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Jack A. Simon, Chief

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PLACE OF COAL IN THE TOTAL ENERGY NEEDS OF THE UNITED STATES

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PLACE OF COAL IN THE TOTAL ENERGY NEEDS OF THE UNITED STATES*

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Coal has had a long history as an important source of energy. Shortly after World War I, coal provided over 75 percent of the total energy used in the United States. Oil and natural gas, however, were favored by technological developments, and the use of these fuels grew rapidly during the 1930s and early 1940s. In 1946 oil and gas surpassed coal as the nation's principal source of energy, but, although the role of coal in the total energy market of the United States has declined in recent years, coal still accounts for a substantial portion of the total energy used. In 1974, of the total 73,121 trillion Btu of energy consumed in the U.S., 18 percent was supplied by coal (fig. 1).

In the recent past, energy consumption in the United States has been growing at an average rate of about 5.0 percent per year. Increasing awareness of the nation's energy problems has led to concerted efforts to conserve energy and reduce the rate of growth, but the Federal Energy Administration recently estimated that, even with conservation measures, the nation's total energy needs by 1990 would increase to 112 quadrillion Btu, 53 percent more than the amount used in 1974 (fig. 2). Use of all available sources of energy must be expanded to supply such an energy demand. To examine the place of coal in this picture, we must look at various sources of energy and the energy potential each offers.

SOURCES OF ENERGY

The sources of energy may be broadly classified into three groups—fossil fuel, nuclear fuel, and other nonfossil energy systems. The principal fossil fuels are coal, oil, natural gas, shale oil, and tar sand. Uranium is the principal nuclear fuel. Nonfossil energy sources include, among others, hydropower, solar power, geothermal power, wind, tidal systems, and fuel cells.

In 1974 over 94 percent of the total 73.1 quadrillion Btu energy used in the United States came from fossil fuels, including petroleum, natural gas, and coal. Nuclear fuel accounted for 1.6 percent of the total used. The re-

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maining 4.2 percent was derived from nonfossil fuel systems, including hydropower and geothermal power. Although nonfossil fuels provided relatively small amounts of the total energy used, they were important in several local areas. The only nonfossil fuel systems that offer promise of future energy supply are solar power and, even farther in the future, nuclear fusion. Hydropower, wind, geothermal, tidal, and other nonfossil fuel systems are expected to provide only a small part of the total energy needs, although they will continue to be significant locally. Efforts are being made to develop technology that would make the use of solar power economically feasible. However, for the rest of this century fossil fuels and uranium will be our major energy sources.

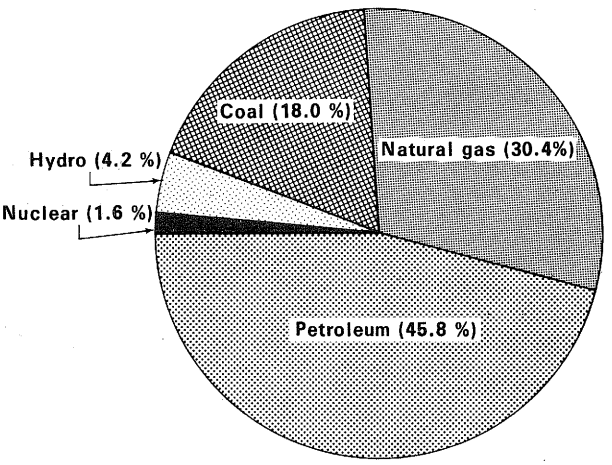

Fig. 1 - Energy consumed in the United States, by source, in 1974. Total consumption 73.1 quadrillion Btu. (Source of data: U.S. Department of Interior News Release, April 3, 1975.)

We shall review briefly the fossil fuels and uranium resources that are available in the United States and the energy potential each resource offers. Of the total estimated 56 quintillion (10^{18}) Btu of energy available from domestic fossil fuels and uranium, more than 60 percent is known to occur in coal (fig. 3). Oil shale and tar sands rank second after coal, but no significant production has yet been achieved for either, although they have been of great interest for 25 years or more. Oil and natural gas, which currently supply more than 75 percent of the total energy used, account for only 10 percent of the total potential energy available from fossil fuel. Under present conventional use, the energy potential of uranium resources is limited. However, with the development of a breeder reactor and possible new developments in nuclear fission technology, these uranium resources would ultimately have energy potentials about twice as great as those estimated for our coal resources. To put these resources in perspective with energy resources now being used to supply energy, the proportion of energy available from the various sources is compared in figure 4 with the energy currently being derived from each source. In the United States we are at present using our

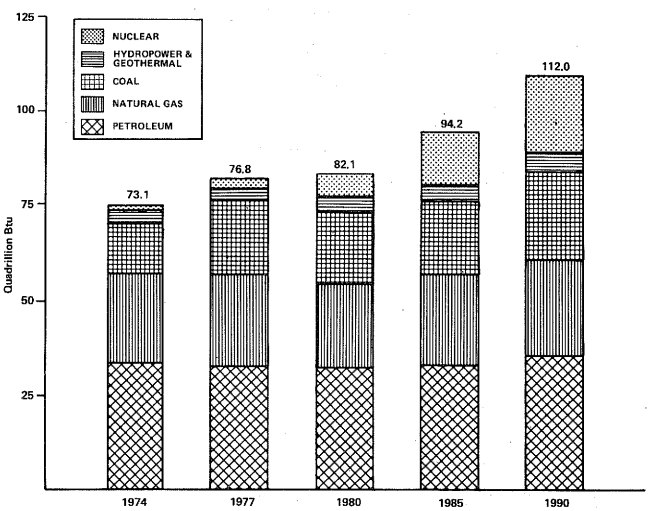

Fig. 2 - Projected gross energy consumption in the United States, 1974-1990, allowing for conservation measures and based on business-as-usual scenario, $11 per barrel oil. (Source of data: Energy Perspectives, U.S. Department of Interior, Feb. 1975.)

