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Coal Data: A Reference

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Preface

Section 205(a)(2) of the Department of Energy Organization Act of 1977 (Public Law 95-91) requires the Administrator of the Energy Information Administration (EIA) to carry out a central, comprehensive, and unified energy data and information program that will collect, evaluate, assemble, analyze, and disseminate data and information relevant to energy resources, reserves, and related economic and statistical information.

The legislation that created EIA vested the organization with an element of statutory independence. EIA does not take positions on policy questions. EIA's responsibility is to provide timely, high-quality information and to perform objective, credible analyses.

As part of EIA's program to provide information on coal, this report, *Coal Data: A Reference*, summarizes basic information on the mining and use of coal, an important source of energy in the United States. This report is written for a general audience. The goal is to cover basic material and strike a reasonable compromise between overly generalized statements and detailed analyses. The section "Supplemental Figures and Tables" contains statistics, graphs, maps, and other illustrations that show trends, patterns, geographic locations, and similar coal-related information. The section "Coal Terminology and Related Information" provides additional information about terms mentioned in the text and introduces some new terms.

The last edition of *Coal Data: A Reference* was published in 1991. The present edition contains updated data as well as expanded reviews and additional information. Added to the text are discussions of coal quality, coal prices, unions, and strikes. The appendix has been expanded to provide statistics on a variety of additional topics, such as: trends in coal production and royalties from Federal and Indian coal leases, hours worked and earnings for coal mine employment, railroad coal shipments and revenues, waterborne coal traffic, coal export loading terminals, utility coal combustion byproducts, and trace elements in coal.

The information in this report has been gleaned mainly from the sources in the bibliography. The reader interested in going beyond the scope of this report should consult these sources. The statistics are largely from reports published by the Energy Information Administration.

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A Brief History of U.S. Coal

Coal was reportedly used by the Indians of the Southwest long before the early explorers arrived in America. The first record of coal in what is now the United States is a map prepared in 1673-74 by Louis Joliet. It shows “charbon de terra” along the Illinois River in northern Illinois. About a quarter of a century later, in 1701, coal was discovered near Richmond, Virginia. A map drawn in 1736 shows the location of several “cole mines” along the upper Potomac River, near what is now the border of Maryland and West Virginia. Before the end of the 1750’s coal was reported in Pennsylvania, Ohio, Kentucky, and West Virginia. Pennsylvania’s anthracite deposits were found about 1762.

Blacksmiths in colonial days used small amounts of “fossil coal” or “stone coal” to supplement the charcoal normally burned in their forges. Farmers dug coal from beds exposed at the surface and sold it by the bushel. Although most of the coal for the larger cities along the eastern seaboard was imported from England and Nova Scotia, some came from Virginia. The first commercial U.S. coal production began near Richmond, Virginia, in 1748, more than a century before the beginning of the domestic oil industry. By the late 1800’s, coal was being produced in most of the States.

Coal became the principal fuel used by locomotives. As the railroads branched into the coalfields, they became a vital link between mines and markets. Coal also found growing markets as fuel for households and steamboats. Another use of coal was to produce illuminating oil and gas. In 1816, Baltimore, Maryland, became the first city to light streets with gas made from coal. With the beginning of the U.S. coke industry in the latter half of the 1800’s, coke soon replaced charcoal as the chief fuel for iron blast furnaces. Briquetting of coal was introduced in the United States about 1870. Coal-fired steam generators began to produce electricity in the 1880’s. The first practical coal-fired electric generating station, developed by Thomas Edison, went into operation in New York City in 1882 to supply electricity for household lights.

In the earliest mines, coal was quarried from beds that were exposed at the surface. To get more coal, the miners had to follow the coalbed underground. Before coal-cutting machines became available in the late 1880’s, coal was mined underground by hand. Mechanical coal-loading equipment introduced in the early 1920’s replaced hand loading and increased productivity. Mules and, to a lesser degree, horses and oxen were used to haul coal and refuse in and around the early mines; a few dogs were used in small mines working thin coalbeds. In time, the animals were replaced by electric locomotives, dubbed “electric mules,” and other haulage equipment.

Strip mining began in 1866 near Danville, Illinois, when horse-drawn plows and scrapers were used to remove overburden so the coal could be dug and hauled away in wheelbarrows and carts. In 1877, a steam-powered shovel excavated some 10 feet of overburden from a 3-foot-thick coalbed near Pittsburg, Kansas. In 1885, a converted wooden dredge with a 50-foot boom was used to uncover a coalbed under 35 feet of overburden. In 1910, surface mining was underway with steam shovels specifically designed for coal mining.

Young workers, mules, open-flame lamps, and soft hats were common in early coal mines.

United States Coal: An Overview

Introduction

The history of America's progress is inextricably linked to the use of coal from its abundant coal resources. In the early 1900's, coal was so widely used that it reigned as the Nation's principal source of energy. Coal fueled industries, powered locomotives, and heated homes. The coal industry provided jobs for workers numbering in the hundreds of thousands and was the foundation of the economy in many areas.

Later, the Nation's use of coal slumped because of competition from other energy sources, chiefly oil and natural gas, which are cleaner and easier to use. The coal industry lost the railroads as consumers of coal, nearly all of the home heating market, and many of the smaller industries. Some predictions made after World War II saw the development of atomic power as leading to the demise of the coal industry. However, history has shown that coal has weathered competition from other energy sources, although the coal mining workforce has decreased dramatically because of extensive mechanization of mine operations.

The traumatic Arab oil embargo of the early 1970's underscored the Nation's precarious dependence on foreign oil and renewed interest in the vast, widely distributed domestic coal deposits. Clean air legislation, ushered in around the same time, shifted coal development to the large, easily mined deposits of low-sulfur coal in the West. Since then, the market for coal has improved almost steadily, and the production and use of coal have reached unprecedented levels. Today, however, coal is used mostly to generate electricity and accounts for about half of the electricity generated annually. So, through its role in generating electricity, coal has indirectly recaptured part of the market it lost years ago.

The coal industry has become the Nation's largest energy-producing industry, representing nearly one-third of U.S. energy production. Coal also accounts for almost one-fourth of total energy consumed and is the only energy source for which exports are greater than imports. The coal industry is the Nation's leading mining industry, based on value of production. Of all mineral commodities mined, the quantity of coal currently produced ranks second only to that of crushed stone.

The importance of the coal industry to the U.S. economy is illustrated by a study made at Pennsylvania State University in 1994 for the National Coal Association. Analyzing the coal industry's economic effects in 1992, the study found that, while the direct contribution of coal production that year was valued at $21 billion, the industry's total contribution to the economy was $132 billion through its impact on other business sectors. Similarly, the coal industry's workforce of about 136,000 persons, including non-production employees, was indirectly responsible for another 1.4 million jobs.

In 1993, the Nation consumed more than 2 million tons[1] of coal per day—about 20 pounds for each person every day. To produce the 1993 coal output, valued at about $19 billion, more than 100,000 miners worked in some 2,500 mines. Although the coal produced was largely for domestic use, a significant amount was shipped to other countries. These coal exports, averaging more than $4 billion in value in recent years, help the Nation's balance of trade. The Nation has always had a trade surplus in coal. Internationally, the United States is prominent as both a producer and exporter of coal.

The magnitude of annual U.S. coal output—currently about 1 billion tons—is difficult to grasp unless it is placed in some familiar perspective. One ton of broken coal occupies about 40 cubic feet, so the 1993 coal output would cover 1 square mile to a height of more than one-fourth of a mile. In other terms, the rate of coal production in 1993 averaged around 30 tons per second, enough to fill a railroad car every 3 seconds.

About 58 billion tons of coal have been produced in the United States since the first commercial mine was opened more than 200 years ago. Even so, U.S. coal deposits still contain more than 200 billion tons of minable coal, a reserve of energy that contributes to the

[1]In this report, "tons" refers to short tons (1 short ton = 2,000 pounds).

Nation's security. Furthermore, the coal deposits in some States have also become significant sources of coalbed methane. Once considered only as a danger to miners, coalbed methane is now being produced and added to the supply of natural gas.

Coal Data: A Reference provides an overview of the many facets of coal mentioned in this section. It spans a range of topics, covering coal deposits, reserves, mining, employment, transportation, use, and environmental issues. Its principal aim is to summarize basic trends, highlighting factors that have influenced the use of coal and, therefore, controlled the rate of coal production. Also included is a review of new technologies being developed to increase the usefulness of coal as a natural resource, making it both a cleaner-burning fuel and a source of chemicals.

The Nature of Coal

Coal, sometimes called "Nature's Black Diamond," is a black or brownish-black, combustible, sedimentary organic rock that contains more than 50 percent carbonaceous material by weight. In popular usage, coal is often called a mineral because it was formed in the earth. However, the scientific use of the term "mineral" is reserved for a naturally occurring inorganic material that has a definite chemical composition and a regular internal structure. Coal is of organic origin and has neither of these.

Compared with other rocks, coal is relatively light, a solid piece weighing about 80 pounds per cubic foot, less than half the weight of granite, limestone, or most other rocks. Coal is also a relatively soft rock, more easily excavated than most other mined material.

Coal is called a fossil fuel because it is derived from plants that grew in vast swamps millions of years ago and were later buried by sediments when the land subsided. Geological and chemical processes involving high pressures and temperatures, working over vast periods of time, compressed and altered the plant remains, increasing the percentage of carbon present, and thus producing the different ranks, or varieties, of coal: lignite, subbituminous, bituminous, and anthracite. Of the various coal ranks in the United States, bituminous coal is the most abundant and widespread. The water-saturated plant debris called peat is not considered a rank of coal, although it is the first stage in the alteration of plants to coal. With increasing rank, or degree of coalification, coal becomes harder and brighter, and its heat value rises. Coal rank is commonly determined by a combination of heat value and chemical analysis of organic matter. The rank of coal can also be determined by measuring the intensity of light reflected from its vitrinite, one of the macerals in coal. Macerals are the combustible organic portions derived from plant substances and comprise three microscopic groups: vitrinite, exinite (or liptinite), and inertinite. The reflectivity of vitrinite increases with coal rank. Macerals are also helpful in identifying and correlating different coals and in predicting the coking properties of coal and coal blends.

Fossil plant material is revealed in this photomicrograph of subbituminous coal from Wyoming's Powder River Basin. As an indication of magnification, the longer side of the photo represents 0.25 millimeters.

Coal occurs in beds, sometimes called "seams" or "veins," that are interlayed between beds of sandstone, shale, and limestone. The thin layers of shale ("partings") sometimes found in a coalbed are mineral sediments that settled from muddy flood waters while the vegetable matter was accumulating. Coalbeds range in thickness from less than an inch to more than 100 feet. According to some estimates, an accumulation of 3 to 10 feet of compacted material was needed for each foot of bituminous coal. Based on estimates that hundreds of years were needed to build up enough plant material to make a foot of bituminous coal, thick coalbeds represent accumulations of plant material spanning many thousands of years. Although generally flat lying, coalbeds are sometimes inclined, folded, or faulted as a result of geologic forces.

Coal is a complex material, its chemical structure still not completely understood. It is composed chiefly of carbon, hydrogen, and oxygen, with smaller amounts of sulfur and nitrogen and variable quantities of trace elements ranging from aluminum to zirconium. All but 16 of the 92 naturally occurring elements have been detected in coal, mostly as trace elements below 0.1 percent (1,000 parts per million, or ppm). Coals of the same rank may appear similar, but their compositions can vary widely, not only from deposit to deposit but also within the same coalbed, because of differences in the environment of the coal swamps and the nature of the original plant debris. The elements found in coal were introduced into the coalbed in one or more different ways: as material washed into the coal swamp, as a biochemical precipitate from the swamp water, as a minor constituent of the original plants, or as a later addition, after the coal was formed, primarily by ground water.

Fossil plant debris gives coal its most obvious and most useful characteristic, namely, that it can be burned. The heat energy of coal ranges from an average of 13 million British thermal units (Btu) per ton for lignite to about 30 million Btu per ton for some bituminous coals (Figure 1). Most of the heat produced from coal is generated from carbon, by far its major component, with the amount present typically more than 70 percent. Although hydrogen generates about four times more heat per pound than carbon, it accounts for a small part of coal (generally less than 5 percent) and not all of this element is available for heat. During combustion, part of it combines with oxygen to form water vapor. The higher the oxygen content of coal, the lower its heating value. This inverse relationship occurs because the oxygen in the coal is bound to the carbon and has, therefore, already partially oxidized the carbon, decreasing its ability to generate heat. The amount of heat from the combustion of sulfur in coal is very small. Because coal has a high ratio of carbon to hydrogen, the burning of coal releases more carbon dioxide per unit of heat than does the burning of oil or natural gas.

Figure 1. Approximate Heat Content of Different Coal Ranks[1]

[1]As received. (Includes natural moisture and combustible and incombustible materials.)

The heat content, or Btu value, of coal is approximately related to its rank, except for anthracite.

Although the quantity of coal produced and consumed is commonly measured in tons, the heating value of a ton of coal varies considerably, reflecting differences by rank as well as variations within rank due to the kinds of plant material from which the coal was formed. For instance, the heating value of bituminous coal delivered to electric utilities in 1993 averaged 24 million Btu per ton, but the range was from 20 million to 27 million Btu per ton. Similarly, the heating value for subbituminous coal averaged 18 million Btu per ton, but it ranged from 16 million to 19 million Btu per ton. Lignite's average heating value of 13 million Btu per ton was based on a range of 12 million to 14 million Btu per ton. Anthracite production averaged about 23 million Btu per ton. Using these averages, 1.3 tons of subbituminous coal, 1.8 tons of lignite, or a little more than 1 ton of anthracite would be needed to produce the amount of heat in 1 ton of bituminous coal. For this reason, coal purchases are often priced in terms of "dollars per million Btu" in addition to "dollars per ton."

Because the annual “mix” in the ranks of coal comprising total coal production includes growing shares of low rank coals, which generate relatively less heat, the average heat content of U.S. coal production is declining. Currently, it is about 22 million Btu per ton. This is approximately equivalent to the energy obtained by burning 21,000 cubic feet of natural gas, 160 gallons of distillate fuel oil, or 1 cord of seasoned hardwood.

Among the various elements in coal, sulfur is the most undesirable. Burning converts the sulfur in coal mostly into sulfur dioxide, an air pollutant as well as the cause of corrosion and deposits in boilers. Sulfur in mine wastes inhibits the growth of vegetation and causes stream pollution. Sulfur in coking coal used by the steel industry lowers the quality of both the coke produced and the resulting iron and steel products; consequently, coal with a low sulfur content is required for making coke. Various laws have been enacted to limit the amount of sulfur released to the environment. The sulfur content (by weight) of the coal produced for electric power plants, the largest market, in recent years ranged from less than 1 percent to about 4 percent, and averaged 1 percent (20 pounds per ton).

Sulfur occurs in coal in three forms: (1) iron sulfides (pyrite and marcasite), (2) secondary sulfates (gypsum and hydrous ferrous sulfate), and (3) organic sulfur chemically bonded to the coal-forming plant material. Most of the iron sulfides occur in the form of pyrite, which is distributed in many ways: as lenses, bands, fractures, and nodules, and as finely disseminated particles. The larger particles can be partly removed by conventional cleaning processes, but the fine particles are difficult to remove unless the coal is finely crushed and the pyrite separated by special treatment. Sulfate sulfur is less easily removed; however, it is normally present in small amounts (generally less than 0.05 percent) and usually of no great concern. Organic sulfur predominates in low-sulfur coal. As the total sulfur content of coal increases, the amount of organic sulfur can rise to more than 1 percent. Organic sulfur cannot be removed by conventional coal-cleaning processes.

High-sulfur coal is a product of swamps that were covered by sea water. Bacteria in the swamp converted the sulfate in the sea water into pyrite that became part of the coal. Low-sulfur coal deposits were developed primarily under fresh-water conditions.

Although the subbituminous coals and lignites mined in the West contain much lower levels of sulfur than do typical bituminous coals, they contain fairly high levels of the alkali metals sodium and potassium. These elements, which generally are chemically bound to the organic coal matrix, affect the physical and chemical properties of the coal ash. Boilers using these coals are specially designed to avoid serious ash-related equipment malfunctions.

Minerals are the incombustible matter in coal that becomes ash after burning. Minerals represent the inorganic parts of coal and include clay (the most abundant inorganic constituent), carbonates, sulfides, and quartz. The ash content of coal produced for electric power plants in recent years ranged from about 5 to 19 percent (by weight) and averaged about 10 percent (about 200 pounds per ton). Ash not only poses significant disposal problems, but it can form incombustible residues in furnaces, causing combustion problems and erosion of boiler components. Some ash is used in land fills and in making concrete and cinder blocks.

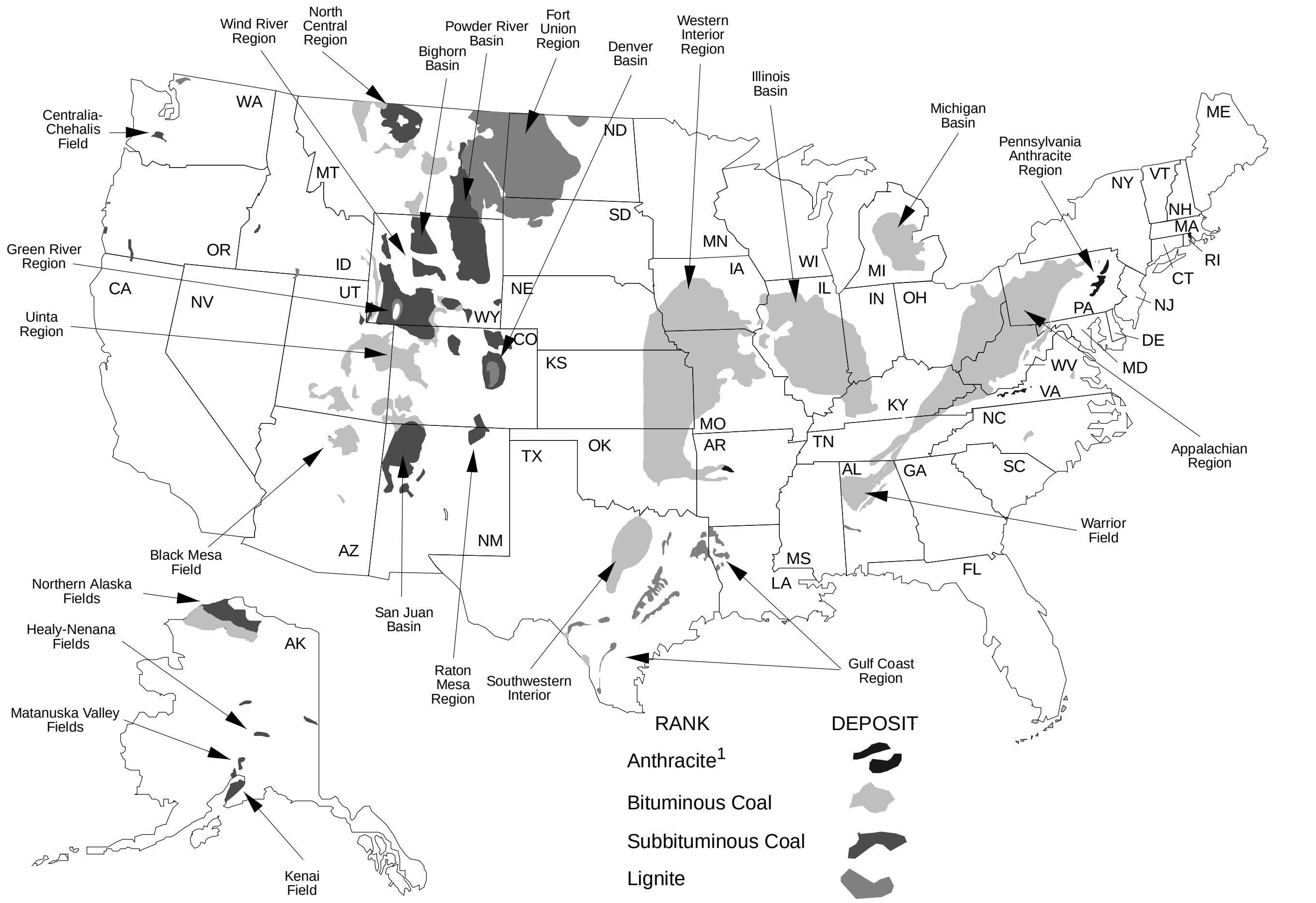
Methane in coal is the result of the chemical and physical processes involved in coal formation. The methane is contained within the structure of the coal and in fractures in the coalbed. Higher rank coals such as bituminous coal generally contain more methane than low ranks such as lignite. Because coal formed under high pressure is apt to contain more methane than otherwise, the methane content of coalbeds increases with depth.

U.S. Coal Deposits

The United States contains some of the world’s largest coal deposits. Coal is present in 38 States and underlies a total of 458,600 square miles or 13 percent of the land area of the United States (Figure 2). The U.S. Geological Survey has identified more than 400 fields and small deposits of coal in the United States. They were formed during periods of Earth’s history when the face and climate of what is now North America were markedly different than they are today. The coal deposits in the East date back mainly to the Pennsylvanian period of the Earth’s geologic history, approximately 300 million years ago, long before the age of dinosaurs. By contrast, most of the coal in the West is geologically younger, formed less than 140 million years ago in the Cretaceous period, when dinosaurs were alive, and in the subsequent Tertiary period, when they became extinct.

Coal in the East generally occurs in beds that tend to be less than 15 feet thick. Geological conditions in the East prevented the coal-forming material from building up; instead, they led to the formation of numerous coalbeds

Figure 2. U.S. Coal Deposits



Note: Alaska not to scale of conterminous United States. Small fields and isolated occurrences are not shown.

1 Principal anthracite deposits are in Pennsylvania. Small deposits occur in Alaska, Arkansas, Colorado, Massachusetts-Rhode Island, New Mexico, Utah, Virginia, Washington, and West Virginia.

Coal is found in 38 States, underlying 458,600 square miles, about 13 percent of the total land area.

Sources: U.S. Geological Survey, Coalfields of the United States, 1960-61 and Coal Map of North America, 1988; Texas Bureau of Economic Geology, Lignite Resources in Texas, 1980; and Louisiana Geological Survey, Near Surface Lignite in Louisiana, 1961.

located between other strata in repetitive sequences. By comparison, thicker coalbeds are common in the West, particularly in Wyoming, where geological conditions enabled large amounts of vegetation to accumulate. Although about 300 coalbeds were mined across the United States in 1993, nearly half of the coal produced was from only 10 beds (Table 1). The average thickness of all coalbeds mined ranged widely, from less than 2 feet to about 65 feet (Figure 3). Individual coalbeds commonly cover large geographic areas. For instance, the heavily mined Pittsburgh coalbed underlies parts of Pennsylvania, West Virginia, Ohio, and Maryland; the Wyodak coalbed, the Nation's leading source of coal, is estimated to cover at least 10,000 square miles in the Powder River Basin of Wyoming and Montana, according to the Wyoming State Geological Survey.

The most important coal deposits in the East are in the Appalachian Region, an area encompassing more than 72,000 square miles and parts of nine States. The region contains the Nation's principal deposits of anthracite (in northeastern Pennsylvania) and large deposits of low- and medium-volatile bituminous coal. Historically, the Appalachian Region has been the major source of U.S.

Table 1. U.S. Coal Production from the 10 Leading Coalbeds, 1993
(Million Short Tons)

Coalbed Name[a]	Production	State with Largest Production by Coalbed
Wyodak	185.7	WY
Pittsburgh	49.4	WV
No. 9	34.8	KY(W)
Hazard No. 5-A	32.4	KY(E)
No 6.	30.7	IL
Beulah-Zap	27.7	ND
Hazard No. 4.	24.5	KY(E)
Lower Kittanning	22.6	WV
Lower Elkhorn	18.0	KY(E)
Rosebud	16.2	MT
Total	**442.0**	**--**
Percentage of U.S. Total	**46.8**	**--**

[a]Name most commonly used.
-- = Not applicable.
Note: Total does not equal sum of components because of independent rounding.
Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

coal, accounting for about three-fourths of the total annual production as recently as 1970. Although the region's output currently is less than half of the national total because of increased coal production in the West, it continues to be the principal source of bituminous coal (including coking coal) and anthracite. The number of coalbeds mined in the Appalachian Region reaches more than 60 in West Virginia, with the bed thickness generally ranging from 3 to 8 feet. In the northern part of the region is the Pittsburgh coalbed, an important source of coal during the development of the U.S. iron and steel industry. For many years the Pittsburgh coalbed was the leading source of coal, but it now ranks second to the Wyodak coalbed in Wyoming. The intensely folded and faulted anthracite fields of northeastern Pennsylvania once supplied a large amount of coal for domestic heating, a major part of it from a series of beds comprising the Mammoth coal zone. Two important sources of bituminous coal in the southern part of the Appalachian Region are Alabama's Blue Creek and Mary Lee coalbeds.

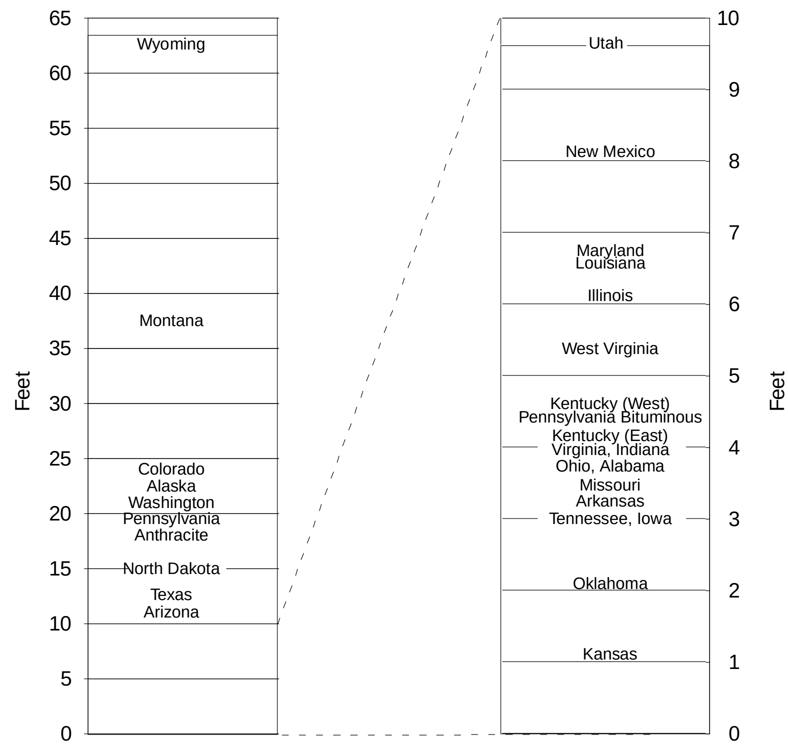
In contrast with the concentration of coal in Appalachia, the coal deposits in the interior region of the United States occur in several separate basins located from Michigan to Texas. The northern part of the region contains large deposits of high-volatile bituminous coal, but their generally high percentage of sulfur and ash hampers their use as a fuel and for coke production. The major sources of bituminous coal are two coalbeds commonly known as No. 6 and No. 9, but also known locally by other names. These beds, which average about 6 feet in thickness, account for a large share of the coal produced in Illinois, Indiana, and western Kentucky. A small area of anthracite is present in Arkansas. In the Gulf Coastal Plain in the southern part of the region are large deposits of lignite that have been used for electricity generation in Texas since the 1970's and in Louisiana since the 1980's. The most important lignite beds are in a succession of strata known as the Wilcox Group and are generally 3 to 10 feet thick.

The western part of the United States has a number of coal basins that contain all ranks of coal. The largest lignite deposit is in the northern Great Plains, underlying parts of North Dakota, South Dakota, and Montana; most of the lignite produced is from the Beulah-Zap bed in North Dakota. In the nearby Powder River Basin of northeastern Wyoming and southeastern Montana is the Nation's major source of low-sulfur subbituminous coal, used primarily for electricity generation. The basin has been the fastest growing coal-producing area in the past two decades and today accounts for about half of the coal mined in the West. The Powder River Basin contains the Wyodak coalbed, which is the leading source of U.S. coal production and one of the thickest coalbeds, averaging 70 feet and exceeding 100 feet in places. The principal deposits of bituminous coal mined in the West are in Utah, Colorado, and Arizona. Alaska has deposits of all coal ranks, but currently the only production is subbituminous coal from the Nenana field, north of Anchorage.

Resources and Reserves

Coal is by far the Nation's most abundant fossil fuel, with the total resources of both identified and undiscovered coal estimated at nearly 4 trillion tons. The quantity of coal considered technically and commercially minable constitutes a *demonstrated reserve base* currently estimated at more than 400 billion short tons. About half of the tonnage is bituminous coal (Figure 4), concentrated in Appalachia and the Interior Region; around 38 percent is subbituminous coal in the West, about 9 percent is lignite, located mostly in the West and the Interior Region; and 1 percent is Pennsylvania anthracite. Underground mining is required for about two-thirds of the reserve base; the rest can be surface mined. The largest reserves of low-sulfur coal are in the West. By contrast, the coal reserves with the highest heat content are mostly in the East.

Figure 3. Average Thickness of U.S. Coalbeds Mined, by State, in 1993
(Weighted Average in Feet)



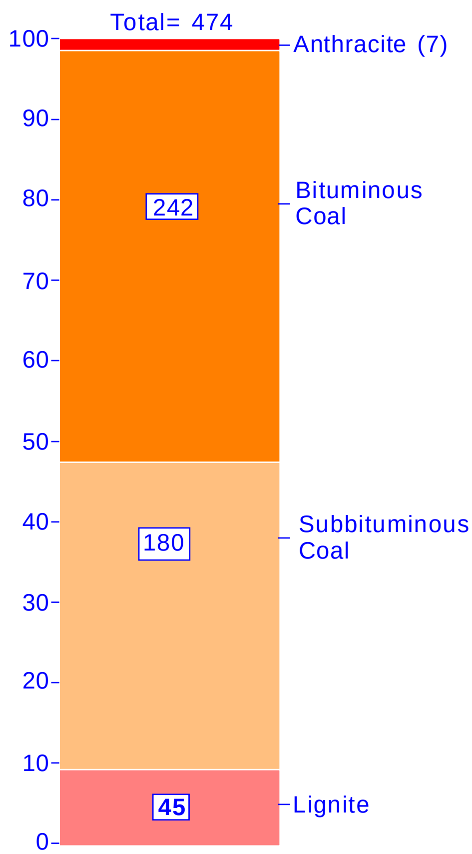
The thickest coalbeds mined in the United States are in the West. The average thickness of all coalbeds mined in 1993 was about 22 feet.

Source: Energy Information Administration, EIA-7A, "Coal Production Report."

The amount of coal that can actually be recovered from the reserve base varies from area to area and ranges from 40 percent at some underground mines to more than 90 percent at some surface mines. The recovery rate is lower for underground mining because some coal must be left untouched to form supporting pillars to prevent the mine from collapsing and the surface from subsiding. At both underground and surface mines, geologic features such as folded, faulted, and interlayered rock strata can reduce the amount of coal that can be recovered. In some areas, coal deposits underlie towns and cities and consequently may not be mined. Other factors that limit mining include environmental and legal restrictions, economic constraints, lack of suitable technology for using low-quality coal, and the fact that many of the highest quality and most accessible coal deposits have already been mined. Nevertheless, for the Nation as a whole, at least half of the reserve base—about 265 billion tons—is estimated to be recoverable. U.S. recoverable coal reserves are estimated to be the second largest in the world, slightly below those in the former Soviet Union.

Based on coal quality, as measured in pounds of sulfur emitted per million Btu, U.S. recoverable coal reserves include an estimated 100 billion tons of low-sulfur coal (0.60 pounds or less of sulfur per million Btu), with 87 percent of this in the West. Medium-sulfur recoverable coal reserves (0.61-1.67 pounds of sulfur per million Btu) are estimated at 84 billion tons, of which 62 percent is in the West and 24 percent in Appalachia. High-sulfur recoverable coal reserves (more than 1.67 pounds of sulfur per million Btu) total 80 billion tons, and are mostly in the interior region (60 percent) and Appalachia (28 percent).

Figure 4. U.S. Demonstrated Reserve Base of Coal, January 1, 1993
(Billion Short Tons)



The reserve base is comprised chiefly of two ranks of coal-bituminous and subbituminous.

Source: Energy Information Administration, *Coal Production 1992*, DOE/EIA-0118(92) (October 1993).

The recoverable coal reserves reported at active mines in 1993 totaled nearly 22 billion tons. About 15 billion tons were at surface mines, mostly in the Western Region. Of the 7 billion tons in underground mines, nearly two-thirds were in Appalachia.

Another energy source from coal is methane, a gas formed by the decomposition of the organic matter in coal. Coalbed methane is recovered in some States (for example, Alabama, New Mexico, and Wyoming) and added to the supply of natural gas, which is composed chiefly of methane. Proved reserves of coalbed methane total 10 trillion cubic feet, located mostly in the San Juan Basin of Colorado and New Mexico. The recoverable resource base for coalbed methane currently comprises an estimated 90 trillion cubic feet in the lower 48 States and 57 trillion cubic feet in Alaska.

Mining

Once a coal deposit has been selected for mining, some 4 to 7 years of planning and development are needed before production begins. Apart from the market for coal, the questions that must be addressed include land ownership, mineral rights, the quality and quantity of the available coal, and the method of mining and transporting the coal.

The mining method used depends on the depth of the coalbed from the surface and the character of the terrain (Figure 5). Coalbeds deeper than 200 feet are usually mined by underground methods. Those that are at shallower depths are worked by surface methods.

Although most underground mines are less than 1,000 feet deep, several reach depths of about 2,000 feet. Underground mines are classified according to the type of opening, or entry, used to reach the coalbed; some mines have several different openings. A *drift* mine is one that has a horizontal entry to a coalbed in a hillside. In a *slope* mine, the entry is inclined from the surface to the coalbed. A *shaft* mine, equipped with elevators, provides vertical access to a coalbed generally deeper than one reached by a slope mine. In addition to the passages providing entry to the coalbed, a network of other passages are also dug to provide access to various parts of the mine and for ventilation.

When the coalbed is reached, it is sectioned into panels, or blocks, several hundred feet wide and several thousand feet long (Figure 6). The actual mining of these blocks is accomplished by three techniques: room-and-pillar, longwall, and shortwall. Sometimes several techniques are used at the same time in different sections of a mine.

Most underground coal is mined by the room-and-pillar system (Figure 7). With this system, the miners extract the coal by cutting a series of rooms into the coalbed and leaving pillars, or columns of coal, to help support the mine roof. As mining advances, a grid-like pattern is formed in the panel of coal, which is about 400 feet wide and more than half a mile long. Generally, the rooms are 20 to 30 feet wide and the pillars 20 to 90 feet wide; the height usually is the same as the coalbed thickness. When mining reaches the end of the panel, the direction of mining usually is reversed. During this "retreat" phase of mining, the miners recover as much coal as possible from the pillars in a

Figure 5. Coal Mining Methods

The method of mining a coal deposit depends on the depth of the coalbed and the nature of the terrain.

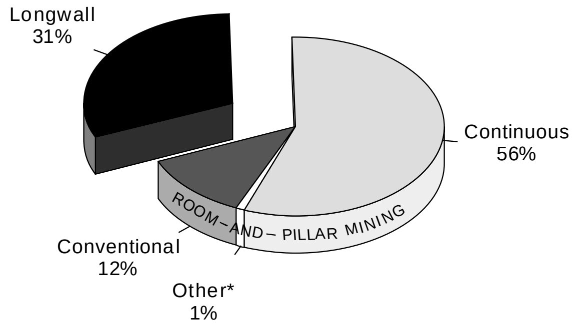
systematic manner until the roof caves in. When this phase of mining is completed, the area is abandoned. Although the goal is to extract all of the coal in the panel, this is not always possible because of natural restraints, such as poor mine roof and floor conditions. Furthermore, pillars are usually left to prevent subsidence of the land surface above the mine. Pillars that are not mined include those along property lines, around shaft bottoms or portals, and around oil and gas wells that penetrate the coalbed. Generally, 50 to 60 percent of the minable coal is recovered with room-and-pillar mining.

