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Coal in the United States: A Status Report

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Summary. Historical trends in U.S. coal production, transportation, and utilization and their causes are analyzed. The changing structure of the coal industry and its possible future direction, as it is driven by the effects of the oil embargo and world oil prices, are examined. National policies in the United States to increase coal use from indigenous sources in order to diversify and increase reliability of supply raise questions as to availability of coal supply and potential markets. Possible constraints on U.S. coal production, transportation, and utilization are appraised, and it is concluded that increased coal consumption is "demand constrained." The causes and potential means of removal of these limitations are examined.

At the turn of the century coal supplied more than 93 percent of U.S. energy requirements, but this share declined steadily until by 1972 it provided only 17.3 percent, with oil and natural gas providing most of the balance. At that time its future was still highly uncertain, with low-cost oil from the Middle East competing vigorously with coal for utility and large industrial markets, aided by newly enacted air and water pollution laws that made coal more costly to use than it otherwise would have been. Natural gas was still in ample supply and, since regulation maintained its price below market clearing levels, it was the preferred fuel for residential and industrial users. The size of the market for coal in the manufacture of coke for U.S. steel production depended entirely on steel demand, which had been declining because of increased competition from other materials and from imported steel. The coal export market was relatively stable but with little prospect for expansion given the low prices for world oil and the absence of a growing steel market for which high-quality U.S. metallurgical coals were used.

In spite of these dim prospects for the future use of a domestic energy source with an almost unlimited resource base, only the coal industry showed any concern about the situation before the 1973–1974 oil embargo. By that time U.S. energy dependence on foreign oil had already risen to 23.5 percent of oil demand and 10.4 percent of total domestic energy requirements, with an even greater future reliance on oil imports a seeming certainty. The embargo demonstrated the potential threat that this heavy reliance on oil imports could have on U.S. economic and military security. The quadrupling of oil prices in 1973–1974 and the fear of even further sharp price rises (which actually occurred in 1979) raised additional concerns about the long-term economic implications of much higher energy cost. Thus, for both security and cost considerations, energy policy-makers turned to the large reserves of domestic coal, which could be supplied at low costs, as a possible means of providing solutions to these newly developed energy problems.

After the oil supply disruption, starting in October 1973, a variety of administrative and legislative actions were taken with the objective of achieving "energy self-sufficiency," "energy independence," or "energy interdependence." These included both national and international initiatives, since the balance of the world was also concerned with reducing oil imports from OPEC countries, and for many countries, including the United States, one possible method of achieving this goal was to increase reliance on coal.

In the United States a number of policy initiatives (*1*) were undertaken to increase coal use, and by 1982 coal's share of U.S. energy supply was 22.1 percent, having risen slightly from a low in 1972 of 17.3 percent. There were several reasons for this change. Government initiatives were designed to increase coal use and price-induced switching to coal occurred wherever possible. Since electric power generation, which is heavily coal-based, was less affected than other fuel uses by the economic recession and conservation efforts, coal's share of the market was less affected than that of other fuels. In spite of this somewhat more favorable situation for coal, the future for coal is still extremely uncertain because of the current (1982–1983) oil glut accompanied by a still undetermined but very significant drop in world oil prices; the sudden development, for the short term at least, of adequate U.S. natural gas supplies (albeit at higher prices); the much higher rail rates for transporting coal that have evolved since rail deregulation; the delayed or scrapped industry plans for constructing synthetic-fuels plants using coal; and the still-to-be-resolved issues of environmental controls (including acid rain). These all contribute to the doubts about coal's role in U.S. energy supply for both the immediate and longer term.

Following is an examination of the current status of the use of U.S. coal resources and the factors that can be expected to influence the future role of coal.

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U.S. Coal Resources and Reserves

Coal resources and reserves (*2*) of the United States are extremely large, with proved reserves alone of more than 280 billion tons, enough to supply all U.S. energy needs for many decades. About three-quarters of the tonnage of surface-minable coal is west of the Mississippi, while nearly equal amounts of underground reserves are found east and west of the Mississippi. All subbituminous coal reserves and virtually all lignite reserves are in the West; comparatively small reserves of anthracite are found in the East.

Most western coal deposits are characterized by their low rank—subbituminous coal has a heating value of about 10,000 Btu's per pound (5600 kcal/kg) and lignite has a heating value of about 7000 Btu's per pound (3900 kcal/kg) compared with a heating value of 11,000 to 14,000 Btu's per pound (6100 to 7800 kcal/kg) for eastern coals. Western coals are generally low in sulfur (0.6 percent is typical) and occur in thick seams—10 feet to more than 200 feet. The sulfur content of eastern coals ranges from 0.6 to more than 6 percent, with a large share of the coals having a sulfur content in the 2.0 to 3.5 percent range. Most of the eastern coal seams are much thinner than western deposits—2.5 to 8 feet thick is common—and many of them are only suitable for underground mining.

Trends in the Coal Industry and Their Causes

Coal production and productivity. Table 1 shows U.S. bituminous coal and lignite production for selected years from 1920 to 1981. Production reached a first peak of 631 million tons in 1947 but declined sharply after the war. By 1954 production had declined to 392 million tons, a drop of one-third in only 7 years. This decline was due to the availability of low-cost oil imports, the development of the more energy-efficient diesel fuel locomotives, and to the construction of long-distance, natural gas pipelines that brought the natural gas from the southwestern United States, where much of it had been flared, to eastern markets. As a result, coal lost virtually all of the residential and part of the industrial market to oil and gas and the railroad market to oil.

