sufficient incentive for the railroads to maintain the development of their coal-carrying capacity consistent with national needs. The ICC and the DOE should examine this concern cooperatively, each contributing a man-year level of effort in FY-1979.

1.2.2 Environmental Impact of Advanced Coal Slurry Pipelines.

Anticipated future advances in coal slurry transport involving coal and liquid fuel mixtures may present potentially severe safety and environmental problems in the event of a pipeline rupture or a spill at terminal transfer points.

Carriers such as alcohol or petroleum may be used instead of water in future coal slurry pipelines. The liquid fuel carrier can be burned with the coal, and the slurry pipeline can operate without the disadvantage of consuming potentially scarce water resources. If the slurry gets outside of the pipeline, the environmental effects of a liquid-fuel/coal slurry appear to be potentially more severe than those of a water/coal slurry. The availability of water may be a future obstacle to the development of water/coal slurry systems, and the emphasis on alternative liquid-fuel/coal slurries can be expected to increase as the technology becomes available. Questions concerning the safety and environmental impact of advanced slurry systems should be answered before rapid development is started. The need is indicated

for an early evaluation and risk assessment of potential safety and environmental concerns relating to the operation of advanced liquid-fuel/coal slurry pipelines. This would provide guidelines for possible R&D program activities that may be necessary. The DECT should support a one man-year effort in this area in FY-1979 or FY-1980.

1.2.3 Congested Waterways

A continuing increase in inland waterway congestion may impact the future value of barge transportation as a competitive alternative for moving coal. Approximately 15% of the bulk coal traffic in the U.S. is transported by barge on inland waterways. Since 1970, there has been a steady increase in waterway traffic ton-miles and the number of barges and towing vessels. Other than slowing traffic, congestion has the potential of increasing transportation cost, and causing casualty events (groundings, rammings, collisions) and pollution.

The impact on coal transportation could be the diversion of some of the traffic to other modes. In the long term, railroad, truck, and potentially also slurry modes could be expected to absorb the coal traffic that may be diverted from the waterways. There is a potential problem associated with short-term responsiveness of competitive modes to waterway congestion, although stockpiling can cushion day-to-day variability in supplies.

This concern may not become significant on a national scale because of the relatively small volume of coal transportation involved. However, the concern is worthy of further review to determine if local impacts may develop that are not protected by alternative supply routes. The final form and impacts of Congressional action on waterway user charges are expected to modify the priority of this concern. No specific programmatic action is recommended pending the outcome of legislative action and the related ongoing evaluation of this concern.

1.3 LATENT CONCERNS

Latent concerns are judged to have the potential, with equal probability, of increasing or decreasing in priority, or changing in nature during the

balance of the century. These concerns do not appear to be serious at present and may be resolved in the future by influences now at work or by alternatives that can be anticipated to develop. The following are examples that should be kept under review to determine their evolution as conditions change. New program activities are not recommended in these areas.

1.3.1 Eminent Domain for Slurry Pipelines

It has been suggested that a major obstacle facing coal slurry pipeline development is the difficulty of acquiring rights-of-way. Currently, coal slurry pipelines have no Federally-granted power of eminent domain, although eight states have extended the right. The lack of the right of eminent domain may be important because railroads have generally refused to sell easements to slurry pipeline companies in the hope of preventing a competitive mode of coal transportation. However, pipeline organizers may ultimately prevail without Federal power by exercising rights under state laws where permitted and by purchasing subsurface rights to property underlying railroad rights-of-way.

1.3.2 Railroad Abandonment Policy

At least one case of premature or unofficial abandonment appears to have taken place in anticipation of later ICC approval. In this case, the railroad's decision to decrease track maintenance anticipated a power company's intention of changing to oil fuel at the affected plant. The resulting condition of the track made coal delivery unreliable when the oil-conversion decision was subsequently reversed. This example would be a concern if it occurred frequently. However, it is expected to be a rare event. In formal abandonment proceedings the ICC investigates the social, economic, and environmental ramifications of the proposed abandonment. The ICC process appears to be complete in considering everything from historical value to the future growth needs of affected communities. The abandonment of essential rail links in the coal delivery system does not appear, therefore, to be a significant concern.

1.3.3 Sabotage Potential

A scenario in the escalation of public reaction to the transportation of coal and other energy materials may involve acts of physical interference,

including sabotage. It would take, at least, an effort organized at the level of a guerrilla war to significantly disrupt railroad service. Railroad vulnerability appears to be less than that of pipelines because of existing redundant routes and inherently rapid repair capabilities. Slurry pipelines might be put out of action for long periods, especially during freezing weather. This could be a severe impact on plants that have no alternative service. Action against individual barges and trucks would have, at the most, transitory impact on local coal supplies. The common practice of stockpiling coal and the overall supply system flexibility mitigate the potential impact of sabotage.

1.3.4 Dependence on Diesel Fuel

Coal transportation by railroad, waterway and by truck depends on diesel fuel for motive power. This is considered by some to be a significant potential vulnerability and future problem. In the event of a future long-term embargo or shortage of petroleum products, diesel fuel is expected to be allocated on a priority basis. If the national use and dependence on coal continue to increase, coal transportation would qualify as a high priority for fuel allocation. Development of strategic fuel storage and the anticipated future production of synthetic fuels tend to mitigate this concern.

1.3.5 Competition for Barges at Harvest Time

Although coal transportation by barge can be affected by the availability of barges at harvest time is not an apparently significant potential problem. As a generally predictable seasonal event the concern should be routinely manageable with appropriate planning, stockpiling and the use of alternative transport modes.

1.3.6 Impact of Requiring Scrubbers on Coal-Fired Plants

The potential consequences of the Clean Air Act Amendments are far-reaching and include a possible impact on the overall growth in coal demand. Other effects may be a reversal in the current shift to the use of Western coal and changes in coal flow patterns. An equilibrium may evolve in which the overall effect may be slower rates of demand growth than rates currently

projected. While this could be a significant impact on the national goal of increasing coal use, concerns relating to the adequacy of coal transportation would tend to be reduced correspondingly.

1.4 PERCEIVED CONCERNS

Problem issues in this category are the focus of controversy, but are judged here to be unsubstantiated or inconsequential. The following items are judged, in their present perspective, not to be significant concerns.

1.4.1 Railroad Capital Requirements

Railroads offer a lower rate of return on investment capital than most industries. Because of this, the necessary capital for locomotive and car building, track maintenance and plant expansion needed to transport the projected increase in coal traffic may not be readily obtainable. Several historic precedents and anticipated future scenarios suggest that this should not critically affect coal transportation. Capital generally follows the opportunity for profit. With continued management initiative, the potential of new coal business revenue on all but totally dilapidated or bankrupt railroads can be expected to generate investment from capital sources in the free market. Utilities are increasingly providing hopper cars for dedicated unit train service and interroad leasing and improved equipment utilization are methods commonly used to increase capacity. A shift to alternative modes of transport would also be encouraged if railroad service became inadequate. This concern appears to be controlled by normal business investment decisions; in an emergency it would be controlled by precedented government intervention and financial assistance.

1.4.2 Availability of Railroad Hoppers and Locomotives to Haul Future Coal Traffic

There has been controversy about whether the projected demands for coal transportation will exceed manufacturers' ability to build hopper cars and locomotives fast enough to provide the necessary service. With the improved equipment productivity provided by unit train operation, the capacity of railroad equipment manufacturers is not expected to be a problem. The pacing

items controlling the increase in coal traffic are mine development and construction of utility generating plants. The lead time for these activities greatly exceeds that for increasing railroad capacity. This concern, therefore, also appears to be unfounded.

1.5 OVERVIEW ON THE ADEQUACY OF DOMESTIC COAL TRANSPORTATION

Current trends in coal transportation suggest a degree of optimism that domestic coal transportation will be adequate to meet future national needs. Competitive transport modes are either in operation or available with current technology to meet projected growth in coal demand. In general, the development of transportation capacity requires less lead time than the lead time required to develop new mines and bring plants on line. Equipment manufacturers appear to have the production capacity for meeting the requirements of future coal traffic growth projections.

The opportunity for profit should be a continuing incentive for management to develop needed transportation capacity and for investors to provide the necessary capital to finance equipment acquisition and facility expansion. Where insolvency may be a deterrent to free market investment, the government has established the precedent of providing financial assistance.

The potential problems in coal transportation that can be identified today are being addressed by a broad range of industry- and government-sponsored effort. Although there appear to be some gaps on the coverage of ongoing research and development, only a relatively modest number of new programs appear to be warranted to fill these gaps.

While local or temporary delivery problems may always occur for any of a number of reasons, coal consumers can isolate themselves from significant variability in supply by stockpiling coal and other forms of anticipatory management. For all of the above reasons, it does not appear that transportation will be a critical impedance in the overall national coal supply system unless a remarkable change occurs in the political or social order of the nation.

The results and recommendations of this study are based on early 1978 perspectives and are expected to require revision as future conditions change.

2.0 INTRODUCTION

Coal has been a major energy source in the United States for a number of years and provided over half the total U.S. energy needs in the period 1890-1940. Although coal's contribution declined thereafter to 17% in 1973, diminishing domestic reserves of petroleum fuels and uncertainties associated with foreign supplies accent the need for coal as a major fuel source of the future.

The demand for coal is anticipated to grow substantially during the balance of the century as other sources of energy become more expensive or are depleted. Projections of 1985 coal production generally agree at approximately 1 billion tons. Forecasts for the year 2000 range from 1.4 billion to 2.0 billion tons. These figures represent the progressive doubling and tripling of the 659 million ton coal production recorded in 1976. It is likely that future problems in coal transportation will result from the need to transport these much larger volumes of coal.

2.1 EMPHASIS AND ORGANIZATION OF THIS REPORT

The primary purpose of each task in this project is to provide information and perspective that may contribute to the evaluation of research and development (R&D) needs and priorities, and to structuring future program plans relating to energy material transportation. This report provides 1) a summary characterization of the existing domestic coal transportation system, 2) the identities and judged priorities of potential future problems in coal transportation and 3) recommendations for specific programmatic effort that may mitigate the anticipated impact of these concerns.

This report addresses potential problems anticipated to impact the adequacy of coal transportation for U.S. domestic needs, between now and the year 2000, with emphasis on concerns which do not appear to be receiving enough attention in current programs. The scope of this study concerns the future adequacy of coal transportation from the mine to the consumer and

transportation for waste products of coal combustion. It is recognized that labor relations in the coal industry may result in prolonged work stoppages that could curtail utility operations and industrial production. Though the impact of this concern may be potentially much larger than that of any potential transportation problem, this problem is considered to be strictly associated with coal production and therefore, outside the scope of this study.

To be concise, this report does not discuss many details of system characteristics and problem issues that are available in the literature. A principal reference for this information is work performed by the Congressional Research Service which provides detailed reviews and analyses of national energy transportation systems, issues and problems.⁽¹⁾

Several concerns which appeared to be of high priority initially have been resolved or delegated to lower priority during the course of this study. Other potential problems were judged to increase in importance as this work progressed. This report considers potential problems in coal transportation as they appear to exist or can be forecasted in the first quarter of 1978.

The balance of this report is organized as follows:

- Section 3 provides a summary characterization of the existing U.S. coal transportation system, including growth forecasts to the year 2000.
- Section 4 contains summary assessments of specific potential problems, consequences, the basis for these problems and related program activities. Recommendations for new programmatic effort and priority judgements are also included.
- Section 5 identifies potential concerns that are judged not to require additional effort at present.

References are listed in Section 6, and supplemental information is contained in the appendices.

3.0 COAL TRANSPORTATION SYSTEM OVERVIEW

Section 3 summarizes coal production projections, geographic coal supply and demand distributions, and the characteristics of existing coal transportation systems. This overview provides perspective on the potential problems and recommendations contained in Sections 4 and 5.

3.1 PROJECTED COAL PRODUCTION

Although coal production has continued to expand slowly during this century, it has provided a declining fraction of the nation's energy until the last two years. Between 1950 and 1975, coal production increased more than 40% to 648 million short tons.^(1,2) During this period, coal's contribution to the national energy supply dropped from 38% to a low of 17%. Recent policy decisions have attempted to reverse this trend, and by 1985 production is expected to approximately double as coal replaces diminishing sources of alternative energy.