Two basic variations are used in room-and-pillar mining: (1) conventional mining, the oldest, which consists of a series of operations that involve cutting the coalbed so it breaks easily when blasted and then loading the broken coal; and (2) continuous mining, which uses a machine called a continuous miner that combines cutting, drilling, and loading coal in one operation and requires no blasting. Because of the steps involved, conventional mining requires a larger crew at the coal face—for example, 10 miners as compared with 6 for continuous mining. Generally, mining advances into the coalbed in steps of about 10 feet for conventional mining and about twice that in continuous mining. Since the 1950's, continuous mining has increased and now accounts for 56 percent of the coal output from underground mines, whereas the share from conventional mining has fallen to about 12 percent. Regardless of the mining variation used, room-and-pillar mining usually is not suitable for coalbeds at depths greater than about 1,000 feet. As depth increases, larger pillars are needed to support the overlying strata and less coal can be produced.

Figure 6. Underground Mining Systems

Room-and-pillar mining is the most common way to mine coal undergound. Longwall mining is used to mine large blocks of coal where the bed is relatively flat and thick. A continuous mining operation includes roof bolting equipment and can use a coal-loading machine and shuttle cars (not shown) instead of a conveyor belt.

Figure 7. Underground Coal Production by Mining Techniques, 1993



*Includes shortwall, scoop loading, and hand loading.

Underground coal is mined mostly with continuous mining machines, which dig and load coal in one operation.

Source: Energy Information Administration, *Coal Industry Annual 1993,* DOE/EIA-0584(93) (Washington, DC, December 1994).

The second technique of underground coal mining is longwall mining, which is gaining importance in the United States and can be used at greater depths than room-and-pillar mining. Nearly one-third of the coal currently produced underground is from about 100 longwall mining operations, most of them in the Appalachian Region. In longwall mining, a cutting machine operates back and forth across a panel of coal averaging about 800 feet in width and 7,000 in length, with the broken coal removed from the coal face by an armored flexible conveyor. Two types of cutting devices are used, shearers and plows. The shearer, by far the more widely used, has a large drum-shaped cutting head that strips 20 to 36 inches from the coal face on each pass. It rides on a special track on the armored flexible conveyor. A plow is a much simpler machine that is blade-like and fitted with bits or a saw-tooth edge that cuts the coal face into slices up to 6 inches deep as the plow is pulled across the coal face. Longwall mining is done under movable hydraulic roof supports, or shields, that are advanced as the bed is cut; the roof in the mined-out area is allowed to fall as mining advances, forming an area of broken rock called "gob."

The widely used continuous mining machine excavates coal through the use of cutting heads, while the broken coal is gathered by loading arms.

In longwall mining, a shearing machine excavates coal as it moves back and forth across a coal face hundreds of feet long.

Production of coal per shift from longwall mining generally is higher than that of either conventional or continuous mining. The longwall technique often has a better recovery rate. It is also safer because the working area is protected by overhead steel supports, coal haulage is simplified, and ventilation is better controlled. However, longwall mining has certain limitations. It is generally not suitable if the coalbed thickness varies widely or if the coalbed is broken by geologic faults. The mine roof or floor also must be strong enough to provide a solid surface for the supports, and the mine roof must cave evenly and not “hang up.” Also constraining are high capital costs for equipment and mine development.

The third technique of underground mining is shortwall mining, used in a few mines. Shortwall mining involves the use of a continuous mining machine and movable roof supports to shear coal panels 150 to 200 feet wide and more than half a mile long. Although similar to longwall mining, shortwall mining is generally more flexible because of the smaller working area. Productivity is lower than with longwall mining because the coal is hauled by shuttle cars rather than by conveyor.

All underground coal mining is a complex undertaking requiring the miners to use not only special machinery to cut and remove coal, but also special techniques such as roof bolting to prevent the mine roof from collapsing. A number of safety procedures must be followed to comply with Federal and State health and safety regulations. Entries, or passage ways, consist of at least three parallel entries, so that if one is accidentally blocked, the others afford a means of escape. Multiple entries also provide adequate ventilation to carry away methane, other gases, and coal dust, with brattices and other stoppings used to direct the flow of air; they also are used to drain water from the mine.

Areas where underground mining has occurred are subject to subsidence when the mine roof collapses. Subsidence can affect buildings and other structures, and can also have hydrologic impacts, disrupting the flow of water on the surface and underground. Subsidence from longwall mining is generally more uniform and more predictable because it usually begins as coal extraction progresses. By contrast, subsidence due to room-and-pillar mining is difficult to predict because the supporting pillars deteriorate at some later time. The amount of subsidence from both types of mining depend on such factors as the depth of mining, the thickness of the coalbed extracted, and the thickness and strength of the overlying rock.

A coalbed can be surface mined when it is less than 200 feet deep. Surface mining, also called strip mining, is the least expensive mining method, and sometimes it is the only safe and efficient way of mining coal at shallow depths. Surface mining is also less restrictive than underground mining, because equipment can be easily moved, although heavy equipment requires stable ground. Coal-recovery rates at surface mines can exceed 90 percent.

Surface mining is essentially large-scale earthmoving that consists of excavating the overburden from the coalbed and then removing the coal. At some surface mines, mainly those in Appalachia, two or more coalbeds are mined during the same mining operation. The amount of overburden, or spoil, excavated per ton of coal recovered, called the *overburden ratio,* ranges from 1 to more than 30 cubic yards. The lower the overburden ratio, the more productive the mine. The lowest overburden ratios are generally in the West.

Area surface mining is practiced on flat ground and consists of a series of cuts 100 to 200 feet wide, with the overburden from one cut used to fill the mined-out area of the preceding cut (Figure 8). By comparison, *contour surface mining* follows a coalbed along hillsides. When contour mining becomes uneconomical, additional coal can be produced from the mine's highwall

Figure 8. Area Surface Mining with Dragline and Shovel

In area mining, long strips are excavated to uncover the coal. The overburden from the strip being mined is deposited in the strip previously mined.

Thick coalbeds that can be easily surface mined, such as this one in Wyoming, enable a mine to achieve a high rate of productivity.

by the use of augers to drill 100 feet or more into the bed, or by opening a small drift mine called a *punch mine. Open-pit mining* is used where thick coalbeds are steeply inclined, as in southwestern Wyoming and the anthracite area of Pennsylvania. An open-pit mine, which combines the techniques of contour mining and area mining, can reach depths of several hundred feet. The equipment used at surface mines includes dragline excavators, power shovels, hydraulic shovels, bulldozers, front-end loaders, and bucketwheel excavators.

Draglines remove overburden while power shovels and hydraulic shovels load coal. However, bulldozers and front-end loaders are often used to remove overburden in small mines; front-end loaders can also load coal. The few bucketwheel excavators in use operate in flat areas with soft overburden, such as in parts of the Midwest and Texas. Continuous surface mining machines equipped with rotating cutting heads and conveyors are used in some lignite mines.

In the anthracite area of Pennsylvania, surface mining includes the mining of culm and silt banks—waste accumulations of coal and rock from earlier mining operations that are now being used as fuel. Another form of surface mining in parts of Appalachia is dredging, which recovers coal that was dumped into rivers from early preparation plants or eroded from coal stockpiles or coalbeds beneath the rivers.

Because surface mining disturbs the land and can produce unsightly areas, surface mine operators are required to reclaim mined land by restoring natural vegetation and drainage. Properly reclaimed mining areas can be restored to a variety of uses, such as farmland, wildlife areas, or parkland.

Production

Coal has been mined commercially in the United States for more than 200 years, beginning in 1748 near Richmond, Virginia. Westward expansion across the country stimulated local demands for coal, so that by the beginning of the 20th century coal was being produced in most of the Nation's coalfields. The historical record of coal production reflects a record of industrial progress, competition from other fuels, coal miners' strikes, economic conditions, wars, environmental regulations, and health and safety laws.

Coal was produced in 26 States in 1993, with more than half of the total output (almost 1 billion tons) from three States: Wyoming, Kentucky, and West Virginia (Table 2). Although Wyoming was the leader in tonnage produced, Kentucky was the leader based on the energy content of the coal produced and on the value of production.

Table 2. The 10 Leading U.S. Coal-Producing States, 1993
(Million Short Tons)

States	Production	Percent of Total
Wyoming	210.1	22.2
Kentucky	156.3	16.5
West Virginia	130.5	13.8
Pennsylvania	59.7	6.3
Texas	54.6	5.8
Illinois	41.1	4.3
Virginia	39.3	4.1
Montana	35.9	3.8
North Dakota	32.0	3.4
Indiana	29.3	3.1
Total	**788.8**	**83.4**
U.S. Total	**945.4**	**100.0**

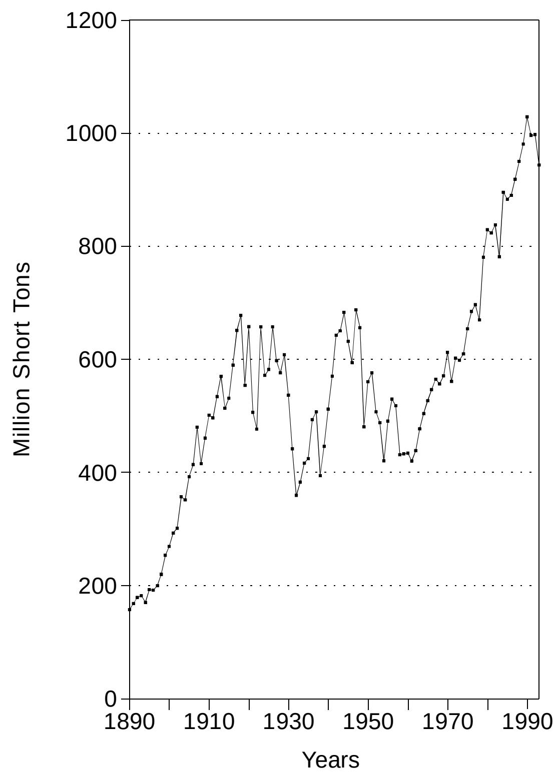
Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

About 60 percent of the coal produced was bituminous coal, historically the predominant rank. Most of the balance was subbituminous coal and lignite, both of which have been produced in increasingly larger quantities since 1970 to satisfy the demand for utility coal. The share of total production from subbituminous coal has risen from 4 percent in 1970 to 29 percent in 1993, and that from lignite has risen from less than 2 percent to 9 percent. By contrast, anthracite production, which accounted for less than 1 percent of the 1993 total, has been declining for several decades because of competition from other fuels and difficult mining conditions, which keep the price of anthracite relatively high. Internationally, the 1993 U.S. coal output was estimated to rank second to China among the more than 50 coal-producing countries.

Historically, annual coal production, fueling industrial development, reached 200 million tons before 1900 (Figure 9). It then climbed to more than 600 million tons before declining during the Depression years. Production increased during World War II and peaked at nearly 700 million tons in 1947, before trending downward in the postwar years as coal markets were lost to low-cost oil and natural gas. Not only was oil easier and cleaner to handle, with low-cost oil imports supplementing the domestic supply, but long-distance pipelines were built to bring natural gas from the Southwest to eastern markets, where its convenience of use cut sharply into the market for coal for home heating and other uses. Coal was also confronted with another rival in the utility market—the development of nuclear generated electricity. Further hampering the use of utility coal was a growth in hydroelectric power. As the market for coal weakened, coal production dropped from more than 500 million tons in the 1950's to a little more than 400 million tons in the early 1960's, although it rose from time to time mostly because of increased exports.

In the 1970's, however, coal production once again rose. Following the Arab oil embargo, which disrupted the

Figure 9. U.S. Coal Production, 1890-1993



The trend of U.S. coal production reflects competition from other energy sources, economic conditions, strikes and wars. The rise since 1960 is due to increased use of coal to generate electricity.

Sources: Energy Information Administration, *State Coal Profiles*, DOE/EIA-0576 (Washington, DC, January 1994), and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

supply of foreign oil and sharply increased oil prices, interest was renewed in the largely unused domestic coal reserves as a way of reducing dependence on foreign oil. In addition, the enactment of clean air standards spurred the opening of large mines in the West to supply low-sulfur coal for electric utilities. As the coal market improved and new mines opened, coal production expanded to record levels, surpassing 800 million tons in 1980 and 1 billion tons in 1990, dropping only slightly since then. In the last two decades, the coal output from many States reached an all-time high (Table 3). The upward trend for coal production, despite several coal miners' strikes, was in notable contrast with the generally declining production trends (based on total Btu content) for domestic crude oil and natural gas. Cumulative U.S. coal production from 1890 through 1993 is about 58 billion tons (Table 4).

Table 3. Peak Year of U.S. Coal Production by State, Through 1993
(Thousand Short Tons)

State	Year	Production
Alabama	1990	29,030
Alaska	1988	1,745
Arizona	1991	13,203
Arkansas	1907	2,670
California	1880	237
Colorado	1993	21,886
Georgia	1903	417
Illinois	1918	89,291
Indiana	1984	37,555
Iowa	1917	8,966
Kansas	1918	7,562
Kentucky	1990	173,322
Louisiana	1992	3,240
Maryland	1907	5,533
Michigan	1907	2,036
Missouri	1984	6,733
Montana	1992	38,889
New Mexico	1993	28,268
North Carolina	1922	79
North Dakota	1993	31,973
Ohio	1970	55,351
Oklahoma	1978	6,070
Oregon	1904	112
Pennsylvania	1918	277,377
Anthracite	1917	99,612
Bituminous	1918	178,551
South Dakota	1941	71
Tennessee	1972	11,260
Texas	1990	55,755
Utah	1990	22,058
Virginia	1990	46,917
Washington	1992	5,251
West Virginia	1947	176,157
Wyoming	1993	210,129
U.S. Total	**1990**	**1,029,076**

Sources: U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbook*, various issues, and Energy Information Administration, *Coal Production*, DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 4. Cumulative Coal Production by State, 1890-1993
(Billion Short Tons)

States	Production	Percent of Total
Pennsylvania	[a]15.3	26.3
West Virginia	10.8	18.5
Kentucky	7.1	12.2
Illinois	5.6	9.6
Ohio	3.5	6.0
Wyoming	2.9	5.0
Indiana	2.1	3.6
Virginia	2.0	3.5
Alabama	1.9	3.2
Other States	**7.1**	**12.2**
Total	**58.1**	**100.0**

[a]Includes 10.7 billion short tons of bituminous coal and 4.6 billion short tons of anthracite.

Source: U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbook*, and Energy Information Administration, *Coal Production*, DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

The high level of coal production was accompanied by shifts in both the geographic distribution of coal production and in the share of coal produced by surface mining. In 1970, most of the coal was mined east of the Mississippi River, principally from the Appalachian Region. By 1993, however, the share of production from eastern coal mines was only about 55 percent, while the rest was from western mines. Equally significant, surface mines gained a larger proportion of production, about 60 percent in 1993 as opposed to 44 percent in 1970, most of it in the West.

The major share of the additional coal production has been from leases on federally administered lands, principally Federal lands but also Indian lands. Coal production from Federal leases—the fastest-growing segment of U.S. coal production—has risen from 7 million tons in 1970, when it accounted for about 1 percent of the U.S. total, to 258 million tons in 1993, when it comprised 30 percent, due chiefly to highly productive leases in Wyoming. During the same period, the coal output from leases on Indian lands increased from 5 million to 28 million tons. Indian coal leases

Wyoming's Black Thunder surface mine, shown here, is the Nation's largest coal mine. Its 1993 output of 34 million short tons was more than the entire production of many States.

leases are on the tribal lands of the Navajo and Hopi in Arizona, the Navajo in New Mexico, and the Crow in Montana. They are administered by the U.S. Department of the Interior's Bureau of Indian Affairs. Coal sales from Federal coal leases generate substantial royalties ($265 million in 1993) that are distributed to the U.S. Department of the Treasury and to the States in which the leases are located. Royalties from Indian coal sales ($65 million) are disbursed to the tribal governments and Indian allotment owners.

The large amount of coal currently produced is from fewer but larger mines than in the past. The 1993 coal output, for example, was from about 2,500 mines, whereas in 1970 about 6,000 mines produced 40 percent less coal. The greater output from today's coal mines is due to advances in mechanization that brought continuous mining machines and longwall mining systems to underground mines and large-capacity power shovels, draglines, and coal-hauling equipment to surface mines. In 1970, mines with an annual output of more than 500,000 tons represented about 5 percent of the total number of mines and accounted for almost 60 percent of total coal production. By comparison, in 1993 this category of mines represented 14 percent of the total number, but supplied more than three-fourths of a considerably larger output. In addition, nearly 200 mines in 1993 produced at a level of 1 million tons or more, together accounting for two-thirds of the total coal mined. Of the 10 leading U.S. coal mines in 1993, 8 were surface mines in Wyoming. The largest surface coal mine was the Black Thunder, which was operated by ARCO Coal Company in Wyoming's Powder River Basin; it produced 34 million tons—more coal than was mined in 18 States. The largest underground coal production, 7 million tons, was from the Enlow Fork Mine of Consol Energy, Inc., in Pennsylvania.

Paralleling the trend of increasing mine size, coal-producing companies have also become larger. This has occurred because the mechanization of mines requires larger capital investments. Some small coal companies, lacking the financial resources to continue independently, have merged with other coal companies; however, many small mining companies have closed. In addition, some large coal consumers, such as electric utilities, have acquired interests in coal mining companies in order to secure long-term coal supplies. Some petroleum companies have expanded their interest in energy by acquiring shares in coal-producing companies.

Because the bigger coal companies generally operate a number of large mines, often in different States, they have gained a greater share of total production. In the mid-1950's, for example, the 10 largest coal companies produced about one-third of the Nation's coal output. In 1993, with production at a much greater level, the top 10 coal companies accounted for more than 40 percent of the output (Table 5). Although foreign companies have interests in U.S. companies, the coal industry is predominantly controlled by domestic companies. Currently the top three coal-producing companies are the Peabody Holding Company, which is controlled by Hanson PLC, a British firm; Cyprus Minerals, a U.S. company; and Consolidation Coal Company, which is affiliated with Du Pont / Rheinbraun AG, which represents U.S., Canadian, and German interests. In 1993, these three companies together were responsible for about one-fifth of the total U.S. coal output.

Table 5. The 10 Leading U.S. Coal-Producing Companies, 1993
(Million Short Tons)

Company	Production	Percent of Total Production
Peabody Holding Co., Inc.	69.7	7.4
Cyprus Minerals Co.	65.3	6.9
Consol Energy, Inc.	50.7	5.4
Zeigler Coal Holding Co.	37.5	4.0
ARCO Coal Co.	37.4	4.0
Kennecott Energy Co.	36.7	3.9
Exxon Coal USA Inc.	28.1	3.0
Texas Utilities Co.	27.6	2.9
Montana Power Co.	26.4	2.8
North American Coal Corp.	26.3	2.8
Total	**405.6**	**43.0**
U.S. Total	**945.4**	**100.0**

Note: Totals may not equal sum of components because of independent rounding.
Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Quality of Coal Production

If coal were a uniform product, it could be used with fewer problems. However, its composition varies significantly. Although characteristics such as fixed carbon, volatile matter, grindability, ash-fusion temperature, and coking ability have long been important in using and marketing coal, the heat value and the percentage of sulfur and ash, by weight, are of special interest. The heat value indicates how much energy is purchased per dollar. The sulfur content is an environmental concern because sulfur dioxide, a pollutant, is emitted when coal is burned. The ash content represents the incombustible material that can be emitted as particulate matter and also contributes to the erosion of boiler components.

The average heat value of coal is highest in the East, where virtually all of the coal is bituminous in rank, and relatively low for coal in the West, which has large deposits of subbituminous coal and lignite. Although annual coal production has increased, the total heat content of production has not risen at the same rate because of the greater amounts of low-rank coal mined for electric utilities. For example, in 1970, the average heat value of the 613 million tons of coal produced was 23.8 million Btu per ton, resulting in energy production of 14.6 quadrillion Btu. By comparison, the 1993 production was nearly 1 billion tons, more than 50 percent larger, but the energy value was 20.2 quadrillion Btu, only about 38 percent higher, because the average heat value of the coal declined to 21.4 million Btu per ton. For utility coal, the average heat content dropped from 22.6 million Btu per short ton in 1970 to 20.6 million Btu in 1993, whereas the estimated heat content of coking coal was relatively constant during the period, averaging 26.8 million Btu per short ton annually. Coal consumed by other industrial users declined slightly in heat value, from 23.0 million Btu per short ton in 1970 to 22.2 million Btu in 1993. The small amount of coal used by residential and commercial consumers fluctuated between an estimated 22.2 million and 23.7 million Btu per short ton during the period.

The average sulfur content of coal production, based on utility coal production, has been declining because of the larger amounts of low-sulfur coal from the West. Over the 1973-1993 period, the average sulfur content (by weight) of utility coal fell from 2.3 percent to 1.2 percent. Similarly, the average ash content (by weight) of utility coal also decreased over the period, dropping from 13.0 percent to 9.5 percent, due to the greater use of Wyoming utility coal, which has a relatively low ash content. Coal for industrial use in 1993 contained an average of 2.5 percent sulfur and 13.5 percent ash.

Coal Prices

In general, coal is the least expensive domestic fossil fuel produced, based on its heat content. Coal is about one-third as expensive as crude oil and nearly half as costly as natural gas. When adjusted for inflation, the average price of coal in 1993 (about $20 per ton) was about 44 percent lower than it was a decade earlier and less than half of the price in the mid 1970's. The highest price of coal in "real" dollars (adjusted for inflation and expressed in 1987 dollars) was $39 per ton in 1975, which amounted to $19 per short ton in current dollars and was the result of the oil embargo in 1973-74. The embargo caused a sharp rise in oil prices, and coal prices also rose mainly because producers expected a rapid and widespread switch from oil to coal. Coal prices reached $27 per ton in 1982 (real price of $32 per ton) before falling as the price of oil declined and the conversion from oil to coal slowed.

The price of coal varies by coal rank, mining method, geographic region, and coal quality. Surface-mined coal is generally lower-priced than underground-mined coal. Where coalbeds are thick and near the surface, as in Wyoming, mining costs and, therefore, coal prices tend to be lower than where the beds are thinner and deeper, as in Appalachia. The higher cost of coal from underground mines reflects the more difficult mining conditions and the need for more miners. Coals with a high heat content are generally higher priced. Low-sulfur coals can command a higher price than high-sulfur coals. The average price per ton of coal in 1993 was about $9 for subbituminous coal, $11 for lignite, $26 for bituminous coal, and $33 for anthracite.

Transportation costs add significantly to the delivered price of coal. In some cases, as in long-distance shipments of Wyoming coal, transportation costs can be more than the price of coal at the mine. The average delivered price of coal shipped to electric utilities, the major coal consumers, reached highs in the early 1980's of about $35 per ton (real price of about $39 per ton). Since then, the average delivered price of utility coal has generally declined, dropping in 1993 to about $29 per ton (real price of $24 per ton).

Employment, Productivity, and Earnings

The number of workers employed in the coal industry has declined so precipitously that the size of the coal mining labor force today is less than one-third the size it was a century ago—despite record levels of coal production. In contrast to a range of 400,000 to 800,000 workers employed in coal mining from 1900 to 1950, the number was around 100,000 in 1993. About 6,000 women were employed by the coal industry in production and other work. Before 1973, government records showed no women coal miners, reflecting biases and superstitions, such as the belief that women brought bad luck into the mine. By 1979, however, their ranks had grown to about 2,600, and in 1982, employment of women coal miners peaked at 11,600. The rise was spurred by the 1964 Civil Rights Act, a 1965 Executive order barring discrimination in employment and requiring affirmative action plans for businesses receiving Federal contracts, and a 1978 U.S. Department of Labor training program for women who wanted to begin coal-mining careers.

The drop in the size of the total coal mining workforce has been due to the replacement of manual labor by machines in virtually every phase of mining. At underground mines, the improvement of equipment and the introduction of remote-controlled mining and roof-bolting and other innovations have reduced crew sizes while improving safety and productivity. At surface mines, operations have speeded up and the number of employees has dropped through the use of larger and faster excavating and transporting equipment and improved blasting techniques. At both types of mines, computers have become an integral part of mine planning and operations and are also having a positive influence on productivity.

The greatest loss of miners has been in the coalfields in Appalachia, where the number has been reduced by more than half since 1980, falling from 171,000 to 71,000 in 1993. Nevertheless, Appalachia continues to be the center of the U.S. coal mining workforce, with about 7 out of every 10 U.S. coal miners in 1993. Nearly half of the coal miners worked in Kentucky and West Virginia (Table 6).

Table 6. The 10 Leading States in U.S. Coal Mine Employment, 1993

State	Average Number of Miners	Percent of Total
Kentucky	24,063	23.7
West Virginia	22,979	22.7
Pennsylvania	10,940	10.8
Virginia	8,339	8.2
Illinois	7,303	7.2
Alabama	5,399	5.3
Ohio	3,866	3.8
Indiana	3,331	3.3
Wyoming	3,159	3.1
Texas	1,841	1.8
Total	**91,220**	**90.0**
U.S. Total	**101,322**	**100.0**

Note: Average number working daily. Includes employees engaged in production, preparation, processing, development, maintenance, repair, shop or yard work at mining operations. Excludes office workers and mines producing less than 10,000 short tons of coal during the year and preparation plants with less than 5,000 employee hours.

Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

About 100,000 coal miners were employed in 1993. On average, they produced 5 short tons of coal per hour, earning $17 per hour.

Although coal mine employment has fallen, overall productivity in the U.S. coal industry has reached record levels. Productivity in 1993 was nearly 5 tons per miner per hour, almost six times higher than in 1950, due mostly to a higher rate at surface mines. Productivity at surface mines has consistently been higher than at underground mines, primarily because fewer workers are required. Productivity rose from about 2 tons per miner hour in the 1950's to a peak of nearly 5 tons per miner hour in 1974, dropped to about 3 tons in 1978, and since then steadily grew to 7 tons in 1993. The decline in 1978 was due to several factors. One was the opening of smaller, less efficient mines (often worked by younger, inexperienced miners) in response to rising coal prices due to the oil embargo in the early 1970's. Many of these mines later closed when the price of coal dropped and mining became uneconomical. Another factor that initially depressed surface mining productivity was the enactment of the Federal Surface Mining and Reclamation Act of 1977 and State reclamation laws, which require restoration of mined land, thereby diverting some employees and equipment from production activities. Factors that have been significant in raising the average productivity at surface mines are increases in the size and power of surface mining equipment and the large-scale mining of very thick coalbeds in the West.

In underground mines, improvements in productivity have been less dramatic. As recently as the early 1950's, underground miners averaged less than 1 ton per hour. The rate approached 2 tons per hour when the Federal Coal Mine Health and Safety Act of 1969 imposed many new safety regulations (such as the need to stop work between coal cuts to install roof supports). These initially hampered underground productivity, which fell to a low point of about 1 ton per miner hour in 1978. However, the regulations became less of a constraint as miners learned to adapt to the changes without compromising safety. As with surface mines, productivity was also hampered by the opening of many small, less efficient mines in response to rising coal prices and rising demand due to the oil embargo, mines that later became uneconomical and closed. Also taking their toll on productivity in the 1970's were several major coal miners' strikes by the United Mine Workers of America. However, by 1993 underground productivity reached nearly 3 tons per miner hour, reflecting the greater use of continuous-mining machines and longwall mining.

Coal miners, in general, are the highest paid workers in the mining industry, including oil and gas extraction; their wages are above the average paid in the steel, automobile, and chemical industries, according to the U.S. Department of Labor. In 1993, coal mine production workers averaged $765.90 per week (in current dollars), or $17.25 per hour, working an average of 44.4 hours. A decade earlier they earned $547.83 per week (current dollars), or $13.73 per hour, for 39.9 hours.

Health and Safety

Coal mining, particularly underground coal mining, historically has been a dangerous occupation, but the risk has been reduced dramatically. In recent years, the injury incidence rate for coal mining has been generally below that in many sectors of the construction and manufacturing industries, according to the U.S. Bureau of Labor Statistics.

The Federal Government has been involved in mine safety since 1910, when Congress established the Bureau of Mines as a research and fact-finding agency on coal mining. In 1941, Congress authorized Federal inspection—but not regulation—of coal mines. After 119 miners were killed in a coal mine explosion in West Frankfort, Illinois, in 1951, Congress enacted the Federal Coal Mine Safety Act of 1952, which increased the Bureau's inspection authority and empowered it to close underground mines engaged in interstate commerce that did not follow mandatory safety standards for underground coal mines; surface mines and underground mines operations employing fewer than 15 workers were exempted. The Federal Coal Mine Health and Safety Act of 1969 vastly increased the Government's enforcement powers by covering virtually every aspect of coal mining and by mandating fines for violations, authorizing criminal penalties for intentional violations, and enabling miners to request safety inspections. In addition to imposing mandatory safety training, the new law requires coal-mine operators to have plans for ventilation, roof support, and emergency evacuation approved by the Mining Enforcement and Safety Administration (MESA). MESA was created in 1973 in the U.S. Department of the Interior to handle mine inspections previously performed by the Bureau of Mines. It is the predecessor of today's Mine Safety and Health Administration (MSHA), formed in 1978 as part of the U.S. Department of Labor. MSHA is required to inspect underground coal mines four times per year and surface coal mines two times per year. It has the authority to issue citations and stop mining operations when conditions are dangerous.

As a result of more stringent safety regulations, mechanization, and roof bolting, the record for mine safety has greatly improved. In 1993, coal mining claimed 47 lives. In the 1980's, an average of 79 coal miners lost their lives each year, whereas in the 1970's, the toll averaged 129. The worst year in the history of coal mining was 1907, when 3,242 miners perished.

Explosions of coalbed methane and coal dust, which are ignited by a flame or spark, cause the major coal mine disasters and claim the greatest number of lives where coal is mined underground. In the United States, the first reported coal mine explosion occurred around 1810 near Richmond, Virginia. The worst U.S. coal mine disaster, taking the lives of 362 miners, was due to an explosion at Monongah, West Virginia, in December 1907. Mine safety regulations and practices have markedly reduced the danger of explosions by requiring sufficient mine ventilation to prevent the accumulation of high levels of methane and coal dust in the mine atmosphere. Coal dust is also controlled by making it noncombustible through the use of watersprays and by "rockdusting" mine areas with pulverized limestone or similar noncombustible material. Other safety measures include the use of explosives and electrical equipment that have passed certain safety tests and are formally approved as "permissible" by MSHA.

Historically, winter is the most hazardous time for coal mine explosions. From October through March, MSHA notifies underground coal miners of a "Winter Alert," warning them that methane and coal dust explosions are more likely to occur during this period than at any other time of the year. Hazards increase because dry winter air entering a mine becomes warm and absorbs moisture from the mine workings. As the mine "dries out," more coal dust becomes suspended in the mine air, increasing the risk of ignition. In addition, a sudden drop of barometric pressure causes methane to expand and flow from inactive areas of the mine to areas where the miners are working.

Mining research includes the development of technology that will enable a miner to be located in a safe place while using a computer to control a mining machine.

Although explosions are responsible for the most dramatic disasters in underground coal mines, roof falls historically have been the single most frequent cause of fatal accidents in U.S. coal mines. Roof falls occur when part of the mine roof or rib (side) breaks away. Usually this occurs within 25 feet of the working face, before the area is permanently supported. More roof fall fatalities occur with the room-and-pillar mining method than with longwall mining. Fatalities at surface mines are largely caused by falls of rock from the side of the mine and accidents involving machinery. Haulage-related accidents generally rank second as the cause of coal mine fatalities.

Apart from accidents, coal miners also face the danger of contracting coal workers pneumoconiosis, or “black lung,” the consequence of breathing and retaining too much coal dust. When coal dust collects in the small passages leading to air spaces in the lungs, the lung tissues react with the dust to form masses of dense fibrous tissue. Black lung, a progressive disease, causes difficulty in breathing and persistent coughing, and can put a fatal strain on the heart. Miners with the disease are eligible for disability under the Federal Black Lung Benefits Act of 1977 and its amendments, a program funded through taxes paid on coal production at a rate of $1.10 per ton for underground mines and 55 cents per ton for surface mines. However, most of the Black Lung claims filed before 1973 are administered through the Social Security Administration.

Coal Miners’ Unions and Strikes

The United Mine Workers of America (UMWA) ranks first among about 40 labor unions that represent U.S. coal miners. Formed in 1890, the UMWA has been the leading coal miners union and has been in the forefront as a collective bargaining organization representing coal miners. It is the major union in the coalfields in the East. UMWA coal miners currently account for about 40 percent of the U.S. coal mining workforce and produce about one-fourth of the total coal output. Other unions represent 4 percent of the coal miners and account for a 9-percent share of production. By contrast, nonunion workers compose about 55 percent of the coal mining workforce and account for about two-thirds of U.S. coal production.

Major coal miners' strikes—those creating a significant disruption on coal supplies—are generally precipitated when a contract expires and no agreement is reached between the UMWA and the Bituminous Coal Operators Association (BCOA) over the terms of a new contract. The principal bargaining issues focus on wage and fringe benefits, including health and retirement benefits. Contract agreements between the UMWA and the BCOA traditionally set the pattern for contracts between smaller unions representing coal miners and other mining companies or associations that do not belong to the BCOA, such as the Independent Bituminous Coal Bargaining Alliance. Overall production is usually not significantly affected by the small "wildcat" strikes that occur locally from time to time, usually over miners' grievances and local issues.

During a major strike, nonunion mines may also be idled by pickets or by miners walking out in "sympathy" strikes. Generally, strikes by the UMWA are most significant at underground mines in Appalachia, the center of UMWA membership. Before 1984, major coal miners' strikes were generally nationwide. Since then, the UMWA's tactic has been to call selective strikes against one or more companies. The striking miners are supported through UMWA payroll assessments into a selective strike fund.

The early history of the coal industry often featured long strikes, commonly over needed reforms. In 1922, anthracite miners in Pennsylvania went on strike for 160 days and bituminous coal miners for 140 days. The Nation's longest coal miners' strike—166 days in the anthracite region—was in the fall and winter of 1925-26, before the Taft-Hartley Act for ending strikes was enacted. In 1949-1950, a coal miners' strike lasted 116 days, although the miners went back to work several times during that period. Since 1960, major coal miners' strikes have occurred in 1966 (16 days), 1968 (13 days), 1971 (44 days), 1974 (28 days), 1977-78 (111 days), and 1981 (72 days). In October 1984, a nationwide strike was averted for the first time in 20 years with the signing of a new UMWA-BCOA contract extending through January 1988, and in early February 1988 another new agreement was ratified without striking. The new contract was for 5 years, whereas past contracts usually lasted about 3 years.

From April 1989 through most of February 1990, a UMWA strike against the Pittston Coal Company, with which it was negotiating a separate contract, affected the company's mines in Virginia, West Virginia, and Kentucky before a 4 1/2-year agreement was reached. At issue were job security and health and retirement benefits. In 1993, unsuccessful contract negotiations between the UMWA and the BCOA led to a series of selective strikes that idled more than 16,000 miners in seven States in Appalachia. The first selective strikes were against the operations of Peabody Holding Company, the Nation's top producer, and Eastern Associated Coal Corporation. The strikes lasted from February 2 to March 3 and ended when the negotiators agreed to extend the contract for 60 days. Failing to reach an agreement at the end of the period, the union expanded its selective strikes to include large mines operated by other companies. This new series of strikes lasted from May 10 until December 14, 1993, when an agreement was reached that will remain in effect through August 1, 1998. In addition to increasing wages and pensions, the new agreement provides for 60 percent of new job openings to be filled by UMWA workers, increases health care benefits, and gives the company the right to establish 7-day work schedules. In a separate collective bargaining agreement signed June 20, 1994, the UMWA and the Pittston Coal Company concluded a new labor pact in June 1994 that extends through 1998.

Preparation

Most of the coal produced in the United States undergoes some degree of processing, or preparation, to make it a more marketable product. The amount of preparation required depends on the customer's specifications. Some coal is blended at the mine where, for example, high-sulfur coal from one area can be mixed with low-sulfur coal from another to produce a medium-sulfur coal that is acceptable to a consumer. Roughly half of the bituminous coal currently mined is sent to preparation (or processing) plants for some form of coal cleaning. About two-thirds of the bituminous coal mined in the East for electric power plants is cleaned, whereas the subbituminous coal and lignite shipped from western mines to electric utilities is generally only crushed and screened to facilitate handling and to remove extraneous material introduced during mining. Nearly all of the coal used to make coke for steelmaking undergoes a high level of cleaning.