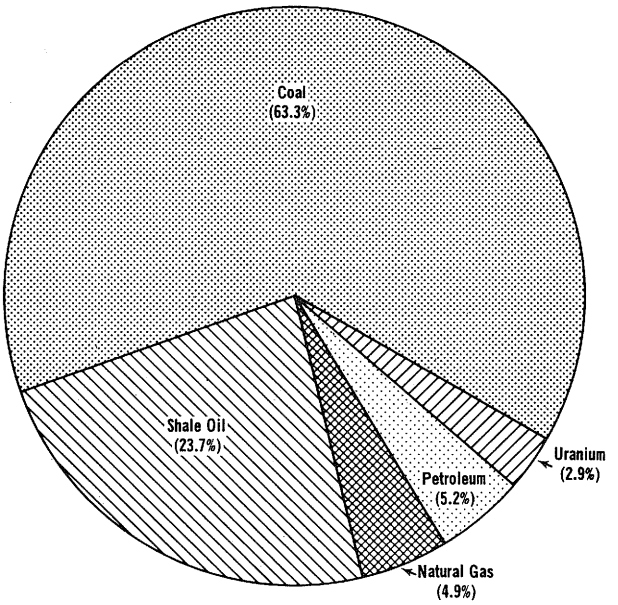

Fig. 3 - Sources of energy for future needs in the United States. Total available energy is estimated at 55.6 x 10^{18} Btu. (Source of data: Federal Power Commission "National Gas Survey," 1974.)

most limited resources liberally and our most abundant resources meagerly. This is one of the reasons why we are now facing an energy dilemma. Disproportionate utilization of resources has not only caused depletion of a large portion of our prime energy resources, petroleum and natural gas, but it has also made us increasingly dependent on foreign oil-producing countries for a substantial part of our energy needs.

Figures 3 and 4 show that coal is the principal fossil fuel resource of the United States, but no clear indication has yet been given that coal is being used to meet the nation's growing energy needs, in spite of the fact that technology already exists for economic and extensive use of this resource to generate electricity, heat, and power. Coal also offers great potential for the production of synthetic fuels, such as low-Btu gas, pipeline-quality gas, petroleum, and solvent-refined products, that could substitute for the natural oil and gas that is in increasingly short supply.

COAL RESOURCES AND RESERVES

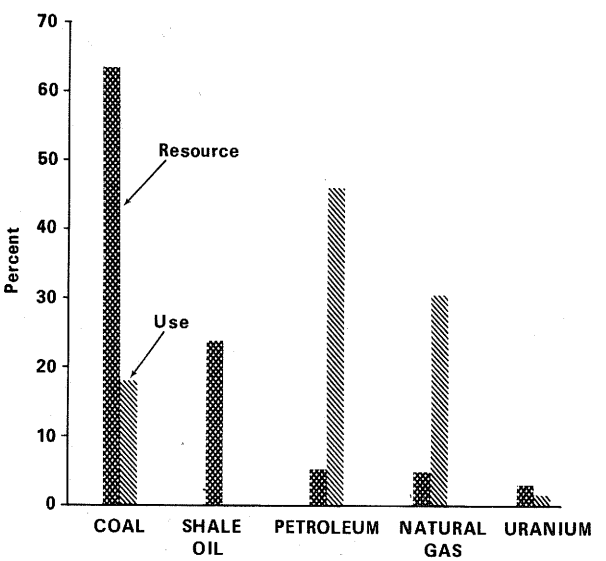

Fig. 4 - Potential resources compared with fuels consumed. (Source of data: Federal Power Commission, "National Gas Survey," 1974; Department of Interior News Release, April 3, 1975.)

Geographically, coal resources occur throughout the nation, and substantial reserves are located near the areas where they are needed. Coal occurs in 34 states (fig. 5), although only 11 states are generally regarded as having significant minable reserves. The coal resources of the United States may be classified broadly into six provinces. The Eastern Province includes Appalachian bituminous and anthracite coal fields that extend from Alabama through Pennsylvania; the Interior Province includes bituminous coal deposits from Oklahoma to Michigan; the Northern Great Plains include subbituminous coal and lignite deposits that are known to occur in eastern Montana, northeastern Wyoming, and in North and South Dakota; the Rocky Mountain Province contains lignite,

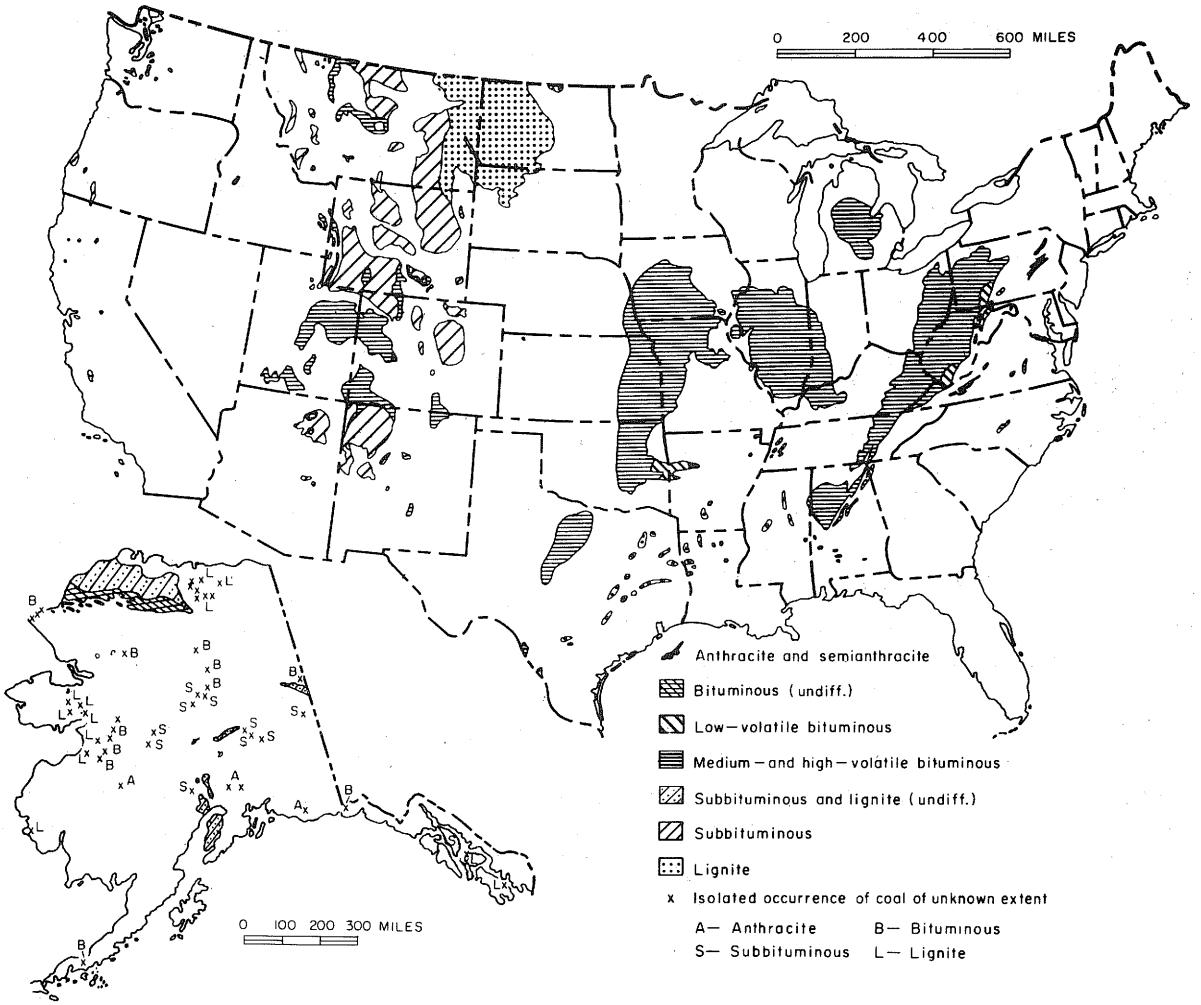

Fig. 5 - Coal fields of the United States (from U.S. Geological Survey Bulletin 1275, 1969).

subbituminous, and bituminous coal deposits; the Pacific Coast Province contains subbituminous coal and minor deposits of lignite; and the Gulf Province deposits are largely lignite. In addition to these areas, Alaska has lignite, subbituminous, and bituminous coal deposits.