The anticipated level of coal production through 2000 has been forecast in several surveys, as shown in Table 1. The National Coal Utilization Assessment (NCUA) Program conducted by Argonne National Laboratory provides several scenarios which project 1985 coal production between 926 and 979 million tons, and year 2000 coal production between 1.4 and 2 billion tons.⁽³⁾

The Project Independence scenarios, business-as-usual (BAU) and accelerated demand (AD), consider coal production in seven coal-producing regions.⁽⁴⁾ New mines were assumed to be opened annually to add new coal sources as well as to replace depleted mines. The BAU growth rate was assumed to be 5.4% per year from 1972 to 1980 and 3.8% per year after 1980. The accelerated demand scenario assumes that air pollution control regulations would have no adverse impacts on coal consumption and that public lands would be leased as necessary for new mines. Recent legislative pressures to require scrubbers on all coal-fired generating plants suggests that the accelerated demand scenario may be unreasonably optimistic.

The Bureau of Mines (BOM) coal forecast, United States Energy Through the Year 2000,⁽⁵⁾ is a forecast of consumption based on specific assumptions.

TABLE 1. Coal Projections Through 2000

		Million Short Tons								
	Annual Growth Rate (Percent)	1973	1974	1975	1976	1977	1980	1985	1990	2000
National Coal Utili- zation Assessment Program ⁽³⁾				645				926 to 979		1394 to 2020
Project Independence (FEA) ⁽⁴⁾										
Business as Usual	5.4 ≤ 1980 3.8 > 1980	599				754	895	1100	1300	
Accelerated Demand						927	1376	2063	2803	
U.S. Energy Through the Year 2000 (BuMines) ⁽⁵⁾	3.8		616				806	998		1660
U.S. Energy Outlook An Initial Appraisal (NPC) ⁽⁶⁾				724			910	1071		
U.S. Energy Outlook	6.7			754		1023	1570			
Coal Availability	4.5			713		876	1134			
NPC ⁽⁷⁾	3.6			695		830	1004			
Actual Coal Production		591	609	648	659	341 ^(a)				

(a) Six months preliminary statistics.

These assumptions were that strip mining regulations would not become too restrictive, leases would be available for Western coal lands, and government support of energy R&D in coal mining, conversion, and utilization would continue.

The National Petroleum Council^(6,7) published three scenarios of future coal supply through 1985. The annual growth rate of 6.7% was chosen as the maximum feasible growth rate under present conditions. The minimum growth rate anticipated was 3.6% per year.

There is a fair consensus among these forecasts if the accelerated demand and 6.7% growth scenarios are discounted. The other 1985 estimates are between 926 and 1,100 million tons and the range of year 2000 projections in the NCUA Program is consistent with the BOM forecast. Many factors that were not fully considered in these forecasts can limit coal production or demand. Recent developments in the mining industry including increased safety precautions, deteriorating labor-management relations, and a decreasing average age of miners have resulted in a downward trend in mine productivity. The possible requirement for scrubbers^(a) on all coal-fired generating plants could greatly increase the cost of electricity and significantly reduce demand. Any or all of these factors have the potential of reducing future coal production or demand below the levels of current projections.

3.2 GEOGRAPHICAL DISTRIBUTION OF COAL SUPPLY AND DEMAND

Transportation requirements for coal, now and in the future, depend on the geographical distribution of supply and demand regions.

3.2.1 Supply Regions

The continental U.S. coal resources are estimated to be greater than three trillion tons. Two hundred billion tons are reserves recoverable under present economic conditions and available technology; 400 billion tons are considered to be exploitable under anticipated future conditions.⁽²⁾ Coal reserves are grouped by United States Geological Survey (U.S.G.S.) province

(a) This concern is discussed in Subsection 5.1.

FIGURE 1. Coal Reserves of the U.S. Grouped by U.S.G.S. Province (Arabic numerals, dashed lines) and Geographic Divisions (Roman numerals, solid lines)

and by geographical region in Figure 1. These provinces and regions are defined in Appendix A. Four U.S.G.S. coal provinces, the Eastern, Interior, Northern Great Plains, and Rocky Mountains, contain 90% of the coal reserves in the contiguous states.

U.S. coal resources and reserves are summarized in Table 2^(4,8) and resources are listed by rank in Table 3⁽⁹⁾. Approximately 60% of the national coal reserves contain one percent or less sulfur by weight; most of this is Western coal. When sulfur, moisture and ash content is considered per Btu, the advantage of Western coal over Eastern coal is reduced somewhat. Mandatory requirements for scrubbers in coal-fired plants could further decrease this advantage.

Alaskan coal reserves are estimated to contain a trillion tons of coal. With existing technology, more than 130 billion tons of this coal could be mined. Unfortunately, there is presently no cost-competitive way to ship this coal to consumers in the lower 48 states. During the last 15 years, nine coal mines have opened in Alaska and all nine have subsequently gone out of business. The only active Alaskan operation is the Usibelli Coal Mine, Inc., 120 miles south of Fairbanks. It produces 750,000 tons a year, all consumed within Alaska.

TABLE 2. U.S. Coal Resources and Reserves^(4,8)
(billions of tons)

Province	Resources			Reserves			
	Identified	Undiscovered	Total	Identified	Quadrillion Btu	Bituminous Coal Only	Mean Sulfur Content (%)
Eastern	276	45	321				
North Appalachian				73.2	1922	66.1	2.0
South Appalachian				39.1	1052	38.9	1.0
Interior	277	259	536				
Midwest				104.6	2492	104.5	3.1
Gulf				4.3	71	4.3	1.0
Norther Great Plains	695	763	1458	175.4	3364	175.4	0.5
Rocky Mountains	187	395	582	23.7	568	23.6	0.5
Pacific Coast	<u>146</u>	<u>181</u>	<u>327</u>	<u>13.6</u>	<u>262</u>	<u>13.6</u>	0.2
Total	1581	1643	3224	433.9	9731	426.4	

TABLE 3. Rank of Identified
U.S. Coal Resources ⁽⁹⁾

<u>Rank</u>	<u>Identified Resources Billions of Tons</u>
Anthracite	21
Bituminous	686
Subbituminous	424
Lignite	<u>449</u>
Total	1580

The development of a coal field depends on compositional characteristics such as depth, seam thickness, and availability of water resources and also to a large extent on the ownership of the land and mineral rights. The Federal government owns approximately 48% of all coal lands located in Alaska, Utah, Colorado, Montana, North Dakota, Oklahoma, and Wyoming. Federal ownership in these states ranges from 4% in Oklahoma to 97% in Alaska. The major coal lands east of the Mississippi are primarily privately owned. The Federal government owns less than 4% of the coal lands in all other states.

Most U.S. coal is mined today from privately owned lands. In 1971, only 3% of the coal mined in the U.S. came from about 800,000 acres owned by the Federal government. However, more than 85 million acres of coal lands are Federally owned and future development of coal mining will be predominantly on these lands.

3.2.2 Demand Regions

A projection of coal demand by major consuming sectors ⁽⁵⁾ is shown in Table 4 for the period 1974-2000. The consumption sectors, ranked by current percentage of the total demand, are as follows: electrical generation, industrial, export, household and commercial, and synthetic fuels. In this BOM forecast the annual domestic consumption is projected to be 923 million tons in 1985, and 1.56 billion tons in 2000.

TABLE 4. Consumption of United States Coal Resources by Major Consuming Sectors, 1974 Preliminary and Projected to the Year 2000(a)(5)

	1974	1980	1985	2000
Domestic Consumption				
Household & Commercial				
Million short tons	10.9	4	3	--
Trillion Btu	292	100	100	--
Percent of total (b)	2.0	0.5	0.4	0
Industrial				
Million short tons	155	185	190	228
Trillion Btu	4,210	4,800	4,930	5,910
Percent of total (b)	28.5	25.2	21.1	15.7
Electrical Generation				
Million short tons	390.6	547	704	941
Trillion Btu	8,668	12,250	15,700	20,700
Percent of total (b)	58.7	64.3	67.3	55.1
Synthetic Gas				
Million short tons	--	--	26	300
Trillion Btu	--	--	520	6,000
Percent of total (b)	0	0	2.2	16.0
Synthetic Liquids				
Million short tons	--	--	--	91
Trillion Btu	--	--	--	2,140
Percent of total (b)	0	0	0	5.7
Total Domestic Demand				
Million short tons	556.5	736	923	1,560
Trillion Btu	13,170	17,150	21,250	34,750
Percent of total (b)	89.2	90.0	91.0	92.5
Export Demand (c)				
Million short tons	59.1	70	75	100
Trillion Btu	1,584	1,900	2,100	2,800
Percent of total (b)	10.8	10.0	9.0	7.5
Total Demand				
Million short tons	615.6	806	998	1,660
Trillion Btu	14,774	19,050	23,350	37,550

(a) Includes anthracite, bituminous, and lignite.

(b) Based on Btu content.

(c) Net exports.

3.2.2.1 Electrical Utilities

In 1975, domestic coal deliveries to electrical utilities reached 429.2 million tons, a 46.6 million ton increase over 1974. In 1974, electrical generation consumed 59% of the coal available. This percentage is anticipated to increase to 67% in 1985 and decrease to 55% by 2000, as is shown in Table 4. The decrease is due to the anticipated production of synthetic fuel from coal.

The Federal Power Commission (FPC) report summarizing the 1975 cost and quality of steam plant fuels⁽¹⁰⁾ is the source of data in Tables 5 through 7. Coal deliveries to utilities ranked by geographical region are listed in Table 5. The five major coal-producing states are shown in Table 6. Most of the coal from these states is consumed in the East. The distribution of Western coal mined for utilities is given in Table 7. Fifty-six percent of this coal remains in the West.

TABLE 5. Coal Deliveries to Electric Utility Power Plants 25 MW or Greater^(a)⁽¹⁰⁾

Geographic Region	1974 Deliveries (1000 tons)	1975 Deliveries (1000 tons)	Absolute Difference	Percent Change
New England	1,941	1,274	-667	-34.4
Middle Atlantic	43,834	43,752	-82	-0.2
East North Central	130,806	144,742	13,936	10.7
West North Central	36,685	43,471	6,786	10.7
South Atlantic	75,604	79,215	3,611	4.8
East South Central	56,057	70,831	14,774	26.4
West South Central	5,137	9,146	4,009	78.0
Mountain	28,468	32,587	4,119	14.5
Pacific	4,100	4,200	100	2.4
U.S. TOTALS	382,632	429,218	46,586	12.2

(a) Excludes anthracite and imported coal.

TABLE 6. Five Largest Coal-Producing States for Electric Utility Use⁽¹⁰⁾

State	1974 (1000 tons)	1975 (1000 tons)	1975 Percent of Total
Kentucky	90,118	100,941	23.5
Illinois	46,337	49,250	11.5
West Virginia	41,533	43,924	10.2
Pennsylvania	41,806	42,003	9.8
Ohio	36,222	39,607	9.2
TOTAL	256,016	275,725	64.2

TABLE 7. Destination of Western Coal Mined for
Electric Utilities (in 1000 tons)⁽¹⁰⁾

<u>Destination</u>	<u>1974</u>	<u>1975</u>	<u>Difference</u>	<u>% Change</u>
Western States	37,834	43,379	5,545	14.7
Nonwestern States				
States in the West				
North Central Region (Nebraska, Kansas, Missouri, Minnesota, Iowa)(a)	10,659	12,713	2,054	19.3
States in the East				
North Central Region (Wisconsin, Illinois, Indiana, Ohio, Michigan)	13,004	20,592	7,588	58.3
Other	200	175	-25	-12.5
Total Nonwestern States	<u>23,863</u>	<u>33,480</u>	<u>9,617</u>	<u>40.3</u>
TOTAL	61,697	76,859	15,162	24.6

(a) For this tabulation, the Dakotas were included with the Western States.

3.2.2.2 Industrial

In 1974, the industrial sector consumed 155 million tons of coal or 28.5% of the available coal. This is anticipated to increase to 190 million tons in 1985 (21.1%) and 228 million tons in 2000 (15.7%), as shown in Table 4. Coal's share of the industrial market will decline from 17.5% in 1974 to 13.6% in 2000; purchased electricity is expected to compensate this decline as shown in Table 8.

Industrial consumption can be broken into six categories: primary metals; chemicals and allied products; aggregates; paper and allied products; food and kindred products; and transportation equipment. The energy consumption for these groups and their energy intensiveness is included in Table 9.

Half the energy used in the industrial sector is for heating processes. The average heat transfer efficiency of direct heat operations ranges from 20% to 30%. Heat treating furnaces also operate at 30% heat transfer efficiency. Space heating consumes a small portion of the coal used by industry.