Both the geographic distribution of coal production and the share of coal produced by surface mining have shifted radically in recent years. In 1970 about 93 percent of all coal was produced east of the Mississippi River, largely in the Appalachian region. Western coal production grew from 44 million tons in 1970 to 268 million tons in 1981, when it represented about 33 percent of total coal production (*3*). During the same period surface mine coal production increased from 272 million tons in 1970 (44 percent of total production) to 494 million tons in 1981 (61 percent of total production) (*4*).

Table 1. U.S. bituminous coal and lignite production, selected years, 1920 to 1981 (*33*).

Year	Production (thousands of short tons)
1920	568,667
1930	467,526
1940	460,772
1947	630,624
1950	516,311
1954	391,706
1955	464,633
1960	415,512
1965	512,088
1970	602,932
1971	552,192
1972	595,386
1973	591,000
1974	603,406
1975	648,438
1976	678,685
1977	691,344
1978	665,127
1979	677,286
1980	699,061
1981	814,716

Passage of the Coal Mine Health and Safety Act of 1969, combined with other coal industry developments, reduced productivity in the predominantly eastern underground coal mines about 46 percent in 10 years—from 15.6 tons per man-day in 1969 to a low of 8.38 tons per man-day in 1978 (*5*). Surface mine productivity, concentrated in the West, declined only 29 percent during this period and enhanced the economic attractiveness of surface-mined coal. Since then productivity has increased about 25 percent in both surface and underground mines.

Coal prices. Average coal prices at the mine (expressed in constant dollars), rose by a factor of 2 between 1969 and 1981. However, prices vary widely among regions: in the western states in 1980 the weighted average value of production was $11.17 per ton or $0.55 per million Btu's, while the average value of Appalachian underground coal was $35.69 per ton or $1.55 per million Btu's (*6*).

Domestic coal consumption. After the loss of the residential and railroad markets during the 1940's, major domestic markets for coal were for electricity generation; manufacture of coke for steel production; and, in the industrial sector, for process heat, steam, and power. Consumption by the industrial sector declined from the early post–World War II years to about 1978 but has increased slightly since then (*7*). Coal used for coke production continues to decline as steel production declines.

Generation of electricity grew at a rapid rate starting in the middle 1920's. The very recent decline in the growth rate in electricity demand is due partly to the general economic recession and partly to conservation. However, the electric utility market for coal has not been as adversely affected as has the market for other fuels. Although electricity production grew an average of only 1 percent per year between 1979 and 1981, coal use by the electric utility industry grew by about 6 percent per year during that period (*8*). This is a reflection of the less-than-projected additions of nuclear electricity-generating plants and of the preference for using coal in place of other fossil fuels whenever it was possible to do so.

One reason for the preference for coal for electricity generation is that it can be delivered to utility plants at a much lower cost per million Btu's than can either oil or gas. In September 1982 the cost advantage of coal was a factor of more than 2 over gas and nearly a factor of 3 over oil (*9*). Although there is some economic penalty for using coal in place of other fuels, since it involves higher capital costs (coal stockpiling and grinding equipment and equipment to remove particulates and sulfur oxides) and higher operating costs (ash and sulfur oxide control and disposal of collected solids), at current, delivered prices coal can be utilized at most utilities at lower cost than other fuels.

Coal exports. Exports became an important market for U.S. coal producers following World War II, when Western Europe was short of fuel. Between 1950 and 1979 coal exports varied between 30 million and 75 million tons per year, with an average year's export being about 50 million tons (*10*). Most of the coal exported in this period was of metallurgical quality.

The renewed worldwide interest in using fuels other than petroleum, stimulated by the 1973–1974 oil embargo and sharp price increases that accompanied it, had matured by 1979 and was intensified by the doubling of oil prices in that year. Coal exports jumped from 66 million tons in 1979 to 92 million tons in 1980 and to 113 million tons in 1981 (*11*).

Most of the growth in demand was for coal to be used for steam generation (by the electric utility and industrial sectors) rather than its traditional use for coke production. This very large increase in exports in 1980 and 1981 was in part a result of disruptions in supplies from other exporting countries. Importers turned to the United States for supplies that had become unavailable elsewhere.

Structure of the coal industry and work force. Historically, the coal industry consisted of a large number of small companies operating many small mines and a few major companies with large productive capacity. Starting after World War II, a major technological change took place in the industry: mechanization of production, which required much larger capital investments than had been previously needed to open new mines. The high capital costs of mechanization increased barriers to entry to small operators; as a result, production has become concentrated in the last 25 years, with fewer companies accounting for a larger share of total production. In 1965, the category of the largest coal mines (500,000 tons per year or more) represented only 3.6 percent of all mines, but produced 57 percent of all the coal, while the smallest mines produced 14 percent of the total (*12*). By 1981 the largest mines accounted for 60 percent of production and the smallest mines about 6 percent.

This concentration of production in larger mines was mainly the result of changes in ownership patterns. In 1960, 20 of the 25 largest coal-producing groups consisted of companies devoted only to coal mining or steel companies extracting coal from their captive operations for use in steelmaking. By 1980, of the 15 top producing groups, only two were devoted entirely to coal production. The others were captive operations of steel or electric utility companies, large energy companies (mainly oil), and conglomerates.

The shift to mechanization of underground coal mines that raised their labor productivity, the increased share of production from less labor-intensive surface mining, and the decrease in total coal production during the 1950's greatly reduced the mining work force. Employment dropped from more than 400,000 miners in 1950 to about 130,000 in the early 1960's. The increase in demand for coal that started in the 1960's and the sharp decline in underground productivity after 1969 (a less steep one occurred in surface mining) required additional manpower, and by 1980 about 225,000 miners were employed by the industry (*13*).