The U.S. Geological Survey stated in a recent report that the in-the-ground coal resources, as defined in the study, of the United States total 3.97 trillion tons (fig. 6). Of this total, 1.79 trillion tons has been identified by detailed mapping and exploration. After deducting the coal that occurs in thin beds and is not economically recoverable, the U.S.G.S. estimated 1.04 trillion tons of coal resources as recoverable, only 217 billion tons of which were considered economically and legally extractable at the beginning of 1974. Even this substantially reduced figure is over 350 times the present level of annual production. Economically and legally recoverable coal reserves are known to occur mainly in Montana, Illinois, Wyoming, West Virginia, Pennsylvania, and Kentucky (fig. 7).

There is a substantial difference in the heating value of coal from one region to another. When the heating value of the coal reserves is con-

sidered, West Virginia, which ranks fourth in tonnage, becomes third. Montana, however, continues to lead Illinois, although the difference on a heating value basis is significantly narrower than on the tonnage basis.

With the introduction of the Clean Air Act of 1970, the sulfur content of coals became a more significant factor in evaluation of coal resources. The distribution of major low-sulfur coal resources is shown in figure 8. The Illinois Basin has produced substantial tonnages of low-sulfur coal, although reserves are relatively small compared to areas shown on the figure. More than 88 percent of the total low-sulfur coal reserves is situated in the western states; however, only 21 percent of the total current production of low-sulfur coal comes from these states. Eastern states, where only 12 percent of the total low-sulfur reserves are known to occur, are now supplying more than 79 percent of the low-sulfur coal used. Much of the eastern low-sulfur coal reserves is premium

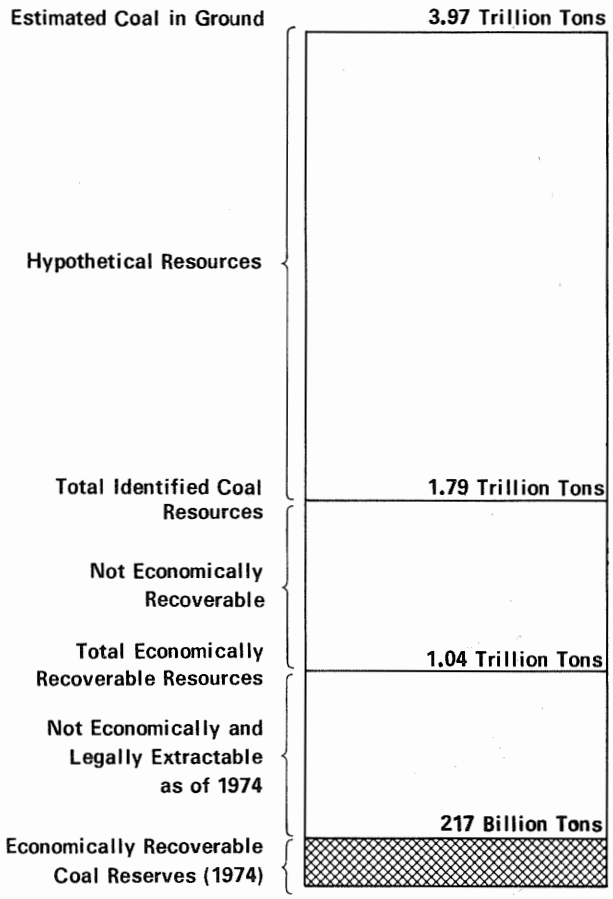

Fig. 6 - Coal resources and reserves of the United States. (Source of data: U.S. Geological Survey Bulletin 1412, 1975.)

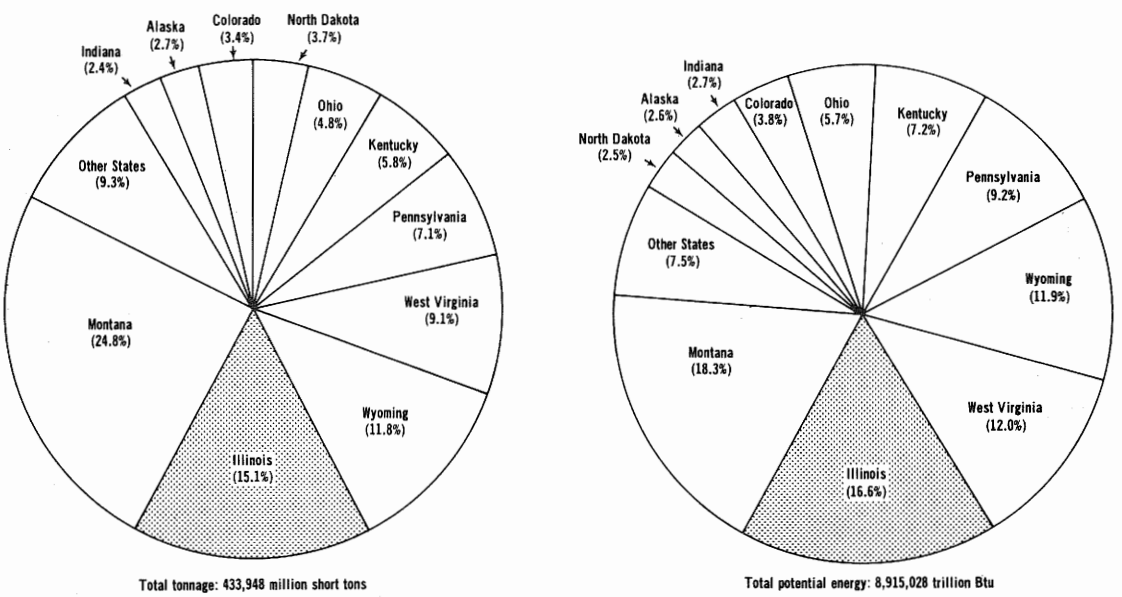

Fig. 7 - Distribution of demonstrated coal reserves by tonnage (left) and heat value (right) Tonnage figures are from U.S. Bureau of Mines (1974).