TABLE 8. Consumption of Energy in the Industrial Sector,
1974 Preliminary Data and Projections to the
Year 2000(8)

	1974	1980	1985	2000
Coal:				
Fuel Uses				
Million tons	150.7	177	180	210
Trillion Btu	4,093.3	4,600	4,680	5,460
Nonfuel Uses				
Million tons	4.2	8	10	18
Trillion Btu	114.7	200	250	450
Total coal				
Million tons	154.9	185	190	228
Trillion Btu	4,208	4,800	4,930	5,910
Percent of total	17.5	18.5	17.1	13.6
Liquid hydrocarbons:				
Million barrels	1,137	1,358	1,539	2,103
Trillion Btu	6,044	7,500	8,500	11,600
Percent of total	25.1	29.0	29.5	26.7
Gaseous Fuels:				
Billion cubic feet	10,900	9,700	9,490	11,250
Trillion Btu	11,129	10,000	9,740	11,260
Percent of total	46.2	38.6	33.8	25.9
Purchased Electricity: (a)				
Billion kWh	617	1,057	1,647	4,302
Trillion Btu	2,699	3,600	5,620	14,680
Percent of total	11.2	13.9	19.6	33.8
Total Sector Energy Inputs:				
Trillion Btu	24,080	25,900	28,790	43,450

(a) Includes industrial hydroelectric power.

TABLE 9. Annual Fuel Consumption and Energy
Intensiveness of Industrial Users(8)

Industrial Group	Coal and Coke Consumption 10 ¹² Btu/Year	Relative Energy Intensiveness (a)
Coke and coal	--	0.072
Chemical	696	0.066
Primary metals	1706	0.052
Stone, clay, glass and concrete	702	0.090
Paper and allied products	373	0.063
Food and kindred products	177	--
Transportation equipment	78	--
Total	3732	

(a) Energy intensiveness: Value of energy consumed per
dollar value of production goods shipped out.

3.2.2.3 Residential and Commercial

In 1974, the residential and commercial sector consumed 30% of the energy used in the United States; 10.9 million tons of coal, representing 2% of the coal supply, was the source of part of this energy. Space heating and cooling and water heating are the major coal consumers in this category. In 1985, only 3 million tons of coal is expected to be used for these purposes, and by 2000 this use of coal will become negligible as indicated in Table 4.

3.3.2.4 Other

By the year 2000, coal conversion to synthetic gas and liquid is expected to be significant, generating a coal demand approaching 400 million tons according to Table 4. Although foreign coal is consumed in the U.S., mainly by the electric utilities, net exports are anticipated to increase to 100 million tons per year in 2000.

3.3 TRANSPORTATION MODES

Five transportation modes are presently used to move coal in bulk. The modal analysis of coal transportation in 1975 provided by the U.S. General Accounting Office (GAO)⁽¹¹⁾ is shown in Table 10, together with the BOM scenarios for 1985 and 2000.⁽⁵⁾

TABLE 10. Coal Transportation by Mode
(millions of tons)

	1975 ⁽¹¹⁾	BOM Scenarios ⁽⁵⁾	
	<u>Actual</u>	<u>1985</u>	<u>2000</u>
Rail	418	637	1023
Water	69	106	170
Truck	79	120	193
Mine-mouth use	74	113	181
Other (including slurry pipelines)	<u>8</u>	<u>12</u>	<u>19</u>
Total	648	988	1586

The BOM scenarios do not project any significant change in the relative traffic share of each mode. There are many future conditions which may, in fact, cause the distribution of coal traffic to change between the competing modes. These factors include future slurry pipeline, waterway and synthetic fuel developments, the financial stability of the railroads and energy conservation policies. Current coal transportation statistics (including fuel consumption, shipping distances, container numbers, capacity, utilization, shipment size, average speed, transit time and relative costs) are summarized in Table 11 based on data supplied by References 8, 9, 11, 12 and 13.

For distances greater than 50 miles, bulk coal transportation is dominated by the railroads and waterways, which generated 75% and 23% respectively of the total ton miles in 1973. Trucks, conveyors and slurry pipelines accounted for the remaining 2% of these ton miles. These are needed to move coal where rail or water transportation is unavailable or impractical.

A summary origin-destination map of domestic coal movements in 1976 is shown in Figure 2. Two types of coal movement are portrayed. Interregional transport is represented by arrows drawn from supply region centers (represented by dots) to the boundaries of demand regions. Intraregional coal transport is indicated by semicircles. The coal volumes transported are represented by the scale size of the respective indicators. Supply regions (dashed line boundaries) and demand regions (solid line boundaries) shown in Figure 2 correspond to those in Appendix A, Figure A-3.

Table 12 shows equipment requirements in 1973 and 1985 projections for rail and waterway traffic.⁽¹³⁾ Bulk coal shipped by rail and waterway currently requires a fleet of over 250,000 hopper cars^(a), 2500 locomotives, and 3700 barges. A significant fraction of railroad equipment has a low duty cycle as a result of inadequate planning and service coordination. However, by accelerating capital improvements and increasing equipment utilization, the transportation industry can be expected to accommodate the additional coal volume that is projected in the balance of the century.

(a) Approximately 70% of all open top hoppers are used in coal service.

TABLE 11. Coal Transportation Statistics^(8,9,11,12,13)

	Fuel Consumption (Btu per (ton mile))	Average Distance Shipped (miles)	Utilization (billion (ton miles)	Number of Containers (thousands)	Container Capacity (ave-max tons)	Container Utilization (ave-best practice ton miles/container percent)
Railroad	250-690 u	300	119	210 - 335 h	77 - 100 h	0.56 x 10 ⁶ 7.2 x 10 ⁶ 7.7%
Water carrier	380	350	37	3.7 b	1160 - 1400 b	9.8 x 10 ⁶ 21 x 10 ⁶ 46.7%
Truck	970	10	0.7		20 r	
Conveyor		5	0.25			
Slurry	295	273	1.4			

	Shipment Size (ave-max containers per shipment)	Shipments at 100% Capacity (min-max thousands shipments)	Average Speed (mph)	Transit Time (hours)	Fixed Costs (\$ per 10 ¹² Btu-mile)	Operating Costs (\$ per 10 ¹² Btu-mile)	Cost (\$ per ton mile)
Railroad	67 - 100 h	30 - 60	<20	15	u 17 c 31	u 266 c 483	u 0.007 c 0.013
Water carrier	10 - 14 b	3 - 15	6	50	16	119	0.003
Truck		6000	10	1	185	1670	0.045
Conveyor					400	1020	0.076
Slurry					177	84	0.006

Key: h = hopper car(s)
b = barge(s)
r = on road
u = dedicated unit train
c = conventional train

FIGURE 2. Domestic Coal Movements Between Geographic Divisions - 1976⁽⁹⁾

TABLE 12. Coal Transportation and Equipment Requirements for 1973 and 1985⁽¹³⁾

Mode	1973	1985
Rail:		
Total tons ^(a) (thousand short tons)	397,158	894,106
Total ton-miles (billions)	119.1	444.9
Average length of haul (miles)	300	512
Hopper cars (100-ton)	161,760	125,700
Hopper cars (76.6-ton) ^(b)	211,170	164,100
Average annual ton-miles/100-ton car equivalent (millions)	0.74	3.54
Locomotives	2,580	6,900
River and ex-river:		
Total tons (thousand short tons)	104,679	229,655
Total ton-miles (billions)	36.6	71.8
Average length of haul (miles)	350	307
Barges: ^(c)		
900-ton	--	1,210
1,400-ton	--	2,640
Total	(d) 3,730	3,850
Total, 1,400-ton equivalent	3,090	3,418
Towboats ^(e)	570	405
Average annual ton-miles/1,400-ton barge equivalent (millions)	12.1	21.0

(a) Includes all-rail and bimodal rail shipments.

(b) Average size hopper car used in 1974.

(c) Differential between barge size dictated by operation capacities of the rivers.

(d) Average size barge in 1973 was 1,160 tons.

(e) 1973 towboats required for coal were estimated by authors.

The characteristics of each principal coal transportation system are discussed in more detail below.

3.3.1 RAILROADS

If coal consumed at the minemouth is excluded, railroads carry about 75% of all coal moved and this generates approximately 15% of the total rail revenue ton-miles. The average rail haul for coal in 1975 was 300 miles, indicating that over half of the coal produced in a region was consumed in the same region. This is supported by a sample of 923 million ton-miles of

coal movement reported in the 1975 Waybill statistics of which 617 million ton-miles or 67% went to destinations in the same region as the origin.⁽¹⁴⁾ The U.S. rail system and regional coal movements are indicated in Figures 3 and 4 respectively. Figure 4 is drawn to the same scale as Figure 2 for comparison.

Coal moves primarily in open hopper cars. New cars, with 100-ton capacity, are replacing older cars of 50 to 70 ton capacity. This trend is expected to continue until the 100-ton car becomes standard as is illustrated in Figure 5.⁽¹³⁾ The most efficient movement is by unit train, which may carry 6,000 tons or more from a single origin to a single destination. Unit trains run directly from mine to utility, are loaded and unloaded mechanically for rapid turnaround, but nevertheless, require a four-man crew to comply with labor laws and union contracts. Unit trains can bypass switching yards enroute and avoid the attendant cost and delay.

A possible threat to unit train operations is their effect on the communities through which they must pass^(a). In addition, unit trains have rates almost one-third less than those of conventional trains and are regulated by the Interstate Commerce Commission (ICC). The adequacy of unit train rates has recently become the subject of controversy requiring re-examination by the ICC.^(b) In prescribing rail rates, the ICC must balance two aspects of the public interest. One is the consumer interest and a need to minimize escalations in the cost of energy. The other is the railroad interest and the need to maintain the development of viable transportation systems to accommodate future growth in coal demand. In 1974, unit trains moved 26% of all coal mined.⁽¹⁵⁾ This is expected to increase to 50% by 1985. In 1973, 81% of the unit trains operated in the eastern U.S.⁽¹³⁾ This is likely to change as increasing emphasis is placed on utilizing Western coal.

(a) This concern is discussed in Subsection 4.1.

(b) This concern is discussed in Subsection 4.2.

FIGURE 3. U.S. Rail System

FIGURE 4. Coal Movement by Railroad - 1976

FIGURE 5. Average Open-Top Hopper Car Capacity⁽¹³⁾

The single carload movement of coal for small industrial consumers requires a small number of coal cars to be hauled in general freight trains. Because general freight may require several switching operations enroute, the single carload shipment of coal is slower and more costly than shipment by unit train. The single carload customer usually lacks rapid unloading facilities, and therefore, the turn-around of cars in single load coal traffic is slower than for a unit train.

Freight cars are generally owned by individual railroads with payment required from other railroads which use them and from shippers who hold them in excess of a reasonable time period. Per diem charges are relatively low and often cheaper than warehousing so that there is little incentive for shippers and railroads to provide rapid turnaround for off-road cars. Railroads have had difficulty keeping track of cars and only recently has automation begun to alleviate car identification and allocation problems. There has been a trend recently for electric utilities to purchase their own hopper

cars. This is anticipated to continue because of the advantages afforded in favorable rates and better car control. Electric utility ownership totaled 4979 cars in 1974.⁽¹⁶⁾

The use of unit trains usually involves large investments for loading and unloading facilities which are economical only if frequent shipments are processed. The current best operating practice, estimated from 1973 experience, shows that unit trains can be moved at an average 20 miles per hour during a 300-day year. A car in unit train service would be capable, therefore, of producing 7.2×10^6 ton-miles annually. Best practice for mixed train loading was estimated at one-fourth the ton-mile capacity of a car used in unit trains, or 1.8×10^6 ton-miles annually. Average effectiveness of coal hopper cars in mixed train service was about 0.6×10^6 ton-miles annually.⁽¹³⁾

With the trend toward heavier coal cars, more track maintenance may be needed. Railroads typically have a low rate-of-return on investment. Uncertainties about the railroads' ability to raise sufficient capital are a source of concern about the future adequacy of coal transportation.^(a) In most cases, railroads can be expected to operate coal traffic at a profit. This, together with the need for gradual, not rapid, expansion to meet the anticipated growth in demand provides a basis for optimism, that the overall future capacity of the railroads will be adequate.

3.3.2 Waterway

The domestic waterway system consists of 25,543 miles of useable inland channels plus the Great Lakes and intracoastal waterways. The principal systems are shown in Figure 6. In 1973 about 23% of the total ton-miles generated by coal movement were on domestic waterways. Coal transport amounted to 15% of all tonnage shipped by water. The average water movement distance for coal is about 350 miles.⁽¹¹⁾ In 1975 over 100 million tons of coal were shipped on the inland water system, whose primary arteries are the Mississippi, Monongahela, Green, Ohio, Tennessee, and Illinois Rivers.