Cleaning upgrades the quality and heating value of coal by removing or reducing the amount of pyritic sulfur, *Coal quality is upgraded in a preparation plant. This plant in western Maryland can process 1,500 short tons of coal per hour.*

rock, clay, and other ash-producing material. Cleaning also removes materials that becomes mixed with the coal during mining, such as wire and wood. Conventional cleaning methods generally remove up to one-third of the inorganic (pyritic) sulfur in coal, but none of the organic sulfur. Currently, commercial technology is not available for reducing the levels of the alkali metals sodium and potassium. In general, about 30 tons of refuse are removed from every 100 tons of raw (as-mined) coal that is cleaned.

Coal cleaning is based on the principle that coal is lighter than the rock and other impurities mixed or embedded in it. The impurities are separated by various mechanical devices using pulsating water currents and rapidly spinning water. The large buoyancy difference between coal's combustible matter and its mineral impurities is exploited efficiently with the use of liquids of different densities in dense-medium systems, which are used in about two-thirds of the plants. The finely powdered coal (coal fines) produced during mining, handling, and crushing operations is usable but difficult to clean and handle. Finely sized coal is cleaned by froth flotation, a relatively high-cost chemical / physical process in which the coal adheres to air bubbles in a reagent and floats to the top of the washing device while the refuse sinks to the bottom. About 40 percent of the U.S. coal cleaning capacity consists of plants that use froth flotation to recover coal fines. The remaining plants either discard the coal fines as refuse or mix uncleaned coal fines with the cleaned coal for shipment to customers. Oil agglomeration has been used to a limited extent to clean ultra fine coal. The oil clings to the coal surface, causing it to agglomerate while other refuse particles remain suspended and are removed.

Coal cleaning consists of the following basic steps involving physical preparation and physical cleaning: (1) crushing, grinding and / or breaking, to prepare the coal for the washing process; (2) sizing, to separate coal into different dimensions, both to match the specifications for the various cleaning devices and to meet market requirements; (3) washing, to remove ash and sulfur components from coal; (4) dewatering and drying, to remove excess moisture and prepare the cleaned coal for shipment and also to increase its heat value (Figure 10). Cleaned coal of different sizes and properties can be blended at the plant to meet consumer requirements.

Figure 10. Basic Flow of Coal Through a Preparation Plant

Coal preparation reduces the amount of impurities (sulfur and ash-producing minerals) and improves the heating value; coals with different characteristics can be blended to meet certain specifications.

There were 270 coal preparation plants operating in the United States in 1993, according to *Coal* magazine. Varying widely in levels of complexity, the plants had capacities ranging from 40 tons to 3,200 tons per hour. Most of the plants were in the East, with those in West Virginia and Pennsylvania accounting for nearly half of the U.S. total. The largest preparation plant was the Bailey plant of Consol Pennsylvania Coal Company in Graysville. Preparation plants in the bituminous coal region are sometimes called “tipples,” because in the past coal cars were “tippled,” or dumped, into the top of the plant; today, transfer is accomplished by conveyor. In the anthracite region, preparation plants are often called “breakers,” a name originating in the fact that anthracite, a relatively hard coal, is broken and sized in the plant.

Transportation

The coal industry depends heavily on the transportation network for delivering coal to customers across the country. The flow of coal is carried by railroads, barges, ships, trucks, conveyors, and a slurry pipeline. Coal deliveries are usually handled by a combination of transportation modes before finally reaching the consumer. The methods of transportation and the shipping distance greatly influence the total cost of coal to the consumer. For some western coals shipped over a great distance, the freight cost may represent three-fourths of the delivered cost of coal.

Railroads are the foundation of the coal distribution system, annually handling about 60 percent of the coal shipped to domestic customers. Just as railroads are important to the coal industry, coal shipments, in turn, are the leading source of freight and revenue for the railroad industry. In 1993, coal constituted nearly 40 percent of railroad freight tonnage and provided over $6 billion in revenue, generating about 21 cents out of every dollar of freight revenue earned, according to the Association of American Railroads.

Since 1970, railroads have accounted for a steadily larger share of coal shipments from the West (increasing from 61 percent to nearly 70 percent of the total in 1993), reflecting a greater demand for low-sulfur western coal as well as improvements in the area’s rail transportation system, particularly in Wyoming. Over the same period, railroads handled an average of 55 percent of Appalachia’s coal shipments. Rail’s share of coal shipments in the interior region dropped from 51 percent to 45 percent, due mainly to a fall in the demand for the region’s high-sulfur coal to produce electricity and for its coking coal. Currently, the three leading States in which domestic coal shipments originate by rail are Wyoming (35 percent of U.S. rail shipments in 1993), Kentucky (18 percent), and West Virginia (10 percent). The largest coal-carrying railroads are CSX Transportation Incorporated, Burlington Northern Railroad Company, and Norfolk Southern Corporation, which together handle over three-fourths of all U.S. coal shipped by rail.

Unit trains account for more than half of railroad coal shipments. Unlike a conventional coal train or a mixed freight train carrying individual carloads of coal, a unit coal train carries coal from a specified loading facility straight through to a specified customer without stopping. It uses dedicated equipment, whereas other trains carrying coal generally draw the equipment needed from the railroad’s operating pool of locomotives and cars. Sometimes termed “the train with a one-track mind,” a unit coal train operates on a predetermined schedule, following the most direct route and providing high productivity and low shipping rates. Comprising as many as four or five locomotives and 100 to 110 cars, a unit coal train is over a mile long. It can be loaded with 10,000 to 11,000 tons of coal in 2.5 to 3 hours and unloaded in 4 to 5 hours. In some States, unit coal train traffic can be heavy. In Wyoming, the leading coal-producing State, about 40 unit coal trains left the State daily in 1990 while a like number returned for reloading, according to the Wyoming State Geological Survey.

Two types of railroad cars are used for transporting coal, the gondola and the hopper. Gondola cars have flat bottoms, straight sides, and open tops and are unloaded by being tipped over by rotary dumpers. Hopper cars have sloping bottoms with gates that open to discharge the coal. Today’s rail cars hold an average of about 96 tons, nearly 20 percent more than in the early 1970’s and almost double the capacity of railroad cars in the 1930’s. Cars used for eastern coal are slightly smaller than those for western coal, the difference reflecting the density of the coal carried. Eastern coal is denser than western coal and so the equipment designed to haul it has a smaller capacity. Most cars are made of steel, but a large number of aluminum-bodied cars are also used. Lighter in weight, aluminum cars offer a savings in transportation costs because they can carry 5 to 10 tons more than steel cars without exceeding track weight limitations. On the return trip, the lighter cars also result in fuels savings.

Waterborne shipments rank next to railroads in coal shipments, accounting for nearly 2 out of every 10 tons of coal shipped annually to domestic markets. However, the proportion of total domestic coal

The unit coal train is the symbol of coal transportation. Railroads are the foundation of the coal distribution system. Conversely, coal is the leading source of railroad freight and revenue.

shipments moved by water has declined from 29 percent in 1970 to about 17 percent in recent years, reflecting in part the shift of coal production away from the Northeast and Midwest, the regions with the greatest use of water transportation. Kentucky and West Virginia are the leaders in water transport of coal, together accounting for a little more than half of the total in recent years. Coal's approximate share of total domestic shipments of major commodities by type of waterway in 1991, according to the U.S. Army Corps of Engineers, was as follows: coastal, 5 percent; Great Lakes, 17 percent; and inland waterways, 30 percent.

Barges and ships move coal on rivers, the Great Lakes, and tidewater areas. The major inland waterways for coal traffic are the Mississippi, Ohio, and Black Warrior-Tombigbee rivers. Towboats plying these waters typically push 15 to 20 barges loaded with 20,000 to 30,000 tons of coal. The amount of coal shipped in a single tow (a string of barges) is determined by the lock size on the waters navigated. Large tows can be handled in the deeper waters of the lower Mississippi River. On the Great Lakes, domestic coal traffic generally ranks second to iron ore. Shipments are typically made by lake carriers, which are about 700 feet long and 70 feet wide and hold about 20,000 tons of coal. Several lake carriers are about 1,000 feet long and have about three times more capacity. The most extensive coal traffic on the lakes is to destinations in the north and west. Lake carriers sailing south generally contain iron ore or grain. Shipping on the Great Lakes usually is immobilized by ice from mid-December through mid-March. Some coal deliveries from eastern ports to power plants in Massachusetts are carried by a coal-burning collier, *Energy Independence*, placed in service in 1983.

Coal deliveries by truck account for about 1 out of every 10 tons of coal shipped. The level of coal transportation by truck has not varied significantly in the past two decades. Although the use of trucks for hauling coal is widespread, it is very important in a number of States, including Alabama, Indiana, Pennsylvania, Texas, and Utah. Trucks are used for short hauls, generally of less than 50 miles. Frequently, coal transported by rail or barge is first trucked to the loading dock or transferred by truck at some point. In some areas, such as parts of the Appalachian Region, trucks are the only economical way to transport coal. Individual coal shipments by truck are relatively small. Three-axle dump trucks hold about 20 tons; tractor-trailers carry up to 35 tons. The maximum load a truck can carry on highways is limited by State regulations.

Aerial tramways, conveyors, and a coal slurry pipeline together account for about the same amount of coal deliveries as trucks. The percentage of coal shipped by this transportation category has increased from about 4 percent in 1970 to about 13 percent in recent years. This growth was partly due to the rapid growth of coal production in the West, where conveyors are often used to deliver coal directly from mines to nearby power plants.

Aerial tramways cover relatively short distances, but conveyors usually are many miles long, commonly linking mines with power plants. The Nation's only coal slurry pipeline is the Black Mesa line. Spanning 273 miles, this pipeline is 18 inches in diameter and connects a coal mine in northern Arizona to a power plant in southern Nevada. It carries about 4.5 million tons of coal annually in a slurry composed equally of finely ground coal and water, the journey from mine to plant taking about 3 days. About 1 billion gallons of groundwater are used annually. There are 9.7 million gallons of water and 45,000 tons of coal in the pipeline at any one time. The Black Mesa coal slurry pipeline began operations in 1970, about 7 years after the closing of the Nation's first long-distance coal slurry pipeline, the Eastlake, which carried coal from Cadiz, Ohio, to a power plant east of Cleveland.

Supply and Stocks

In recent years the supply of coal from U.S. mines has averaged about 19 million tons per week. This is more than enough to provide the fuel required to generate electricity for a metropolitan area the size of New York City for about a year. The weekly supply of coal from the mines varies considerably. Sharp rises occur in response to increased demand, including increased use of coal-fired electricity generation to offset declines in generation from other sources. These declines occur, for example, when nuclear power generation drops because of scheduled maintenance, when hydroelectric generation falls during periods of low water, or when coal stockpiles are built up in anticipation of a coal miners' strike.

Downward swings in weekly coal production and supply usually are caused by miners' vacations and holidays. Strikes by coal miners and workers involved with coal shipments can sharply curtail the supply of coal from the mines. Delays in delivering railroad cars to the mines can result in a drop in coal shipments. Freezing temperatures can hamper the unloading of railroad cars. Although coal shipped by rail in winter is generally treated with freeze-control agents, this protective treatment can be washed away and the coal can freeze solid in the railroad cars. Coal frozen in railroad cars is thawed in heated sheds and/or mechanically broken into pieces of manageable size. Heavy rains and flooding can also impede mining operations and coal shipments. For instance, from June through August 1993, severe flooding along the upper Mississippi and Missouri river basins disrupted coal deliveries to power plants in about nine Midwest States and to power plants in States beyond that area, because trains were delayed or rerouted around the flooded region.

As insurance against a disruption in deliveries, large coal consumers generally maintain a 45- to 60-day stockpile of coal. Large quantities of coal are generally stored in open stockpiles on the ground, piled in diverse forms, such as cones, blocks, and rows. Coal is also stored in covered ground storage—in bins, bunkers, and silos.

Year-end coal stocks since 1990 have averaged nearly 190 million tons, equivalent to about one-fifth of the average annual coal consumption. More than 80 percent of the stockpiled coal was at electric power plants.

Use

Coal is used in all 50 States and the District of Columbia. In 1993, 10 States accounted for about half of the total coal consumed (Table 7). Of these, Texas, Indiana, Ohio, and Pennsylvania consumed the largest amounts, with a combined share of 29 percent of the tonnage. However, based on the estimated energy content of the coal consumed, the ranking was as follows: Ohio, Pennsylvania, Texas, and Indiana.

The use of coal in the United States has risen almost steadily since the early 1970's, reaching record levels and totaling 926 million tons in 1993. On a per capita basis, coal consumption in 1993 was nearly 20 pounds per person per day, which continued an upward trend

Table 7. The 10 Leading U.S. Coal-Consuming States, 1993
(Million Short Tons)

State	Consumption	Percent of Total
Texas	96.8	10.5
Indiana	60.4	6.5
Ohio	59.0	6.3
Pennsylvania	56.2	6.1
Kentucky	39.1	4.2
Illinois	38.1	4.1
Alabama	33.0	3.6
Michigan	32.2	3.5
West Virginia	32.0	3.5
North Dakota	30.3	3.3
Total	**477.2**	**51.4**
U.S. Total	**925.9**	**100.0**

Note: Total does not equal sum of components because of independent rounding.

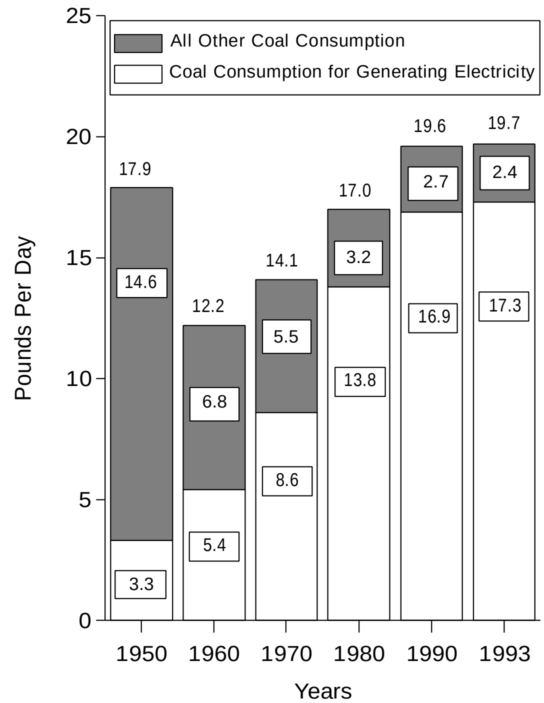
Source: Energy Information Administration, *Quarterly Coal Report October-December 1993,* DOE/EIA-0121(93/4Q) (Washington, DC, May 1994); and *Quarterly Coal Report January-March 1994*, DOE/EIA-0121(94/1Q) (Washington, DC, August 1994).

that began in the 1960's (Figure 11). Virtually all of the growth has been due to the increasing amounts of coal used to generate electricity.

The upward trend in coal consumption was spurred by the Arab oil embargo in the first half of the 1970's, which caused substantial price increases for petroleum, and by a natural gas shortage in the second half of the 1970's. As a result, the share of total U.S. energy consumption supplied by coal has increased significantly. At the time of the Arab oil embargo, coal accounted for 17 percent of U.S. energy consumption. In 1993 its share was 23 percent. Historically, however, this is a markedly smaller proportion than in the early 1900's, when coal supplied nearly all of the U.S. energy needs, or 1940, when it supplied about half.

In recent years, the increase in energy supplied by coal has not matched the increase in coal tonnage. For example, the amount of coal consumed increased by 32 percent from 1980 through 1993, but the energy derived from the coal in 1993 was only 26 percent higher than in 1980. The difference is due to the greater use of subbituminous coal and lignite, which are mined in the West. Both have a relatively low heat content as compared with bituminous coal, which held a larger share of consumption in earlier years.

Figure 11. U.S. Daily Per Capita Coal Consumption, 1950-1993



U.S. daily per capita coal consumption has risen since the 1960's due chiefly to an increase in the amount of coal used for generating electricity.

Source: Bureau of Mines, U.S. Department of Interior, "Mineral Yearbook," various issues; Energy Information Administration, "Quarterly Coal Report," DOE/EIA-0121, various issues; and Bureau of the Census, U.S. Department of Commerce, "Statistical Abstracts of the United States," various issues.

More than 8 out of every 10 tons of the coal used in the United States are for electricity generation, the most important market for coal since the 1950's. The coal is used to produce high-pressure steam for driving an electrical generator (Figure 12). Due to the cost advantage that coal offers over oil and gas, the amount of coal used by utilities annually has trended upwards. Although electricity generated from nuclear power increased in the 1970's and 1980's, at the expense of petroleum and gas, coal's contribution was on an upward trend, generally keeping pace with the growing demand for electricity. Part of the reason for the rise was the Powerplant and Industrial Fuel Act of 1978. The law prohibited the use of oil or gas in most new large boilers and compelled utilities to convert many

Figure 12. Schematic of a Coal-Fired Power Plant

Most coal-fired power plants burn pulverized coal to produce high-pressure steam. The steam, in turn, runs a turbine that drives an electric generator. Most of the coal ash is carried in flue gas as fly ash and removed chiefly by electrostatic precipitators, but fabric filters are also used. Plants with scrubbers remove over 90 percent of the sulfur dioxide in the flue gases. About one-third of the energy released during coal combustion is converted into electricity.

existing oil- and gas-fired boilers to coal. The law was amended in 1978 to repeal restrictions on the use of oil or gas in new baseload power plants if they were designed to permit future conversion to coal, but the later regulations became redundant because rapidly rising petroleum prices and natural gas shortages in the 1970's gave coal the economic advantage.

Utility coal consumption has risen from less than 400 million tons per year during the early 1970's to more than 800 million tons in 1993. The electricity generated from coal has increased from 704 billion kilowatthours in 1970, when it accounted for 46 percent of the total, to a record 1,580 billion kilowatthours in 1993, when its share was 57 percent. By comparison, of the total electricity generated in 1993, nuclear power supplied 21 percent; natural gas and hydropower, 9 percent each; petroleum, 3 percent; and geothermal and other sources, 1 percent.

In addition to the electricity produced by utility companies, a small amount of electricity is generated by nonutility power producers, chiefly industrial plants that produce it for their own use. In 1993, coal-fired generation in this sector totaled about 43 billion kilowatthours.

Most of the coal used to generate electricity is burned in pulverized-coal-fired boilers. Pulverized-coal firing, introduced in the electric utility industry in the early 1920's, is a major improvement over other methods of coal combustion because it permits the use of larger, more efficient boilers. Pulverized coal, which is ground as fine as flour, is blown into the furnace and ignited instantly to burn in suspension. The most common pulverized-coal boilers are classified as having a "dry bottom" because the coal ash does not reach fusion temperature. About 80 percent of the coal ash produced is carried in the flue gases as fly ash, while only 20 percent of the ash settles to the bottom of the furnace. This type of unit operates most efficiently with coals that have an ash fusion temperature that is above the furnace temperature, so that slag (molten ash) does not form. A "wet bottom furnace" is designed so that ash fuses to form slag. The coal ash produced consists of approximately half fly ash and half bottom ash, which is drawn off as slag.

A smaller amount of utility coal is used in stoker furnaces, which are supplied with crushed coal on a moving grate; and in cyclone furnaces, which burn crushed coal carried in a whirling stream of air. A few generating plants use fluidized-bed combustion, a technique for burning crushed coal (often of low quality) in a bed that behaves like a boiling fluid as currents of high-velocity air flows through it.

Currently, U.S. coal-fired power plants produce about 90 million tons of combustion byproducts in the form of fly ash, bottom ash, boiler slag, and flue-gas desulfurization material. About one-fourth of these byproducts are used in various ways, such as in cement and concrete production and as roadbase materials; the rest is disposed of in surface impoundments, landfills, and waste piles.

Nearly 500 of the 3,000 power plants in the United States use coal. In 1993, these coal-burning plants were located in 44 States. Eight of the States relied on coal for over three-fourths of their generating capability. Another 14 States depended on coal for 50 to 75 percent of their electricity generation. The five leading States generating electricity from coal were Ohio, Texas, Pennsylvania, Indiana, and Kentucky. The largest U.S. coal-fired power plants are the Scherer plant (3.3 million kilowatts of summer generating capability) and the Bowen plant (3.2 million kilowatts) of Georgia Power Company; the Gibson plant (3.1 million kilowatts) of PSI Energy, Inc., in Indiana; and the Monroe plant (3.0 million kilowatts) of Detroit Edison Company, in Michigan. Each of these power plants can generate enough electricity for a city with a population of over 1 million. Large power plants consume coal at rates of more than 20,000 tons per day, the amount of coal held by about 200 railroad cars. Some power plants are minemouth plants, constructed near one or more mines that provide a convenient source of coal. In general, each ton of coal consumed at a power plant generates about 2,000 kilowatt hours of electricity. A pound of coal supplies enough electricity to light ten 100-watt bulbs for about an hour.

Another use of coal is to make coke for the iron and steel industry, foundries, and other industries. The presence of large domestic deposits of coking coal, or metallurgical coal, played an important role in the development of the U.S. iron and steel industry. Coke is used chiefly to smelt iron ore and other iron-bearing materials in blast furnaces, acting both as a source of heat and as a chemical reducing agent, to produce pig iron, or hot metal (Figure 13). About 1,100 pounds of coke are consumed for every ton of pig iron produced. Foundries use coke as a source of heat for producing metal castings. Other industrial uses of coke include the smelting of phosphate rock to produce elemental phosphorous and the production of calcium carbide. Small sizes of coke, termed breeze, are used as fuel in sintering finely sized particles of iron ore and other iron-bearing material to produce an agglomerate that can be used in a blast furnace.

Figure 13. Using Coke in a Blast Furnace to Make Iron

Coke, iron ore, and limestone are fed into the blast furnace, which runs continuously. Hot air blown into the furnace burns the coke, which serves as a source of heat and an oxygen-reducing agent to produce metallic iron. Limestone acts as a flux and also combines with impurities to form slag.

Source: American Iron and Steel Institute.

Coke is made by baking a blend of selected bituminous coals (called metallurgical coal or coking coal) in special high-temperature ovens without contact with air until almost all of the volatile matter is driven off. The resulting product, coke, consists principally of carbon. A ton of coal yields about 1,400 pounds of coke and a variety of by-products such as crude coal tar, light oils, and ammonia, which are refined to obtain various chemical products (Figure 14).

The coke industry was once a major market for coal, accounting for about one-fourth of U.S. coal consumption as recently as the late 1950's. Since then, coke production has fallen dramatically and its share of total coal consumption currently is about 4 percent because of a decline in the U.S. iron and steel industry, the principal consumer of coke. In general, the iron and steel industry now requires less coke because it produces smaller amounts of raw steel, relying on imports of finished and semi-finished steel to help meet its needs, and because improved blast-furnace technology has reduced the amount of coke needed to produce a ton of pig iron. Furthermore, less coke is needed due to the greater use of certain steel-making technologies, such as the basic oxygen furnace, which enables scrap iron to replace pig iron in some processes, and the electric arc furnace, which produces steel from a charge consisting of 99 percent scrap iron and recycled steel and 1 percent iron pellets. (The steel industry has not used the open-hearth furnace since 1991.) The substitution of other products for steel (such as plastics, aluminum, magnesium, and titanium) has also indirectly reduced the need for coke.

Among the recent technological changes that are responsible for reducing the use of traditional coke in blast furnaces is the use of pulverized coal injection, a process developed in the 1960's by Armco Steel. By using pulverized coal injection, steel companies can reduce the need for coke by as much as 40 percent, cut down on environmental problems associated with coke production, and reduce the need for other, more costly supplemental blast furnace fuels, such as natural gas. Pulverized coal, which has the consistency of face powder, is made from the relatively abundant lower grades of coal and blown into the blast furnace. Granular coal, similar in size to sugar, is also being tested in blast furnaces.

At the beginning of 1994, 31 coke plants were in operation, less than half the number a decade earlier. Although some plants were closed because of the decline in the steel industry, many closings targeted older plants that were shut down because of the high cost of refurbishing them to meet air pollution

Figure 14. Production of Coke and Coal Chemicals
(Approximate Yields per Ton of Coal)

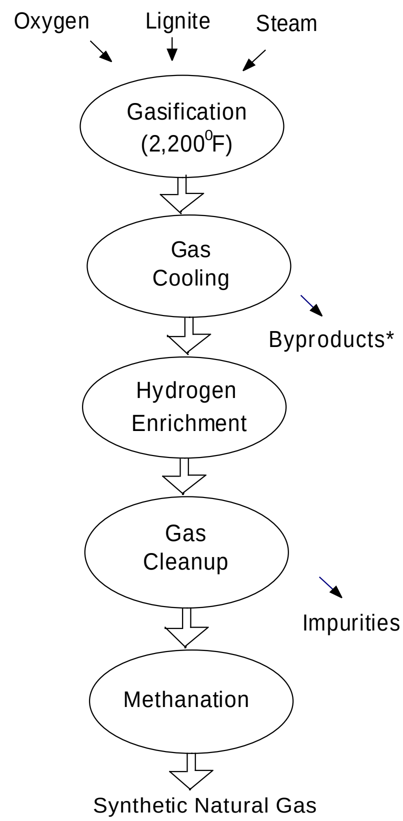
Metallurgical (coking) coal is converted in special high-temperature ovens into coke, which is used in smelting iron ore in a blast furnace. The coking process also yields useful coal chemicals as by-products.

standards. More than half of the active plants are *furnace plants*, operated by iron and steel companies to produce coke for their blast furnaces; these plants account for about 80 percent of the U.S. coke capacity. The other coke plants, called *merchant plants*, sell coke on the open market. Both segments of the coke industry are faced with the advanced age of many of their coke ovens and the rising costs of replacing them with environmentally clean ovens. Indiana and Pennsylvania are the leading coke-producing States.

Coal is also used as a source of heat in other industrial, manufacturing, and commercial establishments, as well as in homes. Most U.S. cement plants burn coal, using about a ton for each 3.5 tons of cement produced. A number of cogeneration plants consume coal to produce steam for generating electricity and for heating.

Since December 1984, lignite has been converted into pipeline-quality gas at the Great Plains Synfuels Plant, near Beulah, North Dakota (Figure 15). The first of its type to operate commercially in the United States, the plant converts an average of 16,000 tons of lignite per day into 142 million cubic feet of gas. In 1987, a coal gasification facility began operations at Plaquemine, Louisiana, to produce gas for the cogeneration of steam and electricity for the Dow Chemical Company. The plant has a coal processing capacity of 2,400 tons per day.

Figure 15. Schematic of Coal Gasification, Great Plains Synfuels Plant, Beulah, North Dakota



*Includes ammonia, sulfur, liquid nitrogen, krypton, xenon, and phenols.

In coal gasification, the molecular structure of coal is broken down to produce hydrogen and carbon, which are combined to form (CH_4), the main constituent of natural gas. Synthetic natural gas forms when carbon monoxide and carbon dioxide react with hydrogen in the presence of a nickel catalyst.

Source: Dakota Gasification Company.

Some coal is used for transportation, but the amount is insignificant. The coal-burning locomotives of the past, now replaced by more efficient diesel-electric locomotives, were once major coal consumers requiring a coal supply that often exceeded 100 million tons per year. Today's coal-burning locomotives are used for tourist attractions and excursions, although one was in regular, short-haul revenue service in Illinois as recently as 1986. (It is interesting to note that research is underway to develop a new generation of coal-fired locomotives fueled with coal-oil mixtures, coal-derived liquids, or coal gas.) A coal-fired ship more than 60 years old was reported in service on the Great Lakes in 1991. A large coal-fired ship, the *Energy Independence*, placed in service in 1983, transports coal from eastern ports to power plants in Massachusetts. The ship, 665 feet long and with a coal-capacity of about 36,000 tons, is the first of its type built in the United States since 1929.

Although primarily a fuel, coal has other uses. The process of converting coal into coke yields by-products of benzene, coal tars, naphtha, and similar chemicals that are used to manufacture solvents, varnishes, perfumes, medicines, dyes, and plastics. In the past, coke plants were a major source of chemicals, but today their output is overshadowed by chemicals produced from petroleum. Coal is also used to manufacture diverse products such as calcium carbide, silicon carbide, refractory bricks, carbon and graphite electrodes, adsorbents, carbon black, and fillers. Since 1983, coal has been used as a raw material at Eastman Kodak's plant in Kingsport, Tennessee, to manufacture acetic anhydride, which is used in making photographic film base, acetate yarns, and other plastic-based materials. Montan wax is extracted from certain lignites at Ione, in northern California, for use in polishes, waxes, carbon paper, phonograph records, inks, coatings, and electrical insulating materials. Resin recovered from coal in Utah is used in making adhesives, rubber, varnish, enamel, paint, coating, thermoplastics, and ink. Oxidized lignite, or leonardite, from North Dakota has been used in oil-drilling mud, in water treatment, in certain wood stains, and as soil conditioners. Activated carbon is manufactured from lignite in Marshall, Texas. Some of the ash from coal-fired power plants is used in manufacturing concrete and cinder blocks, in constructing roads, and in reclaiming surface-mined areas.

Coal and Coke Trade

Coal exports comprise a small but important market for U.S. coal production. The level of coal exports, consisting of nearly all Appalachian bituminous coal, is influenced by a number of factors, such as changes in the economic conditions in the coal-importing countries, coal-miners' strikes in the United States and other coal-exporting countries, and price competition, as well as changes in the international exchange rate of the U.S. dollar, which determines the price foreign consumers pay for U.S. coal.

U.S. coal is currently exported to more than 30 countries (Figure 16). The United States was the world's leading coal exporter until 1984, when Australia gained first place. Annual U.S. coal exports, valued at $3 billion to $6 billion from 1980 through 1993, are a significant contribution to the Nation's balance of trade.

Since 1960, an average of 1 out of every 10 tons of coal mined has been exported. The amount has ranged widely, from 36 million tons in 1961 to a record 113 million tons in 1981 and totaled 75 million tons in 1993. The 1993 coal exports were the lowest since 1979, a decline generally attributed to a combination of adverse factors: a slump in the world economy, a strike by the United Mine Workers of America, a slowdown of barge shipments due to flooding in the Midwest, and price competition from foreign coal producers. Although coal was exported in 1993 from 15 States, West Virginia, Virginia, and Kentucky predominated, together accounting for three-fourths of the total.

Metallurgical coal, or coking coal, is the mainstay of U.S. coal exports, accounting for 67 percent of the 1993 total. However, exports of bituminous steam coal have expanded because many foreign electric power plants, cement plants, and other industries converted from oil to coal when oil prices rose in the 1970's.

Canada, historically, has been the principal export market for U.S. coal, including some anthracite for use in a smelting process to produce paint pigments. Western Europe became a major market for U.S. coal following World War II, especially for metallurgical coal, with the largest tonnages currently shipped to Italy, Belgium and Luxembourg, and the Netherlands. Japan has been predominant as a market for metallurgical coal since 1967. Brazil is the largest South American importer of U.S. metallurgical coal.

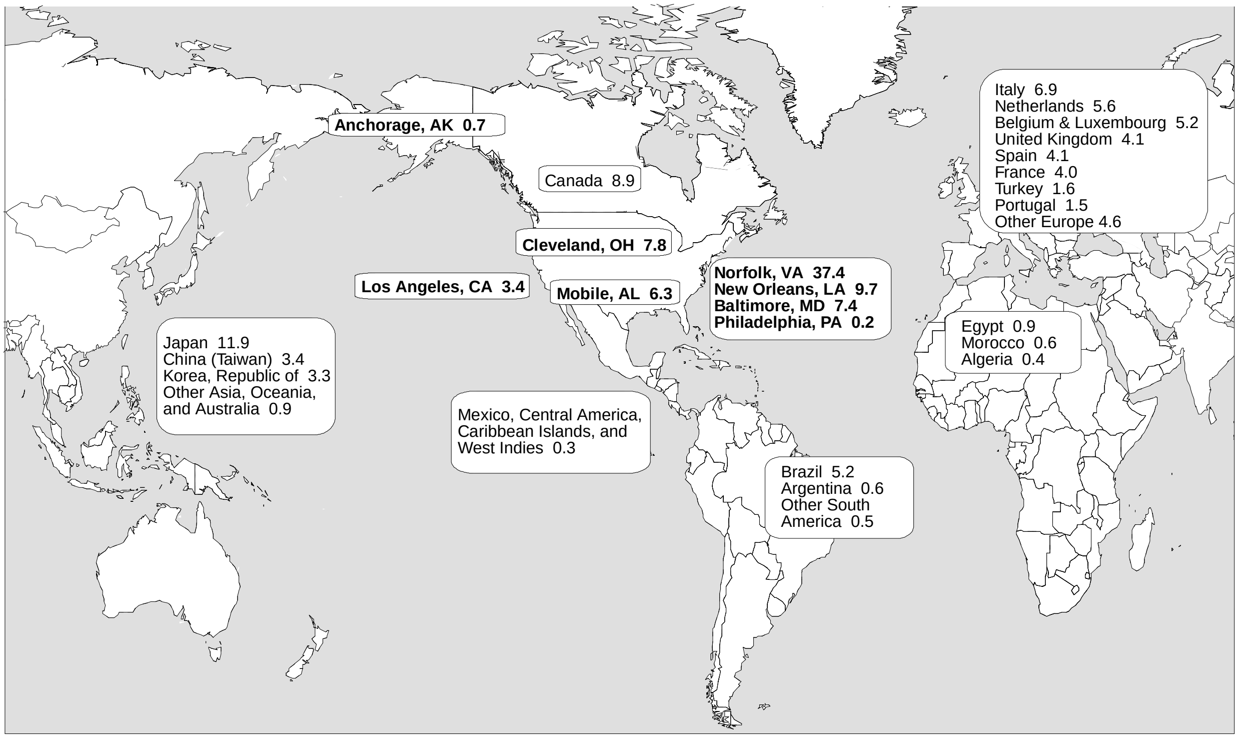
About half of the total U.S. coal exported is shipped from the Norfolk, Virginia, customs district. Other large coal-exporting customs districts are New Orleans, Louisiana; Cleveland, Ohio; Baltimore, Maryland; and Mobile, Alabama.

Channel depths at most U.S. coal-loading terminals limit the vessel size to less than 100,000 deadweight tons. When a large collier (more than 100,000 deadweight tons) cannot be fully loaded because of channel-depth restrictions, it is sometimes loaded by a two stage "top-off" operation. With this technique, the ship is partially loaded at the port and then sails to deeper waters where it is topped-off to full capacity with coal from a self-unloading barge. However, vessels using the Panama Canal are limited in size to 65,000 deadweight tons and are often described as "Panamax" ships. "Capesize" ships are oceangoing vessels too large for the Panama Canal that must travel routes around the capes of Africa or South America.

Coal imports, contrasted with coal exports, are relatively insignificant. In 1993, the 7 million tons of bituminous coal imported were valued at about $219 million. The coal was imported chiefly from Colombia, Venezuela, and Canada. Coal imported from Canada was used primarily to meet the needs of U.S areas not easily supplied by domestic sources. The coal imported from the other countries was delivered to electric power plants in the Southeast at prices below those of competing U.S. coal. Imported coal typically has a low sulfur content and is sometimes blended with high-sulfur domestic coal to enable the latter to meet air-quality emission standards.

U.S. coke exports have been small and chiefly to Canada. Coke exports totaled 0.8 million tons in 1993. Coke imports over the past two decades typically have been less than 1 million tons, although larger amounts have been imported when needed to offset a shortfall in the domestic supply. Coke imports in 1993 amounted to 1.5 million tons, mostly from Japan. Some coke was imported from Canada for use by nonferrous industries in the West.

Figure 16. Major Destinations of U.S. Coal Exports and Shipments from Selected U.S. Coal-Exporting Customs Districts, 1993
(Million Short Tons)



In 1993, a total of 75 million short tons of U.S. coal was exported to more than 30 countries. More than half of the coal was shipped from Norfolk, Virginia.

Source: Energy Information Administration, *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93/4Q) (Washington, DC, May 1994).

Coal and the Environment

Coal has played an important role in the advancement of civilization, but its use has sometimes been accompanied by environmental penalties, due partly to the mining process and partly to the composition of coal itself. Because of this, a number of laws have been enacted to protect the environment.