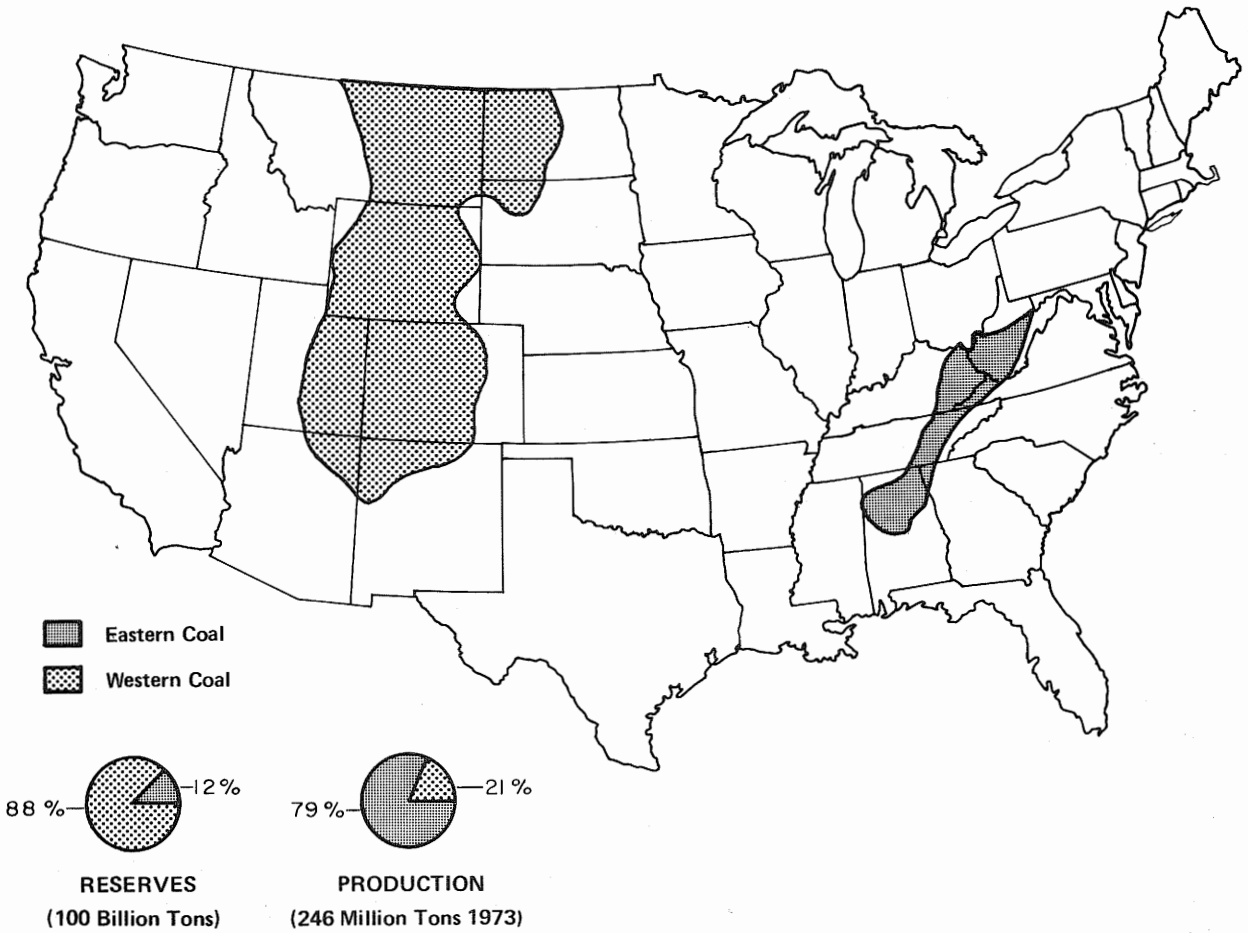

Fig. 8 - Low-sulfur coal reserves of the United States and their production, 1973. (Source: Energy Perspectives, U.S. Department of Interior, February 1975.)

coking coal. A large proportion of the low-sulfur coal that may be required for generating electric energy in the future will have to come from western states unless technology is developed and applied that will permit wider use of higher sulfur coals. The Federal Energy Administration estimates that in 1990 from 235 to 486 million tons of coal will be produced annually in western states, which would be approximately 18 percent of the anticipated total national production. In 1974, these states, despite a large recent increase in production, produced 56 million tons and accounted for less than 10 percent of the total national coal production. In light of the growing concern about strip mining of western coal, the magnitude of the projected increase in coal production in the west may perhaps be too high to be achieved in a 15-year time frame.

ROLE OF COAL IN THE ENERGY MARKET

Electric utilities, the iron and steel industries, the railroads, retail dealers, and industrial and manufacturing plants use coal to produce