Coal Transportation

Coal transport modes. In recent years the electric utilities, by far the largest user of coal, have tried to eliminate or reduce transport costs by siting power plants at the mine mouth or as close to the mine as possible. In 1982, of the coal that was transported, the railroads handled 59 percent of all coal used domestically, with most of the balance transported by barge and truck. Average rail rates increased from $3.71 per ton in 1973 (*14*) to $12.50 per ton in 1982, but rail transport costs as a percentage of the delivered price of coal remained essentially constant at about 30 percent. However, those increases in rail freight rates occurred prior to the passage of the Staggers Rail Act of 1980, which in effect partially deregulated freight transportation. The effect of this legislative change on coal freight rates is still developing.

Barge transportation of coal can be used only for mines with access to the inland waterway system, but is utilized wherever possible, as coal can be transported over long distances at about one-half the cost per ton-mile of rail transport. Barges transported 16 percent of all coal used domestically that was mined in 1982, nearly all in the mid-Atlantic eastern states (*15*).

Trucks accounted for 14 percent of the coal transported for domestic use in 1982 (*16*); they are generally used when coal has to be transported over relatively short distances, either directly to markets or to some other transport mode for further shipment to more distant markets.

Recent developments in coal transportation technology. Although the cost of transportation as a share of the delivered cost of coal has remained constant, there continues to be great interest in reducing transport costs. For large tonnages delivered from a limited number of producers to a few consumers, "unit trains" (*17*), introduced in the 1960's, can reduce transportation costs appreciably. Unit trains moved 54 percent of all coal moved by rail in 1980 (*18*).

Another method of coal transport is by coal slurry pipeline. In this transport mode coal is ground to a fine size, mixed with about an equal weight of water, and then pumped through a pipeline in a manner similar to piping any liquid material. One slurry pipeline is in operation, transporting 5 million tons of coal per year over nearly 300 miles from Arizona to Nevada. With the development in the West of very large surface mines, which must ship coal over long distances to electric utilities, interest has increased in pipeline transportation, since with low-cost, surface-mined coal and long shipping distances, transportation becomes a large part of delivered costs. For example, in 1980 the average price of coal in Wyoming was $10.54 per ton at the mine, but its delivered costs to utilities in Illinois averaged $38.94 per ton. Thus, the transport cost by rail was almost three times the price of the coal (*19*).

Research and Development

Historically, the coal industry had little interest in research and development activities because of the many small companies involved, the almost continuously depressed financial position of the industry, and, during certain periods, the lack of competition for its product. As a result, most coal research was conducted by government on the industry's behalf, but expenditures were very modest. For most of the post–World War II period, federal expenditures on energy research were concentrated on the development of nuclear energy—a coal competitor in the electric utility industry.

With the establishment first of the Energy Research and Development Administration in 1974 and then of the Department of Energy in 1977, and in line with the federal commitment expressed in the National Energy Plans, expenditures on coal research increased substantially: by 1980 the federal R & D coal budget reached about $780 million per year (*20*). The programs included R & D on all aspects of coal research—coal mining, preparation, direct combustion, and conversion to synthetic fuels—with the greatest share being expended for research on conversion of coal to synthetic liquids and gases.

In June 1980 the Synthetic Fuels Corporation was established to promote the creation of a privately financed domestic synfuels industry. The corporation supports new commercial synthetic fuel ventures through the use of price guarantees, purchase commitments, loan guarantees and direct loans, and participation, if necessary, in joint ventures. Under various legislative acts, in the spring of 1983 the corporation has available to it nearly $15 billion in appropriated funds to carry out its mission.

With the establishment of the Synthetic Fuels Corporation and the change in administration in January 1981, the R & D appropriations for the coal program of the Department of Energy were reduced drastically, even though the Synthetic Fuels Corporation is prevent-

ed by its legislation from supporting R & D. The Administration's proposed budget for fiscal year 1983 included under $100 million for coal research, but this was increased by Congress to about $300 million (*21*). Sharp budget cuts have resulted in a greatly reduced national coal research program, since with few exceptions the coal industry is still not investing extensively in research activities.

Future Developments

As noted above, since the mid-1970's U.S. national energy policy, as well as that of other major industrialized countries, has been directed toward increasing coal's contribution to the energy supply. This policy has raised questions as to whether constraints could arise in the various segments of the coal system—production, transportation, and utilization—that would prevent this goal from being met.

Constraints on Coal Production

A large variety of factors can affect the rate of expansion of coal production: the reserve and resource base, equipment, capital, manpower, environmental regulations, health and safety regulations, socioeconomic factors, water resources, and labor-management relations.

There is a more-than-adequate supply of domestic coal for increasing production to any foreseeable level and for any reasonable time (see above). However, while nearly all of the eastern coal deposits are in private ownership, as much as 70 percent of the western reserves are in federal ownership, and not all of the remaining 30 percent is readily available for development. Thus, the timely use of western coal reserves will depend on the actions of government agencies and, to a lesser degree, on those of private groups holding existing coal reserves.

Leasing of additional federal western coal lands involves consideration of many complex problems. Widespread interest in these lands did not develop until the 1960's. By 1971 there was concern that speculation was occurring on federal lands because of the large number of leases in private hands that had been acquired under the liberal terms of the Mineral Leasing Act of 1920.

In May 1971 the Department of the Interior placed a moratorium on leasing of federal coal lands which was not lifted until January 1981. During the moratorium the Federal Coal Leasing Amendments Act of 1976 was enacted; it contained provisions designed to inhibit speculation on federal coal lands.