Coal mining, like all other mining, has a direct impact on the environment. Most visible are surface-mined areas, although proper reclamation can restore the land for other uses after mining. The Surface Mining Control and Reclamation Act of 1977, which was extended and amended by the Abandoned Mine Reclamation Act of 1990, requires surface mine operators to maintain certain environmental standards during mining and reclamation. The Act also requires operators of underground mines to take measures to control land subsidence, which can have a severe impact on roads, water and gas pipelines, buildings, and water-bearing strata. Although subsidence can occur during underground mining, as when longwall methods are employed, it poses a potential threat many years after a room-and-pillar mine has been abandoned because the pillars left to support the overlying strata can deteriorate and collapse. To help pay the costs of reclaiming land and water resources affected by past mining operations, the Act imposes fees on coal production at both surface and underground mines. Companies pay 35 cents per ton of coal mined by surface methods, 15 cents per ton mined underground, and 10 cents per ton of lignite. (These fees were extended through the year 2004 by the Energy Policy Act of 1992.) The 1977 Act also provides funds to control fires in abandoned underground mines. Such fires can travel long distances, fueled by coal remaining in the abandoned workings, and endanger life and property in communities situated above the burning area.

Waste piles from mining and coal preparation and from coal-fired power plants can also create environmental problems. They are regulated by the Resource Conservation and Recovery Act of 1976, the principal law governing the disposal of solid wastes. However, much of the material piled up during surface mining is used during reclamation, when soil and other materials are replaced to reflect natural conditions.

The impact of mining and coal preparation on water quality is controlled by the Federal Water Pollution Control Act of 1972, which has been incorporated into the Clean Water Act of 1977 and its amendments. One of the environmental consequences of coal mining is acid mine drainage, which contains sulfuric acid produced when pyrite and other iron sulfides react with air and water. The acid water increases the solubility of toxic heavy metals, such as arsenic, lead, and mercury, and renders the water toxic to aquatic life and unfit for domestic and municipal use. Acid mine drainage can be reduced by a variety of methods, such as adding alkaline minerals to neutralize the acidity, sealing abandoned underground mines, controlling drainage, and constructing wetlands with cattails, mosses, and other plants to clean the mine water.

When coal is burned, the sulfur in it is converted mostly into sulfur dioxide. In addition, nitrogen oxides are produced from nitrogen in the coal and the air used in combustion, and ash is produced from incombustible material. In the atmosphere, sulfur dioxide and nitrogen oxides are converted to sulfuric and nitric acids, which can react with rain or snow to produce acid rain. Most of the ash produced at coal-fired powered plants is in the form of powder-like particulates called “fly ash,” which are carried in the flue gas. Fly ash is composed mainly of silica and alumina, and may contain potentially hazardous trace elements. The remaining ash is bottom ash, or boiler slag, which is collected at the bottom of the boiler or furnace.

Sulfur dioxide emissions are usually controlled by the technique of “flue gas desulfurization,” generally with the use of “wet scrubbers.” These spray the flue gas with a mixture of water and lime or limestone, which combines with sulfur dioxide to form a sludge. With the less common “dry scrubbers,” a similar spray produces a dry residue. The level of nitrogen oxides emissions usually is controlled by reducing the amount of air used during combustion and by lowering combustion temperatures. Particulates can be removed from flue gas by mechanical devices, but electrostatic precipitators and baghouses are more efficient. With electrostatic precipitators, the most common device in power plants, the particulates are electrically charged and collected on metal plates. In baghouses, powerful fans draw the flue gases through an array of fabric filters that trap the particulates.

To maintain air quality, emission levels for sulfur dioxide, nitrogen oxides, and particulates have been established by the New Source Performance Standards of the Clean Air Act of 1970 and its amendments. Electric utilities and other industrial coal consumers built before 1971 are subject to emission controls set by the States and approved by the Environmental Protection Agency. Those built after 1971 must meet the following Federal limits, in pounds per million Btu: sulfur dioxide, 1.2; nitrogen oxides, 0.7; particulates, 0.1. Electric generating units constructed or modified after September 1978 are subject to the more stringent standards of the Revised New Source Performance Standards. These are based on the level of uncontrolled emissions and defined in terms of percentage reductions. A minimum of 70 percent reduction is required for coal with a low-sulfur content, and a 90 percent reduction for coal with a high-sulfur content. The emission rate for sulfur dioxide under the new standards range from 0.6 to 1.2 pounds per million Btu. For nitrogen oxides, the standards range from 0.5 to 0.8 pound per million Btu, depending on the rank of coal burned and the method of combustion. The limit for particulates is 0.03 pound per million Btu. The emission standards for industrial boilers constructed or modified after June 1986 are similar to those for electric generating units.

In November 1990, the Clean Air Act was amended to strengthen the National commitment to improve air quality. The new legislation establishes as a goal for the year 2000 a reduction in annual sulfur dioxide emissions of at least 10 million tons from the 1980 level. Total sulfur dioxide emissions from all power plants will be limited to 8.9 million tons annually. The reduction will be in two phases. In Phase I (January 1, 1995, through 1999), the 110 largest sulfur-emitting power plants will be allowed to emit an average of 2.5 pounds of sulfur dioxide per million Btu of heat input. In Phase II, beginning in 2000, these plants and almost all others will be required to reduce sulfur dioxide emissions to 1.2 pounds per million Btu.

Near Colstrip, Montana, mined land has been reclaimed for livestock grazing as mining continues in the background.

One of the major breakthroughs in the 1990 Clean Air Act is a permit program for power plants that release pollutants into the air. The Environmental Protection Agency issues annual allowances to power plants, with each allowance permitting 1 ton of sulfur dioxide to be released from the smokestack. Plants may release only as much sulfur dioxide as their allowances cover. If a plant expects to release more sulfur dioxide than it has allowances, it has to get more allowances. It can buy them from another power plant that has reduced its sulfur dioxide emissions, due perhaps to switching to low-sulfur fuel or installing scrubbers, and therefore has allowances to sell or trade. Allowances can also be bought and sold by "middlemen," such as brokers, and can be traded and sold nationwide. The program provides bonus allowances to power plants for, among other things, installing clean coal technology that reduces sulfur dioxide emissions, using renewable energy sources, or encouraging energy conservation by customers. The new legislation also requires a reduction of nitrogen oxides by 2 million tons. EPA will establish new limits for emissions of nitrogen oxides. All power plants under the program will have to install continuous emission monitoring systems to keep track of the amount of sulfur dioxide and nitrogen oxides released into the atmosphere.

Since passage of the Clean Air Act in 1970, billions of dollars have been spent by the Nation's utilities to reduce emissions of sulfur dioxide. Because of this huge investment, the Nation's air is cleaner today than it was about two decades ago. Emissions of sulfur oxides (comprised principally of sulfur dioxide) from all coal-burning sources are responsible for about three-fourths of total sulfur oxide emissions. However, between 1970 and 1992, coal-generated emissions have fallen by about 11 percent even though coal consumption increased by 70 percent. The decline reflects not only a greater number of plants meeting air quality standards through an increased use of scrubbers, but also a drop in the average sulfur content of coal burned.

Also of environmental concern are emissions of carbon dioxide from coal combustion and of methane from coal mines, although controls on the emission of these gases from the use of coal and other fossil fuels have not been imposed. Both carbon dioxide and methane are major greenhouse gases and may contribute to global warming.

The amount of carbon dioxide emitted when coal is burned varies widely, depending on the rank of coal and the State in which it is produced. Potential carbon dioxide emissions from the combustion of bituminous coal, the leading rank of coal consumed, average 205 pounds per million Btu, but range from 201 to 212 pounds per million Btu. By comparison, the average for subbituminous coal, the second leading rank of coal consumed, is 212 pounds per million Btu, while it ranges from 207 to 214 pounds per million Btu. The emission factor averages 216 pounds per million Btu for lignite and 227 pounds per million Btu for anthracite.

Estimates of carbon dioxide emissions from coal combustion must take into account the “mix” of coals received from various sources. A voluntary program for companies to report reductions in gas emissions to the Energy Information Administration was among the provisions of the Energy Policy Act of 1992. The Act addresses many energy-related issues, including the attainment of higher energy efficiency standards and the environmentally sound use of fossil fuels.

Methane emissions occur mostly during production in underground mines. Bituminous coal generally emits more methane than the lower rank coals such as lignite. The amount of methane contained in a coalbed increases with depth. Small amounts of methane can also be released when coal is transported and when it is pulverized for combustion.

Coal Outlook

The Nation’s abundant coal reserves are expected to continue as an important source of energy in the foreseeable future. Annual coal production is projected to remain around 1 billion tons into the next century. Nearly 90 percent of this is projected to be for domestic consumption, principally to generate electricity. The rest of the output is expected to be exported.

Research and development are underway to make coal a more competitive and cleaner-burning fuel, as well as a greater source of chemicals. All parts of the “coal chain” are being investigated, from mine to consumer. Both Federal and State pollution control regulations are giving impetus to the coal industry’s effort to produce a cleaner, more efficient fuel.

Computer-assisted mining systems under development have the potential to advance mining technology through automation, robotics, and networking programs that can monitor a variety of mining activities, resulting in improved health, safety, productivity, reliability, and economy. Equally important are studies concerned with the human factors involved in coal mining.

Although mining disrupts the land for a period of time, considerable progress has been made in reclaiming mined land. This includes the restoration of the land surface, the rehabilitation of soil materials, and revegetation. The goal of reclamation is to restore the mined land to its original use or enable it to be put to another use.

Advanced coal preparation, geared to improving current state-of-the-art techniques, could remove as much as 90 percent of the sulfur and ash from the coal, improving its burning and environmental qualities. This can be accomplished by using sophisticated physical, chemical, and biological methods to clean finely ground coal. The removal of sulfur not associated with mineral impurities and of alkali metal impurities in western coals are challenging goals, because these elements are generally bonded to the organic coal matrix, requiring the use of chemical reagents. Innovative approaches to future coal preparation could include use of microwave and microbial and enzymatic techniques.

Drying techniques are being developed to lower the moisture content in western coals (30 percent is not uncommon). When dried, low-rank coals typically crumble and become very dusty. New drying methods will produce solid pellets of coal that have about two-thirds less moisture and about one-third more heating value. This dried coal can be blended with raw subbituminous coal or lignite to raise the overall heating value, or with high-sulfur coal to reduce sulfur emissions.

Traditional coal-burning methods will continue to be used for many years. However, clean coal technology —a term that entered the energy vocabulary in the 1980’s—offers the potential for a cleaner environment and lower power costs. Included are more effective precombustion coal-cleaning processes, such as methods for keeping sulfur and nitrogen pollutants inside the furnace and scrubber systems capable of removing pollutants in the form of dry solid waste, reducing the disposal problems created by wet sludge. Some clean coal technologies depart from conventional coal-burning methods in that the coal is converted into a gas or liquid that is used as fuel.

Advanced pulverized coal technologies can take pulverized coal combustion—the most widely accepted technology for coal-fired power generation—one step further, by refining the process to gain major improvements. Included are low emission boiler systems, which incorporate emission controls at the outset of design and development instead of adding them to a completed system, and cogeneration, which produces both steam and power for power generation and also heat for process and space heating, and can result in improvement in plant efficiency of over 70 percent.

Coal gasification, an old technology that is being modernized, converts coal into a gaseous product by heating it with steam and oxygen or air. The gas

Pristine coal samples are used by researchers investigating cleaner and more efficient coal use.

produced can be cleaned and used as a fuel or processed further to produce synthesis gas. Synthesis gas (mostly carbon monoxide and hydrogen) can be converted to a substitute for natural gas, chemicals, or liquid fuel. The amount of gas that can be produced from a ton of bituminous coal depends on the technology used and ranges from about 15,000 cubic feet of high-Btu gas (about 1,000 Btu per cubic foot) to 75,000 cubic feet of low-Btu gas (up to 200 Btu per cubic foot). In 1993, three coal gasification plants were in commercial operation in the United States. The Great Plains Synfuels Plant, near Beulah, North Dakota, operated by the Dakota Gasification Company to convert lignite into pipeline-quality gas, obtaining chemical byproducts as part of the process. Tennessee Eastman Company's coal gasification plant in Kingsport, Tennessee, converted bituminous coal into chemicals. At Plaquemine, Louisiana, subbituminous coal was converted by Louisiana Gasification Technology into gas for use in generating electricity and superheated steam for an adjacent chemical complex.

Coal gasification also has potential in development of fuel cells, which generate electricity from the reaction of hydrogen and oxygen. Currently, most fuel cells approaching commercialization are fueled with natural gas. Because hydrogen is produced in coal gasification, coal gasifiers could be integrated into future fuel cell technologies to provide a new approach to power generation.

The research and development of "mild gasification" is aimed at processing coal under lower temperatures and pressures than in a typical coal gasification process. This leads to the production of liquids and solids that can be upgraded into high-value industrial raw material and chemical feedstock, in addition to gas, which can be used to provide heat for the process.

Underground coal gasification is the technology of converting coal to gas without mining. Wells are drilled into a coalbed, which is ignited and encouraged to burn. The burning coal generates combustible gases that can be collected at the surface for use as fuel or as feedstock for producing chemicals, such as ammonia and urea. The Federal Government has sponsored underground gasification tests in Wyoming, West Virginia, and Washington.

Coalbed methane, a danger to mining, is a potentially important source of energy. It is currently produced in some States (principally Alabama, New Mexico, and Wyoming) to supplement the supply of natural gas, which is composed largely of methane; its potential is being evaluated in other States. Methane can be produced from unmined beds or in advance of mining a coalbed. Degasification of a coalbed not only supplies a useful product, but also provides a safety measure because it reduces the amount of methane released into the working areas of a mine.

Coal liquefaction, another old technology, converts coal into liquid fuels by three techniques: indirect, direct, and pyrolysis. With an indirect process, coal is first gasified, and then the coal-derived synthesis gas is converted into a variety of liquid fuels, such as methanol, gasoline, diesel fuel, and octane enhancers. The best-known indirect coal liquefaction facilities are operated in South Africa by South African Coal, Oil and Gas Corporation, Ltd. (SASOL), which produces a range of liquid fuels including gasoline, diesel oil, and jet fuel. With a direct coal liquefaction process, finely ground coal in a solvent is mixed with hydrogen and heated to a high temperature under high pressure to produce "synthetic crude oil." This can be upgraded into higher quality fuels by further processing with existing petroleum-refining techniques. With pyrolysis, dry coal is subjected to high temperatures in a chemically reducing atmosphere to produce a heavy synthetic crude oil, which can be refined, and char, a solid residue that can be used as a fuel. Depending on the process used, a ton of bituminous coal can be converted into 0.5 to 3 barrels (21 to 126 gallons) of liquid fuel.

Solvent-refined coal processes produce a low-ash, low-sulfur fuel from coal high in both ash and sulfur by dissolving pulverized coal in a solvent. The final form of the fuel, whether a liquid or a solid, is determined by the process used.

Mixtures of finely ground coal and oil or water can be substituted for fuel oil in oil-burning facilities. They have the advantage of being transported, stored, and burned in a manner similar to fuel oil. By weight, coal constitutes 40 to 50 percent of coal-oil mixtures and about 70 percent of coal-water mixtures; some chemicals are added to the mixtures to prevent the coal particles from settling out in storage. The technology for producing coal-liquid mixtures has been broadened to include methanol and solvent-refined coal. The idea of using coal-oil mixtures is not new. They were tested in the 1930's as an oil substitute for ships in trans-Atlantic service, and in the 1950's they were evaluated as fuel for blast furnaces. The potential of using coal-water mixtures was first demonstrated at a U.S. power plant in 1961. More recently, mixtures of coal and recycled paper have been tested on a small scale for use as fuel.

Direct coal-fired heat engines represent another aspect of clean coal technologies. They include direct coal-fired gas turbines, which involve the use of both a coal-water slurry and dry pulverized coal, and direct coal-fired diesels, which involve the development of diesel engines that will burn a coal-water slurry rather than distillate petroleum fuels.

Fluidized-bed combustion, a technology dating back to the early 1920's, is well-suited for burning high-sulfur and low-quality coals in an environmentally acceptable manner. It has become commercially competitive for large industrial applications and is currently used to generate electricity. With this technology, crushed coal is burned on a hot turbulent bed of limestone or dolomite, which absorbs most of the sulfur dioxide produced. As a result, the need for flue gas desulfurization units is eliminated. Only a small amount of nitrogen oxides is produced because of relatively low combustion temperatures. The fluidized-bed units in operation burn coal under normal atmospheric pressures. Advanced units under development—pressurized fluidized-bed combustion systems—operate at higher pressures to achieve greater efficiency.

Formcoke is of potential importance as a blast furnace fuel. It is made by heating briquettes of finely pulverized coking coal or other coal, including some subbituminous coals, that has been carbonized to obtain a char, which is further carbonized to produce metallurgical coke. Although pulverized coal is being used in blast furnaces, replacing some of the coke, a clean coal technology project entitled "blast furnace granulated-coal injection system" involves retrofitting blast furnaces with technology to operate with a variety of coal particle sizes. Also under development is COREX (Coal/Ore Reduction), a novel "cokeless" ironmaking process in which coal can be substituted for coke in a special furnace to smelt iron ore. It could replace the conventional two-step coke oven/blast furnace procedure for producing pig iron, eliminating the environmental problems associated with coke making. Sulfur in the coal is captured in the by-product slag.

Magnetohydrodynamic (MHD) conversion is a potential method of burning coal cleanly and at high efficiencies to generate electricity. MHD systems differ from other advanced coal-fired systems in that coal is burned at very high temperatures to produce ionized combustion gases that pass through a magnetic field to create electricity. Linked with a conventional steam turbine-generator, commercial MHD systems are expected to achieve power generating efficiencies of well above 50 percent—more than one-and-a-half times those of conventional coal-burning power plants.

As the complex nature of coal becomes better understood, it could once again become important as a raw material for manufacturing a variety of chemicals. Many of the organic chemicals made today from petroleum were originally by-products of the coke-making process. With the development of sophisticated chemical processes, coal-derived chemicals could provide the building blocks for making special products, such as carbon fibers, composite materials, and fullerenes (a form of carbon discovered in 1985 that has possible applications in high-temperature lubricants, microfilters, more efficient superconductors, and gas adsorbents).

All these and other applied research efforts are being supplemented by fundamental studies of the atomic and molecular structure, composition, and characteristics of coal. Such work provides the basic information that enables practical research to succeed.

The U.S. Department of Energy (DOE) is investing in a Clean Coal Technology (CCT) Demonstration Program, a government-industry co-funded effort to develop new technology with the dual goals of attaining environmental quality and energy security from coal. The CCT program, which started in 1986, is confined to perfecting the early stages of long-term, high-risk research that industry is reluctant to pursue. At the end of 1993, the program comprised 45 demonstration projects either underway or completed in 21 States, representing nearly $2.5 billion in Federal funding and more than $4 billion in cost-sharing from private and State sources. DOE also funds coal projects at U.S. colleges and universities. Since 1979, DOE's University Coal Research Program has provided $76 million for fundamental studies of coal and coal-related topics.

Looking ahead, there is little doubt that the United States has the resources to remain self-sufficient in coal well into the 21st century. The Nation has enormous coal reserves, a well-developed coal industry, and advancing coal technologies. The U.S. coal industry continues to adjust to changes in economic conditions, governmental actions, and environmental constraints that influence the production and use of coal. As a producer of an important source of energy, the coal industry will continue to directly or indirectly touch on almost every phase of our daily lives.

Supplemental Figures and Tables

Removing overburden at a surface mine in Illinois continues into the night.

Figure 17. Selected Developments in the History of U.S. Coal Since 1880

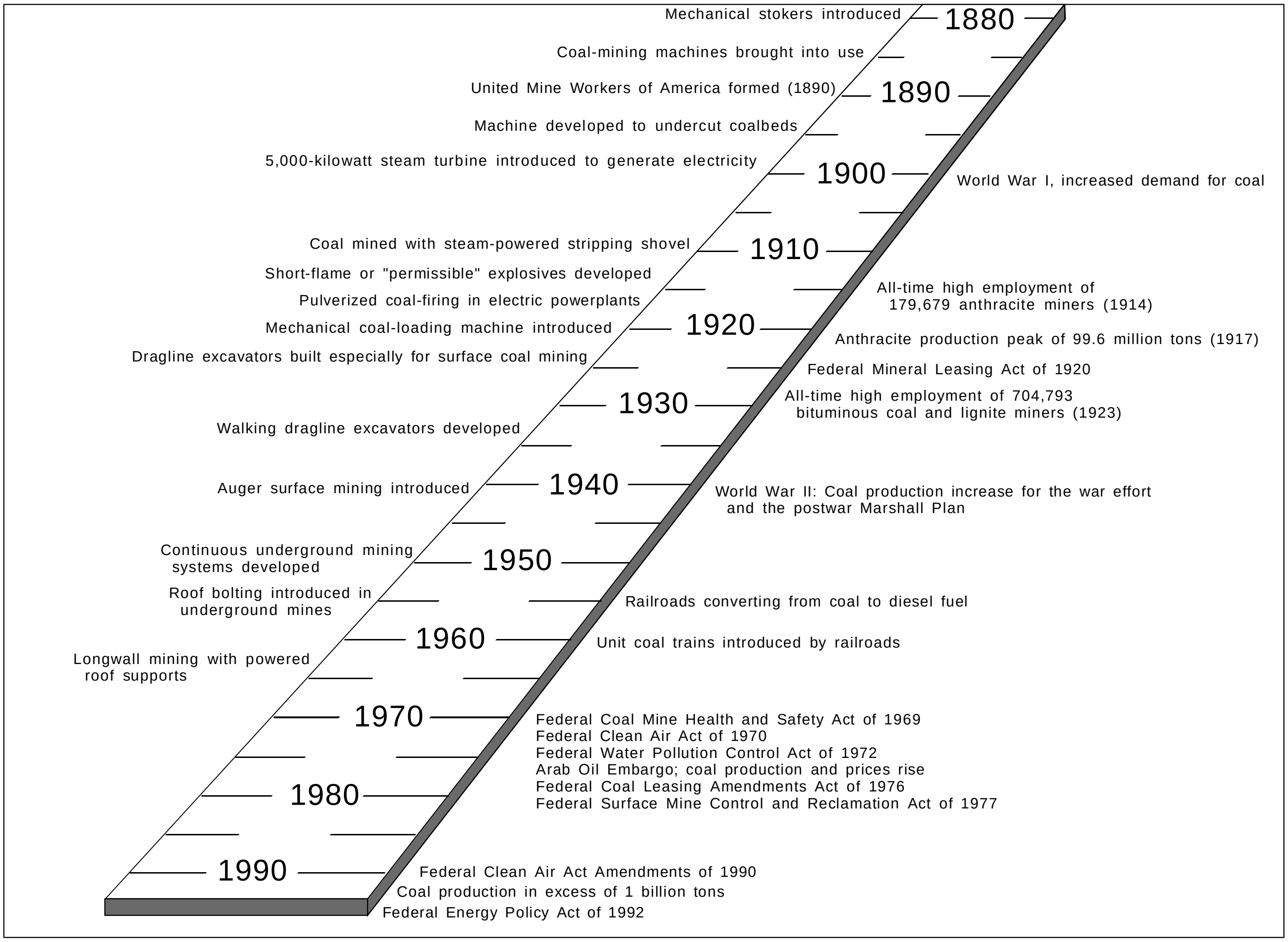
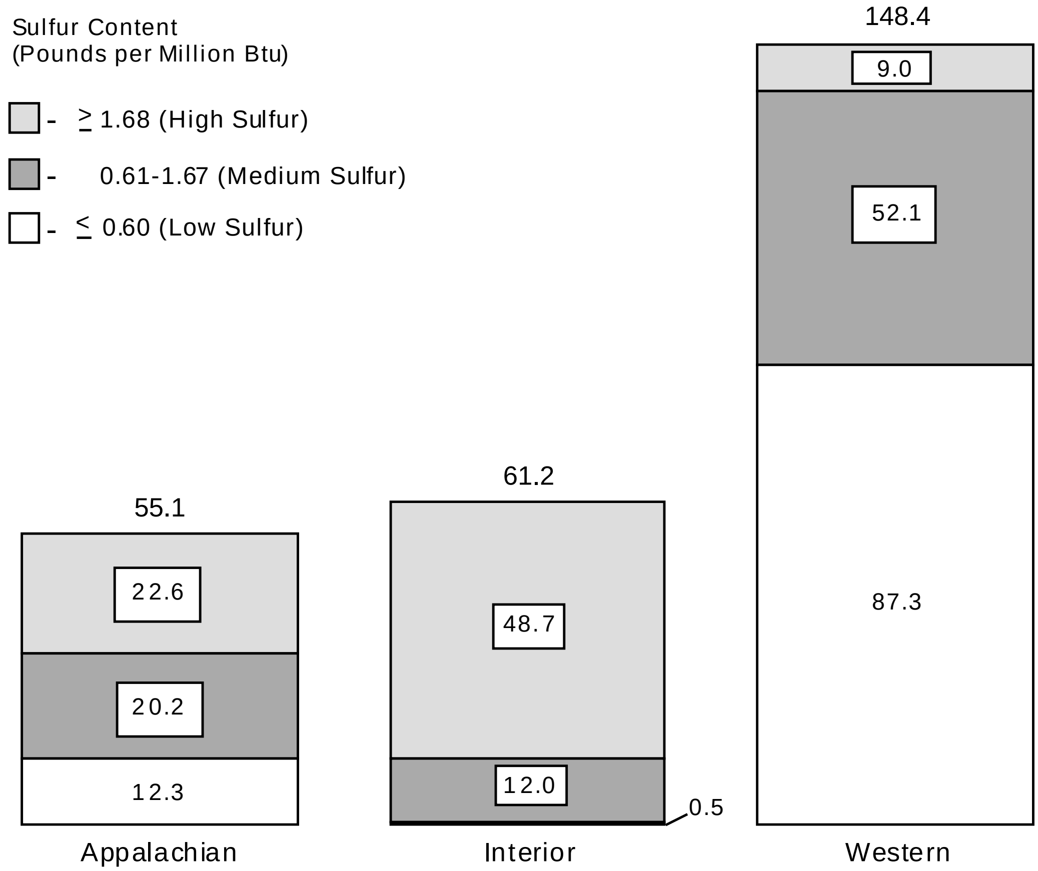


Figure 18. Estimates of Recoverable Coal Reserves by Btu/Sulfur Ranges and Region, January 1, 1992
(Billion Short Tons)



Source: Energy Information Administration, *U.S. Coal Reserves: An Update by Heat and Sulfur Content,* DOE/EIA-0529(92) (Washington, DC, February 1993).

Table 8. U.S. Demonstrated Reserve Base of Coal by Potential Mining Method and Ranked by State Total, January 1, 1993
(Million Short Tons)

State	Underground	Surface	Total
1 Montana	70,959	48,912	119,870
2 Illinois	62,638	15,369	78,007
3 Wyoming	42,535	26,524	69,059
4 West Virginia	31,819	4,679	36,498
5 Pennsylvania	24,562	4,510	29,071
6 Kentucky	23,517	5,287	28,084
7 Ohio	17,895	5,951	23,845
8 Colorado	12,108	4,817	16,925
9 Texas	0	13,198	13,198
10 Indiana	8,885	1,186	10,071
11 North Dakota	0	9,550	9,550
12 Alaska	5,423	711	6,134
13 Utah	5,779	268	6,047
14 Missouri	1,479	4,518	5,998
15 Alabama	1,422	3,296	4,718
16 New Mexico	2,121	2,278	4,399
17 Virginia	1,747	720	2,467
18 Iowa	1,733	457	2,190
19 Oklahoma	1,238	347	1,584
20 Washington	1,332	80	1,412
21 Kansas	0	976	976
22 Tennessee	551	291	842
23 Maryland	660	84	744
24 Louisiana	0	480	480
25 Arkansas	273	145	417
26 South Dakota	0	366	366
27 Arizona	102	119	220
28 Michigan	123	5	128
29 Oregon	15	3	18
30 North Carolina	11	0	11
31 Idaho	4	0	4
32 Georgia	2	2	4
U.S. Total	**318,928**	**155,127**	**474,055**

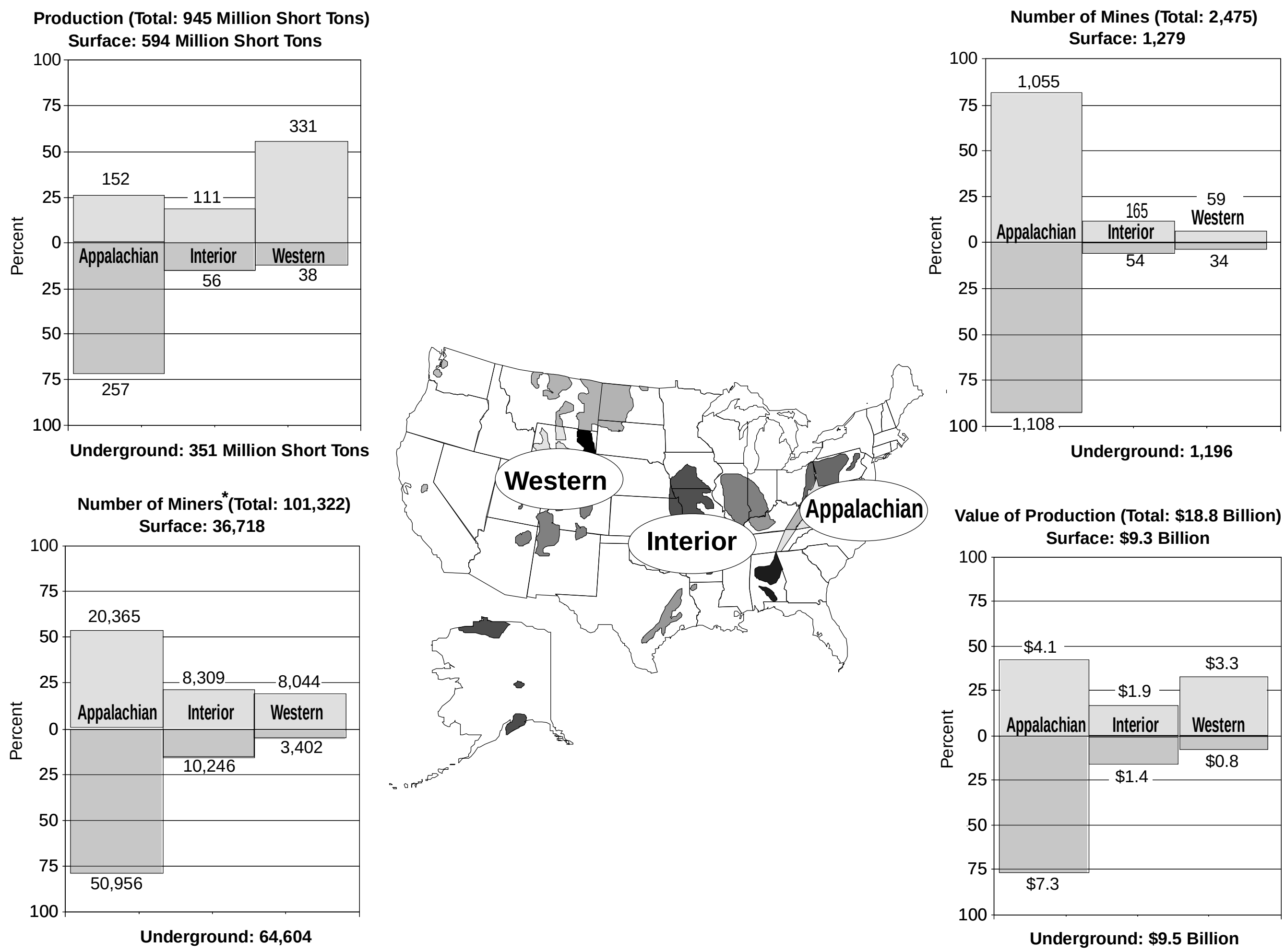
Note: Totals may not equal sum of components because of independent rounding.
Source: Energy Information Administration, *Coal Production 1992*, DOE/EIA-0118(92) (Washington, DC, October 1993).

Table 9. Estimates of U.S. Recoverable Coal Reserves by Btu/Sulfur Content and Region, 1992
(Million Short Tons Remaining as of January 1, 1992)

Region	Sulfur Content (pounds per million Btu)			
	≤.60 (low sulfur)	**0.61-1.67** (medium sulfur)	**≥1.68** (high sulfur)	**Total**
Appalachian	12,291	20,237	22,558	55,086
Interior	548	11,970	48,693	61,210
Western	87,332	52,098	8,956	148,386
U.S. Total	**100,171**	**84,305**	**80,206**	**264,682**

Note: Totals may not equal sum of components due to independent rounding. Btu = British thermal unit.
Source: Energy Information Administration, *U.S. Coal Reserves: An Update by Heat and Sulfur Content*, DOE/EIA-0529(92) (Washington, DC, February 1993).

Figure 19. Regional Patterns of U.S. Coal Production, 1993

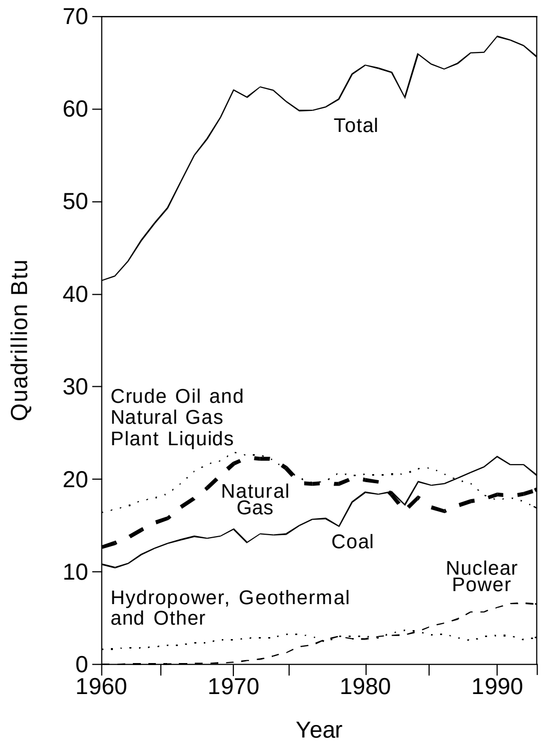


*At mines that produced 10,000 or more short tons.

The Appalachian Region is the Nation's principle source of coal. In 1993, it accounted for almost half of the total output, most of the mines and miners, and more than half of the total value of the coal produced.