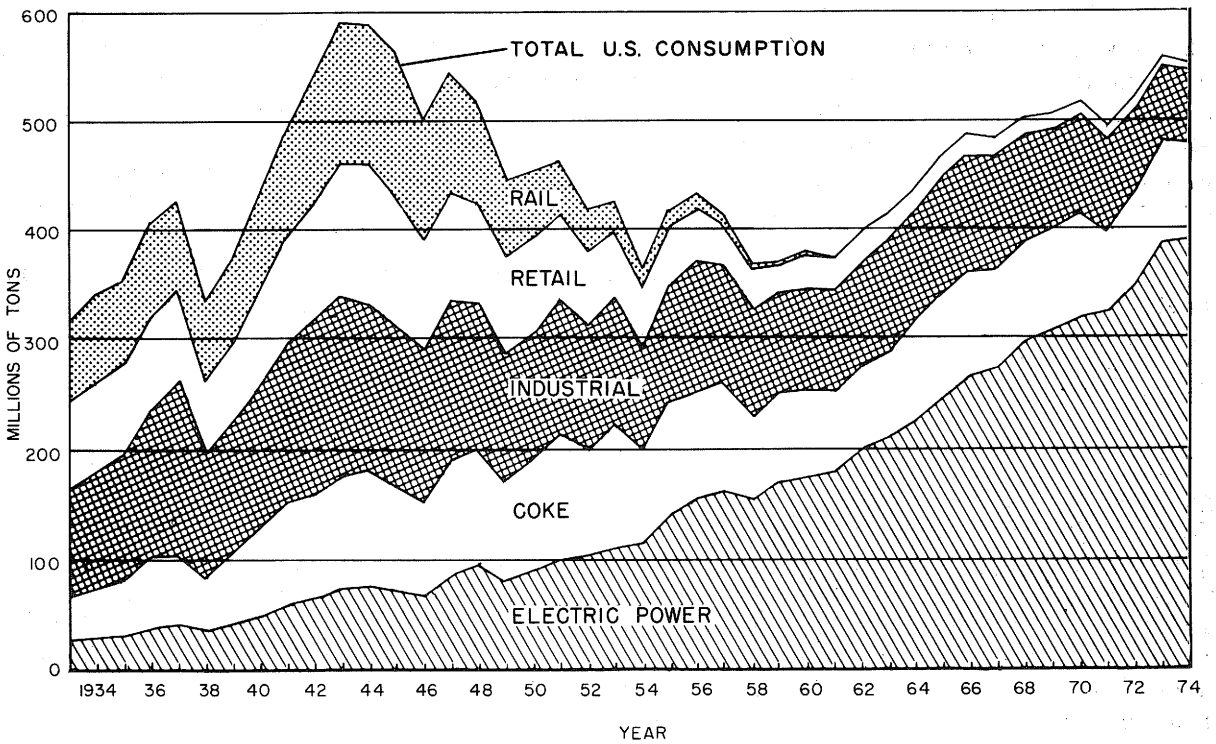

Fig. 9 - United States consumption of coal, 1933-1974, by consumer group. (Source of data: U.S. Bureau of Mines Minerals Yearbooks, 1933-1974.)

energy, heat, and carbon by-products. Trends in major uses of bituminous coal and lignite in the United States from 1933 through 1974 are shown in figure 9.

Within each coal-consuming sector, the role of coal as a source of energy has changed. The use of coal by railroads has declined, from 132 million tons in 1944 to less than 2 million tons in 1961 and a negligible amount thereafter, as the railroad companies shifted from coal-fired steam locomotives to diesel engines. The use of retail coal, primarily for residential and commercial heating, has been for the most part replaced, first by the use of oil and later by the use of natural gas when pipelines were extended throughout most of the nation. More recently, electric heat has been used to an increasing extent.

As they have in retail markets, oil and gas have made heavy inroads into the industrial coal market. As a result the demand for industrial coal has declined 40 percent within the past two decades.

Coke, which is made from coal, is used primarily in the production of pig iron in blast furnaces. From 1955 through 1974, pig-iron production increased more than 30 percent; however, the amount of coke used during the same period declined about 16 percent. This decline was caused primarily by improvements in blast furnace technology. In 1955, 0.862 ton of coke was consumed per ton of pig iron produced, whereas in 1974 only 0.597 ton of coke was needed to produce a ton of pig iron. This represents a more than 30 percent decrease in coke consumption per ton of pig iron produced.

From 1955 to 1975, the output of electric energy by utilities grew at an average annual rate of more than 8 percent. However, because of greater efficiency in fuel utilization and the consumption of oil and natural gas, coal use by electric utilities grew at a somewhat slower rate, averaging only about 5 percent per year. Despite this slow growth, the amount of coal consumed by electric utilities within the past two decades has almost tripled and to a large degree has offset the losses coal has suffered in other markets.

The changes in use of coal are shown by energy-consuming sector in figure 10. Consumption of coal by electric utilities increased from 47.4 percent of the national total in 1964 to more than 66 percent in 1974. During the same period the use of coal in all other consuming sectors declined.

Coal as the principal fuel for electric utilities is being seriously challenged in new plants by the development of nuclear technology for power generators and by the enforcement of sulfur oxide emission standards. The Federal Power Commission estimates that by the year 2000 about 61.9 percent of the total 10,180 billion kilowatt hours of electricity that will be generated will come from nuclear plants. Only about 5.9 percent came from nuclear plants in 1974. Despite this increase in nuclear power generation, the FPC also estimates that by the year 2000 more than 903.3 million tons of coal will be needed to meet the nation's electric power needs—a 134 percent increase in the amount used for that purpose in 1974.

Coal consumption in the various states is shown in figure 11. The states lying east of the Mississippi River consume more than 80 percent of the coal used in the United States. Midwestern states (Ohio, Illinois, Indiana,

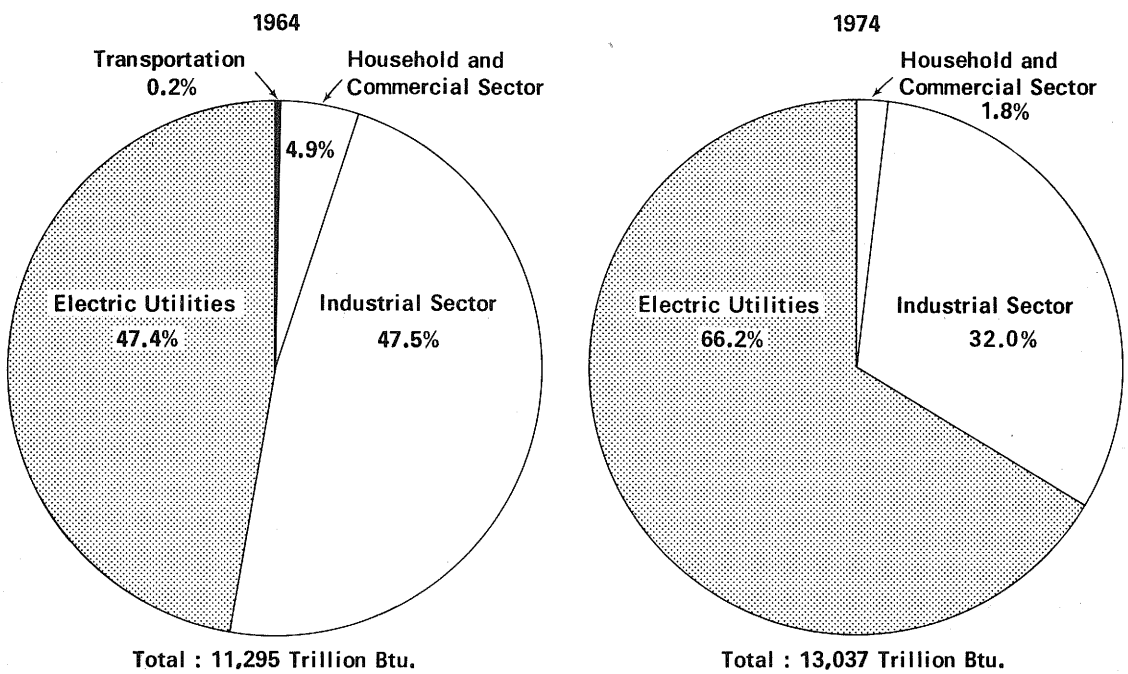

Fig. 10 - Distribution of energy derived from coal in the United States, by sector. (Sources of data: U.S. Bureau of Mines Minerals Yearbook, 1964, and U.S. Dept. of Interior News Release, April 3, 1975.)