When the moratorium was invoked in 1971, an estimated 16 billion tons of federal coal were under lease, with an additional 5.4 billion tons in "preference right lease applications" (*22*). After leasing was resumed, an additional 2.2 billion tons of coal were leased and are now in private hands for development. The major question is whether these coal resources are sufficient to provide the competition that is necessary for the orderly development of the western coal resources. Although the tonnage leased is large compared with current western coal production, not all of it can be economically recovered; part is in units too small to justify development, part is found under geological conditions that make economic development impractical at this time or that make the resources disqualified for development under the Surface Mining Act of 1977, and part is held by lessees unwilling or unable to undertake development. Moreover, projections of demand for western coal indicate a continuation of a rapidly expanding market (between 1970 and 1981 production increased at nearly 20 percent per year), and with dedicated reserves of 30 years or more needed to satisfy large potential coal consumers, the leased tonnage may be insufficient to provide competition among suppliers.

Although there are relatively few manufacturers of large underground equipment or certain types of surface mining equipment, no serious shortages of either have been experienced in recent years, and no change in this situation is expected. However, the anticipated growth in demand for coal in the next 10 years will require large investments of capital to open new mines. With long-term purchase commitments for the coal to be produced, raising this capital should present no difficulties. The total investment needed for new mines would be about $60 billion to $70 billion or about $4.5 billion to $5.5 billion per year. For the large oil and conglomerate companies now engaged in coal mining, investments of this size in the coal industry, with sales of $21 billion per year, should present no problems.

There were occasional local manpower shortages after the large, existing labor pool had been absorbed during the current period of coal production expansion that started in the early 1970's. However, there has been no difficulty in recruiting needed personnel. Training of new miners requires time and productivity suffers for a period, but manpower availability has not been, and in the long run should not prove to be, a constraint. With much of the new production expected to come from western surface mines, manpower will be even less of a problem in the future. Surface mines have much higher productivity and do not require workers with the specialized training necessary for underground mining. Thus, manpower can be recruited from a much larger labor pool, since the skills sought are similar to those used in large earth-moving operations and these are not scarce.

The Surface Mining Act of 1977 made environmental regulations related to coal production much more restrictive for surface than for underground mining. For underground coal mines, water pollution mainly involves acids and dissolved and suspended solids formed during the mining operation; these can be controlled with relative ease. Control technology for surface mines is more difficult than for underground mines, and depends mainly on managing surface waters so they do not become contaminated or, if they should, impounding and treating them before discharge. The best and most economic methods of achieving this control are a matter of dispute and have led to a number of challenges to the regulations promulgated to enforce the Surface Mining Act of 1977. These are currently in the courts awaiting decision.

Much larger tonnages of solid waste are created at surface mines than at underground mines, and these surface mine wastes tend to be more chemically heterogeneous. More careful treatment in disposal is thus required. In the case of contour surface mining, which produces large volumes of excess spoil, very complex and expensive disposal methods are required.

Experience gained in complying with the Surface Mining Act of 1977 has indicated that surface mining can be conducted successfully at nearly all sites without producing unacceptable levels of environmental degradation if proper planning and control measures are taken. The major impact of meeting these environmental standards is an increase in the cost of surface-mined coal estimated to be from $1 to as much as $5 per ton, depending on geological conditions (*23*).

Providing safe working conditions for miners is much more difficult in underground than in surface mines. The Coal Mine Health and Safety Act of 1969 greatly strengthened the regulations for coal mine working conditions. As a result fatality and accident rates have been reduced significantly, as has exposure to those conditions that are thought to cause black lung disease. These regulations increased coal production costs, but even the approximate amount caused

by the more restrictive regulations has been difficult to estimate.

Adequacy of water resources does not present a major problem for eastern coal mining but is of concern at many proposed mining locations in the arid regions of the West. In those regions, water availability for new uses can present problems because of the complex water right laws of western states, the Indian tribes' claims for water, and the political difficulties of transferring water from existing low-value users to other users and of transferring water from one region to another. Nevertheless, the relatively small quantities of water required by the expected increase in coal production should not put limits on production for the next 10 to 20 years. Of greater concern is that the water needed for the large number of power plants and conversion facilities that would be using coal (or other fossil fuels) could constrain the number of plants that can ultimately be constructed.

There is a long history of labor disputes between the United Mine Workers (UMW) union, which until recently represented a very large percentage of coal miners, and industry management. The UMW now represents a much smaller share of the miners, with union participation concentrated in eastern mines. This could reduce the importance to the industry of future contract negotiations. Recent labor-management regulations and disputes have occurred, in part, because of the changing nature of the coal mining work force and the aspirations of new, young miners to share in the benefits generated by the revitalization of the coal industry during the 1960's and 1970's. The long strikes that occurred as recently as 1978–1979 (111 days) and 1981 (76 days) reinforced the public perception of an industry with major unsettled labor problems and raised questions among consumers, both at home and abroad, about reliability of coal supplies that could affect future coal use.

Many other uncertainties still remain about future legal and regulatory changes that could affect coal production and use. These include possible modifications in health and safety and environmental regulations, in federal leasing terms and conditions and frequency and number of leases offered, in possible legal limitations on industry structure (including ownership patterns and horizontal and vertical integration), in antitrust issues, in sanctity of contracts for the coal export market, in tax policies affecting coal production, and in federal severance taxes on coal. In addition, possible federal actions that affect the coal industry's transportation services and its market competitors have been under review frequently. These include, for example, interpretations of recent legislation that partially deregulated the rail and trucking industries, possible repeal of the Fuel Use Act of 1978 that prohibits use of other fossil fuels in new electricity-generating plants, uncertainty about the frequency rates and size of leases offered for outer continental shelf oil and gas production, and recent proposals for natural gas price deregulation.