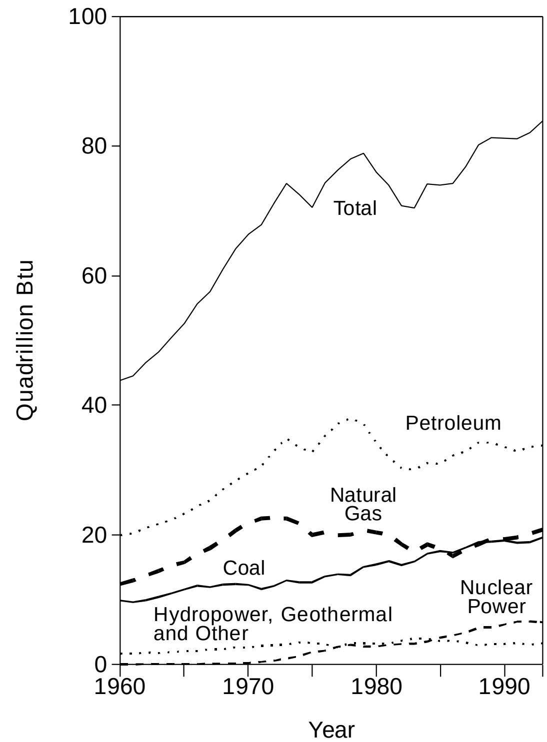
Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Figure 20. U.S. Production of Energy by Source, 1960-1993



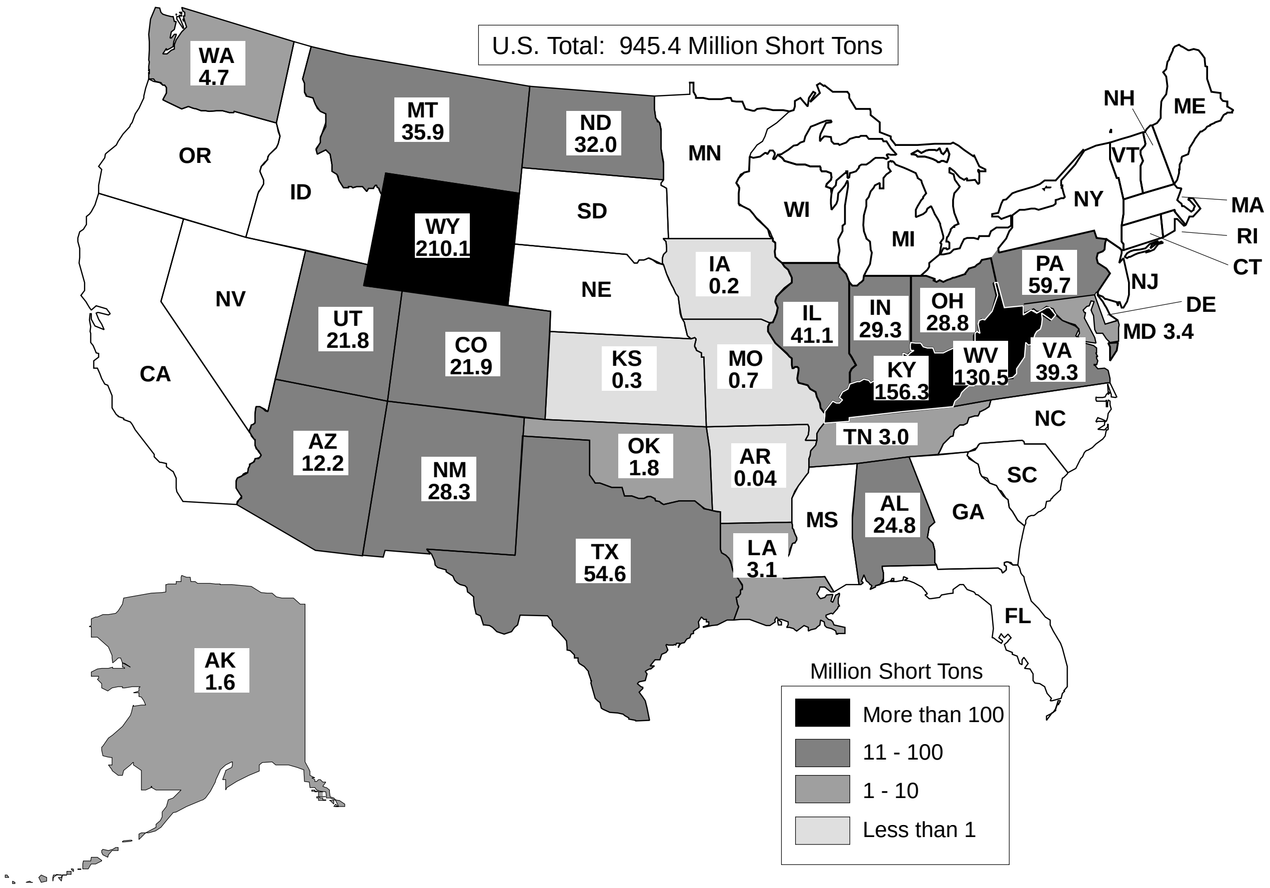
Source: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994).

Figure 21. U.S. Consumption of Energy by Source, 1960-1993



Source: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994).

Figure 22. U.S. Coal Production by State, 1993



Of the 26 States with coal production in 1993, Wyoming, Kentucky, and West Virginia predominated. Together, they accounted for about half of total production.

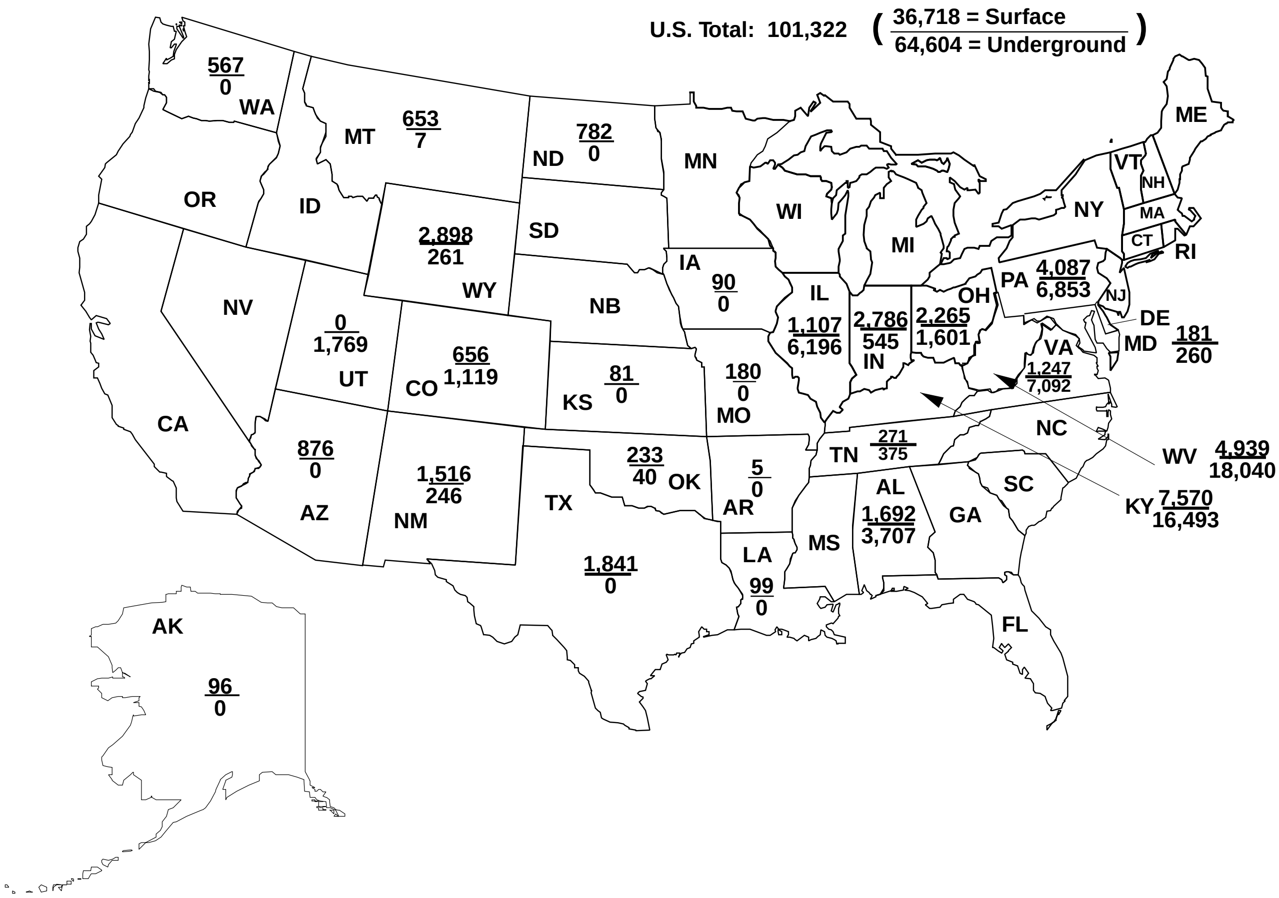
Note: States with no data did not produce coal.
Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Figure 23. U.S. Coal-Producing Counties in the United States, 1993

Note: There are no counties in Alaska. In 1993, coal was produced from one mine near Healy, south of Fairbanks, in Yukon River Borough.

Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Figure 24. Average Number of U.S. Coal Miners by Type of Mining, 1993



Note: Average number of miners excludes mines producing less than 10,000 short tons during the year. States with no data did not produce coal.

Source: Energy Information Administration, *Coal Industry Annual 1993,* DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 10. U.S. Coal Production and Related Statistics, Selected Years, 1980, 1985, 1990-1993

Characteristics of Coal Production	1980	1985	1990	1991	1992	1993
Production (million short tons)						
Total	830	884	1,029	996	998	945
Mining Method						
Underground	338	351	425	407	407	351
Surface	492	533	605	589	590	594
Region						
Appalachian	444	427	489	458	457	410
Interior	176	188	206	195	196	167
Western	209	269	334	343	345	369
Federally Administered Lands						
Total	93	184	273	269	267	286
Federal Coal Leases	69	159	246	240	239	258
Indian Coal Leases	24	25	28	27	28	28
Coal Rank						
Anthracite	6	5	4	3	3	4
Bituminous	629	614	693	651	651	577
Subbituminous	148	193	244	255	252	275
Lignite	47	72	88	87	90	90
Average Value (dollars per short ton)[a]						
Total	24.65	25.61	21.76	21.49	21.03	19.85
Underground	33.50	33.36	28.58	28.56	27.83	26.92
Surface	18.78	20.59	16.98	16.60	16.34	15.67
Number of Mines[b]						
Total	3,969	3,355	2,707	2,394	2,196	2,030
Mining Method						
Underground	1,887	1,695	1,422	1,255	1,138	1,034
Surface	2,082	1,660	1,285	1,139	1,058	996
Region						
Appalachian	3,498	2,962	2,377	2,071	1,098	1,743
Interior	337	278	228	230	198	199
Western	134	115	102	93	90	88
Large Mines[c]						
Total	323	343	375	358	352	348
Underground	170	186	190	183	179	162
Surface	153	157	185	175	173	186
Percentage of Production	60	67	75	77	78	78
Longwall Mining Installations	NA	108	96	93	90	85
Employment (thousands)[d]						
Total	229	169	131	121	110	101
Mining Method						
Underground	151	107	84	78	71	65
Surface	78	62	47	43	39	37
Region						
Appalachian	171	122	95	86	78	71
Interior	40	32	23	22	20	19
Western	18	15	13	13	12	11
Productivity (short tons per miner hour)						
Total	1.9	2.7	3.8	4.1	4.4	4.7
Mining Method						
Underground	1.2	1.8	2.5	2.7	2.9	3.0
Surface	3.2	4.2	5.9	6.4	6.6	7.2
Region						
Appalachian	1.4	1.9	2.6	2.7	3.0	3.0
Interior	2.3	2.8	3.9	4.0	4.2	4.4
Western	5.6	8.6	11.8	12.4	12.7	13.6

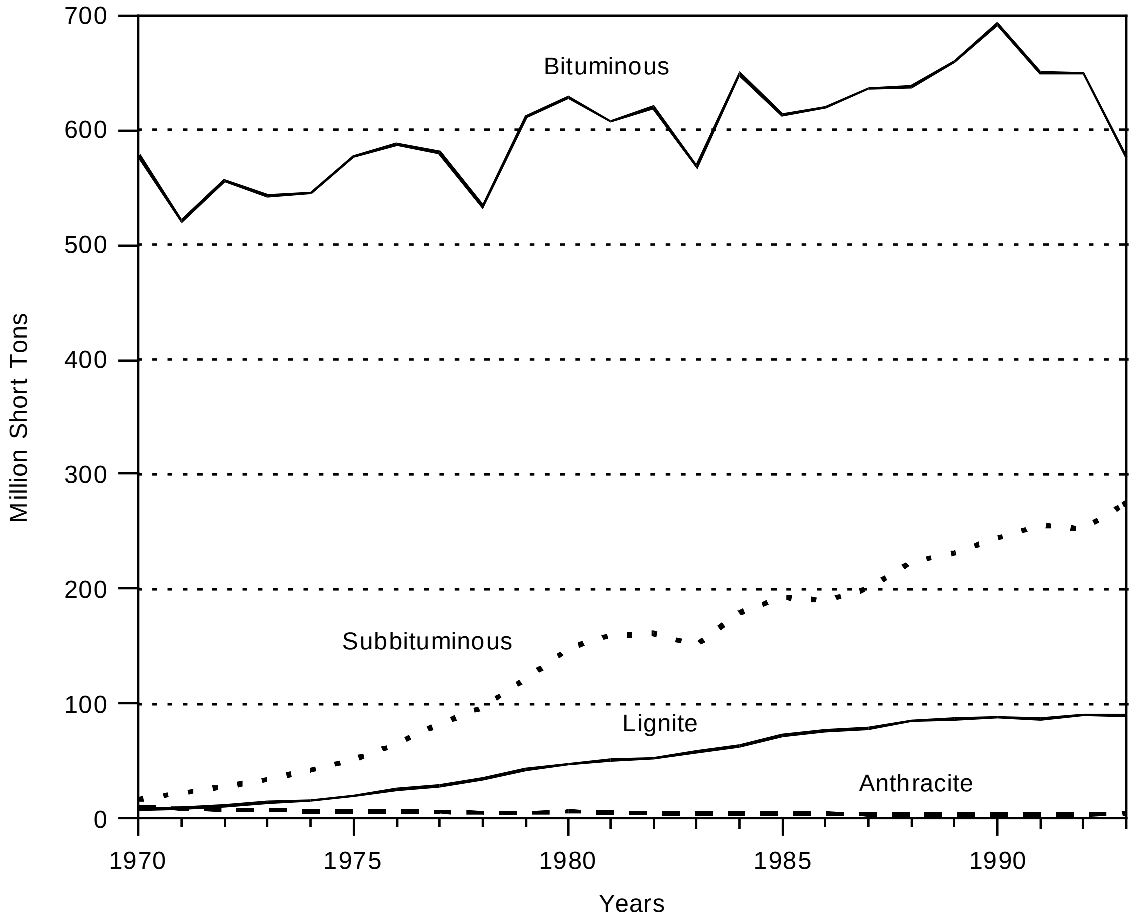
See footnotes at end of table.

Table 10. U.S. Coal Production and Related Statistics, Selected Years, 1980, 1985, 1990-1993 (Continued)

Characteristics of Coal Production	1980	1985	1990	1991	1992	1993
Fatalities	133	68	66	61	54	47
Average Coal Quality						
Production						
Heat content (million Btu per short ton)	22.4	21.9	21.8	21.7	21.6	21.4
Utility Coal						
Heat content (million Btu per short ton)	21.3	21.0	20.9	20.8	20.8	20.6
Average Coal Quality						
Utility Coal						
Sulfur Content						
(percentage by weight)	1.6	1.4	1.4	1.3	1.3	1.2
Ash Content						
(percentage by weight)	11.1	10.0	9.9	9.8	9.7	9.6
Cost Disposition (million short tons)						
Domestic Consumption						
Total	703	818	895	888	892	926
Electric Utilities	569	694	774	772	780	814
Exports	92	93	106	109	103	75

[a]Current dollars.
[b]Annual production over 10,000 short tons each.
[c]Annual production over 500,000 short tons each.
[d]At mines that produced over 10,000 short tons per year.
NA = Not available.
Note: Totals may not equal the sum of components because of independent rounding.
Sources: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994); *Coal Production*, DOE/EIA-0118, various issues; *Quarterly Coal Report*, DOE/EIA-0121, various issues; *Cost and Quality of Fuels for Electric Utility Plants*, DOE/EIA-0191, various issues; U.S. Department of the Interior, *Mineral Revenues 1993, Report on Receipts from Federal and Indian Leases* and prior issues; and U.S. Department of Labor, Mine Safety and Health Administration, *Injury Experience in Coal Mining*, various annual issues; annual longwall census made by *Coal* magazine, and predecessor *Coal Mining and Processing*.

Figure 25. U.S. Coal Production by Rank, 1970-1993



Bituminous coal is the major rank of coal mined in the United States, but lower-rank coals are becoming more important while anthracite is declining.

Source: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994); and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 11. U.S. Coal Production by Coal-Producing Region and State, Selected Years, 1970, 1980, 1990-1993
(Thousand Short Tons)

Coal-Producing Region and State	1970	1980	1990	1991	1992	1993
Appalachian Total	**427,569**	**444,314**	**488,993**	**457,808**	**456,565**	**409,718**
Alabama	20,560	26,403	29,030	27,269	25,796	24,768
Georgia	0	3	0	0	0	0
Kentucky, Eastern	72,498	109,186	128,396	117,220	119,382	120,191
Maryland	1,615	3,760	3,487	3,773	3,341	3,355
Ohio	55,351	39,394	35,252	30,569	30,403	28,816
Pennsylvania Total	90,220	93,125	70,514	65,381	68,981	59,700
Anthracite	9,729	6,056	3,506	3,445	3,483	4,306
Bituminous	80,491	87,069	67,008	61,936	65,498	55,394
Tennessee	8,237	9,850	6,193	4,290	3,476	3,047
Virginia	35,016	41,009	46,917	41,954	43,024	39,317
West Virginia	144,072	121,584	169,205	167,352	162,164	130,525
Interior Total	**149,945**	**176,309**	**205,671**	**195,418**	**195,659**	**167,174**
Arkansas	268	319	59	52	58	44
Illinois	65,119	62,543	60,393	60,258	59,857	41,098
Indiana	22,263	30,873	35,907	31,468	30,466	29,295
Iowa	987	559	381	344	289	175
Kansas	1,627	842	721	416	363	341
Kentucky, Western	52,807	40,958	44,926	41,760	41,686	36,108
Louisiana	0	0	3,186	3,151	3,240	3,134
Missouri	4,447	5,503	2,647	2,304	2,886	653
Oklahoma	2,427	5,358	1,698	1,841	1,741	1,758
Texas	0	29,354	55,755	53,825	55,071	54,567
Western Total	**35,145**	**209,077**	**334,411**	**342,758**	**345,321**	**368,532**
Alaska	549	791	1,706	1,436	1,534	1,601
Arizona	132	10,905	11,304	13,203	12,512	12,173
California	0	0	61	57	103	0
Colorado	6,025	18,846	18,910	17,834	19,226	21,886
Montana	3,447	29,872	37,616	38,237	38,889	35,917
New Mexico	7,361	18,425	24,292	21,518	24,549	28,268
North Dakota	5,639	16,975	29,213	29,530	31,744	31,973
Utah	4,733	13,236	22,058	21,945	21,339	21,847
Washington	37	5,140	5,001	5,143	5,251	4,739
Wyoming	7,222	94,887	184,249	193,854	190,172	210,129
East of the Miss. River	**567,758**	**578,688**	**630,218**	**591,294**	**588,525**	**516,219**
West of the Miss. River	**44,901**	**251,012**	**398,858**	**404,690**	**408,970**	**429,205**
U.S. Total	**612,659**	**829,700**	**1,029,076**	**995,984**	**997,545**	**945,424**

Note: Totals may not equal sum of components because of Independent rounding.

Sources: **1970**: U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbook*; **1980-1993**: Energy Information Administration, *Coal Production*, DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

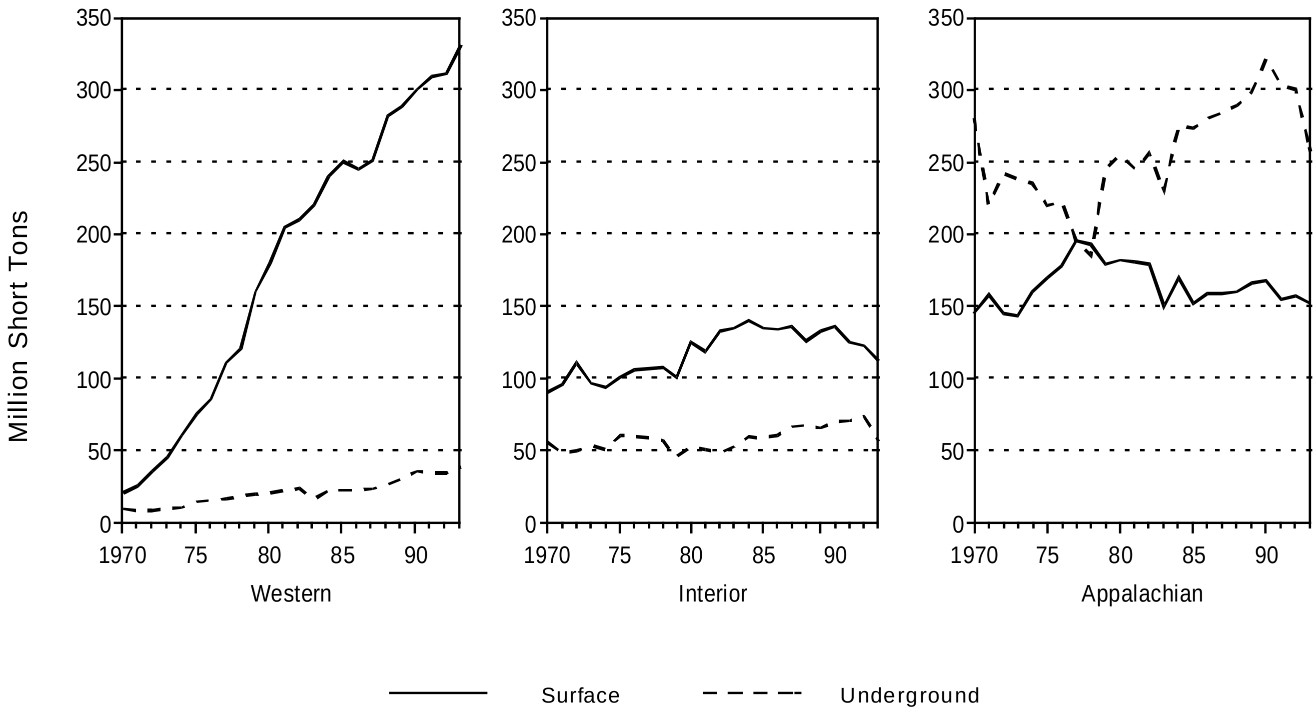
Table 12. Total U.S. Coal Production and Number of Mines by State and Type of Mining, 1993
(Thousand Short Tons)

Coal-Producing State and Region	Underground		Surface		Total	
	Number of Mines	Production	Number of Mines	Production	Number of Mines	Production
Alabama	12	15,557	73	9,211	85	24,768
Alaska	0	0	1	1,601	1	1,601
Arizona	0	0	2	12,173	2	12,173
Arkansas	1	2	5	43	6	44
Colorado	13	12,843	7	9,043	20	21,886
Illinois	26	33,096	13	8,002	39	41,098
Indiana	5	2,583	51	26,713	56	29,295
Iowa	0	0	2	175	2	175
Kansas	0	0	2	341	2	341
Kentucky, Total	446	92,207	250	64,092	696	156,299
Kentucky, Eastern	425	71,919	197	48,272	622	120,191
Kentucky, Western	21	20,288	53	15,820	74	36,108
Louisiana	0	0	2	3,134	2	3,134
Maryland	4	2,528	17	827	21	3,355
Missouri	0	0	7	653	7	653
Montana	1	10	7	35,907	8	35,917
New Mexico	1	719	6	27,549	7	28,268
North Dakota	0	0	8	31,973	8	31,973
Ohio	9	10,437	126	18,379	135	28,816
Oklahoma	1	98	16	1,661	17	1,758
Pennsylvania, Total	116	36,934	408	22,766	524	59,700
Anthracite	52	416	96	3,889	148	4,306
Bituminous	64	36,517	312	18,877	376	55,394
Tennessee	22	1,896	15	1,151	37	3,047
Texas	0	0	14	54,567	14	54,567
Utah	15	21,847	0	0	15	21,847
Virginia	181	30,166	56	9,151	237	39,317
Washington	0	0	3	4,739	3	4,739
West Virginia, Total	339	87,997	163	42,528	502	130,525
Northern	73	27,133	64	6,669	137	33,802
Southern	266	60,864	99	35,859	365	96,723
Wyoming	4	2,136	25	207,993	29	210,129
Appalachian Total	**1,108**	**257,433**	**1,055**	**152,285**	**2,163**	**409,718**
Interior Total	**54**	**56,065**	**165**	**111,109**	**219**	**167,174**
Western Total	**34**	**37,555**	**59**	**330,977**	**93**	**368,532**
East of the Miss. River	**1,160**	**313,399**	**1,172**	**202,820**	**2,332**	**516,219**
West of the Miss. River	**36**	**37,654**	**107**	**391,551**	**143**	**429,205**
U.S. Total	**1,196**	**351,053**	**1,279**	**594,371**	**2,475**	**945,424**

Note: Coal production excludes silt, culm, refuse bank, slurry dam, and dredge operations except for Pennsylvania anthracite. Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Figure 26. U.S. Coal Production by Region and Type of Mining, 1970-1993



Surface-mined coal production in the West has increased markedly since 1970, largely because of a rapid rise in the coal output from the Powder River Basin in northeastern Wyoming.

Source: **1970-1975**: U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbook*; **1976 and forward**: Energy Information Administration, *Coal Production*, DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 13. U.S. Underground Coal Production by Coal-Producing Region, State, and Coalbed Thickness, 1993
(Thousand Short Tons)

Coal-Producing Region and State	Less than 25 Inches	25-48 Inches	49-72 Inches	73-96 Inches	More than 96 Inches	Total Production
Appalachian Total	**915**	**113,950**	**106,350**	**30,003**	**5,535**	**256,754**
Alabama	0	3,055	12,489	0	0	15,544
Kentucky, Eastern	808	45,862	21,043	1,885	2,085	71,683
Maryland	0	14	0	2,500	0	2,514
Ohio	0	4,494	5,943	0	0	10,437
Pennsylvania Total	7	9,422	18,273	8,886	207	36,795
Anthracite	0	50	138	51	41	280
Bituminous	7	9,371	18,135	8,836	166	36,515
Tennessee	0	1,792	64	0	0	1,857
Virginia	0	17,753	11,240	1,091	13	30,096
West Virginia	101	31,559	37,298	15,641	3,229	87,827
Interior Total	**0**	**3,477**	**31,898**	**17,670**	**3,019**	**56,063**
Illinois	0	0	13,711	16,366	3,019	33,096
Indiana	0	170	1,108	1,305	0	2,583
Kentucky, Western	0	3,209	17,079	0	0	20,288
Oklahoma	0	98	0	0	0	98
Western Total	**0**	**353**	**410**	**8,846**	**27,938**	**37,548**
Colorado	0	0	410	2,954	9,478	12,842
Montana	0	0	0	10	0	10
New Mexico	0	0	0	719	0	719
Utah	0	153	0	5,163	16,525	21,841
Wyoming	0	200	0	0	1,935	2,136
East of the Miss. River	**915**	**117,329**	**138,248**	**47,673**	**8,553**	**312,720**
West of the Miss. River	**0**	**451**	**410**	**8,846**	**27,938**	**37,645**
U.S. Total	**915**	**117,780**	**138,658**	**56,519**	**36,492**	**350,365**

Notes: Data for bed thickness and production are given as reported on Form EIA-7A and do not necessarily represent complete coverage; they exclude mines that produced less than 10,000 short tons. Total may not equal sum of components because of independent rounding.
Source: Energy Information Administration, Form EIA-7A, “Coal Production Report.”

Table 14. U.S. Surface Coal Production by Coal-Producing Region, State, and Coalbed Thickness, 1993
(Thousand Short Tons)

Coal-Producing Region and State	Less than 25 Inches	25-48 Inches	49-72 Inches	73-96 Inches	More than 96 Inches	Total Production
Appalachian Total	**17,869**	**72,592**	**32,365**	**13,732**	**14,594**	**151,152**
Alabama	5,268	3,255	21	606	0	9,150
Kentucky, Eastern	4,235	23,498	12,615	4,396	3,367	48,110
Maryland	41	494	89	195	6	824
Ohio	2,026	13,740	2,492	0	0	18,258
Pennsylvania Total	4,176	14,463	2,014	624	904	22,182
Anthracite	17	1,758	938	228	774	3,715
Bituminous	4,160	12,705	1,076	395	131	18,467
Tennessee	106	827	0	211	0	1,144
Virginia	908	5,019	2,726	464	0	9,118
West Virginia	1,108	11,296	12,409	7,236	10,317	42,366
Interior Total	**15,947**	**28,511**	**22,385**	**11,914**	**32,354**	**111,011**
Arkansas	0	17	0	0	0	17
Illinois	340	3,054	3,980	622	0	7,996
Indiana	4,276	12,094	7,362	2,946	15	26,692
Iowa	0	168	0	0	0	168
Kansas	341	0	0	0	0	341
Kentucky, Western	1,250	8,573	4,916	1,064	0	15,802
Louisiana	0	0	0	3,134	0	3,134
Missouri	365	284	0	0	0	648
Oklahoma	744	901	0	0	0	1,645
Texas	8,632	3,421	6,127	4,148	32,239	54,567
Western Total	**98**	**2,988**	**19,087**	**5,132**	**303,662**	**330,966**
Alaska	0	0	0	0	1,601	1,601
Arizona	0	757	0	1,964	9,451	12,173
Colorado	0	211	1,293	598	6,938	9,039
Montana	0	0	0	0	35,907	35,907
New Mexico	98	1,723	14,895	2,361	8,472	27,549
North Dakota	0	0	2,141	0	29,825	31,966
Washington	0	297	0	0	4,443	4,739
Wyoming	0	0	758	209	207,026	207,993
East of the Miss. River	**23,734**	**96,313**	**48,623**	**18,364**	**14,608**	**201,642**
West of the Miss. River	**10,180**	**7,778**	**25,214**	**12,414**	**335,901**	**391,487**
U.S. Total	**33,915**	**104,090**	**73,837**	**30,778**	**350,510**	**593,129**

Notes: Data for bed thickness and production are given as reported on Form EIA-7A and do not necessarily represent complete coverage; they exclude mines that produced less than 10,000 short tons. Total may not equal sum of components because of independent rounding.
Source: Energy Information Administration, Form EIA-7A, “Coal Production Report.”

Table 15. U.S. Coal Production by Coal-Producing Region, State, and Coalbed Thickness, 1993
(Thousand Short Tons)

Coal-Producing Region and State	Less than 25 inches	25-48 inches	49-72 inches	73-96 inches	More than 96 inches	Total Production
Appalachian Total	**18,785**	**186,542**	**138,716**	**43,735**	**20,128**	**407,906**
Alabama	5,268	6,310	12,510	606	0	24,694
Kentucky, Eastern	5,043	69,359	33,658	6,281	5,452	119,793
Maryland	41	508	89	2,695	6	3,339
Ohio	2,026	18,234	8,435	0	0	28,695
Pennsylvania Total	4,183	23,885	20,288	9,510	1,112	58,977
Anthracite	17	1,808	1,076	279	815	3,995
Bituminous	4,166	22,077	19,211	9,231	297	54,982
Tennessee	106	2,619	64	211	0	3,000
Virginia	908	22,772	13,966	1,555	13	39,214
West Virginia	1,208	42,855	49,706	22,877	13,546	130,193
Interior Total	**15,947**	**31,987**	**54,283**	**29,585**	**35,272**	**167,074**
Arkansas	0	17	0	0	0	17
Illinois	340	3,054	17,692	16,988	3,019	41,091
Indiana	4,276	12,264	8,469	4,251	15	29,275
Iowa	0	168	0	0	0	168
Kansas	341	0	0	0	0	341
Kentucky, Western	1,250	11,782	21,994	1,064	0	36,090
Louisiana	0	0	0	3,134	0	3,134
Missouri	365	284	0	0	0	648
Oklahoma	744	998	0	0	0	1,743
Texas	8,632	3,421	6,127	4,148	32,239	54,567
Western Total	**98**	**3,341**	**19,497**	**13,978**	**331,600**	**368,514**
Alaska	0	0	0	0	1,601	1,601
Arizona	0	757	0	1,964	9,451	12,173
Colorado	0	211	1,703	3,552	16,416	21,881
Montana	0	0	0	10	35,907	35,917
New Mexico	98	1,723	14,895	3,080	8,472	28,268
North Dakota	0	0	2,141	0	29,825	31,966
Utah	0	153	0	5,163	16,825	21,841
Washington	0	297	0	0	4,443	4,739
Wyoming	0	200	758	209	208,691	210,129
East of the Miss. River	**24,650**	**213,642**	**186,871**	**66,038**	**23,162**	**514,362**
West of the Miss. River	**10,180**	**8,228**	**25,624**	**21,260**	**363,840**	**429,132**
U.S. Total	**34,380**	**221,870**	**212,495**	**87,298**	**387,001**	**943,494**

Notes: Data for bed thickness and production are given as reported on Form EIA-7A and do not necessarily represent complete coverage; they exclude mines that produced less than 10,000 short tons. Total may not equal sum of components because of independent rounding.

Source: Energy Information Administration, Form EIA-7A, “Coal Production Report.”

Table 16. Production (Sales Volume) from Federal and Indian Coal Lands Compared with Production from Other Sources and Coal Royalties, Selected Years, 1970, 1975, 1980-1993

Year	Production (Sales Volume) from Federally Administered Lands (million short tons)			Production from Other Sources (million short tons)	Total U.S. (million short tons)	Coal Royalties[a] (million dollars)		
	Federal	Indian	Total			Federal	Indian	Total
1970	7.4	4.6	12.0	600.6	612.7	1.1	0.7	1.8
1975	26.9	16.7	43.6	611.1	654.6	4.9	3.5	8.3
1980	69.1	23.8	92.9	736.8	829.7	32.3	7.9	40.1
1981	116.5	22.3	138.8	685.0	823.8	43.0	8.6	51.6
1982	101.1	28.9	130.0	708.1	838.1	61.9	8.5	70.4
1983	98.7	25.6	124.3	657.8	782.1	52.3	9.4	61.7
1984	115.8	20.5	136.3	759.6	895.9	69.4	7.6	77.0
1985	159.2	25.4	184.6	699.0	883.6	103.5	23.4	126.9
1986	166.7	22.9	189.7	700.6	890.3	108.4	29.5	137.9
1987	171.2	24.0	195.2	723.6	918.8	152.5	30.5	183.0
1988	199.2	26.2	225.4	724.8	950.3	172.8	46.7	219.5
1989	209.3	27.0	236.3	744.5	980.7	194.5	47.7	242.2
1990	245.9	27.5	273.4	755.7	1,029.1	236.1	60.8	296.9
1991	240.4	27.4	267.8	728.2	996.0	276.7	62.9	339.6
1992	238.5	28.1	266.6	730.9	997.5	259.5	65.9	325.4
1993	257.6	28.1	285.7	659.7	945.4	264.2	64.8	329.0

[a]Current dollars.

Notes: Output from Federal and Indian lands is reported as sales volume, the basis for royalties. It is approximately equivalent to production, which includes coal sold and coal added to stockpiles. Total may not equal sum of components because of independent rounding.

Sources: **1970-1975**: U.S. Department of the Interior, *Energy Resources on Federally Administered Lands*; Bureau of Mines, *Minerals Yearbook*. **1980 forward**: U.S. Department of the Interior, Minerals Management Service, *Mineral Revenues 1993, Report on Receipts from Federal and Indian Leases* and prior issues; Energy Information Administration, *Coal Production*, DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 17. U.S. Coal Mining Acreage, Production (Sales Volume) and Royalties from Federal and Indian Leases by State, 1993

State	Federal Leases			Indian Leases		
	Acres Leased	Production (sales volume thousand short tons)	Royalties[a] (thousand dollars)	Acres Leased	Production (sales volume thousand short tons)	Royalties[a] (thousand dollars)
Alabama	3,456	469	984	0	0	0
Arizona	0	0	0	64,858	12,258	24,286
Colorado	38,399	12,901	24,343	0	0	0
Kentucky	818	106	178	0	0	0
Montana	36,728	25,955	38,665	14,746	3,518	1,786
New Mexico	14,142	4,600	16,827	36,026	12,316	29,965
North Dakota	5,714	2,147	1,063	0	0	0
Oklahoma	2,760	478	532	0	0	0
Utah	51,243	18,856	31,025	0	0	0
Washington	241	686	116	0	0	0
Wyoming	114,529	191,365	150,509	0	0	0
U.S. Total	**268,030**	**257,564**	**264,242**	**115,630**	**28,091**	**64,750**

[a]Current dollars.

Notes: Output from Federal and Indian lands is reported as sales volume, the basis for royalties. It is approximately equivalent to production, which includes coal sold and coal added to stockpiles. Total may not equal sum of components because of independent rounding.