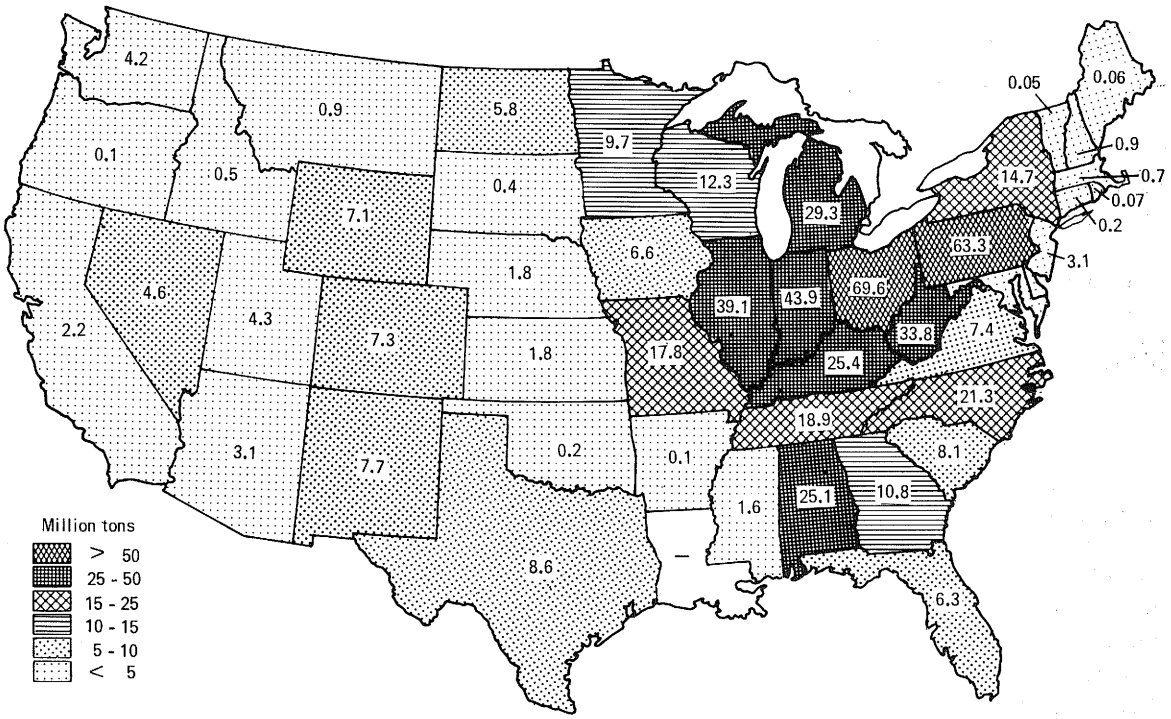

Fig. 11 - United States coal consumption in 1974. (Source of data: Bituminous Coal and Lignite Distribution, Calendar Year 1974, Mineral Industry Surveys, U.S. Bureau of Mines, 1975.)

Michigan, and Wisconsin) lead in consumption as a group, accounting for about 36 percent of the total. In 1974, about 50 percent of the total coal consumed in the states lying west of the Mississippi River was used within a few states, including Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas.

In 1974, all the states except Louisiana, a principal producer of oil and natural gas, reported some consumption of coal. Ohio, which consumed 69.6 million tons of coal in 1974, was the leading coal-consuming state in the nation. The principal consumers of metallurgical coal included Pennsylvania, Indiana, Ohio, New York, Alabama, and West Virginia.

The demand for coal is growing rapidly in various parts of the nation, even though the base was low for some states. For example, from 1965 through 1974, the demand for coal in the Mountain States (Wyoming, New Mexico, and Arizona) more than tripled, in Texas the demand increased more than sixfold, and in Florida, Georgia, North Carolina, South Carolina, West Virginia, Missouri, North Dakota, Nebraska, and Kansas the demand nearly doubled. During the same period, however, the demand for coal in the New England states and in New York, New Jersey, Virginia, Illinois, Michigan, and Wisconsin declined.

FUTURE OUTLOOK

In light of the probable future inadequacy of supplies of petroleum and natural gas, the nation's increasing need for coal—our principal energy

TABLE 1—PROJECTED DEMAND FOR COAL
(million tons)

Scenario	1977	1980	1985	1990
Business as usual	755	895	1,100	1,300
Accelerated development	927	1,376	2,063	2,803

(Source of data: Project Independence Blueprint, Federal Energy Administration, November 1974.)

TABLE 2—FUTURE COAL MARKETS
(million tons per year)

Market	1985	1995	2000
Electric utilities	700	1,225	1,600
Synthetic fuels	310	930	1,200
Metallurgical	120	150	160
General industry	65	70	70
Export	65	70	70
Total	1,260	2,445	3,100

(Source of data: Second Symposium on Coal Utilization, 1975, p. 96; National Coal Coal Association and Bituminous Coal Research Conference and Expo II.)

resource for some years to come—is a certainty. The Federal Energy Administration estimates (table 1) that, to meet the projected increase in demand for coal, United States coal production will need to be increased to 1.3 billion tons by 1990 in a *business as usual scenario* and to more than 2.8 billion tons in an *accelerated development scenario*. Since in 1974 United States coal production totaled about 600 million tons, the projected increase in demand would require the coal mining capacity to be at least doubled, and possibly quadrupled, by 1990.

Various forecasts have been made as to energy-consuming sectors where the use of coal is likely to increase. A representative of AMAX Coal Company