Constraints on Expansion of Coal Transportation

Rail transport. The impact of the Staggers Rail Act of 1980, which partially deregulated railroad freight rates, cannot yet be fully evaluated. To the extent that it provides the railroads the means for increasing their operating efficiency and permits them to improve their earnings, it should be of benefit to the coal industry. If, however, freight rates for coal are increased sharply or set so that coal traffic essentially subsidizes transport costs for other commodities, the coal industry would be adversely affected. Small coal producers are concerned that their bargaining power under deregulation is less than that of the large producers and that they will be placed at an economic disadvantage relative to them. Recent developments have raised great concern in the coal industry about the tests that are being used by the Interstate Commerce Commission (ICC) to determine "market dominance," which could lead to much higher freight rates for some railroads than had been anticipated. On 24 February 1982, the ICC proposed guidelines for establishing railroad coal rates which the coal industry believes are so broad that they will result in monopoly rates.

In addition to tariff considerations, two major problems could arise if more coal must be transported: these are the ability of the railroads in the West, where much of the expansion in coal production is expected, to handle the increased traffic, and the ability of the railroads in the East to finance the additional physical plant required to continue to provide adequate service.

As far as rail equipment is concerned, the railroads should be able to obtain the necessary cars and locomotives for any increased demands that the coal industry may place upon them. This can be achieved in part by improving the utilization of existing equipment through greater efficiency of operation and more widespread use of unit trains and, in the East, by abandonment of the less profitable lines. If it appears that more equipment is needed, the railroads would have sufficient lead time to order and receive the new equipment in the time required to open the new mines where the coal would be produced.

Western railroads, faced with the possible need to handle much larger tonnages, may find it necessary to increase the amount of track and to purchase additional rolling stock. Part of the requirement for new track could result from rerouting existing lines away from towns to avoid noise and pollution and to prevent interruption in local highway traffic. Expansion of western rail facilities to meet coal transport demands does not appear to be difficult, but bottlenecks could occur on certain routes and at certain times.

Barge transport. In the mid-Atlantic eastern states, barge transport of coal, along with other commodities, has been hampered in recent years by congestion at a number of locks on the inland waterway system. Delays in shipping have occurred at locks even when the economy was operating at normal levels and at current coal production rates. It will not be possible to handle increased movement of large new coal tonnages until the locks are replaced or enlarged. There has been extensive study of new facilities to handle larger barges and to increase lock capacity, but no construction has been started on locks handling coal traffic.

Trucks. The Motor Carrier Act of 1980 partially deregulated motor transport. Truck transportation is used mainly by eastern coal mines and is especially important to the smaller coal producers. They are concerned that the recent partial deregulation of motor transport will work to the advantage of larger producers.

There should be no constraint on availability of equipment to transport coal by truck, but concerns have been raised about the adverse environmental impacts (dust, noise, congestion) that could be created should there be a large increase in coal movement by truck. More important, particularly to small eastern producers, is the condition of coal haulage roads. States with major road construction and reconstruction needs have initiated programs to improve their coal haul roads, but these efforts have not been large enough to solve the problem. This could be critical to some small mines, but even if the roads are not satisfactorily repaired, it should not significantly impair major coal deliveries.

Coal slurry pipelines. Two major obstacles are delaying the construction of new coal slurry pipelines in the United

States—water availability and the rights-of-way needed for siting the pipelines. There have been major objections to water use for coal slurry transport on environmental and other grounds, with water availability a much more important issue in the West than in the East.

Attempts to obtain federal legislation for eminent-domain rights for coal slurry pipelines have a 20-year history, and new legislation is now under consideration by Congress. Plans for construction of at least one pipeline to transport western coal are well advanced, and a proposal to transport Appalachian coal through the southern states to Florida has been extensively studied. During the summer of 1982 Virginia Electric Power Company (VEPCO) announced the results of a study of a proposed coal slurry pipeline to carry coal from southern West Virginia to VEPCO's coal-burning power plants in the East. According to VEPCO, coal rail freight rates for this traffic are $19.50 per ton. Pipeline costs for the same distance were estimated (*24*) at $7.50 to $8.26 per ton (with a 10 percent return on investment) for a pipeline capacity of 5 million tons per year and about $4.50 per ton for a pipeline capacity of 20 million tons per year.

Ports for export coal. In 1980 and 1981 U.S. coal export port capacity was insufficient to handle coal export demand, and long, costly delays in loading coal-bearing ships resulted. This constraint on coal export appears to have been eliminated by the more efficient use of existing facilities and construction of new coal-handling facilities at other U.S. ports. A large number of major expansions were announced for Baltimore, Hampton Roads, New Orleans, and Mobile, but since port congestion has now been relieved, it is uncertain how many of these will actually materialize.

U.S. coal ports still cannot handle ships larger than 60,000 dead weight tons (dwt), and even larger ships (150,000 to 200,000 dwt) are becoming increasingly important in international coal trade. To help maintain a competitive position for U.S. coal exports, ports will have to handle these larger ships. Still unresolved, however, is the question of who will bear the costs of deepening the ports, with user fees one possibility being considered.

Constraints on Coal Utilization

Although numerous factors can adversely affect the rates and costs of coal production and transportation, broadly speaking it appears that as much coal as can be utilized could be produced and transported to consumers. Growth in coal demand will then be determined by total energy growth, relative costs of producing, transporting, using fuels by consumers, and national policies that influence market share. Coal's remaining competitive markets are for electricity generation, industrial uses, and, in the future, for conversion of coal to liquid and gaseous fuels. Coal's two other large markets, coal for making coke for steel production and for export, are not competitive with other U.S. fuels, although they are with foreign coal suppliers. For coal's competitive markets, constraints on its use are:

1) Utilization costs,

2) Environmental regulations for direct combustion (air pollution, including acid rain, water pollution, and solid waste disposal),

3) Commercialization rates of coal conversion plants (environmental regulations, resource availability, and socioeconomic factors), and

4) Coal exports.