Sources: U.S. Department of the Interior, Minerals Management Service, Royalty Management Program, *Mineral Revenues: The 1993 Report on Receipts from Federal and Indian Leases.*

Table 18. U.S. Production Trends in Bituminous Coal and Lignite, 1900-1993

Year	Production (thousand short tons)			Miners[a] Employed
	Underground	Surface	Total	
1900	212,316	NA	NA	304,375
1901	225,828	NA	NA	340,235
1902	260,217	NA	NA	370,056
1903	282,749	NA	NA	415,777
1904	278,660	NA	NA	437,832
1905	315,063	NA	NA	460,629
1906	342,875	NA	NA	478,425
1907	394,759	NA	NA	516,258
1908	332,574	NA	NA	516,264
1909	379,744	NA	NA	543,152
1910	417,111	NA	NA	555,533
1911	405,907	NA	NA	549,775
1912	450,105	NA	NA	548,632
1913	478,435	NA	NA	571,882
1914	421,436	1,268	422,704	583,506
1915	439,792	2,832	442,624	557,456
1916	498,500	4,020	502,520	561,102
1917	546,273	5,518	551,791	603,143
1918	571,275	8,111	579,386	615,305
1919	460,270	5,590	465,860	621,998
1920	559,807	8,860	568,667	639,547
1921	410,865	5,057	415,922	663,754
1922	412,059	10,209	422,268	687,958
1923	552,625	11,940	564,565	704,793
1924	470,080	13,607	483,687	619,604
1925	503,182	16,871	520,053	588,493
1926	556,444	16,923	573,367	593,647
1927	499,385	18,378	517,763	593,918
1928	480,956	19,789	500,745	522,150
1929	514,721	20,268	534,989	502,993
1930	447,684	19,842	467,526	493,202
1931	363,157	18,932	382,089	480,213
1932	290,069	19,641	309,710	406,380
1933	315,360	18,270	333,630	418,703
1934	338,578	20,790	359,368	458,011
1935	348,726	23,647	372,373	462,403
1936	410,962	28,126	439,088	477,204
1937	413,780	31,751	445,531	491,864
1938	318,138	30,407	348,545	441,333
1939	357,133	37,722	394,855	421,788
1940	417,604	43,167	460,771	439,075
1941	459,078	55,071	541,149	456,981
1942	515,490	67,203	582,693	461,991
1943	510,492	79,685	590,177	416,007
1944	518,678	100,898	619,576	393,347
1945	467,630	109,987	577,617	383,100
1946	420,958	112,962	533,922	396,434
1947	491,229	139,395	630,624	419,182
1948	460,012	139,506	599,518	441,631
1949	331,823	106,045	437,868	433,698

See footnotes at end of table

Table 18. U.S. Production Trends in Bituminous Coal and Lignite, 1900-1993 (Continued)

Year	Production (thousand short tons)			Miners[a] Employed
	Underground	Surface	Total	
1950	392,844	123,467	516,311	415,582
1951	415,842	117,823	533,665	372,897
1952	356,425	110,416	466,841	335,217
1953	349,551	107,739	457,290	293,106
1954	289,112	102,594	391,706	227,397
1955	343,465	121,168	464,633	225,093
1956	365,774	135,110	500,874	228,163
1957	360,649	132,055	492,704	228,635
1958	286,884	123,562	410,446	197,402
1959	283,434	128,594	412,028	179,636
1960	284,888	130,624	415,512	169,400
1961	272,766	130,211	402,977	150,474
1962	281,266	140,883	422,149	143,822
1963	302,256	156,672	458,928	141,646
1964	321,808	165,190	486,998	128,698
1965	332,661	179,427	512,088	133,732
1966	338,524	195,357	533,881	131,752
1967	349,133	203,494	552,626	131,523
1968	344,142	201,103	545,245	127,894
1969	347,132	213,373	560,505	124,532
1970	338,788	264,144	602,930	140,140
1971	275,888	276,304	552,192	145,664
1972	304,103	291,284	595,386	149,265
1973	299,353	292,384	591,738	148,121
1974	277,309	326,098	603,406	166,701
1975	292,826	355,612	648,438	189,880
1976	294,880	383,805	678,685	202,280
1977	265,950	425,394	691,344	221,428
1978	242,177	422,950	665,127	242,295
1979	320,321	455,978	776,299	224,203
1980	336,925	486,719	823,644	224,938
1981	315,875	502,477	818,352	226,250
1982	338,572	494,951	833,523	214,400
1983	299,882	478,111	778,003	173,543
1984	351,474	540,285	891,759	175,746
1985	350,073	528,856	878,930	167,009
1986	359,800	526,223	886,023	152,668
1987	372,238	542,963	915,202	141,065
1988	381,546	565,164	946,710	133,913
1989	393,322	584,058	977,381	130,103
1990	424,119	601,449	1,025,570	129,619
1991	406,901	585,638	992,539	119,441
1992	406,815	587,248	994,062	108,979
1993	350,637	590,482	941,119	100,099

[a]After 1978, excludes miners employed at mines that produced less than 10,000 tons.

NA = Not available; relatively small amounts included with underground.

Note: Subbituminous coal is included with bituminous coal. Totals may not equal sum of components because of independent rounding.

Sources: **1900-1976**: U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbooks;* **1977-1978**: Energy Information Agency, *Bituminous Coal & Lignite Production and Mine Operations;* **1979-1990**: *Coal Production*, DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 19. Production Trends in Pennsylvania Anthracite, 1900-1993

Year	Production (thousand short tons)			Miners[a] Employed
	Underground	Surface[b]	Total	
1900	NA	NA	57,368	144,206
1901	NA	NA	67,472	145,309
1902	NA	NA	41,374	148,141
1903	NA	NA	74,607	150,483
1904	NA	NA	73,157	155,861
1905	NA	NA	77,660	165,406
1906	NA	NA	71,282	162,355
1907	NA	NA	85,604	167,234
1908	NA	NA	83,269	174,174
1909	NA	NA	81,070	171,195
1910	NA	NA	84,485	169,497
1911	NA	NA	90,464	172,585
1912	NA	NA	84,362	174,030
1913	NA	NA	91,525	175,745
1914	NA	NA	90,822	179,679
1915	NA	NA	88,995	176,552
1916	NA	NA	87,578	159,869
1917	NA	NA	99,612	154,174
1918	NA	NA	98,826	147,121
1919	NA	NA	88,092	154,571
1920	NA	NA	89,598	145,074
1921	NA	NA	90,473	159,499
1922	NA	NA	54,683	156,849
1923	NA	NA	93,339	157,743
1924	NA	NA	87,927	160,009
1925	NA	NA	61,817	160,312
1926	NA	NA	84,437	165,386
1927	73,658	6,438	80,096	165,259
1928	69,725	5,623	75,348	160,681
1929	69,964	3,864	73,828	151,501
1930	64,926	4,459	59,646	150,804
1931	53,460	6,186	49,855	139,431
1932	43,834	6,021	49,541	121,243
1933	41,032	8,509	57,168	104,633
1934	48,575	8,593	52,159	109,050
1935	43,783	8,376	54,580	103,269
1936	44,727	9,853	51,856	102,081
1937	42,566	9,290	46,099	99,085
1938	38,142	7,957	51,487	96,417
1939	42,572	8,915	69,385	93,138
1940	41,517	9,968	51,485	91,313
1941	43,877	12,491	56,368	88,054
1942	45,237	15,091	60,328	82,121
1943	42,736	17,908	60,644	79,153
1944	41,775	21,926	63,701	77,591
1945	34,886	20,048	54,934	72,842
1946	38,084	22,423	60,507	78,145
1947	36,963	20,227	57,190	78,600
1948	37,175	19,965	57,140	16,215
1949	27,031	15,671	42,702	75,377

See footnotes at end of table.

Table 19. Production Trends in Pennsylvania Anthracite, 1900-1993 (Continued)

Year	Production (thousand short tons)			Miners[a] Employed
	Underground	Surface[b]	Total	
1950	28,156	15,921	44,077	72,624
1951	26,342	16,328	42,670	68,995
1952	24,748	15,835	40,583	65,923
1953	17,893	13,056	30,949	57,862
1954	16,852	12,231	29,083	43,996
1955	14,499	11,706	26,205	33,523
1956	15,055	13,845	28,900	31,516
1957	12,616	12,722	25,338	30,825
1958	10,699	10,472	21,171	26,540
1959	9,415	11,234	20,649	23,294
1960	7,696	11,121	18,817	19,051
1961	6,785	10,661	17,446	15,792
1962	6,673	10,221	16,894	14,010
1963	6,715	11,552	18,267	13,498
1964	5,889	11,295	17,184	13,144
1965	5,297	9,569	14,866	11,132
1966	4,088	8,853	12,941	9,292
1967	3,258	8,998	12,256	7,750
1968	2,450	9,011	11,461	6,932
1969	2,106	8,367	10,473	5,927
1970	1,742	7,987	9,729	5,938
1971	1,287	7,440	8,727	5,800
1972	944	6,162	7,106	4,783
1973	726	6,104	6,830	4,083
1974	657	5,960	6,617	3,847
1975	641	5,562	6,203	3,907
1976	584	5,644	6,228	3,686
1977	642	5,219	5,861	3,655
1978	595	4,442	5,037	3,472
1979	570	4,265	4,835	3,094
1980	583	5,473	6,056	3,631
1981	621	4,802	5,423	3,052
1982	579	4,009	4,588	2,717
1983	487	3,602	4,089	2,099
1984	576	3,586	4,162	2,102
1985	727	3,982	4,708	2,272
1986	638	3,654	4,292	1,977
1987	636	2,925	3,560	1,602
1988	610	2,945	3,555	1,453
1989	513	2,835	3,348	1,394
1990	427	3,080	3,506	1,687
1991	324	3,121	3,445	1,161
1992	424	3,058	3,483	1,217
1993	416	3,889	4,306	1,124

[a]After 1978, excludes miners employed at mines that produced less than 10,000 tons.
[b]Surface production includes culm bank and river dredging operations.
NA = Not available; relatively small amounts included with underground.
Note: Totals may not equal sum of components because of independent rounding.
Sources: **1900-1976**: U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbooks;* **1977-1978**: Energy Information Agency, *Coal-Pennsylvania Anthracite;* **1979-1990**: *Coal Production*, DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 20. U.S. Labor Productivity in Coal Mining, 1949-1993
(Average Short Tons per Miner per Hour)

Year	Bituminous Coal and Lignite Coal Mines			Anthracite Mines	All Mines
	Underground	Surface	Average		
1949	0.68	1.92	0.80	0.36	0.72
1950	0.72	1.96	0.85	0.35	0.76
1951	0.76	2.00	0.88	0.37	0.80
1952	0.80	2.10	0.93	0.38	0.84
1953	0.88	2.22	1.02	0.41	0.93
1954	1.00	2.48	1.18	0.50	1.08
1955	1.04	2.65	1.23	0.50	1.14
1956	1.08	2.67	1.29	0.53	1.19
1957	1.11	2.73	1.32	0.52	1.23
1958	1.17	2.73	1.42	0.55	1.31
1959	1.26	2.87	1.53	0.64	1.43
1960	1.33	2.91	1.60	0.70	1.52
1961	1.43	3.16	1.73	0.70	1.64
1962	1.50	3.40	1.84	0.74	1.74
1963	1.60	3.66	1.98	0.78	1.87
1964	1.72	3.76	2.11	0.76	1.99
1965	1.75	4.10	2.19	0.82	2.09
1966	1.83	4.28	2.32	0.86	2.23
1967	1.88	4.48	2.40	0.90	2.31
1968	1.93	4.33	2.42	0.95	2.35
1969	1.95	4.50	2.49	0.93	2.41
1970	1.72	4.53	2.36	0.89	2.30
1971	1.50	4.49	2.25	0.79	2.19
1972	1.49	4.54	2.22	0.86	2.18
1973	1.46	4.58	2.20	0.89	2.16
1974	1.41	4.74	2.35	0.98	2.31
1975	1.19	3.26	1.83	0.93	1.81
1976	1.14	3.25	1.80	0.90	1.78
1977	1.09	3.16	1.82	0.87	1.80
1978	1.04	3.03	1.79	0.81	1.77
1979	1.13	3.12	1.82	1.06	1.81
1980	1.21	3.27	1.94	1.11	1.93
1981	1.29	3.50	2.11	0.92	2.10
1982	1.37	3.48	2.14	0.59	2.11
1983	1.62	3.87	2.52	1.01	2.50
1984	1.72	4.10	2.65	1.02	2.64
1985	1.79	4.32	2.76	1.05	2.74
1986	2.00	4.69	3.04	1.03	3.01
1987	2.21	5.06	3.32	1.13	3.30
1988	2.38	5.41	3.58	1.21	3.55
1989	2.46	5.70	3.73	1.12	3.70
1990	2.54	6.07	3.86	1.03	3.83
1991	2.70	6.51	4.12	1.39	4.09
1992	2.95	6.73	4.41	1.33	4.36
1993	3.24	7.84	4.74	1.85	4.70

Note: After 1978, excludes miners employed at mines that produced less than 10,000 tons. Subbituminous coal is included wit.h bituminous coal. Totals may not equal sum of components because of independent rounding..

Source: Energy Information Administration, *Annual Energy Review*, DOE/EIA-0384(93) (Washington, DC, July 1994); and Form EIA-7A, “Coal Production Report.”

Table 21. Profile of U.S. Coal Miners, 1986

Employment Category	Worker Statistics[a]
Age (mean)	39
Male (percent)	98
Educational (percent)	
High school Diploma	54
Vocational School Diploma	8
Some College	10
College degree	5
Work experience (median, years):	
At present job	4
At present company	8
Total mining	11
Job-related training during the last two years (median, hours)	35

[a]Production workers.

Source: U.S. Department of the Interior, Bureau of Mines, Information Circular 9192, "Characterization of the 1986 Coal Mining Workforce" (1988).

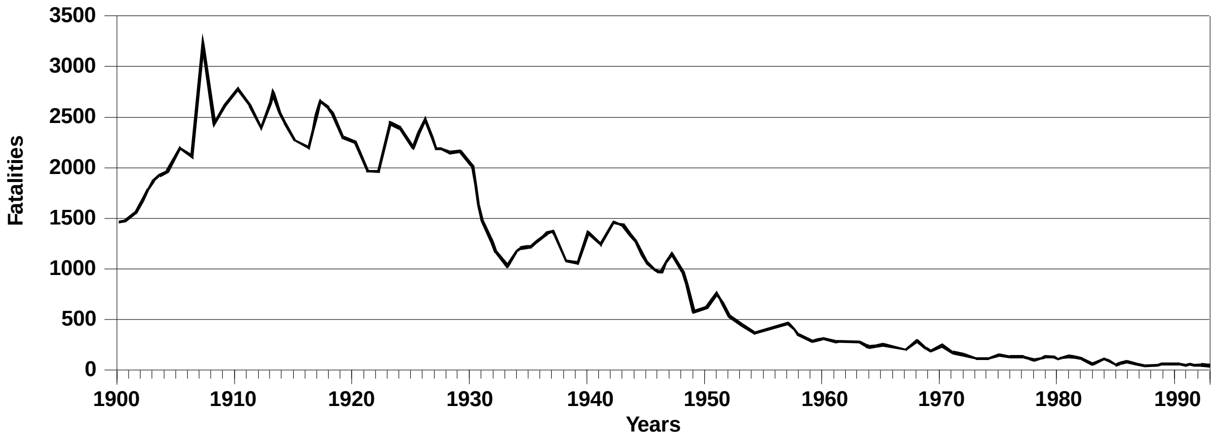
Table 22. U.S. Coal Mining Average Employment, Hours Worked, and Earnings, Selected Years, 1980, 1985, 1990-1993

Employment Category	1980	1985	1990	1991	1992	1993
Average Employment (thousands)						
All Employees	246.3	187.3	146.5	135.5	125.5	105.3
Women	10.5	10.7	8.6	8.3	7.7	6.4
Production Workers	203.8	152.8	118.5	109.8	101.8	83.6
Production Workers						
Average Weekly Hours Worked	40.5	41.1	44.0	44.6	44.0	44.4
Average Hourly Earnings (current dollars)	10.86	15.24	16.71	17.06	17.15	17.25
Average Weekly Earnings (current dollars)	439.83	626.36	735.24	760.88	754.60	765.90

Note: Employment data differ from those collected by the Energy Information Administration due to different survey criteria.

Sources: U.S. Department of Labor, Bureau of Labor Statistics, *Employment, Hours, and Earnings, United States, 1909-90*, Vol. 1, Bulletin 2370 (Washington, DC, March 1991), and *Employment, Hours, and Earnings, United States, 1981-93*, Bulletin 2429 (Washington, DC, August 1993); **1993**: U.S. Department of Labor, Bureau of Labor Statistics, Data Users and Publication Services Group.

Figure 27. U.S. Coal Mining Fatalities, 1900-1993



Although still dangerous, coal mining has become safer due to mechanization, roof bolting, and stringent safety regulations. In 1907, U.S. coal mining claimed a record 3,242 lives.

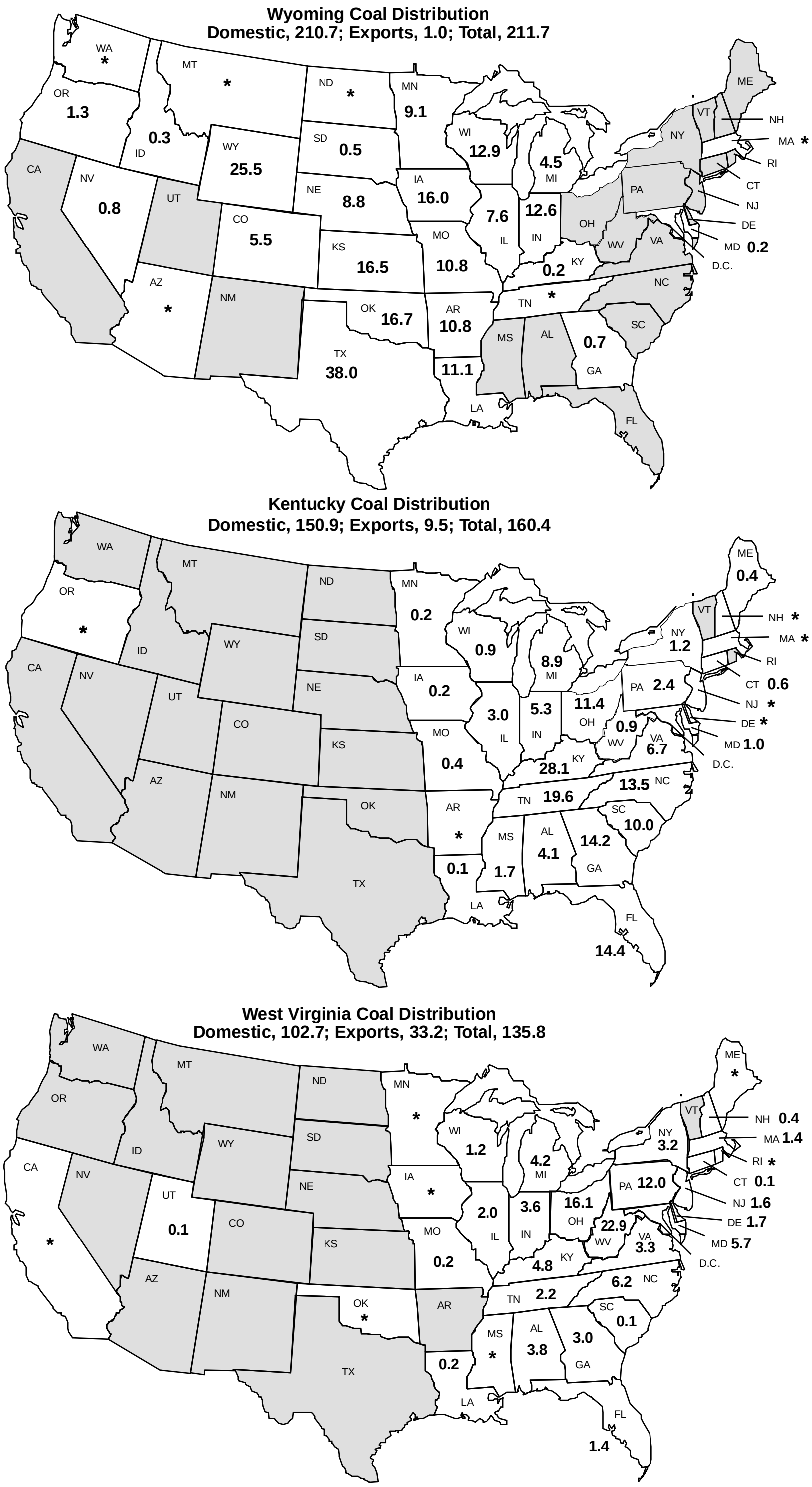
Source: U.S. Department of Labor, Mine Safety and Health Administration, Denver Safety and Health Technology Center.

Table 23. U.S. Coal Mine Injuries, Selected Years, 1975, 1980, 1985, 1990-1993

Injury Experience[a]	1975	1980	1985	1990	1991	1992	1993[b]
Fatal	155	133	68	66	61	54	47
Incidence Rate[c]	0.08	0.06	0.04	0.04	0.04	0.04	0.04
Nonfatal with Days Lost[d]	11,119	18,720	9,082	12,246	11,325	10,055	7,901
Incidence Rate[c]	5.86	8.27	5.06	7.88	7.86	7.28	6.49
Nonfatal with No Days Lost	9,652	3,870	2,520	3,513	3,282	2,959	2,416
Incidence Rate[c]	5.09	1.71	1.40	2.26	2.28	2.14	1.99
Total Injuries	**20,926**	**22,723**	**11,670**	**15,825**	**14,668**	**13,068**	**10,364**

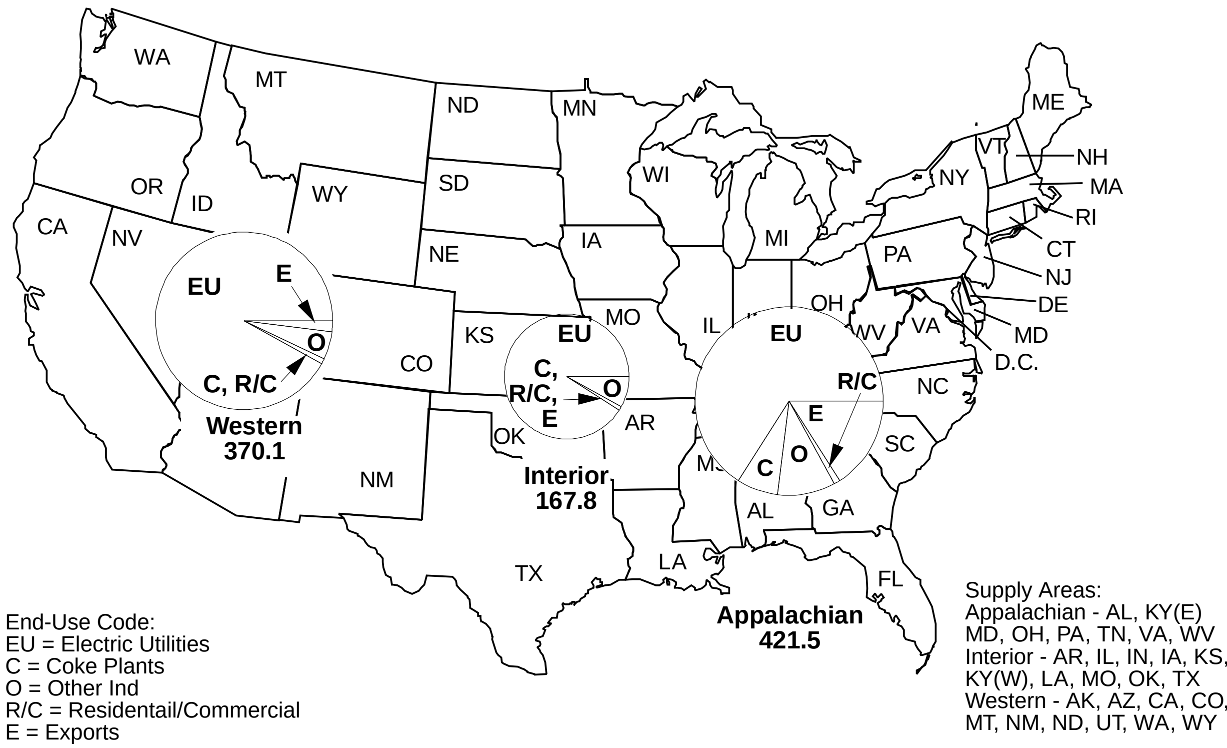
[a]Includes office workers and contractors.
[b]Preliminary.
[c]Numbers of injuries per 200,000 employee-hours.
[d]Includes injuries that result in restricted work activity.
Source: U.S. Department of Labor, Mine Safety and Health Administration, Denver Safety and Health Technology Center.

Figure 28. Coal Distribution from the Three-Leading Coal-Producing States, 1993
(Million Short Tons)



*Amount is less than 0.1 million short tons.
Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

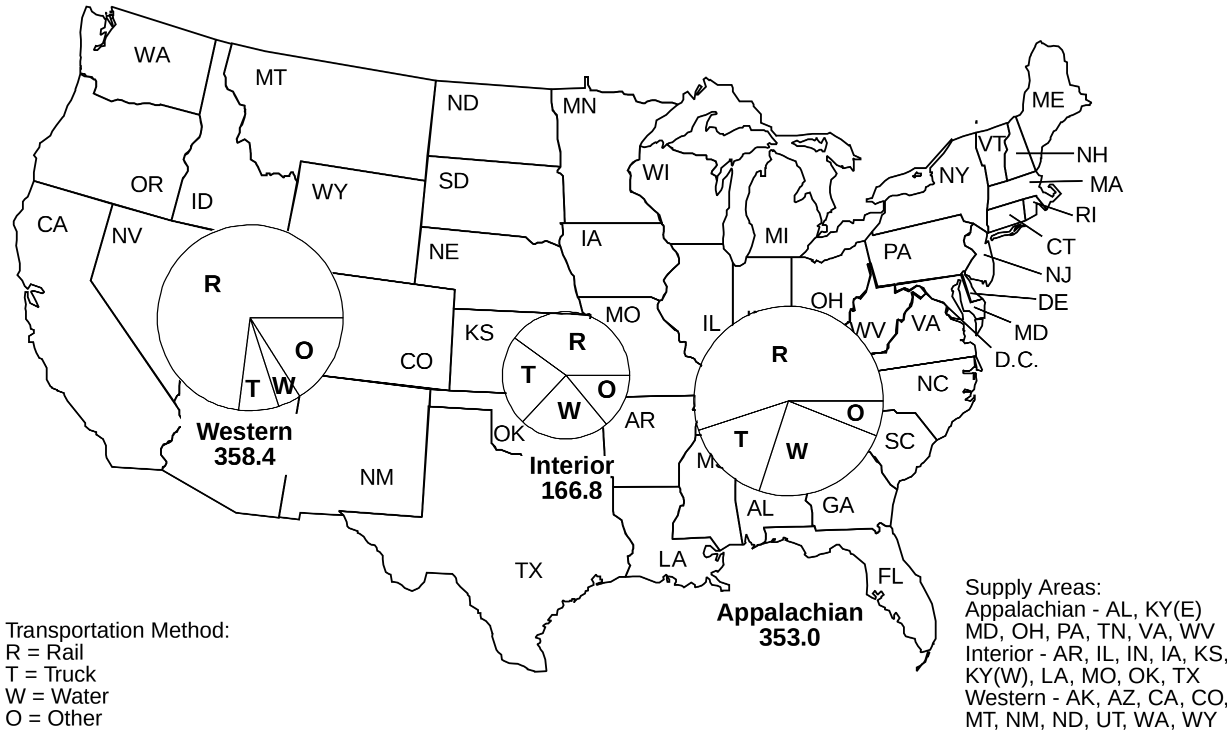
Figure 29. U.S. Coal Production: End Use Distribution by Supplying Area, 1993
(Million Short Tons)



About 80 percent of the coal mined in the United States is sent to electric power plants.

Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Figure 30. Coal Shipments for U.S. Consumption by Supplying Areas and by Transportation Methods, 1993
(Million Short Tons)



"Other" includes tramway/conveyor, slurry pipeline (in Western), and unknown or not revealable methods.

Railroads are the foundation of the U.S. coal transportation system.

Source: Energy Information Administration, Form EIA-6, “Coal Distribution Report.”

Table 24. U.S. Coal Supply and Disposition, 1949-1993
(Million Short Tons)

Year	Supply						Disposition		
	Production			Imports	Changes in Stocks, Losses, and Unaccounted For[a]	Total	Exports	Consumption	Total
	Under-ground	Surface	Total						
1949	358.9	121.7	480.6	0.3	35.1	516.0	32.8	483.2	516.0
1950	421.0	139.4	560.4	0.4	-37.3	523.5	29.4	494.1	523.5
1951	442.2	134.2	576.3	0.3	-8.1	568.6	62.7	505.9	568.6
1952	381.2	126.3	507.4	0.3	-1.4	506.3	52.2	454.1	506.3
1953	367.4	120.8	488.2	0.3	2.8	491.3	36.5	454.8	491.3
1954	306.0	114.8	420.8	0.2	2.8	423.8	33.9	389.9	423.8
1955	358.0	132.9	490.8	0.3	10.3	501.4	54.4	447.0	501.4
1956	380.8	148.9	529.8	0.4	0.5	530.7	73.8	456.9	530.7
1957	373.6	144.5	518.0	0.4	-3.2	515.3	80.8	434.5	515.3
1958	297.6	134.0	431.6	0.3	6.4	438.3	52.6	385.7	438.3
1959	292.8	139.8	432.7	0.4	-9.0	424.1	39.0	385.1	424.1
1960	292.6	141.7	434.3	0.3	1.5	436.1	38.0	398.1	436.1
1961	279.6	140.9	420.4	0.2	6.2	426.8	36.4	390.4	426.8
1962	287.9	151.1	439.0	0.2	3.3	442.6	40.2	402.3	442.5
1963	309.0	168.2	477.2	0.3	-3.6	473.9	50.4	423.5	473.9
1964	327.7	176.5	504.2	0.3	-9.3	495.2	49.5	445.7	495.2
1965	338.0	189.0	527.0	0.2	-4.2	522.9	51.0	472.0	523.0
1966	342.6	204.2	546.8	0.2	0.8	547.8	50.1	497.7	547.8
1967	352.4	212.5	564.9	0.2	-23.5	541.6	50.1	491.4	541.6
1968	346.6	210.1	556.7	0.2	4.1	561.0	51.2	509.8	561.0
1969	349.2	221.7	571.0	0.1	2.2	573.3	56.9	516.4	573.3
1970	340.5	272.1	612.7	*	-17.7	595.0	71.7	523.2	595.0
1971	277.2	283.7	560.9	0.1	-2.0	559.0	57.3	501.6	558.9
1972	305.0	297.4	602.5	*	-21.5	581.0	56.7	524.3	581.0
1973	300.1	298.5	598.6	0.1	17.6	616.3	53.6	562.6	616.2
1974	278.0	332.1	610.0	2.1	7.0	619.1	60.7	558.4	619.1
1975	293.5	361.2	654.6	0.9	-26.5	629.1	66.3	562.6	628.9
1976	295.5	389.4	684.9	1.2	-22.3	663.6	60.0	603.8	663.8
1977	266.6	430.6	697.2	1.6	-19.2	679.7	54.3	625.3	679.6
1978	242.8	427.4	670.2	3.0	-7.3	665.6	40.7	625.2	665.9
1979	320.9	460.2	781.1	2.1	-36.6	746.6	66.0	680.5	746.6
1980	337.5	492.2	829.7	1.2	-36.5	794.4	91.7	702.7	794.5
1981	316.5	507.3	823.8	1.0	20.3	845.2	112.5	732.6	845.2
1982	339.2	499.0	838.1	0.7	-25.6	813.3	106.3	706.9	813.2
1983	300.4	481.7	782.1	1.3	31.1	814.5	77.8	736.7	814.4
1984	352.1	543.9	895.9	1.3	-24.4	872.8	81.5	791.3	872.8
1985	350.8	532.8	883.6	2.0	25.1	910.7	92.7	818.0	910.7
1986	360.4	529.9	890.3	2.2	-2.7	889.8	85.5	804.2	889.8
1987	372.9	545.9	918.8	1.7	-4.0	916.5	79.6	836.9	916.5
1988	382.1	568.1	950.3	2.1	26.3	978.7	95.0	883.7	978.7
1989	393.8	586.9	980.7	2.9	7.8	991.4	100.8	889.7	991.4
1990	424.5	604.5	1,029.1	2.7	-30.5	1,001.3	105.8	895.5	1,001.3
1991	407.2	588.8	996.0	3.4	-2.8	996.6	109.0	887.6	996.6
1992	407.2	590.3	997.5	3.8	-6.4	994.9	102.5	892.4	994.9
1993	351.1	594.4	945.4	7.3	47.7	1,000.5	74.5	925.9	1,000.5

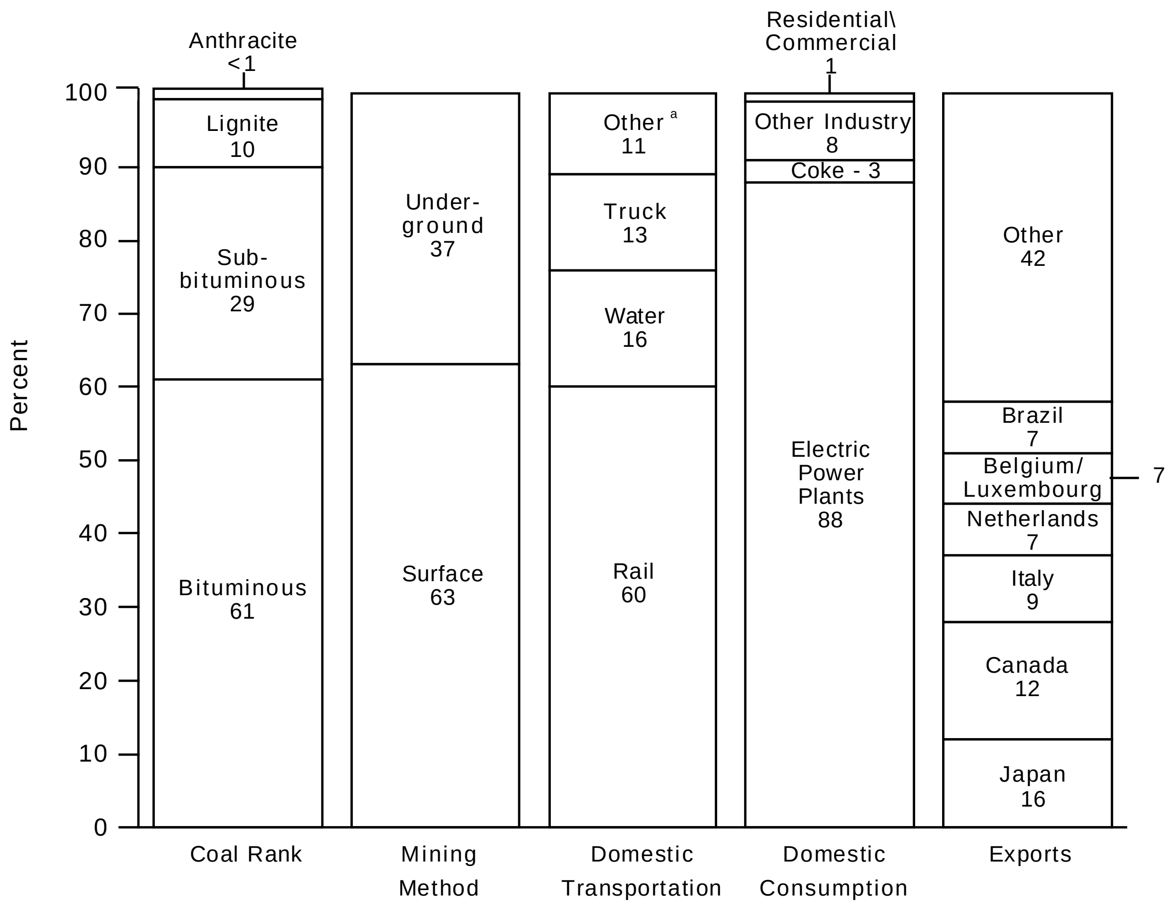
[a]Balancing item between supply and disposition.

*Less than 0.05 million short tons.

Note: Totals may not equal sum of components because of independent rounding.

Sources: **1949-1989**: Energy Information Agency, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994); **1990**: *Coal Production*, DOE/EIA-0118; *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93) (Washington, DC, May 1994); *Quarterly Coal Report January-March 1994,* DOE/EIA-0121(94/1Q) (Washington, DC, August 1994); and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Figure 31. U.S. Coal Supply and Disposition Patterns, 1993



[a]Tramway/Conveyor, slurry pipeline, and unknown or not revealable methods.

Most of U.S. coal production is surface-mined, shipped by railroad, and used by electric utilities.

Note: Totals may not equal sum of components because of independent rounding.
Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994); *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93/4Q) (Washington, DC, May 1994); and Form EIA-6, "Coal Distribution Report."