(a) This concern is discussed in Subsection 5.2.

FIGURE 6. Waterways of the U.S.

Figure 7 indicates the relative inter- and intraregional movement of coal by waterway. Domestic coal movements also take place on the Great Lakes and by tidewater. The projected 1985 total tonnage and average length of haul for coal on various river systems is shown in Table 13.

Because few waterways are directly adjacent to coal mines, most waterway coal movements include a short truck or rail haul from the mine. Most utilities and industrial plants using waterborne coal are located on waterways, and the coal is unloaded directly at the destination. The average waterway is a circuitous route between origin and destination. Nevertheless, waterway rates which have been less than half the corresponding rail rates, make it attractive for coal haulage despite longer distances and slower speeds. This advantage is subject to change with the anticipated implementation of user charges and increasing waterway traffic congestion.^(a)

TABLE 13. Average Length of Haul and Total Tonnage Calculations for Projected 1985 Coal on the River Systems⁽¹³⁾

<u>River</u>	<u>Total Coal Tonnage (thousand short tons)</u>	<u>Mean Length of Haul (miles)</u>
Alabama	1,505	396.0
Arkansas	787	270.8
Green	49,585	98.0
Gulf Intracoastal Waterway	6,336	625.4
Illinois	13,691	225.1
Kanawha	46,824	64.4
Lower Mississippi	5,927	793.1
Ohio	212,533	202.0
Tennessee	19,595	100.0
Upper Mississippi	8,243	593.2
Mississippi River System and Gulf Intracoastal Waterway	229,655	304.6

(a) These concerns are discussed in Subsection 4.2.

FIGURE 7. Coal Movement by River - 1976

Most domestic waterborne coal movement goes by open hopper barge, in barges ranging from 900 (standard) to 1400 (jumbo) tons capacity. Data on barge sizes and comparative rail and waterway costs are given in Appendix B. In 1973 coal traffic required a fleet of 3730 barges with an average capacity of 1,160 net tons. Average waterway speed is about 6 mph but varies depending on whether the tow is traveling up or down stream. The BOM has estimated the equivalent average annual ton-miles per 1400-ton barge based on 1973 data.⁽¹³⁾ For an average haul of 350 miles, utilization would be 12.1 million ton-miles per year. Projections for 1985 indicate an improvement to 21 million ton-miles/year per barge as the number of 1400 ton barges increases.

Barges move in tows, which may consist of as many as 36 units in open water. On the inland waterways most coal moves in tows of 10 to 14 barges. The Monongahela and the Allegheny Rivers are limited to 4 to 6 standard barges. Many sections of inland waterways are becoming congested and further construction of locks and dams is needed to increase capacity. Lock sizes determine the size of individual barges and tows, and the lock system therefore sets the ultimate capacity of the waterway.

As with rail coal movements, many barges make an empty backhaul although hopper barges are not particularly specialized and can handle a variety of bulk materials. In contrast to rail cars, most barges make a rapid turnaround and are rarely used as floating warehouses.

Towboats are diesel powered and recently boats with up to 10,000 horsepower have been developed for use with very large tows. Towboats, which actually push, are used on inland waterways while tugboats, designed for open seas, operate the coastal waterways. Major coal movement on the intra-coastal waterway is in the Gulf, out of the Southern Appalachian fields via the Warrior/Alabama river system. Coal moves from the Northern Appalachian fields to Hampton Roads for export but domestic coal movement in the Atlantic Intercoastal Waterway has fallen off as East Coast utilities shifted to residual oil.

Total tonnage and relative importance for both Great Lakes and tidewater shipments of coal declined in the last decade. Five percent (33 million net tons) and less than one percent (5 million net tons) of total coal

shipments were moved on the Great Lakes and by tidewater in 1976, respectively.⁽⁹⁾ Great Lakes shipments of coal in 1973 originated primarily at Lake Erie ports for movement to United States and Canadian ports. An additional 5.4 million short tons were loaded on Lake Michigan ports.

New superships will be used to transport coal from Superior, Wisconsin, to the Detroit region. This should trigger greater flow of Western coal across the Great Lakes. These ships are a result of a \$180 million sale of low-sulfur coal by Decker Coal Co. to Detroit Edison's St. Clair plant near Detroit. The coal is to be delivered over 25 years by Burlington Northern in 10,000 ton unit trains to a terminal at the head of Lake Superior. Coal will be transferred at a rate of 35,000 tons per hour to ships that are 1000 ft long, 100 ft wide, and have a 62,000 ton capacity.

Domestic tidewater shipments of coal in 1976, as reported by the Bureau of Mines, totaled 5.34 million short tons and were loaded primarily at Hampton Roads, Virginia.

3.3.3 Truck

In 1973 over 11% of the total coal shipments were made by truck, a 3% rise from 1962. Truck transportation is dominant in the short haul segment of coal shipping and is the most flexible mode. However, it is not significant in the cross-country movement of coal. The average truckload haul of coal is 50 to 75 miles.⁽¹⁾ Most truck movements occur at the collection end of mines, railheads or waterways; either very large off-road vehicles or short over-the-road hauls are used to move the coal. Small producers and small consumers are also served by truck.

In 1976 Ohio and Pennsylvania received more than 46% of the total shipments made by truck.⁽⁹⁾ The major disadvantage of truck transport is that trucks are not energy efficient in moving large quantities of bulk materials over long distances.

The operating costs for four off-road truck sizes are presented in Figure 8.⁽¹⁶⁾ This figure shows that the relative transportation differences between truck sizes do not change much with haul distance.

FIGURE 8. Effect of Coal Haul Distance on Cost per Ton⁽¹⁷⁾

3.3.4 Slurry Pipelines

Slurry pipelines are now used in various parts of the world to transport solid materials in liquid carriers. Currently, only one coal slurry pipeline, the Black Mesa line in Arizona, is operating in the U.S. As shown in Figure 9, the 18-inch diameter pipeline (completed in 1971) now moves over 5-1/2 million tons of coal annually 275 miles to the Mohave generating station in southern Nevada from the Kayenta coal mine. The line requires 3,200 acre-feet of water annually, or approximately 11 million gallons per 10^{12} Btu of coal transported. A battery of centrifuges at the power plant removes 72% of the water in the slurry. The resulting coal "cake" is further dried to 25% moisture by burning natural gas in a drying air stream.⁽¹⁷⁾

Several other slurry projects are currently under study in the United States. An 800-mile, 30-inch diameter pipeline is planned to link coal-producing areas in Montana, Utah, Wyoming and Colorado to the Pacific Northwest. Use of a methanol vehicle instead of water is proposed, so that the

FIGURE 9. Route of the Black Mesa Slurry Pipeline

entire slurry can be burned.⁽¹⁷⁾ Five additional pipelines are proposed. The most ambitious project is a 1,036 mile, 38-inch diameter line that would carry 25 million tons of coal a year from the Wyoming mines of Peabody Coal Co. and Kerr-McGee Corp. to the Middle South Utilities system in White Bluff, Arkansas. Other projects proposed include: a 1100-mile, 7 million ton a year line from Craig, Colorado, to Houston, Texas; a 180-mile line from Star Lake in northwestern New Mexico to Snoflake in eastern Arizona, and a 180-mile line from Ablon, Utah, to Arrow Canyon in southern Nevada.

The environmental compatability of slurry pipelines is attractive. Under most circumstances a completed, properly protected, and buried pipeline would be less of a public nuisance than a railroad. After the land surface has been restored, local environmental considerations along the right-of-way tend to favor the pipeline.⁽¹⁸⁾ However, access to water at the input end of the line and water disposal at the destination pose important environmental considerations in the overall operation. Also, holding ponds have traditionally been established at regular intervals along the pipeline to provide slurry containment in the event the pipe must be emptied. Slurry dumping at these locations might be needed if a loss of pumping

power occurs. Some operations now avoid this requirement by leaving the slurry in the pipe during times when pumping power is lost. Careful restart procedures are employed to reslurry the coal. Dumping ponds may still be necessary however, if a major break occurs in the pipeline. The eventual implementation of advanced slurries, such as the methanol-coal system may pose additional environmental problems in the event of a break in the pipeline.^(a)

Although in some cases long-distance large-diameter coal slurry pipelines may be able to transport a given amount of coal more economically than a necessary rail system, other matters should also be considered in establishing a national policy toward coal slurry pipelines.^(a) First, coal slurry pipelines are relatively inflexible point-to-point systems that are highly specialized. On the other hand, railroads are a general transportation system, and much of the needed trackage is already in place. Railroads offer greater flexibility to provide additional capacity for transporting coal, other freight and even passengers. Thus, although coal slurry pipelines may offer some economies on specific routes, it can be argued that the maintenance of a viable rail system, instead of encouraging the widespread use of coal slurry pipelines, may better serve national interests.^(a)

3.3.5 Conveyor

In 1973, about 48 million tons of coal were transported by conveyor.⁽¹³⁾ Only large mines can justify the capital investment for an extensive long-distance belt conveyor. Their operating range is usually between 1 and 10 miles. The conveyor is especially useful for transporting coal across mountainous or rough terrain unsuitable for building roads.

An example of long-distance conveyor use is found at Peabody Coal's Kayenta mine in Arizona. The northern and eastern sides of the 3,200 square mile Black Mesa area are almost sheer escarpments of about 1,800 feet. There is no easy way to get a railroad to the mine. A 6-1/2 mile, three flight conveyor was the solution to the Kayenta mine's coal transportation problem. Built by Marathon Steel Co., of Phoenix, Arizona, it transfers 1400 tons of

(a) These concerns are discussed in Section 4.1.

coal per hour from the mine to four silos on the valley floor 2000 feet below. An 80-car electric unit train then hauls the coal 80 miles to the Navajo power plant near Page, Arizona. Today, the Kayenta conveyor does not have a totally adequate capacity to serve the unit train and is supplemented by truck transport.

Peabody Coal has two other conveyors in operation near Morganfield, Kentucky. A 3-mile conveyor system carries coal from the open pit and underground mining facilities of Simco-Peabody Co., Conesville, Ohio, to the Conesville electric generating station of Columbus and Southern Ohio Electric Co. This coal was formerly trucked. However, as the mining operations moved farther away from the plant, a conveyor was installed to reduce over-the-road hauling. Eventually the conveyor system will double its present length. The coal is carried at the rate of 1000 tons per hour.

A study was conducted by Kennecott Copper Corp. to compare the cost of conveyors versus trucks for hauling ore and overburden. Conveyors were shown to be more economic for transporting ore over the entire range of vertical lift and distances considered. Trucks showed an initial advantage for waste haulage up to about a 240 ft lift. Thereafter, the conveyor again had the advantage. These results, shown in Figure 10, are also applicable to coal transportation.

3.4 SAFETY

There are few statistics available which evaluate the safety record of coal transportation directly. Hittman Associates, Inc., has compiled some accident data for rail, barge, and truck transportation modes and related the accident rate to the percentage of coal transported.⁽¹²⁾ These figures are given in Table 14. These data were compiled from national averages and certain regions have higher accident rates.

The Battelle study of coal consumption impacts in the Northwestern States⁽¹⁹⁾ estimates 2.5 deaths and 12 disabling injuries per 10^9 ton-miles based on national rail transportation accident statistics. If unit trains accident rates are proportional^(a), the 445 billion ton-miles projected in

(a) The validity of this assumption is not known.

ORE HAULAGE AND CRUSHING

WASTE HAULAGE AND CRUSHING

FIGURE 10. Comparison of Truck and Conveyor Costs

TABLE 14. Coal Transportation Accidents
per 10¹² Btu Equivalent Hauled

	<u>Fatal</u>	<u>Nonfatal</u>	<u>Man-Days Lost</u>
Rail	0.0610	0.585	59.5
Barge	0.00193	0.00321	0.243
Truck	0.0324	0.692	45.4

1985⁽¹¹⁾ could be expected to cause over 1000 casualties per year. This represents the most significant safety concern in coal transportation.

The nation's railroads are active in a concerted effort to minimize grade crossing accidents and the injuries and property damages that result.

3.5 COAL TRANSPORTATION OVERVIEW

In coal transportation, as in other transportation systems, there is much that can and should be improved. The railroads typically do not operate as efficiently or as dependably as current technology would allow. Operational safety should be improved in all transport modes. Modal and intermodal operations, cooperation and equipment utilization need better management.