Utilization costs. The consumer cost of energy is made up of the delivered cost per unit of heat in the fuel and the cost of using it. Coal is more expensive to use than oil or gas because (i) it must be stored to ensure a dependable supply (requiring land area and specialized stockpile equipment), (ii) it requires equipment for crushing and pulverizing before use, (iii) it uses more complex and expensive feeding systems, (iv) it requires larger boilers for the same steam-generating capacity, and (v) it requires larger and more sophisticated equipment for air pollution control. In addition to the higher capital costs for this extra equipment, higher operating costs are involved for labor, energy, supply and maintenance of equipment, and disposal of ash and of solid wastes from scrubbers used to prevent air pollution.

Reduction of these extra costs of using coal depends upon development of new and more efficient technologies for each of the operations described above. Fluidized-bed combustion (both pressurized and atmospheric) and coal-oil or coal-water mixtures are two of the more promising new coal combustion technologies under development. They hold the potential for reducing some of the extra costs involved in using coal, but their commercial utilization is still at a very early stage.

Environmental regulations for direct combustion (*25*). Both electric utility generating plants and larger industrial consumers are required to meet environmental regulations covering air and water pollution and solid-waste disposal. For coal, conforming to these regulations is much more costly than for other fossil fuels and can increase effective coal costs by as much as 10 percent or more, thus representing a significant deterrent to expanding coal markets.

In the direct combustion of coal, air pollution standards must be met for sulfur oxides, nitrogen oxides, and particulates. Other air pollutants are receiving attention, but standards for compliance do not yet exist. The standards for sulfur oxides have been the most difficult to meet and the most vigorously enforced.

Control technologies for meeting the nitrogen oxide standards are available, but improved and lower-cost methods are still being investigated. Particulate removal devices are commercially available and, unless new standards are established that require less emission or removal of very fine particulates, particulate emission standards can be met.

The justification for the sulfur oxide emission levels that have been established was based primarily on the adverse health effects attributed to these emissions. In addition, sulfur oxides damage plants and materials and are believed to be an important contributor to reduced air visibility. In the last several years sulfur oxides have received attention as the cause or one of the causes of acid rain—a probable source of the acidification of lakes in the northeastern United States, Canada, and Sweden.

Concern over air pollution has been a major constraint to increased coal utilization. The unanswered technical and scientific questions, the complexity of the chemical processes occurring after emission and before deposition, and the lack of a good data base from which to assess reliably the magnitude of the problem, including the health problem, have left considerable doubt about the rationale for the regulatory standards. In addition to the uncertainties in the scientific information, the formulation of air pollution regulations has been erratic and based on policy approaches that have not solved the problem and have required frequent modifications in timetables established to achieve stated emission levels. The involvement of Canada in the acid rain phenomenon, with its international ramifications, has greatly increased the complexity of the already difficult problems of dealing with air pollution issues. As a result, there is great uncertainty about what actions Congress will undertake with respect to the Clean Air Act.

Acid rain, the most recent concern that could affect future coal use, is gener-

ally associated with industrial activities. Acid rain is probably caused by the emissions of sulfur oxides and nitrogen oxides from the combustion of fossil fuels, but a good understanding of how these precursor pollutants are transformed into acidic materials, transported from their emission sources, and deposited to cause acidification has not yet been obtained.

With this lack of knowledge of how lakes become acidified, but with the urgent regional and national demands to find solutions to the problem, some of the proposed amendments to the Clean Air Act now being considered would require sharp reductions in total sulfur oxide emissions. Estimates by the Department of Energy predict that the new regulations would impose a $200-billion to $300-billion burden on electricity consumers over the next 30 years (*26*). The North American Reliability Council stated (*27*) that "absent appropriate rate increases to consumers, utilities may be forced to delay or even cancel many needed generating and transmission projects."

The uncertainties about the content and timing of air pollution standards that will have to be met have made it more difficult to justify investments in coal-utilizing facilities, which are the most affected by air pollution control requirements. In addition to uncertainties about how to meet the requirements for "nonattainment regions" (*28*) and for "prevention of significant deterioration" (*29*), a number of new potential regulations are under consideration along with studies to identify new air pollution issues. These include possible revisions of the new source performance standards, development of regulations for the now-unregulated hazardous air pollutants, revision of state implementation plans, revision of the "offset" ruling (*30*) for new facilities in nonattainment areas, and development of a visibility protection program. Studies include a review of the effects of sulfates and fine particulates, of ambient air quality standards, and of stack height regulations.

Only relatively minor water-pollution problems occur during direct combustion of coal at power plants and industrial plants producing steam and/or power. With the current ruling of the Environmental Protection Agency that solid wastes—such as those from the combustion of coal and from coal mining—are to be classified as "special wastes," their disposal does not require any special treatment and has not created a major problem for the coal industry. However, any change in this designation might have far-reaching impacts on the coal industry.

Where flue gas scrubbers using "throwaway" processes (*31*) for sulfur oxide control are used, the volume of solids produced is much greater than that of the coal ash. Almost all of this sludge is now disposed of by "ponding" (*32*); while this prevents pollution from the sludge, it may not be a satisfactory long-term solution, and it will be necessary to find some method other than ponding for long-term safe storage.