Table 25. Year-End Stocks of U.S. Coal by End-Use Sector, 1949-1993
(Million Short Tons)

Year	Electric Utilities	Industrial			Residential and Commercial[b]	Total Consumer Stocks
		Coke Plants	Other Industrial[a]	Total		
1949	22.1	10.0	16.1	26.0	1.4	49.5
1950	31.8	16.8	26.2	43.0	2.5	77.3
1951	38.5	15.3	26.2	41.6	1.8	81.8
1952	41.5	14.5	24.7	39.2	1.7	82.4
1953	45.6	16.6	22.8	39.4	1.5	86.6
1954	46.1	12.4	16.4	28.8	0.8	75.7
1955	41.4	13.4	15.9	39.3	1.0	71.7
1956	48.8	14.0	17.4	31.5	1.1	81.3
1957	53.1	14.2	15.5	29.7	0.9	83.7
1958	51.0	13.1	13.7	36.7	0.9	78.7
1959	52.1	11.6	13.6	25.2	1.0	78.4
1960	51.7	11.1	11.6	22.8	0.7	75.2
1961	50.1	10.5	11.9	22.4	0.5	73.0
1962	50.4	8.4	12.0	20.4	0.5	71.3
1963	50.6	8.1	12.3	20.4	0.5	71.5
1964	53.9	10.2	12.2	22.5	0.4	76.7
1965	54.5	10.6	13.1	23.8	0.4	78.6
1966	53.9	9.3	12.2	21.5	0.2	75.6
1967	71.0	11.1	12.3	23.4	0.2	94.6
1968	65.5	9.7	11.7	21.3	0.2	87.0
1969	61.9	9.1	10.8	19.9	0.2	81.9
1970	71.9	9.0	11.8	20.8	0.3	93.0
1971	77.8	7.3	5.6	12.9	0.3	91.0
1972	99.7	9.1	7.6	16.7	0.3	116.8
1973	87.0	7.0	10.4	17.4	0.3	104.6
1974	83.5	6.2	6.6	12.8	0.3	96.6
1975	110.7	8.8	8.5	17.3	0.2	128.3
1976	117.4	9.9	7.1	17.0	0.2	134.7
1977	133.2	12.8	11.1	23.9	0.2	157.3
1978	128.2	8.3	9.0	17.3	0.4	145.9
1979	159.7	10.2	11.8	21.9	0.3	182.0
1980	183.0	9.1	12.0	21.0	NA	204.0
1981	168.9	6.5	9.9	16.4	NA	185.3
1982	181.1	4.6	9.5	14.1	NA	195.3
1983	155.6	4.3	8.7	13.1	NA	168.7
1984	179.7	6.2	11.3	17.5	NA	197.2
1985	156.4	3.4	10.4	13.9	NA	170.2
1986	161.8	3.0	10.4	13.4	NA	175.2
1987	170.8	3.9	10.8	14.7	NA	185.5
1988	146.5	3.1	8.8	11.9	NA	158.4
1989	135.9	2.9	7.4	10.2	NA	146.1
1990	156.2	3.3	8.7	12.0	NA	168.2
1991	157.9	2.8	7.1	9.9	NA	167.7
1992	154.1	2.6	7.0	9.6	NA	163.7
1993	111.3	2.4	6.7	9.1	NA	120.5

[a]Includes transportation sector.
[b]Stocks at retail dealers.
NA = Not available.
Note: Totals may not equal sum of components because of independent rounding.
Sources: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994); and *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93) (Washington, DC, May 1994).

Table 26. U.S. Coke Supply and Disposition, 1949-1993
(Million Short Tons)

Year	Supply				Disposition		
	Production	Imports	Stock Change[a]	Total	Exports	Consumption[b]	Total
1949	63.64	0.28	-0.18	63.74	0.55	63.19	63.74
1950	72.72	0.44	0.66	73.82	0.40	73.42	73.82
1951	79.33	0.16	-0.37	79.12	1.03	78.09	79.12
1952	68.25	0.31	-0.42	68.15	0.79	67.36	68.15
1953	78.84	0.16	-0.78	78.22	0.52	77.70	78.22
1954	59.66	0.12	-0.27	59.51	0.39	59.12	59.51
1955	75.30	0.13	1.25	76.68	0.53	76.15	76.68
1956	74.48	0.13	-0.63	73.98	0.66	73.32	73.98
1957	75.95	0.12	-0.81	75.26	0.82	74.43	75.26
1958	53.60	0.12	-0.67	53.05	0.39	52.66	53.05
1959	55.86	0.12	-0.66	55.13	0.46	54.67	55.13
1960	57.23	0.13	-0.06	57.30	0.35	56.95	57.30
1961	51.71	0.13	0.70	52.53	0.45	52.09	52.53
1962	51.91	0.14	0.14	52.19	0.36	51.82	52.19
1963	54.28	0.15	1.02	55.45	0.45	55.00	55.45
1964	62.15	0.10	0.91	63.16	0.52	62.64	63.16
1965	66.85	0.09	-0.73	66.21	0.83	65.38	66.21
1966	67.40	0.10	-0.38	67.12	1.10	66.02	67.12
1967	64.58	0.09	-2.39	62.28	0.71	61.57	62.28
1968	63.65	0.09	-0.52	63.23	0.79	62.44	63.23
1969	64.76	0.17	2.87	67.80	1.63	66.17	67.80
1970	66.53	0.15	-0.99	65.69	2.48	63.21	65.69
1971	57.44	0.17	0.59	58.20	1.51	56.69	58.20
1972	60.51	0.19	0.59	61.28	1.23	60.05	61.28
1973	64.33	1.08	1.76	67.16	1.40	65.77	67.16
1974	61.58	3.54	0.25	65.37	1.28	64.09	65.37
1975	57.21	1.82	-4.07	54.96	1.27	53.69	54.96
1976	58.33	1.31	-1.49	58.15	1.32	56.83	58.15
1977	53.51	1.83	0.05	55.39	1.24	54.14	55.39
1978	49.01	5.72	2.91	57.64	0.69	56.95	57.64
1979	52.94	3.97	-1.65	55.27	1.44	53.83	55.27
1980	46.13	0.66	-3.44	43.35	2.07	41.28	43.35
1981	42.79	0.53	1.90	45.22	1.17	44.05	45.22
1982	28.12	0.12	-1.47	26.77	0.99	25.78	26.77
1983	25.81	0.04	4.67	30.51	0.67	29.85	30.52
1984	30.40	0.58	-0.19	30.79	1.05	29.74	30.79
1985	28.44	0.58	1.16	30.18	1.12	29.06	30.18
1986	24.92	0.33	0.49	25.74	1.00	24.73	25.73
1987	26.30	0.92	1.00	28.22	0.57	27.65	28.22
1988	28.95	2.69	-0.52	31.12	1.09	30.02	31.11
1989	28.05	2.31	-0.34	30.02	1.09	28.93	30.02
1990	27.62	0.77	*	28.39	0.57	27.81	28.38
1991	24.05	1.10	-0.19	24.96	0.74	24.22	24.96
1992	23.41	1.74	0.22	25.37	0.64	24.73	25.37
1993	23.18	1.53	0.42	25.13	0.84	24.30	25.14

[a]Negative numbers denote a net addition to stocks or a reduction in supply. Positive numbers denote a net withdrawal from stocks resulting in an addition to supply. Includes producer and distributor stocks beginning in 1979.

[b]Apparent consumption

*Less than 0.01 million short tons.

Note: Totals may not equal sum of components because of independent rounding.

Sources: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994); and *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93) (Washington, DC, May 1994).

Table 27. U.S. Coal Consumption by End-Use Sector, 1949-1993
(Million Short Tons)

Year	Electric Utilities	Industry and Miscellaneous			Transportation	Residential and Commercial	Total
		Coke Plants	Other Industry and Miscellaneous	Total			
1949	84.0	91.4	121.2	212.6	70.2	116.5	483.2
1950	91.9	104.0	120.6	224.6	63.0	114.6	494.1
1951	105.8	113.7	128.7	242.4	56.2	101.5	505.9
1952	107.1	97.8	117.1	214.9	39.8	92.3	454.1
1953	115.9	113.1	117.0	230.1	29.6	79.2	454.8
1954	118.4	85.6	98.2	183.9	18.6	69.1	389.9
1955	143.8	107.7	110.1	217.8	17.0	68.4	447.0
1956	158.3	106.3	114.3	220.6	13.8	64.2	456.9
1957	160.8	108.4	106.5	214.9	9.8	49.0	434.5
1958	155.7	76.8	100.5	177.4	4.7	47.9	385.7
1959	168.4	79.6	92.7	172.3	3.6	40.8	385.1
1960	176.7	81.4	96.0	177.4	3.0	40.9	398.1
1961	182.2	74.2	95.9	170.1	0.8	37.3	390.4
1962	193.3	74.7	97.1	171.7	0.7	36.5	402.3
1963	211.3	78.1	101.9	180.0	0.7	31.5	423.5
1964	225.4	89.2	103.1	192.4	0.7	27.2	445.7
1965	244.8	95.3	105.6	200.8	0.7	25.7	472.0
1966	266.5	96.4	108.7	205.1	0.6	25.6	497.7
1967	274.2	92.8	101.8	194.6	0.5	22.1	491.4
1968	297.8	91.3	100.4	191.6	0.4	20.0	509.8
1969	310.6	93.4	93.1	186.6	0.3	18.9	516.4
1970	320.2	96.5	90.2	186.6	0.3	16.1	523.2
1971	327.3	83.2	75.6	158.9	0.2	15.2	501.6
1972	351.8	87.7	72.9	160.6	0.2	11.7	524.3
1973	389.2	94.1	68.0	162.1	0.1	11.1	562.6
1974	391.8	90.2	64.9	155.1	0.1	11.4	558.4
1975	406.0	83.6	63.6	147.2	*	9.4	562.6
1976	448.4	84.7	61.8	146.5	*	8.9	603.8
1977	477.1	77.7	61.5	139.2	*	9.0	625.3
1978	481.2	71.4	63.1	134.5	[a]	9.5	625.2
1979	527.1	77.4	67.7	145.1	[a]	8.4	680.5
1980	569.3	66.7	60.3	127.0	[a]	6.5	702.7
1981	596.8	61.0	67.4	128.4	[a]	7.4	732.6
1982	593.7	40.9	64.1	105.0	[a]	8.2	706.9
1983	625.2	37.0	66.0	103.0	[a]	8.4	736.7
1984	664.4	44.0	73.7	117.8	[a]	9.1	791.3
1985	693.8	41.1	75.4	116.4	[a]	7.8	818.0
1986	685.1	36.0	75.6	111.8	[a]	7.7	804.3
1987	717.9	37.0	75.2	112.1	[a]	6.9	836.9
1988	758.4	41.9	76.3	118.2	[a]	7.1	883.7
1989	766.9	40.5	76.1	117.5	[a]	6.2	889.7
1990	773.5	38.9	76.3	115.2	[a]	6.7	895.5
1991	772.3	33.9	75.4	109.3	[a]	6.1	887.6
1992	779.9	32.4	74.0	106.4	[a]	6.2	892.4
1993	813.5	31.3	74.9	106.2	[a]	6.2	925.9

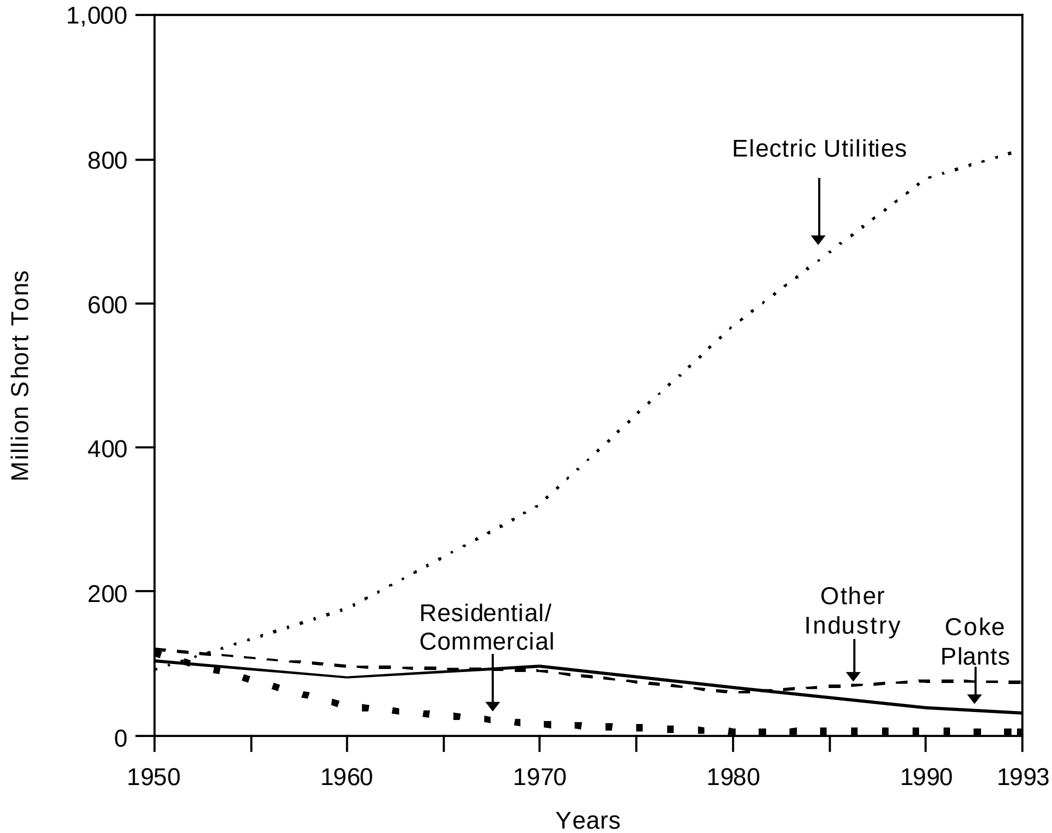
[a]Included in the Other Industry and Miscellaneous category.

*Less than 0.05 million short tons.

Note: Totals may not equal sum of components because of independent rounding.

Sources: **1949-1989**: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(90) (Washington, DC, July 1994); **1990 on**: *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93) (Washington, DC, May 1991); and *Quarterly Coal Report January-March 1994*, DOE/EIA-0121(94/1Q) (Washington, DC, August 1994).

Figure 32. U.S. Coal Consumption by End-Use Sector, 1950-1993



The pattern of U.S. coal consumption has changed significantly since 1950. Coal consumption has risen mainly because more coal is used to generate electricity.

Source: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93)(Washington, DC, July 1994); *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93/4Q)(Washington, DC, May 1994); and *Quarterly Coal Report January-March 1994*, DOE/EIA-0121(94/1Q) (Washington, DC, August 1994).

Table 28. U.S. Coal Consumption by Census Division and State, 1989-1993
(Thousand Short Tons)

Census Division and State	1989	1990	1991	1992	1993
New England Total	**7,021**	**6,771**	**7,012**	**7,298**	**6,485**
Connecticut	890	971	856	849	788
Maine	271	265	374	856	449
Massachusetts	4,641	4,337	4,451	4,257	3,811
New Hampshire	1,183	1,186	1,315	1,311	1,428
Rhode Island	27	5	4	5	3
Vermont	9	8	12	20	6
Middle Atlantic Total	**76,177**	**73,812**	**70,594**	**71,418**	**70,389**
New Jersey	3,545	3,029	2,326	2,348	2,353
New York	14,105	13,465	13,338	12,996	11,878
Pennsylvania	58,526	57,319	54,931	56,074	56,158
East North Central Total	**205,586**	**209,619**	**208,583**	**200,660**	**210,632**
Illinois	32,374	33,904	34,677	31,599	38,135
Indiana	57,388	61,701	60,790	58,765	60,353
Michigan	34,885	34,713	33,879	31,554	32,217
Ohio	61,016	59,205	58,578	58,671	59,031
Wisconsin	19,922	20,097	20,659	20,071	20,887
West North Central Total	**114,245**	**116,268**	**116,707**	**115,505**	**120,940**
Iowa	17,126	17,929	18,741	17,992	19,188
Kansas	14,963	15,175	14,881	14,227	17,386
Minnesota	18,279	18,377	16,993	16,924	18,321
Missouri	26,348	25,836	25,773	25,180	23,381
Nebraska	7,587	8,266	8,859	8,212	9,666
North Dakota	27,401	28,114	28,597	30,301	30,302
South Dakota	2,541	2,571	2,863	2,670	2,696
South Atlantic Total	**153,008**	**149,455**	**144,073**	**144,178**	**150,580**
Delaware	2,357	2,293	2,186	1,770	2,446
District of Columbia	60	69	66	50	51
Florida	25,447	25,233	26,004	26,368	26,430
Georgia	27,918	30,067	26,957	25,481	27,081
Maryland	11,541	11,193	10,709	9,713	10,268
North Carolina	22,239	21,150	20,877	24,075	25,760
South Carolina	11,981	11,447	11,451	11,285	12,914
Virginia	14,279	13,105	13,980	13,418	13,584
West Virginia	37,186	34,896	31,843	32,019	32,046
East South Central Total	**87,655**	**91,126**	**90,785**	**93,804**	**104,027**
Alabama	27,537	27,640	29,349	31,510	33,047
Kentucky	32,792	34,449	34,517	34,704	39,095
Mississippi	3,831	4,159	3,812	3,485	4,030
Tennessee	23,496	24,878	23,107	24,106	27,854
West South Central Total	**130,093**	**131,478**	**133,635**	**135,210**	**140,797**
Arkansas	11,547	12,092	12,261	12,538	11,447
Louisiana	12,471	12,547	12,965	13,674	13,676
Oklahoma	15,086	15,423	16,345	17,430	18,866
Texas	90,989	91,415	92,064	91,568	96,809
Mountain Total	**106,212**	**107,158**	**105,177**	**112,163**	**110,673**
Arizona	16,871	16,419	16,805	17,915	18,991
Colorado	16,393	16,710	16,218	16,696	17,070
Idaho	533	549	673	535	528
Montana	10,458	9,676	10,549	11,040	9,247
Nevada	7,667	7,442	8,091	8,088	7,806
New Mexico	15,295	15,111	12,858	14,832	15,012
Utah	15,044	15,738	14,834	15,719	15,848
Wyoming	23,952	25,514	25,150	27,339	26,171
Pacific Total	**9,120**	**9,792**	**11,055**	**12,186**	**11,422**
Alaska	299	784	802	792	863
California	2,551	2,899	2,816	2,821	2,453
Hawaii	32	28	37	47	73
Oregon	396	934	1,940	2,124	2,099
Washington	5,843	5,147	5,461	6,402	5,934
Unknown	**581**	**0**	**0**	**0**	**0**
U.S. Total	**889,699**	**895,480**	**887,621**	**892,421**	**925,944**

Note: Totals may not equal sum of components because of Independent rounding.

Sources: Energy Information Administration, *Quarterly Coal Report,* DOE/EIA-0121 (October-December issues); and *Quarterly Coal Report January-March 1994*, DOE/EIA-0121(94/1Q) (Washington, DC, August 1994).

Table 29. U.S. Coal Consumption by End-Use Sector and by Census Division and State, 1993
(Thousand Short Tons)

Census Division and State	Electric Utilities	Coke Plants	Other Industrial	Residential and Commercial	Total
New England Total	**5,936**	**0**	**647**	**102**	**6,485**
Connecticut	745	0	W	W	788
Maine	0	0	W	W	449
Massachusetts	3,852	0	W	W	3,811
New Hampshire	1,339	0	W	W	1,428
Rhode Island	0	0	W	W	3
Vermont	0	0	W	W	6
Middle Atlantic Total	**51,079**	**W**	**W**	**1,498**	**70,383**
New Jersey	2,123	0	W	W	2,353
New York	8,699	W	*	W	11,878
Pennsylvania	40,257	*	*	1,257	56,158
East North Central Total	**179,833**	**11,643**	**17,699**	**1,458**	**210,632**
Illinois	31,744	W	3,970	W	38,135
Indiana	48,836	6,591	4,587	339	60,353
Michigan	28,479	W	3,230	W	32,217
Ohio	51,456	2,892	4,100	584	59,031
Wisconsin	19,049	W	1,811	W	20,897
West North Central Total	**107,584**	**W**	**12,753**	**W**	**120,940**
Iowa	16,623	0	2,494	70	19,188
Kansas	17,226	0	137	23	17,386
Minnesota	16,844	0	1,370	107	18,321
Missouri	21,945	W	1,177	W	23,381
Nebraska	9,297	0	W	W	9,666
North Dakota	23,290	0	W	W	30,302
South Dakota	2,360	0	W	W	2,696
South Atlantic Total	**132,885**	**W**	**W**	**904**	**150,580**
Delaware	2,223	0	W	W	2,446
District of Columbia	0	0	0	51	51
Florida	25,108	0	1,307	16	26,430
Georgia	25,339	0	1,720	22	27,081
Maryland	9,521	W	731	W	10,268
North Carolina	23,055	0	2,476	229	25,760
South Carolina	10,410	0	2,395	109	12,914
Virginia	9,447	W	2,863	W	13,584
West Virginia	27,782	W	2,406	W	32,046
East South Central Total	**90,365**	**W**	**W**	**417**	**104,027**
Alabama	27,533	3,206	2,268	40	33,047
Kentucky	35,264	W	2,392	W	39,095
Mississippi	3,767	0	W	W	4,030
Tennessee	23,801	W	3,942	W	27,854
West South Central Total	**134,009**	**0**	**6,780**	**8**	**140,797**
Arkansas	11,116	0	330	1	11,447
Louisiana	13,089	0	W	W	13,676
Oklahoma	17,668	0	W	W	18,866
Texas	92,135	0	4,667	6	96,809
Mountain Total	**104,093**	**W**	**5,163**	**W**	**110,673**
Arizona	18,316	0	674	1	18,991
Colorado	16,252	0	780	38	17,070
Idaho	0	0	486	43	528
Montana	8,869	0	W	W	9,247
Nevada	7,608	0	W	W	7,806
New Mexico	14,942	0	W	W	15,012
Utah	13,995	W	727	W	15,848
Wyoming	24,111	0	1,873	187	26,171
Pacific Total	**7,924**	**0**	**2,677**	**821**	**11,422**
Alaska	298	0	2	563	863
California	0	0	2,311	142	2,453
Hawaii	0	0	W	W	73
Oregon	1,981	0	W	W	2,099
Washington	5,646	0	174	114	5,934
U.S. Total	**813,508**	**31,323**	**74,892**	**6,221**	**925,944**

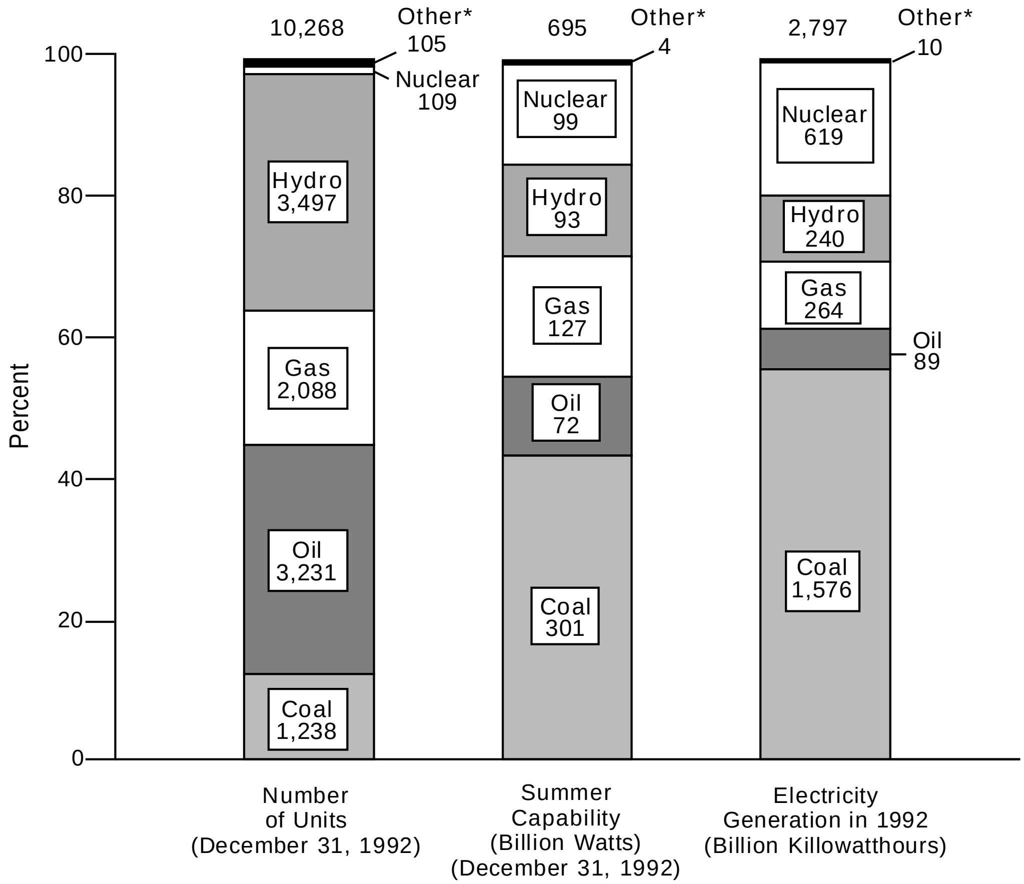
*Less than 0.05 million short tons.

W = Withheld to avoid disclosure of individual company data.

Note: Totals may not equal sum of components because of Independent rounding.

Sources: Energy Information Administration, *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93/4Q) (Washington, DC, May 1994); and *Quarterly Coal Report January-March 1994*, DOE/EIA-0121(94/1Q) (Washington, DC, August 1994).

Figure 33. Coal-Fired Generating Units: Number, Generating Capability, and Electricity Generation in 1992 as Compared with Other Energy Sources



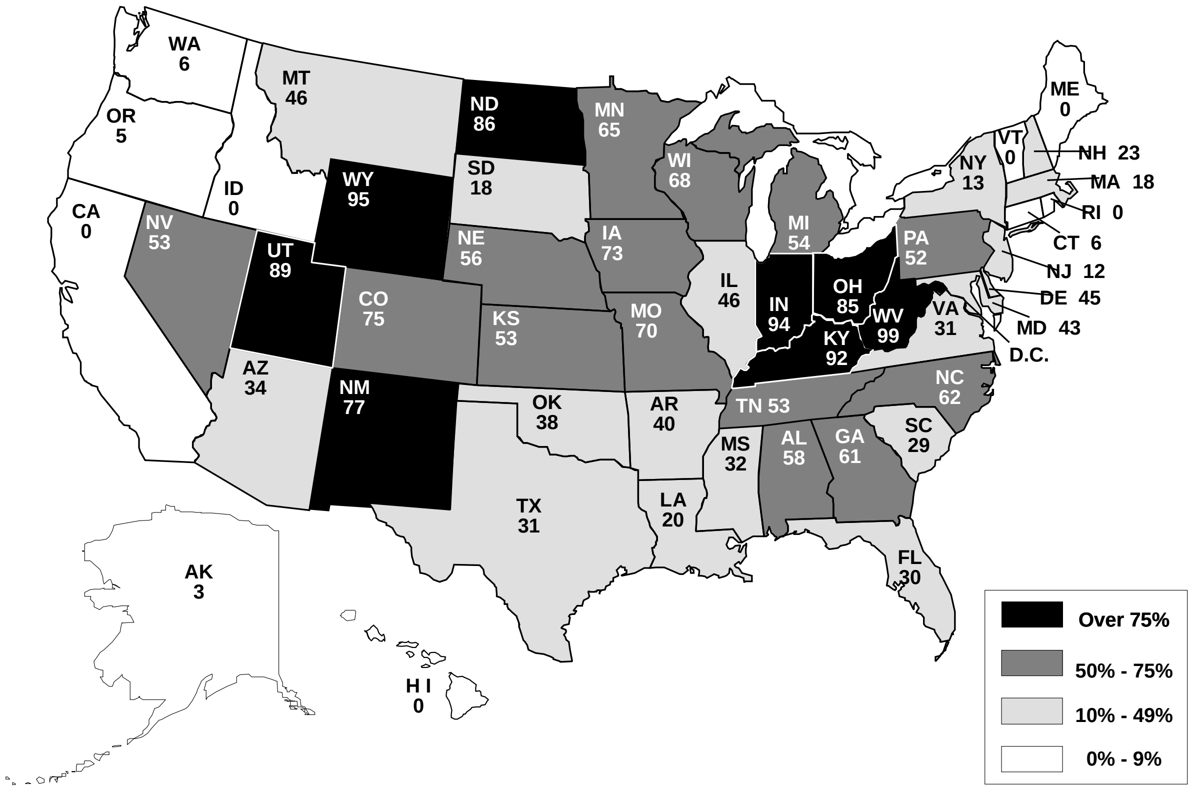
*Geothermal, wood, wind, waste, refuse, and solar.

For their number and capability, coal-fired generating units account for a large share of electricity generation. This is because they are mostly base-load units, operating continuously and supplying electricity at a generally constant rate.

Note: Total may not equal sum of components due to independent rounding.

Sources: Energy Information Administration, *Inventory of Power Plants in the United States 1992*, DOE/EIA-0095(92) (Washington, DC, October 1993); and *Monthly Energy Review July 1994*, DOE/EIA-0035(94/O7) (Washington, DC, July 1994).

Figure 34. Percentage of Total Electricity Generating Capability Using Coal, by State, December 31, 1992
(Billion Short Tons)



At the end of 1992, coal was the primary fuel for 300,547 megawatts of electric generating capability, or 43 percent of the U.S. total of 695,059 megawatts.

Source: Energy Information Administration, *Inventory of Power Plants in the United States 1992,* DOE/EIA-009(92) (Washington, DC, October 1993).

Table 30. U.S. Coal Prices, 1949-1993
(Dollars per Short Ton)

Year	Bituminous Coal[a] and Lignite		Anthracite		All Coal	
	F.O.B.[b] Mines		At Plants and Mines[c]		CIF[d] Electric Utility Power Plants	
	Current	1987 Dollars[e]	Current	1987 Dollars[e]	Current	1987 Dollars[e]
1949	4.88	24.52	8.90	44.72	NA	NA
1950	4.84	23.96	9.34	46.24	NA	NA
1951	4.92	23.10	9.94	46.67	NA	NA
1952	4.90	22.79	9.58	44.56	6.61	30.74
1953	4.92	22.36	9.87	44.86	6.61	30.05
1954	4.52	20.36	8.76	39.46	6.31	28.42
1955	4.50	19.65	8.00	34.93	6.07	26.51
1956	4.82	20.42	8.33	35.30	6.32	26.78
1957	5.08	20.82	9.11	37.34	6.64	27.21
1958	4.86	19.52	9.14	36.71	6.58	26.43
1959	4.77	18.63	8.55	33.40	6.37	24.88
1960	4.69	18.04	8.01	30.81	6.26	24.08
1961	4.58	17.41	8.26	31.41	6.20	23.57
1962	4.48	16.65	7.99	29.70	6.02	22.38
1963	4.39	16.14	8.64	31.76	5.86	21.54
1964	4.45	16.06	8.93	32.24	5.74	20.72
1965	4.44	15.63	8.51	29.96	5.71	20.11
1966	4.54	15.44	8.08	27.48	5.76	19.59
1967	4.62	15.25	8.15	26.90	5.85	19.31
1968	4.67	14.69	8.78	27.61	5.93	18.65
1969	4.99	14.94	9.91	29.67	6.13	18.35
1970	6.26	17.78	11.03	31.34	7.13	20.26
1971	7.07	19.06	12.08	32.56	8.00	21.56
1972	7.66	19.74	12.40	31.96	8.44	21.75
1973	8.53	20.65	13.65	33.05	9.01	21.82
1974	15.75	35.08	22.19	49.42	15.46	34.43
1975	19.23	39.09	32.26	65.57	17.63	35.83
1976	19.43	37.15	33.92	64.86	18.38	35.14
1977	19.82	35.46	34.86	62.36	20.37	36.44
1978	21.76	36.12	35.25	58.46	23.75	39.39
1979	23.65	36.11	41.06	62.69	26.15	39.92
1980	24.52	34.20	42.51	59.29	28.76	40.11
1981	26.29	33.32	44.28	56.12	32.32	40.96
1982	27.14	32.39	49.85	59.49	34.91	41.66
1983	25.85	29.64	52.29	59.97	34.99	40.13
1984	25.51	28.03	48.22	52.99	35.12	38.59
1985	25.10	26.59	45.80	48.52	34.53	36.58
1986	23.70	24.46	44.12	45.53	33.30	34.37
1987	23.00	23.00	43.65	43.65	31.83	31.83
1988	22.00	21.17	44.16	42.50	30.64	29.49
1989	21.76	20.06	42.93	39.57	30.15	27.79
1990	21.71	19.16	39.40	34.77	30.45	26.88
1991	21.45	18.22	36.34	30.88	30.02	25.51
1992	20.98	17.32	34.24	28.27	29.36	24.24
1993	[E]20.56	16.55	[E]37.80	30.43	[P]28.64	23.06

[a]Includes subbituminous coal.
[b]Free on board.
[c]For 1949-1979, prices are f.o.b. preparation plants. For 1979 forward, prices are f.o.b. mines.
[d]Cost, insurance and freight.
[e]Calculated by using gross domestic product implicit price deflators.
P = Preliminary data. E = Estimate. NA = Not available.
Source: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994).

Table 31. Average Mine Price of U.S. Coal by Mining Method, 1980-1993
(Dollars per Short Ton)

Year	Underground	Surface	Total
1980	33.50	18.78	24.65
1981	35.78	20.60	26.40
1982	35.78	21.46	27.25
1983	34.47	20.68	25.98
1984	33.36	20.59	25.61
1985	32.91	20.13	25.20
1986	30.33	19.34	23.79
1987	29.63	18.58	23.07
1988	28.97	17.43	22.07
1989	28.44	17.38	21.82
1990	28.58	16.98	21.76
1991	28.56	16.60	21.49
1992	27.83	16.34	21.03
1993	26.92	15.67	19.85

Note: Average mine price is in current dollars.
Sources: Energy Information Administration, *Coal Production,* DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 32. Average Mine Price of U.S. Coal by Rank, 1980-1993
(Dollars per Short Ton)

Year	Lignite	Subbituminous Coal	Bituminous Coal	Anthracite[a]
1980	W	11.08	29.17	42.51
1981	W	12.18	31.51	44.28
1982	W	13.37	32.15	49.85
1983	W	13.03	31.11	59.29
1984	10.45	12.41	30.63	48.22
1985	10.68	12.57	30.78	45.80
1986	10.64	12.26	28.84	44.12
1987	10.85	11.32	28.19	43.65
1988	10.06	10.45	27.66	44.16
1989	9.91	10.16	27.40	42.93
1990	10.13	9.70	27.43	39.40
1991	10.89	9.68	27.49	36.34
1992	10.81	9.68	26.78	34.24
1993	11.11	9.33	26.15	32.94

[a]Produced in Pennsylvania.
Note: Average mine price is in current dollars.
W = Withheld to avoid disclosure of individual company data.
Sources: Energy Information Administration, *Coal Production,* DOE/EIA-0118, various issues; and *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 33. Average Mine Price of U.S. Coal by State and Mining Method, 1993
(Dollars Per Short Ton)

State	Type of Mining		Total
	Under-ground	Surface	
Alabama	42.00	42.91	42.34
Alaska	--	W	W
Arizona	--	W	W
Arkansas	--	W	W
Colorado	20.53	20.10	20.35
Illinois	25.54	24.18	25.27
Indiana	W	W	22.89
Iowa	--	W	W
Kansas	--	W	W
Kentucky Total	25.07	24.35	24.77
Eastern	25.42	25.63	25.50
Western	23.84	20.45	22.36
Louisiana	--	W	W
Maryland	W	W	25.21
Missouri	--	W	W
Montana	W	W	11.05
New Mexico	W	W	22.96
North Dakota	--	7.63	7.63
Ohio	30.73	26.51	28.04
Oklahoma	W	W	24.91
Pennsylvania Total	27.35	25.09	26.50
Anthracite	36.02	32.71	32.94
Bituminous	27.29	23.55	26.03
Tennessee	W	W	27.23
Texas	--	12.87	12.87
Utah	20.81	--	20.81
Virginia	27.26	25.29	26.80
Washington	--	W	W
West Virginia	28.54	25.57	27.58
Wyoming	W	W	7.32
U.S. Total	**26.92**	**15.67**	**19.85**

-- = Not applicable.

W = Withheld to avoid disclosure of individual company data.

Notes: Average mine price is in current dollars.

Source: Energy Information Administration, *Coal Industry Annual 1993*, DOE/EIA-0584(93) (Washington, DC, December 1994).