However, if the future adequacy of domestic coal transportation is considered from an overall point of view, current trends provide a basis for optimism. Competitive transport modes are either in operation or available with current technology to meet projected growth in coal demand. In general, the development of transportation capacity requires less lead time than the lead time required to develop new mines and bring plants on line. Coal consumers can also isolate themselves from significant variability in supply by stockpiling coal and other forms of anticipatory management. When coal traffic can be operated profitably capital sources in the free market should be available. Precedented assistance by the government can be expected in the event that a major component of the system fails financially. While local delivery problems may always occur for any of a number of reasons, it does not appear that transportation will be a critical impedance in the overall

national coal supply system unless a remarkable change occurs in the political or social order of the nation.

The potential problems in coal transportation that can be identified today are being addressed in a broad range of industry- and government-sponsored effort. Although there appears to be some gaps in the coverage of ongoing research and development, only a relatively modest number of new programs appear to be warranted to fill these gaps.

Section 4 of this report identifies potential problems and consequences which may interfere with some aspects of the development of the coal transportation system required to meet future growth in demand. These concerns should receive immediate or near term attention in R&D programs conducted by industry and the government. Section 5 discusses several apparently less immediate concerns that are presently unsubstantiated or in a state of flux. Time appears to be available to permit monitoring these concerns so that they may be addressed according to their real future significance as conditions change. These concerns therefore, do not appear to warrant new program activities at this time.

4.0 POTENTIAL PROBLEM IDENTIFICATION, EVALUATION AND RECOMMENDATIONS

The primary objective of this task is to identify and prioritize potential problem concerns which may affect the adequacy of domestic coal transportation during the balance of the century. A supporting objective is to recommend necessary and appropriate action to mitigate the potentially adverse effects of problems which may not be receiving adequate attention in other related programs. These assessments and recommendations are intended to provide information and perspective that may be useful to industry and government for evaluating R,D&D needs and priorities, and for structuring future program plans relating to coal transportation.

Specific concerns have been identified which are judged to be important, inadequately addressed by current programs and also appropriate for consideration by the DOE for inclusion in FY 1979 programs. Two categories of these concerns are presented in Section 4: (1) concerns which are potentially serious and may impact in the next decade; and (2) currently moderate concerns with longer-term potential impact.

Concerns were identified by analysis of problem issues associated with currently projected growth scenarios for coal production in the United States, and the characterization of coal transportation contained in Section 3. Additional information and insight were gained from contact with experts in government and in the electric utility, coal mining, and transportation industries. The relative priorities of concerns were judged on their potential impact on the whole transportation system and the potential immediacy of that impact. Domestic coal production levels of ~ 1 billion tons in 1985 and 2 billion tons by 2000 were assumed; if actual future growth is less than these projections, then the possible impact of some concerns may be reduced or delayed.

The diversity of potential problems affecting energy material transportation has suggested the use of a special format for the presentation of the results of the study. The approach taken is the treatment of each specific

potential problem in an independent subsection called a Concern Package, which contains the following summary statements:

- Concern
- Basis
- Related Work
- Appraisal
- Recommended Action
- Priority

In this report, a concern is the statement of a potential problem and its consequences which may impact the future development of coal transportation. The basis is the background evaluation of a potential problem and includes the identification of situations or trends tending to cause the problem. Ongoing or planned programs investigating problem solutions are summarized, when possible, in the related work subsections. The appraisal subsection provides the overall perspective on the concern as a guide to recommending action. Recommendations are made for programmatic and task-level effort to address the concern and gaps in the coverage of related programs. A judgment of priority, the appropriate level of manpower, and timing of the recommended effort are included in the Concern Package for each potential problem.

An almost limitless number of potential problems can be raised as conjectural issues. An attempt has been made to avoid issues which are nebulous, too general, or philosophical. A total of 24 potential problem issues were identified as being worthy of investigation. These issues were analyzed to determine their immediacy and potential impact on coal transportation in the balance of the century. This process eliminated some trivial issues and generated the smaller number of concerns addressed in this and the following section. Several problems can be identified which relate to the development of equipment and equipment reliability to meet the anticipated heavier duty requirements of coal transportation in the future. Other problems have been identified that relate to desirable improvements in system performance and management. These problems appear to be either adequately addressed in current industry and government programs, or relate to the

normal business prerogatives of industrial managers. Neither of these problem categories is discussed among the following concerns.

4.1 POTENTIALLY SERIOUS NEAR-TERM CONCERNS

Concerns identified in this category include public acceptance of coal transportation, impacts of frozen coal, impacts of proposed coal slurry pipelines, and preparedness for sludge transportation.

4.1.1 Public Acceptance of Coal Transportation

- CONCERN

The transportation of coal generates many effects that could cause a deterioration in public acceptance of the system. Reduced public acceptance could lead to new and tighter regulations which might escalate the cost and hinder the development of adequate coal transportation systems. Protests in the form of physical interference and sabotage conceivably could also result.

- BASIS

There is a growing general tendency for some segments of the public to associate undesirable effects with the transport of all energy materials. Coal transportation by rail has been described as causing noise, dust, odors and the interruption of highway traffic at grade crossings. Coal-hauling trucks are considered to cause accelerated deterioration of rural highways. Aesthetically undesirable effects of loading and unloading coal are recognized in all modes of transport.

- RELATED WORK

The Congressional Office of Technology Assessment (OTA) reviewed aspects of community disruption caused by railroad coal traffic in a recent assessment of coal slurry pipeline and unit train technology.⁽²⁰⁾ The assessment included examples of predicted annual injury and death statistics and added highway vehicle operating costs and travel time resulting from increased railroad coal traffic. This study suggested that advanced planning and

cooperation by the railroads and affected communities can help to avoid some of the serious negative impacts of increased coal traffic.

A 1975 Radian Corporation publication documented the environmental impact of 38 energy resource development scenarios.⁽²¹⁾ The result of the Radian study was a ranking of the various scenarios according to several criteria such as overall efficiency and environmental impact for different end uses. The social impact of transportation was one of the considerations in the rating system.

The URS Company examined the effects of unit coal train operation in Colorado.⁽²²⁾ The study investigated rail conditions along the proposed routes, estimated local traffic levels, considered alternate routes, and identified environmental, social, and economic impacts. The study concluded that inadequate planning had contributed to the adverse effects of unit coal train operation through Colorado cities.

A Department of Interior document published in 1975 expressed the need for a national system of transportation and utility corridors.⁽²³⁾ The report recognized the potential effects of a proliferation of right-of-ways and concluded that a national system is both feasible and desirable.

The Hudson Institute conducted a coal transport study for Burlington Northern which compared projected railroad and slurry traffic volumes.⁽²⁴⁾ Cost structure, operational flexibility, equipment requirements, and specific environmental and safety issues were examined. Finally, a study conducted by the Aerospace Company examined pollution and waste problems of various energy technologies.⁽²⁵⁾ This study included the analysis of potential environmental problems associated with various transport modes. The study proposed general approaches to the solution of transport problems in social impacts. An inventory of public interest issues and their potential impacts is listed in the report.

- APPRAISAL

Segments of the public are already objecting to the interruption of commerce by unit coal trains running frequently through small towns in the Western states and of trucks using rural highways. Continued escalation of

this concern could result in public pressure for Federal, state and local action to place new restrictions on coal transportation. This could impact the national coal transport system by reducing the capacity of crucial links in the delivery network and increasing overall operating costs. An escalation of public reaction may include physical interference and sabotage, which would be a threat to safe operation of the system. Railroads already experience widespread and costly interference from vandals. If transportation should become an environmental villain in public opinion, vandalism and sabotage may become socially acceptable methods of protest.

To date, efforts directed toward resolution of this concern have concentrated on identifying environmental impacts and a few general solutions. Because increasing levels of public reaction can be anticipated as the volume of coal increases, a new program is warranted to evaluate the future consequences of this concern and to establish guidelines for action to solve the potential problem.

- RECOMMENDED ACTION

A study is warranted to evaluate this concern and its future consequences, and to establish guidelines for action to solve the potential problem. The study should contain the following tasks:

- Evaluate at what level nuisance effects of coal traffic aggregate into major environmental disturbances as perceived by the public.
- Prepare a priority list of which effects are tolerable and which are not.
- Identify the future potential impact of coal traffic on community life along specific routes.
- Study alternatives and recommend solutions and financing mechanisms on the basis of cost/benefit assessments.

The recommended effort should provide a basis for involving public opinion and knowledge of public psychology in system planning and engineering.

- PRIORITY

This concern has a high priority because it is a current and probably growing problem. A two man-year level of effort in FY-1979 and 1980 is recommended. The results of this study should provide a basis for supporting future RD&D effort addressing this problem. The DECT should be involved in this activity.

4.1.2 Impact of Frozen Coal

- CONCERN

In winter, coal freezing in rail cars and barges prevents normal delivery schedules from being met. Under prolonged and severe cold weather conditions, this could create a regional shortage of coal during a period of high demand.

- BASIS

Most coal is transported wet; underground operations add water during the mining process and some coal is raised from the mines as a slurry. Western, strip-mined coal is usually wetted to control dust during transfer at loading facilities. At temperatures below 40°F with wind chill effects the water can freeze in rail hopper cars, barges, and even stockpiles. The impact is potentially more severe in the railroad case because railroads carry the bulk of the coal traffic. The standard practice for unloading frozen coal is the use of thawing sheds. Hopper cars are run one or two at a time into heated enclosures. Freeing the frozen coal from each hopper can take up to 40 minutes for a moderate freeze. Severe freezes have reduced the unloading rate to as low as two to three cars/day. This compares to dump rates of 100 cars/day which may be required at a typical power station to maintain the supply. Frozen coal, therefore, can cause a significant logistic problem by reducing the rate of coal delivery and by slowing the rate of returning empty hoppers to the mines.

- RELATED WORK

Companies which manufacture devices for freeing frozen coal from rail cars are generally not in the financial position to undertake major research programs. Some companies appear to be willing to do minor development work and custom-build installations. Other companies have expressed a desire for joint corporate efforts; however, no one has yet taken the initiative to implement this approach. Concern over legal issues with respect to proprietary rights has generated the tendency to preclude involvement of equipment manufacturers in government-supported programs. One notable exception to the above discussion is the Dow Chemical Corporation. At present, Dow Chemical Corporation is developing a process involving a freeze conditioning agent (FCA). The concept behind the FCA is to decrease the compressive strength of ice crystals. Testing of FCA began in January 1977, and to date the results appear favorable.

Atlantic Research is developing coatings for the protection of coal during transport and storage in a DECT-supported project. The approach is to combine coal particles with a latex coating material (80%-coal, 20%-coating) to provide a sealant for stockpiles that prevents water infiltration, reduces the combustion and leaching potential and also physically stabilizes the pile. The result of this work should be available in September 1978 and may be applicable to coal in hopper cars and barges.

- APPRAISAL

Except for the above examples, there appears to be little effort ongoing that may produce new solutions to this problem.

In past winter difficulties with the handling of frozen coal has restricted industrial output.⁽²⁶⁾ Research and development should be planned on the assumption that this may be a typical winter experience during the balance of the century. A program of innovative research and development is needed now to address this concern.

- RECOMMENDED ACTION

An innovative research and development program is recommended to find faster and cheaper methods for preventing the occurrence or reducing the logistic impact of coal freezing in transport containers and stockpiles. This program should evaluate all options that are potentially useful and applicable anywhere in the coal delivery cycle. The initial task of this program should provide a technology assessment to establish the emphasis and direction of future effort. This assessment should include:

- An overview of current technology techniques for handling or preventing frozen coal.
- An analysis and evaluation of the energy intensiveness, safety, and the environmental acceptability of present techniques.
- An investigation of potentially novel coal handling techniques that may have been overlooked but represent possible solutions to the problem.
- Energy and cost effectiveness comparisons of newly identified methods with present methods.
- Recommendations for additional RD and D effort that may be potentially attractive.

- PRIORITY

The anticipated increase in coal consumption in the U.S. will tend to amplify logistic problems resulting from coal freezing during transportation. The investigation of possible solutions should begin immediately to reduce the future impact of this existing problem. An initial one man-year effort in FY-1979 is recommended to determine potentially profitable areas for the research and development. DECT should support this effort where environmental issues may be involved.

4.1.3 Impact Of Proposed Coal Slurry Pipelines

- CONCERN

Important comparative data still need to be developed before it can be decided that coal slurry pipelines are sufficiently attractive on a whole-system basis to warrant government involvement or encouragement.