Commercialization rates of synthetic fuels plants. Conversion of coal to liquid and gaseous fuels represents a very large potential new market for coal. By far the greatest impediment to commercialization of coal-based synthetic fuels plants is that existing conversion technologies do not now make these fuels economically competitive with petroleum and natural gas. World oil prices have declined and pressure for even further decreases continues. At the same time, the supply of domestic natural gas has improved greatly, and concern over its availability at prices less than those of synthetic gas produced from coal has disappeared for the present. Finally, the soft demand for energy due to national and international conservation efforts and the worldwide recession have also contributed to the declining interest in synthetic fuels investments. The proposed installation of coal conversion plants has raised a number of environmental issues. The plants produce two types of air pollutants: those that result from the direct use of coal for the generation of steam and power (see above) and those produced by the conversion process. The air pollutants that may be released from conversion processes are hydrogen sulfide, organic sulfur compounds, carbon monoxide, and possible trace organic hydrocarbon compounds. Most processes require that these potential air pollutants be removed to enable satisfactory operation. Thus, virtually the only emissions to the atmosphere should be from accidents and leaks.

The amount and type of water pollutants generated at conversion plants depend to some extent on the processes used. Of greatest concern is the liquid discharge from the raw gas cooler stream. This water stream can contain hydrogen sulfide, ammonia, cyanides, phenols, benzene, oils, and tars in addition to suspended and dissolved solids. Treatment of this contaminated stream by using conventional technologies similar to those at coke-oven plants should eliminate this problem.

Another method for handling water pollutants from synthetic fuels plants involves the management of the water streams so as to successively reduce the volume and increase the degree of contamination of the water streams. The final, contaminated stream can be evaporated to dryness, eliminating all water pollution problems.

Solid wastes produced in coal conversion processes are highly variable in both amount and chemical composition and depend on the conversion process, the coal ash content, and the chemical composition of the ash. The amount of ash to be disposed of depends on the ash content of the coal feed. The physical form of the ash and the amount of organics contained in it vary from process to process. Disposal of solid wastes as landfill requires special precautions to prevent leachable salts, heavy metals, and organic compounds from entering the ground or surface water systems.

Some environmental pollutants, such as coal tars, gases containing sulfur compounds, and spent catalysts produced at synthetic fuels plants, will require specialized control technologies, but most of these have already been demonstrated at other types of industrial plants. The real concern is the very large quantities of potential pollutant emissions that must be controlled, so that very conservative designs must be used for control technologies, and plants must be operated with great care to achieve satisfactory pollution control.

Two major resources required by coal conversion plants are coal and water. In both the eastern and western regions of the United States, coal resources would be adequate for the number of conversion plants that would conceivably be constructed in the next 30 years or more. Water resources in the eastern region are generally adequate, but in the western region water availability could be a constraint to the construction of a large number of plants and would have to be considered on a case-by-case basis.

Coal exports. In European markets U.S. coal exports compete mainly with Polish and South African coals and in Pacific Rim countries with Australian and, to a lesser extent, South African coals. In both regions the delivered cost of U.S. coals is higher than that of its competitors. Nevertheless, markets are retained by U.S. suppliers because of reliability of supply, the desire of the consumer for diversity of supply, and, for some coking coals, because of superior quality. Any change in U.S. regulations or laws that increases the cost of producing or transporting (over land or sea) U.S. coals to foreign ports will make

U.S. coals even less competitive and increase the penalty to the consumer for seeking reliability, diversity, and quality of supply. The potentially adverse effect on U.S. coal exports is obvious.

Another factor that affects the quantity of all international coal trade is the trends in world oil prices—lower oil prices or high coal prices deter conversions of existing equipment to coal or installation of new coal-burning or coal conversion facilities. Current declines in world oil prices may reduce both U.S. and other coal export trade.

Conclusion

Expanded production and use of domestic coal reserves have been a goal of U.S. energy policy for nearly 10 years. The policy was adopted to achieve security of energy supply (reduce oil imports) and to provide U.S. energy requirements at lowest cost. Coal reserves of the United States are very large and could satisfy U.S. and world needs for many decades. Coal can be used directly in competition with other fuels in all markets except motor vehicle or air transportation, but it is at an economic, convenience of use, and environmental disadvantage in the railroad, residential/commercial, and small industrial markets. U.S. coal exports have increased sharply in the past 2 years and may present a market opportunity in the future for the U.S. coal industry, but the size of the market will depend on world oil prices and prices of coal from other exporting countries compared with those from the United States.

Coal is transported by rail, barge, and truck—the mode used depending on availability and price. One coal slurry pipeline is in operation and others are planned; these may present an economic alternative to conventional transport modes. Coal export ports experienced overcrowding in 1980 and 1981 but have enlarged their capacity and are currently operating without delays.

While U.S. coal productive capacity could be overtaxed for short periods and in limited geographic areas, there appear to be no overriding constraints to satisfying any expected increase in coal demand. However, meeting demand will require timely investments in the coal-producing and transporting sectors, and these would be immeasurably aided by stability in governmental policies and regulations. Absent such stability, delays could occur and costs could rise significantly.

Changes in the structure of the coal industry and in government regulations have caused a substantial shift in production from eastern to western areas of the United States. Governmental policies with respect to leasing of federal lands, environmental regulations, coal transportation policies, and legislation and resolution of water rights issues by federal and state agencies will continue to affect the future location of new major coal-producing and coal-utilizing facilities.

Because of the favorable situation with respect to production and delivery of coal to users, increased coal consumption is "demand constrained." Coal's future use in those domestic markets in which it competes will be greatly influenced by world oil prices, by future government policies on oil imports, by factors affecting the delivered price of competing domestic fuels and coal, and by the nature of environmental regulations related largely to air pollution emissions. New technology that would permit coal to be used at lower cost or would reduce pollution control costs would be of great benefit in increasing coal use.