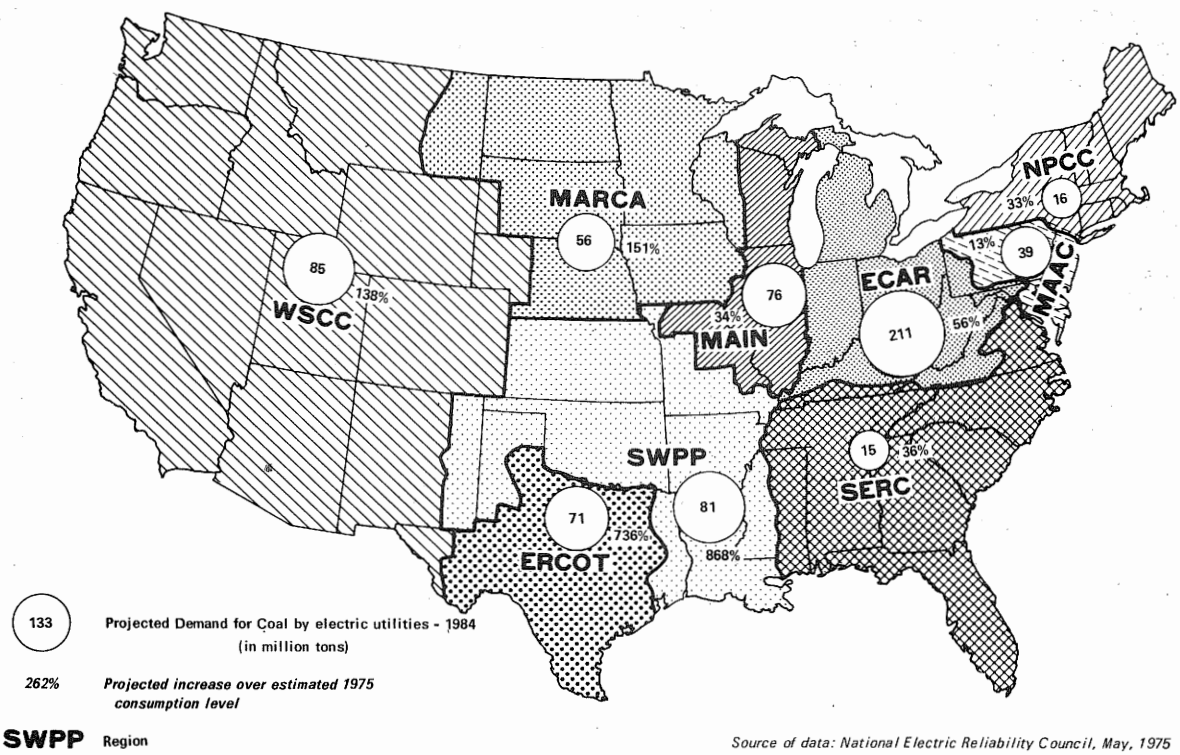

Fig. 12 - Projected demand for utility coal in the United States by the end of 1984. (Source of data: National Electric Reliability Council, May 1975.)

recently presented a forecast of future coal markets at the second symposium on coal utilization in Louisville, Kentucky (table 2). His forecasts for electric utility and synthetic fuels were a little more optimistic than earlier projections. The analysis does emphasize, however, that the largest growth in coal use is likely to occur in the electric utility and synthetic fuels markets.

Electric Utilities

As mentioned earlier, in spite of the increase in nuclear power for generating electricity, an increase in the use of coal is also projected for this purpose. The National Electric Reliability Council's data on the projected increase in electric utility coal needs by geographic regions of the United States are illustrated in figure 12. The demand for coal is expected to increase in all regions. The largest increase in coal consumption (8 to 9 times the estimated 1975 consumption) is forecast for the ERCOT and SWPP regions, which include the states of Texas, Oklahoma, Kansas, Arkansas, Louisiana, and parts of Mississippi, Missouri, and New Mexico. A two- to three-fold increase is projected for the MARCA and WSCC regions. The least growth (13 percent) is projected for the MAAC region, which includes New Jersey, Delaware, and parts of Pennsylvania and Maryland.

The National Electric Reliability Council projects that by 1984 over 780 million tons of coal will be consumed by electric utilities in the United States. The demand would increase to 941 million tons by the year 2000, according to a recent U.S. Bureau of Mines estimate.

Manufacturing Plants

The manufacturing plants now relying mainly on natural gas and fuel oil to produce heat and power also are likely to turn to coal for their energy needs as the other sources of energy become difficult and expensive to obtain. One way to estimate the size of the industrial coal market that could result if the manufacturing plants now using natural gas and fuel oil should turn to coal is to examine data on the consumption of natural gas and fuel oil. In 1971, manufacturing plants in the United States consumed an estimated 318.1 million tons of natural gas and fuel oil, in terms of coal equivalent, to produce heat and power. If 10 percent of the total energy derived from natural gas and fuel oil by manufacturing plants in 1971 had been instead derived from coal, an additional 31.8 million tons of coal would have been needed. That amount would have increased to 79.5 million tons if 25 percent of the 1971 energy total that came from natural gas and fuel oil had been supplied by coal and to 159 million tons if half that energy had been furnished by coal.

The largest markets for coal for manufacturing plant use (fig. 13) would have developed in Texas, Louisiana, Pennsylvania, and California. Other areas where large demand for coal for industrial use would have developed include Ohio, Illinois, Indiana, and Michigan.

The U.S. Bureau of Mines in a recent estimate projects that by 1985, 190 million tons of coal will be consumed by the industrial and manufacturing plants. This amount would increase to 228 million tons by the end of the century.