- BASIS

A variety of issues relate to coal slurry pipelines and whether they offer an attractive alternative transportation mode for coal when judged on a whole-system basis. Most of these issues relate to the comparison of unit trains and slurry pipelines and are still controvesial, including the following:

1. Economics of pipelines versus rail transport.
2. Economic health of railroads.
3. Environmental impacts and relative safety of pipeline and unit train transport.
4. Water availability for slurry pipelines.
5. Energy efficiency of rail and pipeline transport.
6. Employment impact if pipelines are built.
7. Reliability of slurry pipelines versus railroads.

1. Economics of Pipelines Versus Rail Transport

It is difficult to generalize about the relative economics of coal slurry pipelines versus unit trains because the comparison depends heavily on route conditions such as the relative circuitry of each system and the terrain. However, several general statements can be made:

- The construction cost per mile for slurry pipelines exceeds that of a railroad track with equivalent capacity.
- Railroads have much higher variable costs than pipelines and consequently their rates are more susceptible to inflation.
- Pipelines are only economically competitive with railroads when the transport distance is relatively long (probably over 500 miles) and the throughput is large (probably over 10 million tons annually).

2. Economic Health of Railroads

If coal slurry pipeline competition significantly increases, the financial position of railroads could be affected and in turn service to other shippers and the general public may deteriorate. Pipeline proponents have counterarguments to the claims of financial impact advanced by the railroads. They point out that only one pipeline (Tennessee to Florida) has been proposed to move coal originating east of the Mississippi. Pipelines therefore will not be competing with the financially troubled Northeastern railroads. In the West, pipeline proponents argue that pipelines would provide needed competition to what otherwise would be a railroad monopoly on coal transportation. Approximately half of the growth in coal production to 1985 is expected to occur in the West.

3. Environmental Impacts and Relative Safety of Pipeline and Unit Train Coal Transport

The nature of the environmental impacts of the two modes are quite different. After the one-time effects of construction, the most significant pipeline impact is probably the use and disposal of water required for operation. In some cases, this water may be used for power plant cooling, but in any case, it would have to be treated to remove suspended solids. If pumps fail or lines break, the impacts of dumping the slurry could also be potentially significant.^(a) An increase in grade crossing accidents is a potentially serious result of increasing coal traffic on the railroads. Otherwise most of the environmental impact of rail traffic is in the form of public nuisance effects.^(b)

In comparison to unit trains, operation of pipelines is relatively safe. One author has estimated that if all proposed coal slurry pipelines are built, they would result collectively, in 1.2 additional deaths per year, whereas railroads moving the same coal could be expected to cause about 220 additional deaths per year.⁽²⁸⁾ There is, however, little agreement between these and other estimates.^(19,20)

(a) See also Environmental Impact of Advanced Coal Slurry Pipeline Subsection 4.2.2.

(b) Discussed in Public Acceptance of Coal Transportation, Subsection 4.1.1.

4. Water Availability for Slurry Pipelines

Water seems the most emotional issue associated with coal slurry pipelines. In the major coal-producing areas of the West, water is not plentiful and water rights are jealously guarded. It is unlikely, though, that construction of slurry pipelines would have more than a minimal effect on alternative water uses in these states. Nevertheless, the water issue seems likely to be the single most important political obstacle to their construction. In support of this conclusion, at least two western states, Colorado and Montana, have enacted legislation prohibiting the export of water to other states. Whether this type of legislation would be upheld in a court test or be struck down as an unreasonable burden on interstate commerce is an open question.

Energy efficiency comparisons between the two modes that are available in the literature are of limited value because they are generally computed on a subsystem, not a whole system basis. For example, the energy requirement of the existing Black Mesa Slurry pipeline is estimated at 295 Btu per mile.⁽²⁹⁾ However, additional energy is required to separate and dry the coal before it can be burned. The Burlington Northern Railroad has claimed the average energy efficiency for its unit trains, including car return, is 250 Btu per ton-mile. However, for other unit coal train operations values up to approximately 700 Btu per ton-mile are considered reasonable. A further consideration is the source of energy used in the transportation process. Railroads depend on diesel fuel and, therefore, on predominantly foreign petroleum supplies. Slurry pipelines use electrically-driven pumps that may use energy derived from indigenous fuels. The controversy about the relative energy efficiency of the two modes will continue unless energy assessments include consistent whole-system, case-by-case and life-cycle analyses of equivalent system options.

5. Employment Impact of Slurry Pipelines are Built

During construction, both railroads and pipelines are labor intensive. However, the railroads are already built and provide common carrier service. Additional labor will be required for upgrading road bed and trackage that is needed for unit train service using 100 ton hoppers.

Unit trains are also more labor-intensive than slurry pipelines during normal operations. The proposed Wyoming to Arkansas pipeline, for example, will employ about 300 people when it begins operation. The equivalent transportation provided by unit trains would employ about 2,000 people. Pipeline advocates point to this difference when arguing that rail tariffs will be much more susceptible to inflation than pipeline tariffs.

As a counterargument, unit train advocates suggest that coal by rail should still be the desired choice because labor intensive transportation is preferable in times of high unemployment. It will be unfortunate if decisions that might favor railroads were based on the relative make-work potential offered by unit train operations.

7. Reliability of Slurry Pipelines Versus Railroads

Railroads argue convincingly that they are entirely capable of procuring sufficient rolling stock and upgrading other facilities needed to handle future coal traffic. However, the railroads are continuously subject to criticism that equipment availability and quality of service is less than desirable. Pipelines may be more reliable than railroads. The Black Mesa pipeline owned by the Southern Pacific Transportation Company has had an availability factor of about 99%, compared with approximately 90% for unit trains.⁽²⁹⁾ Pipelines however are potentially more vulnerable to sabotage than railroad operations and possess no system redundancy in the event of a breakdown.^(a) The impact of this would be potentially amplified where one proposed pipeline would serve several customers.

• RELATED WORK

The technology assessment of coal slurry pipelines published by the OTA in March 1978, provides a comprehensive comparison of unit train and slurry technologies, economics and environmental impacts.⁽²⁰⁾ This investigation also examined sociological, legal and regulatory implications of the two systems. The OTA study shows that out of four cases, economic choices favored slurries in two cases and unit trains in the other two cases.

(a) This concern is discussed in Subsection 5.1.

In addition to the OTA effort, extensive consideration of the above controversies is available in the literature including the National Energy Transportation Study⁽¹⁾ and references contained therein and other references in this report.^(a) In general, the collective research conducted to date provides detailed and useful assessments of most issues relevant to this concern. However, this broad range of effort has been focussed on subsystems and specific issues to the extent that the whole-system perspective is still somewhat nebulous.

- APPRAISAL

A variety of issues relate to coal slurry pipelines and whether they offer an attractive alternative transportation mode for coal when compared with unit trains operating on a whole-system basis. The bottom-line concern is, however, that Federal and state governments may encourage the development of slurry lines by granting rights of eminent domain and water rights without full consideration of the advantages and disadvantages of the alternatives. Progress dictates that genuine technology advancements should be encouraged at the expense of existing systems. However, the recent OTA study has demonstrated that the advantages of slurries versus those of unit coal trains are highly sensitive to route and system specifications. The comparisons were constrained by specific assumptions of system capability and scenarios of future conditions. These assumptions leave a number of important areas where sensitivity analysis may change the order of preference of the systems.

Controversy still exists about the whole-system cost/benefit relationships for coal slurry pipelines and their potential impact on railroad operations and financial stability. Further review is needed to bring order to this situation and add important perspective to the fundamental question of whether government should encourage and/or subsidize coal slurry systems. An in-depth energy assessment of slurry and railroad unit train operations is particularly important and has not been emphasized in related program effort to date.

(a) References 3, 4, 12, 19, 22, 23, 28, 29, 30, 31 and 32.

- RECOMMENDED ACTION

Using the OTA assessment and other relevant studies as a starting point, the DOE should generate a comprehensive position paper on the slurry versus unit train controversy, with emphasis on whole-system, lifetime energy comparisons for route specific cases. This is needed to provide a broader data base for proceedings such as those relating to the questions of eminent domain and water rights in which an understanding of the merits of the competing systems is important. Consideration of environmental and safety issues in this effort would suggest that the DECT be involved. A DOE position on coal slurry systems should be available for consideration in future regulatory hearings on slurry pipeline issues.

- PRIORITY

This concern does not strictly meet the criterion of having a potentially direct impact on coal transportation in the next decade. However, regulatory decisions are expected in the next two years which will have a far-reaching effect on the future impact of coal slurries in the balance of the century. For this reason the recommended research is currently a high priority and should be a three to four man-year effort in FY-1979.

4.1.4 Transportation Preparedness for Sludge Removal

- CONCERN

The lack of future preparedness to transport large amounts of sludge and ash may restrict the use of coal in future environmentally compatible generating stations and plants.

- BASIS

The Clean Air Act and its amendments are intended to protect the environment from the effects of increased coal consumption.⁽³³⁾ The Act contains New Source Performance Standards (NSPS) and the concept of Best Available Control Technology (BACT). Presently 12.3% of the U.S. coal reserves comply with the NSPS of 1.2 lb SO₂/10⁶ Btu. This percentage will decrease if the NSPS are lowered to 0.2 lb SO₂/10⁶ Btu as is presently proposed. Compliance

with these standards will likely require the widespread use of SO₂ removal techniques. A current interpretation of the BACT provision, which has yet to be enforced, requires the SO₂ removal systems not only to meet the NSPS but also be the best system existing at the time of installation. With today's technology this implies the mandatory installation of SO₂ scrubbers.

Limestone scrubbers, presently the most accepted SO₂ removal system, generate large amounts of sludge. When combined with the ash collected, and depending on the sulfur content, the quantity of waste requiring disposal may approach one half ton for every ton of coal consumed. Current disposal sites and techniques appear to have adequate capacity to accommodate these waste quantities through the early 1980s. Large increases in coal consumption will accelerate the depletion of present disposal sites and force the expansion of waste disposal systems. This expansion will likely involve increased shipping distances and thus develop an increased dependence on adequate and compatible transportation facilities. Present transportation planning efforts do not appear to give adequate attention to the long-term implications of greatly increased sludge production.

- RELATED WORK

Two programs have been identified to date which investigate the physical properties, disposal cost, and environmental hazards of sludge. The Aerospace Corporation⁽³⁴⁾ seeks to identify potential problems that may be associated with sludge disposal. As part of this study, the physical properties of several sludges were characterized and their toxicity examined. The program also assesses several disposal methods, the economics of solutions to sludge disposal problems, and makes recommendations for sludge disposal.

A program conducted by the Mitre Corporation⁽³⁵⁾ assessed the environmental and economic implications of the National Energy Plan (NEP) issued in April 1977.⁽³⁶⁾ The Mitre Corporation report discusses solid waste problems relating to both production and consumption in various energy technologies. In this report, the Southwest is identified as one region that should expect major increases in solid wastes from coal production

and consumption. A similar situation is identified for a small area in Colorado where solid waste problems from oil shale operations are anticipated.

In addition to the above two projects, PEDCO Environmental Inc., under contract to the Environmental Protection Agency (EPA), publishes an annual survey of SO₂ scrubbers.⁽³⁷⁾ The survey reviews scrubber types, coal characteristics, plant operating parameters, and occasionally waste characteristics and disposal methods. The annual report is supplemented by quarterly updates on scrubber status and operational history.

- APPRAISAL

An apparent preoccupation with the front end of the coal energy cycle has resulted in ignoring what may eventually become a significant constraint to increased utilization. Current practice for the disposal of sludge and ash is to transport it as short a distance as possible and deposit it into sluice ponds. Transportation is normally provided by truck or pipeline and the average distance travelled is about 10 miles. This practice may rapidly deplete acceptable disposal locations and eventually increase shipping distances. Increasing shipping distances will be accompanied by increased volumes as the nation shifts to a higher dependency on coal. The combination of these two increases could catch the transportation industry unprepared to provide sufficient capacity.

One possible solution would be to transport sludge in empty hoppers and barges returning to the mines and loading stations. This would provide additional transport capacity without increased traffic. The feasibility of this concept depends on future disposal techniques and the compatibility of existing transport systems.