Production of liquids and gases from coal could reduce oil imports and provide a large new market for coal. Although commercialization of such plants was not obviously assured even before the recent drop in world oil prices, the lower cost of world oil has caused further delays in the commercialization programs. It appears that large-scale synthetic fuel plants will be constructed only if dramatic process improvements occur to reduce costs of production or if, for policy reasons, large enough incentives are offered to interest industry in building such plants. To date, the incentives offered have not been successful in stimulating the type of developments envisioned when the Synthetic Fuels Corporation was established for this purpose.

References and Notes

1. An expanded R & D program on coal and synthetic fuels, enactment of the Energy Policy and Conservation Act (1975) and the Power Plant and Industrial Fuels Use Act (1978), and a call for increased coal use in three successive National Energy Plans.
2. Resources are the sum total of a given resource estimated to exist. Reserves are resources well identified as to location and size and commercially producible at current prices with current technology.
3. *Weekly Coal Production Report* [DOE/EIA 0218 (82/18), Energy Information Administration, Department of Energy, Washington, D.C., May 1982].
4. *Weekly Coal Production Report* [DOE/EIA 0173 (81), Energy Information Administration, Department of Energy, Washington, D.C., May 1982].
5. *Annual Report to Congress* [DOE/EIA-0384 (82), Energy Information Administration, Department of Energy, Washington, D.C., April 1983], p. 135.
6. *Ibid.*, p. 143.
7. *Quarterly Report* (DOE/EIA 82/3Q, Energy Information Administration, Department of Energy, Washington, D.C., July–September 1982).
8. *Monthly Energy Review* [DOE/EIA 0035 (83/03), Energy Information Administration, Department of Energy, Washington, D.C., March 1983].
9. *Monthly Energy Review* [DOE/EIA 0035 (83/01), Energy Information Administration, Department of Energy, Washington, D.C., January 1983].
10. *Coal Data, 1976* (National Coal Association, Washington, D.C.) (1950 to 1976); *Monthly Energy Review* [DOE/EIA 0035 (82/09), Energy Information Administration, Department of Energy, Washington, D.C., September 1982] (1977 to 1979).
11. *Monthly Energy Review* [DOE/EIA 0035 (82/09), Energy Information Administration, Department of Energy, Washington, D.C., September 1982].
12. *Minerals Yearbook* (Bureau of Mines, Department of Interior, Washington, D.C., 1965), vol. 2.
13. *Quarterly Coal Report* [DOE/EIA 0121 (82/1Q), Energy Information Administration, Department of Energy, Washington, D.C., August 1982].
14. *Coal—Bituminous and Lignite in 1973* [Bureau of Mines, Department of Interior and Interstate Commerce Commission, Washington, D.C. (1982 data)].
15. *Coal Distribution—January to December 1982* [DOE/EIA 0125 (82/4Q), Energy Information Administration, Department of Energy, Washington, D.C., March 1983], p. 12.
16. *Ibid.*
17. A "unit train" is dedicated to moving a single commodity, usually between a single origin and single destination, ideally on a continuous basis.
18. *American Association of Railroads Coal Book* (American Association of Railroads, Washington, D.C., ed. 1, May 1982).
19. *Coal Data—A Reference, Energy Information* [DOE/EIA 0064 (82), Energy Information Administration, Department of Energy, Washington, D.C., October 1982]; *Coal and Quality of Fuels for Electric Utility Plants, 1980 Annual Report* [DOE/EIA 0191 (80), Energy Information Administration, Department of Energy, Washington, D.C. 1980].
20. *Energy Daily*, 20 January 1980.
21. *Ibid.*, 1 February 1983.
22. *Development and Production Potential of Federal Coal Leases* (Office of Technology Assessment, Congress of the United States, Washington, D.C., December 1981).
23. Estimated from data in *Disposal of Excess Spoil from Coal Mining and the Surface Mining Control and Reclamation Act of 1977* (Board on Mineral and Energy Resources, Commission on Natural Resources, Natural Research Council, Washington, D.C., 1981).
24. *Coal Slurry Pipelines in Virginia: A Preliminary Feasibility Study* (Virginia Center for Coal and Energy Research, Virginia Polytechnic Institute and State University, Blacksburg, 7 July 1982).
25. This section is based in part on "Managing air pollution," in *Energy: The Next Twenty Years* (Ballinger, Cambridge, Mass., 1979).
26. *Costs to Reduce Sulfur Oxide Emissions* (Director of Policy, Planning and Analysis, Department of Energy, Washington, D.C., March 1982).
27. *12th Annual Review of Overall Reliability and Adequacy of North American Bulk Power Systems* (North American Reliability Council, Princeton, N.J., August 1982).
28. "Nonattainment regions" do not meet the air quality provisions of the Clean Air Act.
29. "Prevention of significant deterioration" is called for in regulations designed to maintain air quality for air sheds in compliance with the National Air Quality Standards.
30. New sources of air pollutants must acquire "offset" emission rights from existing sources of pollutant emissions in nonattainment areas.
31. "Throwaway" processes are used to remove sulfur oxides from the flue gases at boiler plants that contact a chemical (usually limestone) with the flue gas and produce a solid residue containing the air pollutant, which is discarded as waste.
32. "Ponding" is the practice of disposing of wet solid residues in excavated pits.
33. Sources: 1920–1970: Bureau of the Census, *Historical Statistics of the U.S., Colonial Times to 1970* (Government Printing Office, Washington, D.C., 1975), series M93; 1971–1975: Bureau of Mines, "Coal—Bituminous and Lignite in 1975," *Mineral Industry Surveys* (February 1977), table 1; 1976–1981: Department of Energy, *Weekly Coal Production* (May 1982), p. 7.