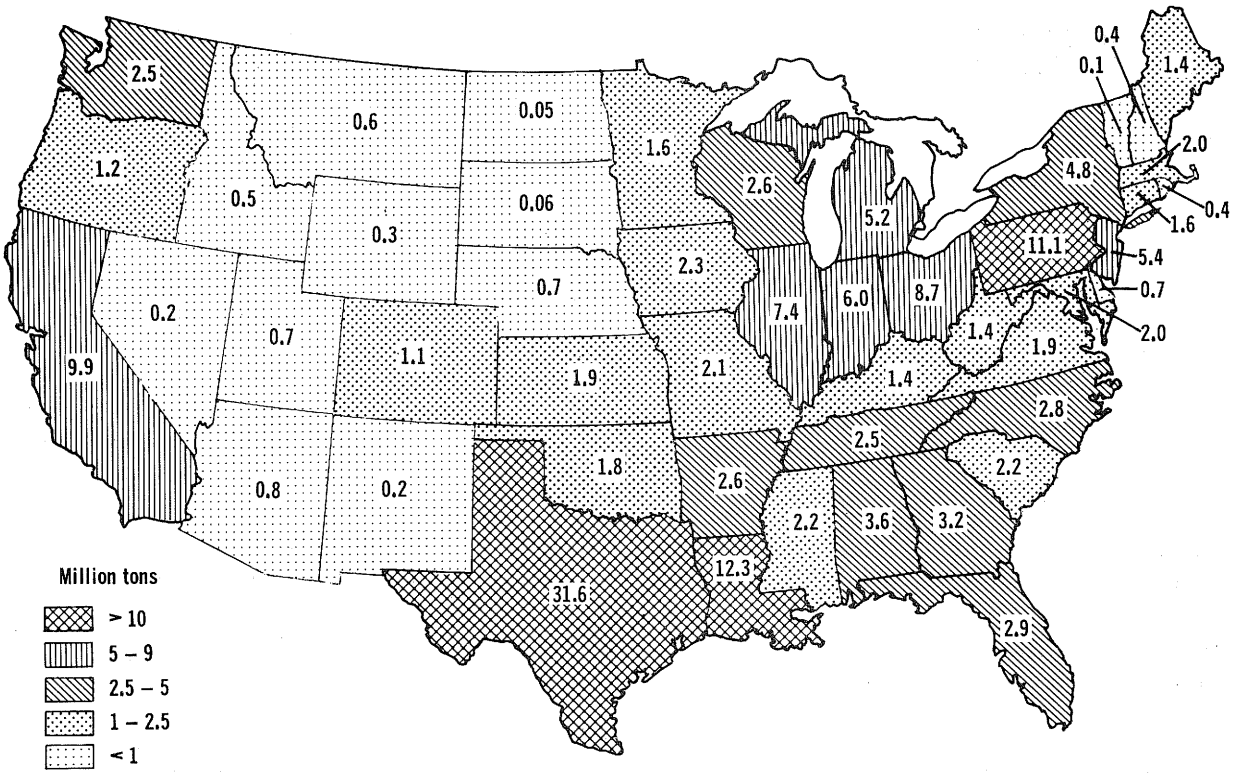

Fig. 13 - Potential new market for industrial coal, total estimated 159 million tons.

Coking Coal

The demand for coking coal for use in the production of pig iron has recently been projected by the U. S. Bureau of Mines (table 3). By 1985 the domestic coking coal demand could amount to 109.4 million tons, 23.8 percent more than the amount used in 1974. The demand for coking coal could decline by about 7 percent if new technologies, such as form coke and direct reduction, are extensively implemented.

The U. S. Bureau of Mines also predicted the United States export market for coking coal could expand to more than 136 million tons per year by 1985. The AMAX Coal Company (table 3) estimated exports of 65 million tons. The best estimate probably lies between the two. In 1974 about 60 million tons of coking coal was exported from the United States.

TABLE 3—PROJECTED DEMAND FOR COKING COAL (1985)

DOMESTIC MARKET		
Under current technology	109.4	million tons
Percent change over 1974 consumption	23.8	percent
With future technology implemented		
Coking coal	57	million tons
Form coke	15	million tons
Total	82	million tons
Change from 1974	- 6.8	percent
EXPORT MARKET		
Present	60	million tons
Projected		
U.S. Bureau of Mines	136.3	million tons
AMAX Coal Company	65	million tons

(Source of data: U.S. Bureau of Mines Information Circular 8677, 1975; Second Symposium on Coal Utilization, National Coal Association and Bituminous Coal Research Conference and Expo II, 1975.)

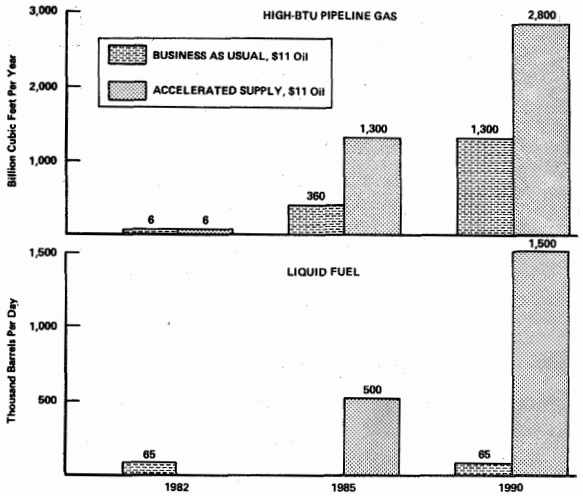

Fig. 14 - Projected production of synthetic fuels from coal. (Source of data: Energy Perspectives, U.S. Department of Interior, February 1975).

Synthetic Fuels

The use of coal to produce synthetic fuels, as mentioned earlier, also is expected to increase (fig. 14). The Federal Energy Administration projects, on an accelerated development scenario, that by 1990, 1.5 million barrels of crude oil per day and 2.8 trillion cubic feet of natural gas per year will be produced from coal. We believe, however, that a large growth in synthetic fuels from coal is not likely to develop much before 1990 and, even under the accelerated scenario, would still fill less than 3 percent of the nation's total oil and gas needs.

Other Uses

The use of coal is also expected to increase in other areas. As coal takes over the markets currently served by petroleum and natural gas, it is bound to be used to produce such commodities as lubricants, chemical feedstock, and hydrocarbon compounds. Coal is already being considered as a potential direct source of methane, which is one of the main components of natural gas. The production of ammonia from coal also has been mentioned.

PROBLEMS FACING COAL INDUSTRY

Even though the use of coal is expected to increase, the coal industry faces several problems. The capital needed to expand the coal mining capacity is one of these. To expand mining capacity to the point where it could produce 1.3 billion tons of coal by 1990, an estimated capital investment of $21.5 billion would be needed, and the cost could increase to $52.5 billion if the production capacity is to be expanded to produce 2.8 billion tons of coal in 1990. In light of the large amount of money needed and the present severe competition for capital, it is likely that the industry will need some incentives and assurances from government to expand coal mining capacity.

The availability of labor is another problem the coal mining industry will face. To produce 2.8 billion tons of coal in 1990, the industry would need an estimated 423,000 coal miners, 265,000 more men than the industry currently employs. The mining industry will find it necessary to make the mining profession sufficiently attractive to draw qualified people from other disciplines into coal mining.

The shortage of mining equipment and lack of new technology also could limit, to an uncertain extent, the projected growth in coal production. Transportation systems, which are vital for moving coal from mines to consumers,

are not at present equipped to handle the projected increase in the demand for coal. Delays in the development of new transportation systems and in the expansion of existing systems could thwart the industry's plans for expansion.

The FEA's projected increase in coal production includes an estimated 287 million tons of coal per year by 1990 that would be mined from western land now controlled by the Federal Government. The development of western coal has already suffered from delays in Federal leasing that have resulted primarily from objections by environmental and local groups. These delays have affected the coal industry's previously announced expansion plans.

State and Federal mining laws and regulations have contributed to a decline in labor productivity in recent years. Without improvements in labor productivity the industry would find it difficult to produce enough coal to meet the nation's energy needs.

Uncertainty about the future price of crude oil and natural gas may also be a restraint to growth of the synthetic fuel industry.

CONCLUSIONS

Solar power and fusion technology are much in the news and are expected to be significant contributors to the total energy supply in the 21st century. If there is a massive infusion of research, development, and governmental participation their impact may be felt earlier.

Geothermal power and hydropower will continue to supply increasing amounts of energy, largely for local markets in the future. These energy systems are not expected to be major contributors to the nation's total new energy needs.

In the immediate future—the rest of this century—the country must depend largely on the fossil fuel resources and nuclear energy. As coal is one plentiful potential resource that we know much about in terms of existing technology and safe use, coal is in the best position of all fuel sources to fill its expected share of the nation's energy needs in the next 25 years.

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