Ocean dumping might be considered as another solution. However, deep ocean dumping would involve relatively expensive transportation to get beyond the continental shelf and dumping in the continental shelf area would raise a number of potential environmental problems. The Northeast Coal Utilization Assessment performed by Brookhaven National Laboratory concludes that ocean dumping of sludge is unlikely in the Northeast or any other U.S. coastal region.⁽³⁸⁾

Regional sludge transportation problems may grow in the 1980s and plateau thereafter as other emission control technologies evolve for sludge are developed. In the future, sludge may be used for landfill, soil conditioning, and stripmine reclamation and as a feedstock for chemical processing and manufacturing. In the meantime industrial coal consumers in the northeast portion of the U.S. appear to have the least waste storage capacity and are likely to be the first to feel the impact of inadequate waste transportation. Local public acceptance of disposal sites may further complicate the transportation and disposal of sludge and ash. Undesirable characteristics of sludge, as with most wastes, make public acceptance of disposal sites a major factor in site location. Increases in shipping distance and capacity may become necessary to accommodate potential siting problems.

To date, inadequate attention has been applied to these potential problems.

- RECOMMENDED ACTION

A review of current disposal site capacities should be made and compared with projected disposal requirements in the 1980s. This review should be used to identify areas where sludge may be a future transportation problem. If sludge transportation development is shown to be needed, a systems approach to planning should be undertaken to assure environmentally acceptable and cost effective transportation of the sludge. Guidelines should be developed that consider alternative solutions for sludge disposal or subsequent use.

- PRIORITY

A high priority exists for this effort, because of the lead time required to assess the magnitude of the problem and to implement solutions. A half man-year effort should be initiated by DECT in FY-1979 to quantify the magnitude and environmental aspects of the problem. The Transportation Branch of DECT should provide a coordinating function to involve other cognizant DOE divisions and agencies during the initial phases of the study.

4.2 MODERATE CONCERNS WITH LONGER TERM POTENTIAL IMPACT

This category includes concerns that may impact coal transportation between the 1980s and the end of the century. These concerns are currently of a moderate priority because their potential impact may occur later and more time is available to address solutions than is apparent in the above cases. Concerns placed in this category relate to unit train rates, environmental impacts of liquid fuel/slurry pipelines, and congested waterways.

4.2.1 Unit Train Rates

- CONCERN

If value of service is not considered as a factor in rate prescription by the ICC, the revenue generated by coal carriage may be reduced to the point that railroad management loses the incentive to expand coal-carrying capacity. This could lead to an inadequate coal transportation system which may not be sufficient to serve the anticipated increases in coal demand and production.

- BASIS

Regulation of rail rates for unit coal trains traditionally has been based primarily upon three factors: cost of service, comparative rates, and value of service.

The San Antonio Rate Case is a matter of concern to the railroad industry because the ICC indicated a departure from its policy of allowing a value-of-service factor in rate-making procedures by the railroads. The ICC decision, affirmed by the Eight Circuit Court of Appeals, prescribed a rail rate for coal based primarily on cost of service plus a revenue factor and suggested that the value of service factor is of minor, if any, importance in determining a just and reasonable rate.^(a) The railroads view the

(a) The "value-of-service" doctrine permits a carrier to adjust its rates to reflect the value of the commodity transported to the shipper and the unavailability of alternative modes of transportation. The ICC has stated that the value-of-service concept "is equivalent to charging what the traffic can reasonably be required to bear." Mountain Pacific Oil Cases, 192 I.C.C. 559, 636 (1933).

implications of this decision as potentially devastating to the rail industry. Coal transport has traditionally generated high revenues and has been used to subsidize the movement of other commodities. If railroad rate structures were based on cost of service alone, the amount of revenue generated by coal transport would decline. This, the railroads believe, would result in insufficient investment capital for new equipment to maintain the development of a viable coal transportation system.

- RELATED WORK

A railroad position in this controversy has been developed for litigation purposes. No programmatic efforts have been identified that examine the probabilistic survival of the railroads based on a particular rate of return or investment. Also no assessments appear to have been made to determine the threshold return rates that still provide management with incentive to cultivate new coal business.

- APPRAISAL

The railroads view the San Antonio decision as potentially harmful to the rail industry. However, neither representatives of the rail industry nor of electric utilities view the San Antonio case as a precedent for a shift in ICC policy. Rather, it is perceived as either aberrational or the continuance of a chaotic ICC decision-making process. Adding to the inability to predict the position of the ICC in relation to coal rate-making is the effect of the Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act).⁽³⁹⁾ The San Antonio case was considered prior to the passage of the 4R Act even though the decision was issued subsequent to enactment of the law. It is felt by the railroads that the 4R Act, one purpose of which was to provide financial assistance to solvent railroads, supports their contention that rail revenues from coal should be maximized. The railroads have thus petitioned the ICC for re-opening of the San Antonio case as the original decision allowed if circumstances warrant it.^(a)

(a) Telephone conversation with the Counsel for Burlington-Northern, August 26, 1977.

Even if the San Antonio policy is adopted with some consistency by the ICC, it is not at all clear what the impact would be on the rail industry. The reliance on the cost of service factor in the San Antonio case still allows for a wide range of discretion by the ICC in setting allowable revenue above cost. In fact, the railroads are not upset by the rate set in the case, which was well above expenses, but rather by the indication that the ICC will utilize costs as the principal basis for establishing rates. Apparently, the railroads fear that the ICC may apply a rigid formula for rate-making which may lead to a greater degree of certainty and predictability in coal rate structures, but create inflexibilities that adversely effect railroad revenues.

The current controversy stems from disagreement with the railroads' claim of decreased revenues. Implementation of a cost of service rate-making method by the ICC in the rail industry could allow for as much flexibility in the amount of coal revenue generated as does the existing ICC decision-making process. There is no evidence currently available which indicates that a cost of service policy, even if adopted by the ICC, would have any adverse impact on the railroad's ability to generate revenue from coal.

- RECOMMENDED ACTION

An evaluation should be initiated to determine the impact of the San Antonio case precedent on both the railroads and the consumers of rail-transported coal. While the San Antonio case is not representative of any consistent ICC policy, cases now pending before the ICC may be decided similarly to it. Further analysis may be needed to provide the ICC with a basis for determining allowable revenue factors which would offer sufficient incentive for the railroads to maintain the development of their coal-carrying capacity consistent with national needs.

- PRIORITY

The recommended action warrants early consideration to avoid increasing the potential impacts of the case on the development of the coal transportation

system and on the future cost of energy. The ICC and the Department of Energy should examine these issues cooperatively. A one man-year effort by each agency in FY-1979 is recommended.

4.2.2 Environmental Impact of Advanced Coal Slurry Pipelines

- CONCERN

The possible future transport of coal slurries composed of coal and liquid fuel mixtures may present potentially severe safety and environmental problems in the event of a pipeline rupture or spillage at terminal transfer points.

- BASIS

Carriers besides water, such as alcohol or petroleum, may be used in future coal slurry pipelines. The liquid fuel carrier would be burned with the coal, and the slurry pipeline could operate without the disadvantage of consuming potentially scarce water resources. A process using methanol to form a suspension of coal under the name Methocoal has been developed by the Methocoal Corporation of Dallas, Texas. Certain petroleum distillates are also potentially usable as slurry vehicles. The ERDA, now the DOE, awarded nearly \$40 million in cost sharing contracts to the San Antonio City Public Service Board and the New England Power Service Company to develop a coal/oil slurry as a primary fuel for generating electricity.⁽⁴⁰⁾

Environmental problems with water-based slurries could result if a line break or pump failure occurred. One widely-publicized study suggests that if either of these two events occurs, the slurry would have to be dumped, there is no immediate solution to the problem, and the associated environmental impacts could prevent the utilization of slurry pipelines.⁽³⁰⁾ This claim is denied by representatives of Energy Transportation Systems Inc. who have testified that slurry pipelines can be shut down and restarted without plugging and that dumping is therefore not required except in extraordinary cases.⁽³¹⁾

Pipeline problems can be managed apparently using the following procedures. In the case of a break, the line would simply be stopped and restarted after the break was repaired. If a single pump failed, the line could be continued at a slower velocity. In cases of extended outage, a slurry might need to be dumped into holding basins spaced along the line. After repair, the slurry could be pumped back from these basins into the pipeline.

The possible environmental effects and safety concerns associated with the above events occurring in a liquid fuel/coal slurry pipelines appear to be potentially more severe than when a water/coal slurry is involved.

- RELATED WORK

A detailed study of the environmental impact of coal slurry pipelines is currently being conducted for the EPA by the Colorado School of Mines. Coal-water slurries are the subject of current programs which are investigating the physical properties and environmental effects of slurry systems.

The University of California, Los Angeles (UCLA) is conducting research sponsored by the DECT which includes the objectives of determining potential interactions between coal slurry water and the environment and assessing water pollution control strategies for slurry systems. The environmental and safety aspects of advanced slurry systems do not appear to be receiving attention.

- APPRAISAL

The major obstacles facing slurry pipeline proponents are obtaining needed rights-of-way and water availability. Pipeline organizers may ultimately prevail without a Federal power of eminent domain^(a) by exercising the right where permitted by state laws and by purchasing subsurface rights to property underlying railroad lines. The water issue in the Western states appears likely to be the most important obstacle to construction of

(a) This concern is discussed in Subsection 5.1.

water/coal slurry systems. As a result, the emphasis on alternative liquid fuel/coal slurries could possibly increase in the future. Questions concerning the safety and environmental impact of advanced slurry systems need to be answered before rapid development is started.

- RECOMMENDED ACTION

The DECT should perform an early evaluation and risk assessment of safety and environment impact concerns relating to the operation of advanced liquid fuel/coal slurry pipelines. This would provide scoping information for possible R&D project activities that may be necessary.

- PRIORITY

A moderate priority is recommended because the operation of advanced slurry systems appears to be at least several years into the future. A one man-year effort is recommended in FY-1979 or FY-1980.

4.2.3 Congested Waterways

- CONCERN

Approximately 15% of the bulk coal traffic in the U.S. is transported by barge on inland waterways. Since 1970, there has been a steady increase in waterway traffic ton-miles and the number of barges and towing vessels. A continuing increase in inland waterway congestion may impact the future value of barge transportation as a competitive alternate for moving coal.

- BASIS

A study by Manalytics, Inc., for the Electric Power Research Institute concluded the waterway system has essentially reached its maximum capacity.⁽³²⁾ This report is not supported by the opinions of experts in waterway transportation and is considered by some to overstate the potential problem. Nevertheless, there is already evidence of traffic congestion on inland waterways. A specific example is the Locks and Dam No. 26 located at

Alton, Illinois. Due to its age and deteriorated condition, tows are frequently delayed. The average time of delay depends on the traffic and weather conditions, but usually ranges from 7 to 72 hours.

There are between 200 and 300 locks and dams on the inland waterways of the U.S. The majority of the locks are on the Ohio and Monongahela Rivers and the New York State Barge Canal. When disabled or closed for repairs, lock and dam systems block waterway transportation. The Army Corps of Engineers has the responsibility for constructing, developing, maintaining and operating the locks and dams on inland waterways, and established standard lock dimensions in 1959. However, many locks, still in operation, were built before 1959 and do not conform to the current standards.

- RELATED WORK

The Corps of Engineers has studied the situation at Locks and Dam No. 26 and submitted a controversial proposal to replace the present lock, add another lock and increase the navigable depth of the adjacent river channel. After a 1974 injunction and court case, a modified recommendation for replacement and increased capacity of No. 26 was presented to Congress on August 25, 1976.

The Locks and Dam No. 26 replacement issue, amended to include a waterway user charge, is presently before the 95th Congress.

The DOT Transportation System Center has ongoing studies relating to waterway congestion and the Waterway Construction Act of 1977 has been amended by the Senate, requiring the DOE to study the impact of waterway user charges and report to Congress by January 1979.

- APPRAISAL

Other than slowing traffic, congestion has the potential of increasing transportation cost, and causing casualty events (groundings, rammings, or collisions) and pollution. The effects of waterway congestion will probably impact the national petroleum delivery system far more than the coal system because of the relative volumes involved.

The impact of congestion on coal transportation could be the diversion of some of the traffic to other modes. In the long term, railroad, truck, and potentially also slurry modes are expected to absorb the coal traffic that may be diverted from the waterways. There is a potential problem associated with short-term responsiveness of competitive modes to congestion. While stockpiling can cushion day-to-day variability in supplies, alternative modes were not able to accommodate the coal traffic immobilized by the freezing of the Ohio river system in the winter of 1976/77.

- RECOMMENDED ACTION

This concern may not become significant on a national scale because of the relatively small volume of coal transportation that may eventually be involved. However, the concern is worthy of further review to determine if local impacts may develop that are not covered by alternative supply routes. The final form and impacts of Congressional action on waterway user changes are expected to modify the priority of this concern. No specific programmatic action is recommended pending the outcome of legislative procedures and ongoing evaluation in this area.

5.0 LATENT AND PERCEIVED CONCERNS

This section contains brief accounts of latent and perceived concerns which, at present, do not appear to warrant additional attention in new programs. However, the trends of these concerns should be monitored to maintain an awareness of possible future changes in their importance.

5.1 LATENT CONCERNS

Latent concerns have the potential, with equal probability, of increasing or decreasing in priority or changing in nature during the balance of the century. These concerns do not appear to be serious at present and may be resolved in the future by influences now at work or by alternatives that can be anticipated to develop. The following items are judged to be latent concerns and should be kept under review to determine their evolution as conditions change.

5.1.1 Eminent Domain for Slurry Pipelines

One major obstacle facing coal slurry pipeline development is the difficulty of acquiring rights-of-way. Currently, coal slurry pipelines have no Federally-granted power of eminent domain, although eight states have extended the right. The lack of the right of eminent domain is important because railroads have generally refused to sell easements to slurry pipeline companies in the hope of preventing a competitive mode of coal transportation. Pipeline organizers may ultimately prevail without a Federal power of eminent domain by exercising rights under state laws where permitted and by purchasing subsurface rights to property underlying railroad rights-of-way. Energy Transportation Systems, Inc., (ETSI) has apparently purchased many of these subsurface rights and successfully tested this practice in state courts.

The U.S. Senate approved a bill granting the right of eminent domain to coal slurry pipelines in 1974.⁽⁴¹⁾ While similar bills have been heard by the House Interior Committee, they have not yet been voted on.⁽⁴²⁾

Predicting the final outcome is difficult. On the one hand, there are no reasonable grounds to flatly deny the right to eminent domain. Even the railroads admit this. John Kenefick, President of the Union Pacific Railroad, was quoted in the Idaho Statesman of April 8, 1976, as saying, "It's obviously within our self-interest to oppose the slurries, the problem is how to justify our position on the issue." While the central issue should be whether the railroads have the right to effectively eliminate this competition (especially when considering that much Western land was donated to the railroads by the Federal government), the debate has focused on issues of cost, technology, and the need for the service. Congress has treated what should be a non-technical issue as an exercise in engineering. As a result, rather than forcing the railroads to justify their stance, the burden of proof has been placed on the pipelines.

A concern more immediate than the eminent domain issue is the question of the value of coal slurry transport compared with other modes on a whole system basis. As recommended in Subsections 4.1.3 and 4.2.2, the DOE should be concerned with the energy, economic, and environmental aspects of coal slurry transportation.

5.1.2 Railroad Abandonment Policy

The abandonment of unprofitable railroad lines is a viable method of protecting the financial health of the national railroads. The ICC can grant permission to abandon specific lines after an exhaustive investigation and hearings. Before it grants this permission, the ICC investigates the social, economic, and environmental ramifications of the proposed abandonment. The ICC process appears to be complete in considering everything from historical value to future growth scenarios of affected communities.

A case of premature or unofficial abandonment appears to have taken place in anticipation of ICC approval. The 25-mile line supplying the Potomac Electric Power Company (PEPCO) plant at Morgantown, Maryland, has experienced frequent derailments resulting in overall inadequate service to the customer.⁽²⁶⁾ In this case, the railroad's decision to decrease track

maintenance was in response to the power company's decision to emphasize oil at that particular plant. PEPCO changed this decision, continued to use the Morgantown plant as a primarily coal-fired station, and now requires reliable service on this section of railroad.

A latent concern is suggested by this type of situation where a reduction in railroad maintenance that might be made in anticipation of a formal abandonment may not accommodate changing local transportation needs for coal and other energy-related materials.

5.1.3 Sabotage Potential

A possible scenario in the escalation of public reaction to the transportation of coal and other energy materials may involve acts of physical interference, including sabotage. It would take a massive effort organized at the level of, at least, a guerilla war to significantly disrupt railroad service. This has been demonstrated by the size of past military efforts needed to interdict supply lines during wartime. Railroad vulnerability appears to be less than that of pipelines because of the redundant routes and rapid repair capabilities possessed by the railroads. Slurry pipelines could conceivably be put out of action for long periods, especially during freezing weather. This would cause a severe impact on plants that have no alternative service.

Action against individual barges and trucks would have, at the most, transitory impact on local coal supplies. The common practice of stockpiling and supply system flexibility mitigate the potential impact of sabotage. Also attacks against plants and equipment at fixed sites would probably be more attractive from a potential saboteur's point of view. For the above reasons, the threat of sabotage to coal transportation appears less important than in the transportation of other energy materials.

5.1.4 Transportation Dependence on Diesel Fuel

Coal transportation by railroad, waterway and by truck depends on diesel fuel for motive power. This is considered by some to be a significant potential vulnerability and future problem. In the event of a future

long-term embargo or shortage of petroleum products, diesel fuel is expected to be allocated on a priority basis. If the national use and dependence on coal continue to increase, coal transportation would qualify as a high priority for fuel allocation. The anticipated development of strategic fuel storage and synthetic fuels will also tend to mitigate this concern.

5.1.5 Competition for Barges at Harvest Time

The issue that coal transportation by barge can be affected by the availability of barges at harvest time does not appear to be a significant potential problem. While the situation may exist, it should be local in effect and another challenge to induce competition by other modes. As a generally predictable seasonal event, the concern should be routinely manageable with appropriate planning, stockpiling and the use of alternative transport modes.

5.1.6 The Requirement for Scrubbers on Coal-Fired Plants

Concern has been expressed that the EPA's potential interpretation of the most recent amendment of the Clean Air Act⁽³³⁾ may require the use of scrubbers on all coal-fired generating plants. The potential consequences of the Act are far-reaching and include a possible impact on the overall growth in coal demand. Other effects may be a reversal in the current shift to the use of Western coal and drastic changes in coal flow patterns. The sludge problem resulting from the use of scrubbers is also important as discussed in Subsection 4.1.4. An equilibrium may evolve in which the overall effect may be slower rates of demand growth than rates currently projected. While this could be a significant impact on the national goal of increasing coal use, concerns relating the adequacy of coal transportation would tend to be reduced correspondingly.

5.2 PERCEIVED CONCERNS

The following concerns are the focus of controversy in current research and debate. For the reasons stated below, these concerns are judged, in their present perspective, to be either unsubstantiated or inconsequential.

5.2.1 Railroad Capital Requirements

Railroads offer a lower average rate of return on investment capital than most industries. Because of this, the necessary capital for locomotive and car building, track maintenance and plant expansion needed to transport the projected increase in coal traffic may not be readily obtainable. This may limit the future coal carrying capacity of the railroad industry and impact the ability to supply the future demand for coal on a national level.

This concern has been raised by experts inside and outside the railroad industry. Railroad reports to the ICC, in mid-1975, showed \$2.8 billion in accumulated deferred maintenance. About \$4.2 billion in projected capital improvements were reported as delayed for lack of funds.⁽⁴³⁾ Internal cash flow in the industry has been insufficient to provide funds to support capital expenditures made in the past few years. This has forced the railroads to draw on working capital, liquidate assets, increase borrowing, and turn to lease financing. Maintenance of unprofitable track competes with requirements for capital to maintain profitable coal-hauling routes.

The ICC concluded that freight rate increases authorized by the Commission through 1975 have not furnished sufficient inducement for carriers to purchase needed equipment for the demands of coal transportation in the next five years.⁽⁴⁴⁾

Several historic precedents and anticipated future scenarios suggest that this concern should not directly affect coal transportation. Capital generally follows the opportunity for profit. The potential of new coal business on all but totally dilapidated or bankrupt railroads can be expected to generate investment from capital sources in the free market. Utilities are increasingly providing hopper cars for dedicated unit train service, and interroad leasing and improved equipment utilization are methods commonly used to increase capacity. The government will, in a last resort, assist financially troubled corporations (as, for example, in cases such as Conrail, Amtrak, and Lockheed) when the public interest is involved. A shift to alternative modes of transport would be encouraged if railroad service became inadequate and this would be a major incentive for the construction of slurry pipelines.

This perceived concern appears to be controlled by normal business investment decisions, and several profit-motivated pathways for free market capital to support needed rail service. In the case of an emergency,precedented government assistance would be available. An unfortunate aspect of this controversy is that with so many claiming this to be a potential problem, momentum may build to make it a self-fulfilling prophesy. Interested parties should stay aware of this situation; however, no new programmatic action is recommended at this time.

5.2.2 Availability of Railroad Hoppers and Locomotives to Haul Future Coal Traffic

Projected increases in coal traffic are considered by some critics to exceed the railroads' ability to maintain a hopper car and locomotive fleet large enough to provide the necessary transportation.

This fear has been expressed by representatives of electric utilities and the coal mining industry and was encouraged by the BOM indicating that the number of hopper cars required in 1985 could reach 674,000.⁽¹³⁾ This estimated increase was compared with 1973 statistics showing that about 211,000 hoppers were used in coal service. The increase would represent a tripling of the coal hopper car fleet in a period of 12 years. The project conducted by Manalytics Incorporated for the Electric Power Research Institute investigated potential logistic problems in future rail and barge coal transportation.⁽³²⁾ Among the results of this study were indications that growth in coal traffic would require 20,000 new hoppers and 1000 locomotives per year. Another 1000 locomotives per would be required to replace retired units and service other traffic. The Manalytics Study interviewed equipment manufacturers to determine if production capacities were adequate for the potential demand. Their report states:

"Neither the locomotive builders nor the car builders foresaw any critical shortage of materials or of skilled labor for expanding their production to meet these equipment requirements."

There are several sources that indicate a future shortage of hopper cars and locomotives is not anticipated.⁽¹⁾ With the improved equipment utilization provided by unit train operation, a car production rate of approximately 15,000 hopper cars and 1000 locomotives per year should be more than adequate to meet the most optimistic traffic growth projections. Current industry capacity exceeds these rates by significant margins.

The pacing items controlling the increase in coal traffic are mine development and construction of utility generating plants. The lead time for these activities greatly exceeds that for railroad investment decisions and equipment manufacturing. In summary, therefore, this perceived concern appears to be unfounded.

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APPENDIX A

GEOGRAPHIC DIVISIONS: U.S.G.S. COAL PROVINCES
AND REGIONAL COAL SHIPMENTS

FIGURE A-1. Geographic Divisions

TABLE A-1. Geographic Divisions Coal Demand Regions

I.	New England Massachusetts Connecticut Maine New Hampshire Vermont Rhode Island	VI.	East South Central Kentucky Tennessee Alabama Mississippi
II.	Middle Atlantic New York New Jersey Pennsylvania	VII.	West South Central Arkansas Oklahoma Texas
III.	East North Central Ohio Indiana Illinois Michigan Wisconsin	VIII.	Mountain Colorado Utah Montana Idaho Wyoming New Mexico Arizona Nevada
IV.	West North Central Minnesota Iowa Missouri North Dakota South Dakota Nebraska Kansas	IX.	Pacific Washington Oregon California Alaska
V.	South Atlantic Delaware District of Columbia Maryland Virginia West Virginia North Carolina South Carolina Georgia Florida

FIGURE A-2. U.S.G.S. Coal Provinces

TABLE A-2. U.S.G.S. Coal Provinces

1. Eastern
2. Interior
3. Gulf
4. Northern Great Plains
5. Rocky Mountains
6. Pacific Coast

FIGURE A-3. Coal Supply and Demand Regions

APPENDIX B

RAIL AND WATER CARRIER DATA

TABLE B-1. Cost Data for Water Carrier and
Railroad(9,15,16) (dollars)

	<u>Present</u>	<u>1985</u>
Dry Cargo Barge	123,000	200,000
5600 HP Towboat	1,700,000	2,000,000
Locomotive	350,000	
	450,000	
Hopper Car	28,000	
Caboose	35,000	
Rail/Mile - Flat Terrain	125,000	
Signals, Switches	200,000	
Grading/Mile		
Locomotive Operating	35.33	
Cost/Hour		
- Fuel, Maintenance		

TABLE B-2. Critical Measurements of Barges,
Towboats and Tugboats(17)

	<u>Length, ft</u>	<u>Breadth, ft</u>	<u>Draft, ft</u>	<u>Capacity, tons</u>
Open Hopper Barge	175	26	9	1000
	195	35	9	1500
	290	50	9	3000
				<u>Horsepower</u>
Towboat	117	30	7.6	1000-2000
	142	34	8	2000-4000
	160	40	8.6	4000-6000
Tugboat	65-80	21-23	8	350-650
	90	24	10-11	800-1200
	90-105	25-30	12-14	1200-3500
	125-150	30-34	14-15	2000-4500

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