Table 34. Foreign Direct Investment in U.S. Coal, and Share of Total U.S. Coal Production, 1980-1992

Year	Foreign Direct Investment in U.S. Coal[a] (billion dollars)[b]	Foreign Share of U.S. Coal Production (percent)
1980	0.5	3.8
1981	1.1	12.9
1982	1.2	16.6
1983	1.3	16.5
1984	2.6	17.2
1985	2.9	16.8
1986	3.5	16.5
1987	3.3	19.8
1988	5.3	20.6
1989	0.9	21.2
1990	0.8	24.7
1991	1.3	24.0
1992	1.6	26.0

[a]Foreign Direct Investment is the value of foreign parent companies' net equity in, and outstanding loans to, affiliates in the United States at the end of the year. A U.S. affiliate is a U.S business enterprise in which a single foreign direct investor owns at least 10 percent of the voting securities, or the equivalent.

[b]Current dollars.

Source: Energy Information Administration, *Profiles of Foreign Direct Investment in U.S. Energy 1992*, DOE/EIA-0466(92) (Washington, DC, May 1994).

Table 35. U.S. Coal Mining Cost Comparisons by Mining Methods
(January 1989 Dollars per Short Ton of Raw Coal)

At 15 Percent DCFROR[a]	Underground						Surface		Multiple Steeply Dipping Coalbeds
	Room and Pillar				Longwall Mining		Few Flat-Lying Thick Coalbeds		
	Continuous Mining		Conventional Mining						
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	(one mine)
Capital Costs	1.42	4.18	0.61	1.11	1.97	4.31	0.72	1.00	3.91
Return of equity capital	0.59	2.68	0.17	0.49	1.42	2.02	0.41	0.63	2.64
15 percent return on capital	0.65	1.50	0.44	0.62	0.55	2.29	0.31	0.37	1.27
Mine operating costs	11.50	14.98	7.48	12.57	9.52	16.51	2.72	3.26	9.89
Labor	7.07	11.99	4.07	7.65	6.57	9.67	1.35	1.72	4.92
Equipment and supplies	2.99	5.28	3.41	4.92	2.96	7.61	1.37	1.68	4.97
Land Costs	0.04	1.65	1.62	3.40	0.00	1.16	0.22	0.78	1.86
Taxes	0.92	2.31	1.96	2.23	1.58	2.71	1.35	1.64	3.37
Federal income	0.19	0.44	0.09	0.16	0.38	0.61	0.09	0.10	0.28
State income	0.03	0.08	0.01	0.03	0.07	0.14	0.00	0.02	0.00
Property and ad valorem	0.01	0.10	0.00	0.01	0.02	0.07	0.16	0.37	0.26
Severance and excise levy	0.00	0.85	0.61	0.78	0.19	1.04	0.47	0.57	1.83
Black lung	0.58	0.74	0.93	1.10	0.59	0.74	0.24	0.26	0.61
Reclamation	0.08	0.10	0.13	0.15	0.09	0.11	0.35	0.35	0.39
Total mining costs	**15.81**	**21.90**	**13.45**	**17.34**	**15.12**	**23.15**	**5.52**	**6.30**	**19.36**

[a]Discounted cash flow rate of return.

Note: Annual production capacity by mining method are as follow, in million short tons: continuous, 0.4-0.9; conventional, 0.4-1.6; longwall, 1.1-2.3; surface, flat-lying thick coalbeds, 3.5-21.03; multiple steeply dipping coalbed, 16.5. The sum of line items may not match totals because line items and totals may be from different mines.

Source: U.S Department of Interior, Bureau of Mines, *A Cost Comparison of Selected Coal Mines from Australia, Canada, Colombia, South Africa, and the United States,* Special Publication (August 1993).

Table 36. Quality and Cost of Coal Receipts of U.S. Electric Utilities of 50 Megawatts or Larger Nameplate Capacity by Coal Rank, 1990-1993

		Average Quality				Average Delivered Cost[a]	
Coal Rank	**Receipts** (thousand short tons)	**Btu** (per pound)	**Sulfur** (percent by weight)	**Sulfur** (pounds per million Btu)	**Ash** (percent by weight)	(cents per million Btu)	(dollars per short ton)
1990							
Anthracite[b]	753	8,070	0.71	0.90	32.7	97.7	15.77
Bituminous	477,782	11,945	1.86	1.58	10.5	153.8	36.75
Subbituminous	232,660	8,741	0.43	0.50	7.2	133.5	23.34
Lignite	75,432	6,433	0.92	1.46	14.0	98.3	12.65
Total	**786,627**	**10,465**	**1.35**	**1.25**	**9.9**	**145.5**	**30.45**
1991							
Anthracite[b]	723	7,961	0.64	0.82	33.4	94.1	14.98
Bituminous	450,462	11,964	1.84	1.56	10.3	153.2	36.66
Subbituminous	239,929	8,722	0.42	0.48	6.9	132.3	23.08
Lignite	78,810	6,372	0.95	1.51	14.9	104.9	13.37
Total	**769,923**	**10,378**	**1.30**	**1.22**	**9.8**	**144.7**	**30.02**
1992							
Anthracite[b]	503	8,470	0.67	0.81	32.0	93.7	15.88
Bituminous	453,732	11,987	1.81	1.53	10.2	149.6	35.86
Subbituminous	241,291	8,754	0.43	0.49	7.0	128.5	22.49
Lignite	80,438	6,346	0.97	1.55	14.6	105.4	13.38
Total	**775,963**	**10,395**	**1.29**	**1.21**	**9.7**	**141.2**	**29.36**
1993							
Anthracite[b]	392	8,267	0.69	0.84	33.0	91.1	15.05
Bituminous	422,690	12,042	1.71	1.44	10.2	147.6	35.55
Subbituminous	265,180	8,763	0.41	0.47	7.0	126.5	22.17
Lignite	80,890	6,374	0.94	1.51	14.4	103.9	13.25
Total	**769,152**	**10,315**	**1.18**	**1.11**	**9.6**	**138.5**	**28.58**

[a]Current dollars.
[b]Includes culm and silt.
Note: Totals may not equal sum of components because of independent rounding.
Source: Energy Information Administration, *Cost and Quality of Fuels for Electric Utility Plants 1993*, DOE/EIA-0191(93) (Washington, DC, July 1994).

Table 37. Cost of Contract and Spot Coal Receipts at U.S. Electric Utilities of 50 Megawatts of Larger Nameplate Capacity, 1981-1993

Year	Contract		Spot		**Average Cost** (dollars per short ton)
	Receipts (million short tons)	Cost (dollars per short ton)	Receipts (million short tons)	Cost (dollars per short ton)	
1981	500.9	31.34	75.5	38.79	32.32
1982	540.6	34.63	57.0	37.60	34.91
1983	523.6	35.21	69.2	33.34	34.99
1984	584.9	35.06	99.3	35.49	35.12
1985	592.4	34.63	74.3	33.73	34.53
1986	601.0	33.51	86.0	31.81	33.30
1987	610.2	32.01	111.1	30.86	31.83
1988	627.8	30.88	100.0	29.30	30.64
1989	620.9	30.38	132.3	29.07	30.15
1990	648.6	30.74	138.0	29.11	30.45
1991	655.5	30.55	114.5	27.02	30.02
1992	649.5	29.89	126.5	26.64	29.36
1993	616.0	28.93	153.2	27.19	28.58

Note: Cost is in current dollars.
Source: Energy Information Administration, *Cost and Quality of Fuels for Electric Utility Plants* 1993, DOE/EIA-0191(93) (Washington, DC, July 1994) and previous issues.

Table 38. U.S. Coal Receipts and Price by Sulfur Content at Electric Utility Plants, by State of Origin and Imports, 1993

State	≤ 0.60 lbs Sulfur per MM Btu		0.61-1.67 lbs Sulfur per MM Btu		> 1.67 lbs. Sulfur per MM Btu		Total		
	Quantity (thousand short tons)	Cents per MM Btu	Quantity (thousand short tons)	Cents per MM Btu	Quantity (thousand short tons)	Cents per MM Btu	Quantity (thousand short tons)	Cents per MM Btu	Lbs. Sulfur per MM Btu
Alabama	5,038	252	11,102	178	599	143	16,739	200	0.98
Arizona	12,122	111	0	--	0	--	12,122	111	0.46
Colorado	17,761	139	292	90	0	--	18,053	138	0.40
Illinois	25	161	10,511	151	29,842	151	40,378	151	2.24
Indiana	538	139	2,594	121	19,784	123	22,916	123	2.23
Iowa	0	--	0	--	18	175	18	175	3.11
Kansas	0	--	0	--	326	130	326	130	2.93
Kentucky	14,980	161	69,812	156	34,963	122	119,755	147	1.37
Louisiana	0	--	2,662	139	441	142	3,103	139	1.12
Maryland	8	191	2,964	141	12	111	2,984	141	1.33
Missouri	0	--	0	--	330	206	330	206	4.21
Montana	16,906	168	16,996	97	0	--	33,901	134	0.57
New Mexico	9,206	157	17,894	141	0	--	27,099	147	0.70
North Dakota	0	--	25,227	74	523	77	25,750	74	1.15
Ohio	2	138	1,794	120	26,471	143	28,267	142	2.81
Oklahoma	2	43	1	23	35	110	38	106	2.68
Pennsylvania	1,390	163	28,885	145	14,863	127	45,138	140	1.54
Tennessee	128	130	1,678	139	162	110	1,968	136	1.07
Texas	0	--	30,763	112	21,075	123	51,839	116	1.66
Utah	15,091	119	9	82	0	--	15,100	119	0.41
Virginia	4,213	169	12,388	161	103	125	16,704	163	0.82
Washington	19	127	4,545	138	0	--	4,564	138	0.96
West Virginia	25,295	169	33,775	148	16,370	142	75,440	154	1.13
Wyoming	189,065	126	12,792	95	0	--	201,858	124	0.42
Imports	**3,816**	**153**	**811**	**153**	**0**	**--**	**4,628**	**153**	**0.54**
U.S. Total	**315,605**	**140**	**287,494**	**140**	**165,919**	**134**	**769,018**	**139**	**1.14**

-- = Not applicable.

Notes: Totals may not equal sum of components because of independent rounding. MM Btu = million British thermal units.

Source: Energy Information Administration, *Quarterly Coal Report October-December 1993*, DOE/EIA-0121(93/4Q) (Washington, DC, May 1994).

Table 39. U.S. Electricity Generation by Energy Source, Selected Years, 1980, 1985, 1990-1993
(Billion Kilowatthours)

Energy Source	1980	1985	1990	1991	1992	1993
Coal	1,162	1,402	1,560	1,551	1,576	1,639
Natural Gas	346	292	264	264	264	259
Petroleum	246	100	117	111	89	100
Nuclear Power	251	384	577	613	619	610
Hydroelectric Power	276	281	280	276	240	265
Geothermal Energy	5	9	9	8	8	8
Other[a]	[b]	1	2	2	2	2
Total	**2,286**	**2,470**	**2,808**	**2,825**	**2,797**	**2,883**

[a]Wood, waste, wind, photovoltaic, and solar.

[b]Less than 1 billion kilowatthours.

Note: Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, *Monthly Energy Review June 1994*, DOE/EIA-0035(94-06) (Washington, DC, June 1994).

Table 40. Major U.S. Coal-Carrying Railroad Systems, 1993

Railroad System	Coal Originated[a] (million short tons)	Percent of Total
Burlington Northern Railroad Company	148.8	27.9
CSX Transportation	148.2	27.8
Norfolk Southern Corporation	110.4	20.7
Consolidated Rail Corporation	41.4	7.8
Denver, Rio Grand & Western	22.7	4.3
Illinois Central Railroad Company	17.1	3.2
Union Pacific Railroad Company	15.8	3.0
Atchison, Topeka & Santa Fe	14.1	2.6
Soo Line	9.6	1.8
Top Nine	528.1	99.0
Others	5.5	1.0
Total	**533.6**	**100.0**

[a]"Originated" refers to coal that is loaded for the first time and begins its journey on a particular railroad.

Note: Totals may not equal sum of components because of independent rounding.

Source: Association of American Railroads, *Freight Commodity Statistics 1993.*

Table 41. U.S. Rail Transportation of Coal, 1980-1993

Year	Tons Originated[a] (million short tons)	Coal Revenue (million dollars)	Coal as Percent of Total Traffic	
			Tons	Revenue
1980	522	4,956	35.0	18.4
1981	528	5,977	36.3	20.2
1982	524	6,307	41.0	23.8
1983	494	5,969	38.2	22.4
1984	567	6,965	39.6	23.3
1985	538	6,556	40.8	23.2
1986	518	6,089	39.6	22.4
1987	523	6,096	38.1	22.1
1988	543	6,430	37.8	21.7
1989	551	6,581	39.3	22.4
1990	579	6,954	40.7	23.4
1991	560	6,903	40.5	23.5
1992	554	6,717	39.6	22.6
1993	534	6,481	38.2	21.4

[a]"Originated" refers to coal that is loaded for the first time and begins its journey on a particular railroad.

Note: Revenue is in current dollars.

Sources: Association of American Railroads, Economics and Finance Department, *Railroad Ten-Year Trends*, Volume No. 3 (1986), *Railroad Ten-Year Trends*, Volume No. 10 (1993), and *Freight Commodity Statistics 1993.*

Table 42. Coal Handled and Revenue Received by Major U.S. Coal-Carrying Railroads, 1993

Railroad	Coal Originated[a] Amount (million short tons)	Coal Originated[a] Share of All Commodities (percent)	Coal Revenues Amount (million dollars)	Coal Revenues Share of All Commodities (percent)
Burlington Northern	148.8	55.2	1,575.9	32.0
CSX Corporation	148.2	49.6	1,464.8	29.9
Norfolk Southern	110.4	52.5	1,257.8	32.9
Consolidated Rail Corporation	41.4	32.8	491.7	14.3
Denver, Rio Grande & Western	22.7	84.3	144.2	40.1
Illinois Central Gulf	17.1	34.6	71.1	12.7
Union Pacific	15.8	10.4	872.9	16.8
Atchison, Topeka & Santa Fe	14.1	17.8	223.3	8.7
Soo Line	9.6	27.5	60.4	9.1

[a]"Originated" refers to coal that is loaded for the first time and begins its journey on a particular railroad.
Source: Association of American Railroads, *Freight Commodity Statistics 1993.*

Table 43. U.S. Waterborne Traffic: Coal and Coal Coke as Compared with Other Fossil Fuels and Other Commodities, 1991
(Million Short Tons)

Commodity	Total[a]	Domestic Coastwise	Domestic Lakewise	Domestic Internal	Foreign Imports	Foreign Exports
Coal	331.8	13.5	18.1	180.0	2.7	113.8
Coal Coke	6.1	[b]	[b]	4.0	1.2	0.6
Crude Petroleum	464.3	122.8	0	45.5	293.0	0.1
Petroleum Products	420.8	108.0	2.0	110.6	96.1	55.9
Chemical and Related Products	216.5	22.9	0.3	80.5	26.3	72.7
Forest Products, Wood, and Chips	52.0	1.6	[b]	16.0	2.9	29.4
Pulp and Waste Paper	12.3	[b]	0	0.4	0.9	10.9
Soil, Sand, Gravel, Rock, and Stone	134.7	11.6	23.4	63.9	14.8	10.7
Iron Ore and Scrap	91.6	0.1	55.3	6.8	15.1	13.8
Non-Ferrous Ores and Scrap	30.9	0.1	[b]	4.6	21.6	4.6
Sulfur, Clay, and Salt	7.6	[b]	[b]	0.9	2.1	4.5
Primary Manufactured Goods	106.3	7.1	3.0	24.9	49.6	21.2
Food and Farm Products	263.9	8.3	0.9	88.7	22.6	143.2
All Manufactured Equipment	43.6	5.9	[b]	3.2	24.1	10.3
Waste and Scrap, Not Elsewhere Classified	11.1	0.5	[b]	6.9	0	0
Total[a]	**2,092.5**	**293.4**	**103.4**	**602.9**	**553.5**	**459.2**

[a]Total is greater than column sums because of commodity groups not included and greater than row sums because of local and intra territories not included.
[b]Less than 100,000 tons.
Source: U.S. Army Corps of Engineers, *The U.S. Waterway System—Facts* (January 1994).

Table 44. U.S. Coal Export Loading Terminals, 1990

Port/Terminal	Existing Annual Terminal Capacity (million short tons)	Storage Capacity	Serving Railroads
EAST COAST			
Philadelphia, PA			
Pier No. 124; Conrail	10.0	800 railcars	CONRAIL
Port Richmond Conrail	0.5	100,000 short tons	CONRAIL
Camden, NJ			
Broadway Terminal	0.5	500,000 short tons	CONRAIL
Baltimore, MD			
Curtis Bay Chessie System	12.0	100 railcars	CSX
Curtis Bay Co.	10.0	350,000 short tons	CSX
Consol Marine Terminal	10.0	750,000 short tons	CONRAIL, CSX
Norfolk, VA			
Pier 6	43.0	7,000 railcars	Norfolk Southern
Newport News, VA			
Pier 9	12.0	NA	CSX
Dominion Terminal	15.0	180 railcars/ 2.05 million short tons	CSX
Morehead City, NC			
North Carolina State Port Authority Bulk Facility	3.0	NA	Norfolk Southern
Charleston, SC			
Massey Coal Terminal	2.5	300 railcars/ 275,000 short tons	CSX; Norfolk Southern
Total	**118.5**	--	--
GULF COAST			
Mobile, AL			
McDuffie Island	23.0	2,000,000 short tons	Burlington Northern; CSX; Illinois Central; Norfolk Southern
Bulk Plant	2.0	1,200,000 short tons	Burlington Northern; CSX; Illinois Central; Norfolk Southern
Mississippi River			
Public Bulk Terminal (MRGO)[a]	5.0	750,000 metric tons	CSX; Illinois Central; Kansas City Southern; Norfolk Southern; Public Belt; Southern Pacific; Union Pacific
Electro-Coal	25.0	4,500,000 short tons	None
International Marine Terminal	15.0	1,500,000 short tons	None
At-Sea Operation	1.0[b]	--	--
Burnside, LA			
Burnside Terminal	6.0	475,000 metric tons	Illinois Central
Mid-Stream Operation			
Delta Trans, Cooper/T. Smith, Paulina, & Darrow	56.5	--	--

See footnotes at end of table.

Table 44. U.S. Coal Export Loading Terminals, 1990 (Continued)

Port/Terminal	Existing Annual Terminal Capacity (million short tons)	Storage Capacity	Serving Railroads
Lake Charles, LA			
Bulk Terminal # 1	4.5	325,000 short tons	Kansas City Southern; Southern Pacific; Union Pacific
Port Arthur, TX			
PABTEX	4.0	500,000 metric tons	Kansas City Southern
Houston, TX			
Bulk Materials Handling Plant	3.0	125 railcars	Atchison, Topeka and Santa Fe; Burlington Northern; Southern Pacific; Union Pacific
Bulk Dock 1	2.5	2,000 railcars	Corpus Christi Terminal Assn; Southern Pacific; Texas Mexican; Union Pacific
Bulk Dock 2	5.0	2,000 railcars	Corpus Christi Terminal Assn; Southern Pacific; Texas Mexican; Union Pacific
Total	**152.5**	--	--
WEST COAST			
Los Angeles, CA			
Berth 49-50	5.5	170,000 metric tons	Atchison Topeka and Santa Fe; Southern Pacific; Union Pacific
Long Beach, CA			
Pier G 214-215	1.0	50,000 tons/ 168 railcars	Atchison Topeka and Santa Fe; Southern Pacific; Union Pacific
Pier G 212-213	4.5		
Stockton, CA			
Bulk Terminal	2.2	2,000,000 short tons/ 300 railcars	Atchison Topeka and Santa Fe; Denver and Rio Grande Western; Southern Pacific; Union Pacific
Seward, AK			
Seward Coal Terminal	3.3	120,000 metric tons	Alaska Railroad
Total	**16.5**	--	--
GREAT LAKES[d]			
Con Rail Dock, Ashtabula	7.0	1,500,000 short tons	CONRAIL
Pittsburgh & Conneaut Dock Co., Conneaut	13.5	6,000,000 short tons	Bessemer & Lake Erie
Codan Marine, Erie	0.4	100,000 short tons	CONRAIL
Lower Lake Dock Co., Sandusky	7.5	1,000,000 short tons + railcars[c]	Norfolk Southern
Toledo Docks, Toledo	16.0	400,000 short tons	CONRAIL; CSX

See footnotes at end of table.

Table 44. U.S. Coal Export Loading Terminals, 1990 (Continued)

Port/Terminal	Existing Annual Terminal Capacity (million short tons)	Storage Capacity	Serving Railroads
Total Lake Erie Terminals	**44.4**	--	--
Other Coal Terminals			
KCBX South Chicago	8.0	450,000 short tons + railcars[c]	Belt Line Railway Co. of Chicago
Superior Midwest Energy Terminal Superior	18.0	7,000,000 short tons	Burlington Northern
Total Other Terminals	**26.0**	--	--
Grand Total Great Lakes Ports	**70.4**	--	--
U.S. TOTAL	**357.9**	--	--

[a]Terminal is actually on the Mississippi River Gulf Outlet.
[b]At-sea transfer capability from sea-going barges.
[c]Number of railcars not reported.
[d]Great Lakes ports are restricted in vessel size to the allowable St. Lawrence Seaway dock dimensions of 730 feet in length, 76 feet beam, and 26 feet draft.
-- = Not applicable.
NA = Not available.
Source: U.S. Department of Transportation, Maritime Administration, Office of Port and Intermodel Development, *Existing and Potential U.S. Coal Export Loading Terminals* (Washington, DC, January 1992).

Table 45. U.S. Coal Exports by Country of Destination, 1960-1993

(Million Short Tons)

Year	Canada	Brazil	Europe										Japan	Other	Total
			Belgium and Luxembourg	Denmark	France	Germany[a]	Italy	Netherlands	Spain	United Kingdom	Other	Total			
1960	12.8	1.1	1.1	0.1	0.8	4.6	4.9	2.8	0.3	0	2.4	17.1	5.6	1.3	38.0
1961	12.1	1.0	1.0	0.1	0.7	4.3	4.8	2.6	0.2	0	2.0	15.7	6.6	1.0	36.4
1962	12.3	1.3	1.3	[b]	0.9	5.1	6.0	3.3	0.8	[b]	1.8	19.1	6.5	1.0	40.2
1963	14.6	1.2	2.7	[b]	2.7	5.6	7.9	5.0	1.5	[b]	2.4	27.7	6.1	0.9	50.4
1964	14.8	1.1	2.3	[b]	2.2	5.2	8.1	4.2	1.4	[b]	2.6	26.0	6.5	1.1	49.5
1965	16.3	1.2	2.2	[b]	2.1	4.7	9.0	3.4	1.4	[b]	2.3	25.1	7.5	0.9	51.0
1966	16.5	1.7	1.8	[b]	1.6	4.9	7.8	3.2	1.2	[b]	2.5	23.1	7.8	1.0	50.1
1967	15.8	1.7	1.4	0	2.1	4.7	5.9	2.2	1.0	0	2.1	19.4	12.2	1.0	50.1
1968	17.1	1.8	1.1	[b]	1.5	3.8	4.3	1.5	1.5	[b]	1.9	15.5	15.8	0.9	51.2
1969	17.3	1.8	0.9	0	2.3	3.5	3.7	1.6	1.8	[b]	1.3	15.2	21.4	1.2	56.9
1970	19.1	2.0	1.9	[b]	3.6	5.0	4.3	2.1	3.2	[b]	1.8	21.8	27.6	1.2	71.7
1971	18.0	1.9	0.8	0	3.2	2.9	2.7	1.6	2.6	1.7	1.1	16.6	19.7	1.1	57.3
1972	18.7	1.9	1.1	[b]	1.7	2.4	3.7	2.3	2.1	2.4	1.1	16.9	18.0	1.2	56.7
1973	16.7	1.6	1.2	0	2.0	1.6	3.3	1.8	2.2	0.9	1.3	14.4	19.3	1.6	53.6
1974	14.2	1.3	1.1	0	2.7	1.5	3.9	2.6	2.0	1.4	0.9	16.1	27.3	1.8	60.7
1975	17.3	2.0	0.6	0	3.6	2.0	4.5	2.1	2.7	1.9	1.6	19.0	25.4	2.6	66.3
1976	16.9	2.2	2.2	[b]	3.5	1.0	4.2	3.5	2.5	0.8	2.1	19.9	18.8	2.1	60.0
1977	17.7	2.3	1.5	0.1	2.1	0.9	4.1	2.0	1.6	0.6	2.1	15.0	15.9	3.5	54.3
1978	15.7	1.5	1.1	[b]	1.7	0.6	3.2	1.1	0.8	0.4	2.2	11.0	10.1	2.5	40.7
1979	19.5	2.8	3.2	0.2	3.9	2.6	5.0	2.0	1.4	1.4	4.4	23.9	15.7	4.1	66.0
1980	17.5	3.3	4.6	1.6	7.8	2.5	7.1	4.7	3.4	4.1	6.0	41.9	23.1	6.0	91.7
1981	18.2	2.7	4.3	3.9	9.7	4.3	10.5	6.8	6.4	2.3	8.8	57.0	25.9	8.7	112.5
1982	18.6	3.1	4.8	2.8	9.0	2.3	11.3	5.9	5.6	2.0	7.6	51.3	25.8	7.5	106.3
1983	17.2	3.6	2.5	1.7	4.2	1.5	8.1	4.2	3.3	1.2	6.4	33.1	17.9	6.1	77.8
1984	20.4	4.7	3.9	0.6	3.8	0.9	7.6	5.5	2.3	2.9	5.3	32.8	16.3	7.2	81.5
1985	16.4	5.9	4.4	2.2	4.5	1.1	10.3	6.3	3.5	2.7	10.3	45.1	15.4	9.9	92.7
1986	14.5	5.7	4.4	2.1	5.4	0.8	10.4	5.6	2.6	2.9	8.4	42.6	11.4	11.4	85.5
1987	16.2	5.8	4.6	0.9	2.9	0.5	9.5	4.1	2.5	2.6	6.6	34.2	11.1	12.3	79.6
1988	19.2	5.3	6.5	2.8	4.3	0.7	11.1	5.1	2.5	3.7	8.5	45.1	14.1	11.3	95.0
1989	16.8	5.7	7.1	3.2	6.5	0.7	11.2	6.1	3.3	4.5	8.9	51.6	13.8	12.9	100.8
1990	15.5	5.8	8.5	3.2	6.9	1.1	11.9	8.4	3.8	5.2	9.5	58.4	13.3	12.7	105.8
1991	11.2	7.1	7.5	4.7	9.5	1.7	11.3	9.6	4.7	6.2	10.4	65.5	12.3	13.0	109.0
1992	15.1	6.4	7.2	3.8	8.1	1.0	9.3	9.1	4.5	5.6	8.5	57.3	12.3	11.4	102.5
1993	8.9	5.2	5.2	0.3	4.0	0.5	6.9	5.6	4.1	4.1	6.9	37.6	11.9	10.9	74.5

[a]Through 1990, the data for Germany are for the former West Germany only. Beginning with 1991, the data for Germany are for the unified Germany, the former East Germany and West Germany.

[b]Less than 50,000 tons.

Note: Totals may not equal sum of components because of independent rounding.

Source: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994).

Table 46. U.S. Bituminous Coal Exports by Grade of Coal, 1975-1993
(Thousand Short Tons)

Year	Metallurgical	Steam	Total
1975	51,587	14,072	65,669
1976	47,804	11,602	59,406
1977	41,891	11,796	53,687
1978	30,240	9,585	39,825
1979	50,698	14,085	64,783
1980	63,103	26,779	89,882
1981	65,234	45,010	110,243
1982	64,585	40,659	105,244
1983	49,964	26,905	76,870
1984	56,975	23,818	80,793
1985	60,313	31,048	91,361
1986	54,977	29,040	84,017
1987	51,679	26,713	78,392
1988	61,950	32,057	94,007
1989	65,128	34,910	100,038
1990	63,459	41,578	105,037
1991	64,652	43,832	108,484
1992	59,446	42,509	101,954
1993	49,687	24,359	74,046

Notes: Totals may not equal sum of components because of independent rounding.

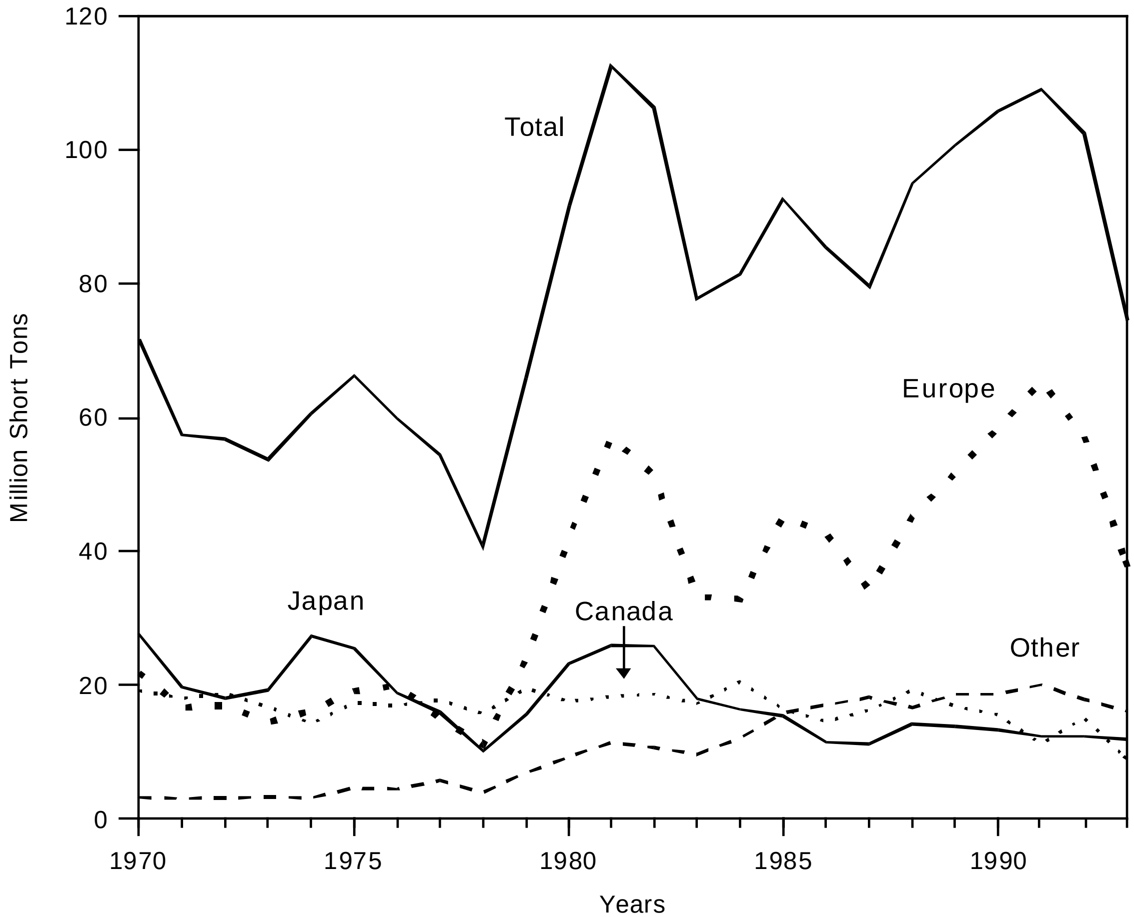
Sources: U.S. Department of Commerce, Bureau of the Census, “Monthly Report EM 522” (Washington, DC, 1974), and National Coal Association, *International Coal Review Annual 1994* (Washington, DC, 1974).

Table 47. U.S. Coal Produced for Export, by Origin and Destination, 1993
(Thousand Short Tons)

Coal-Producing State and Region of Origin	Destination		
	Canada	Overseas[a]	Total
Alabama	0	5,888	5,888
Alaska	0	743	743
Colorado	0	1,128	1,128
Illinois	0	670	670
Indiana	0	188	188
Kentucky Total	1,416	8,106	9,521
Eastern	1,416	7,902	9,318
Western	0	204	204
Maryland	0	295	295
Montana	54	67	121
Oklahoma	0	11	11
Pennsylvania Total	597	4,911	5,508
Anthracite	293	24	316
Bituminous	304	4,887	5,192
Utah	346	2,613	2,959
Virginia	1,229	13,021	14,251
Washington	1	93	94
West Virginia Total	4,108	29,052	33,159
Northern	920	1,607	2,527
Southern	3,187	27,445	30,632
Wyoming	0	974	974
Appalachian Total	**7,350**	**61,069**	**68,419**
Interior Total	**0**	**1,073**	**1,073**
Western Total	**401**	**5,617**	**6,018**
East of the Mississippi River	**7,350**	**62,131**	**69,481**
West of the Mississippi River	**401**	**5,628**	**6,030**
U.S. Total	**7,751**	**67,759**	**75,510**

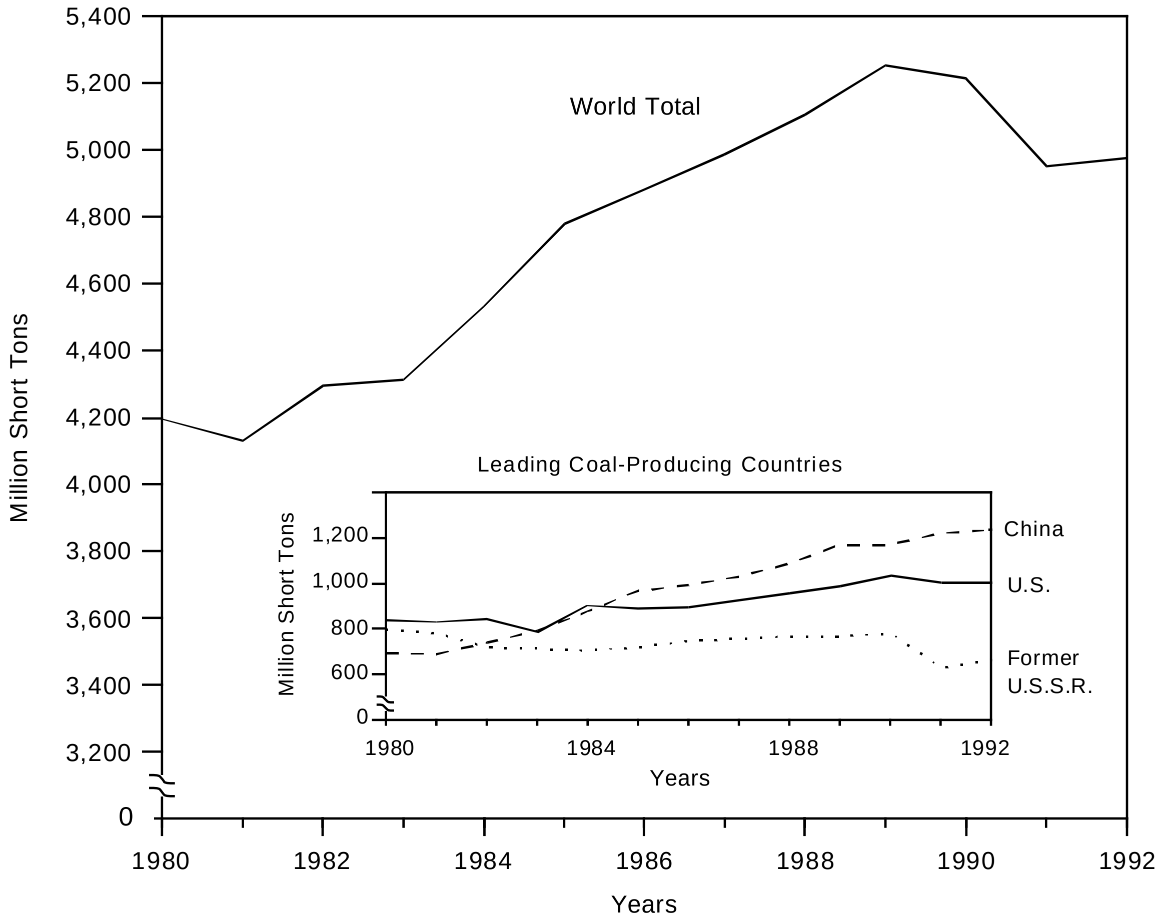
[a]Also includes Mexico.
Note: Totals may not equal sum of components because of independent rounding.
Source: Energy Information Administration, Form EIA-6, “Coal Distribution Report.”

Figure 35. U.S. Coal Exports, 1970-1993



Source: Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994).

Figure 36. World Coal Production and Leading Coal-Producing Countries, 1980-1992

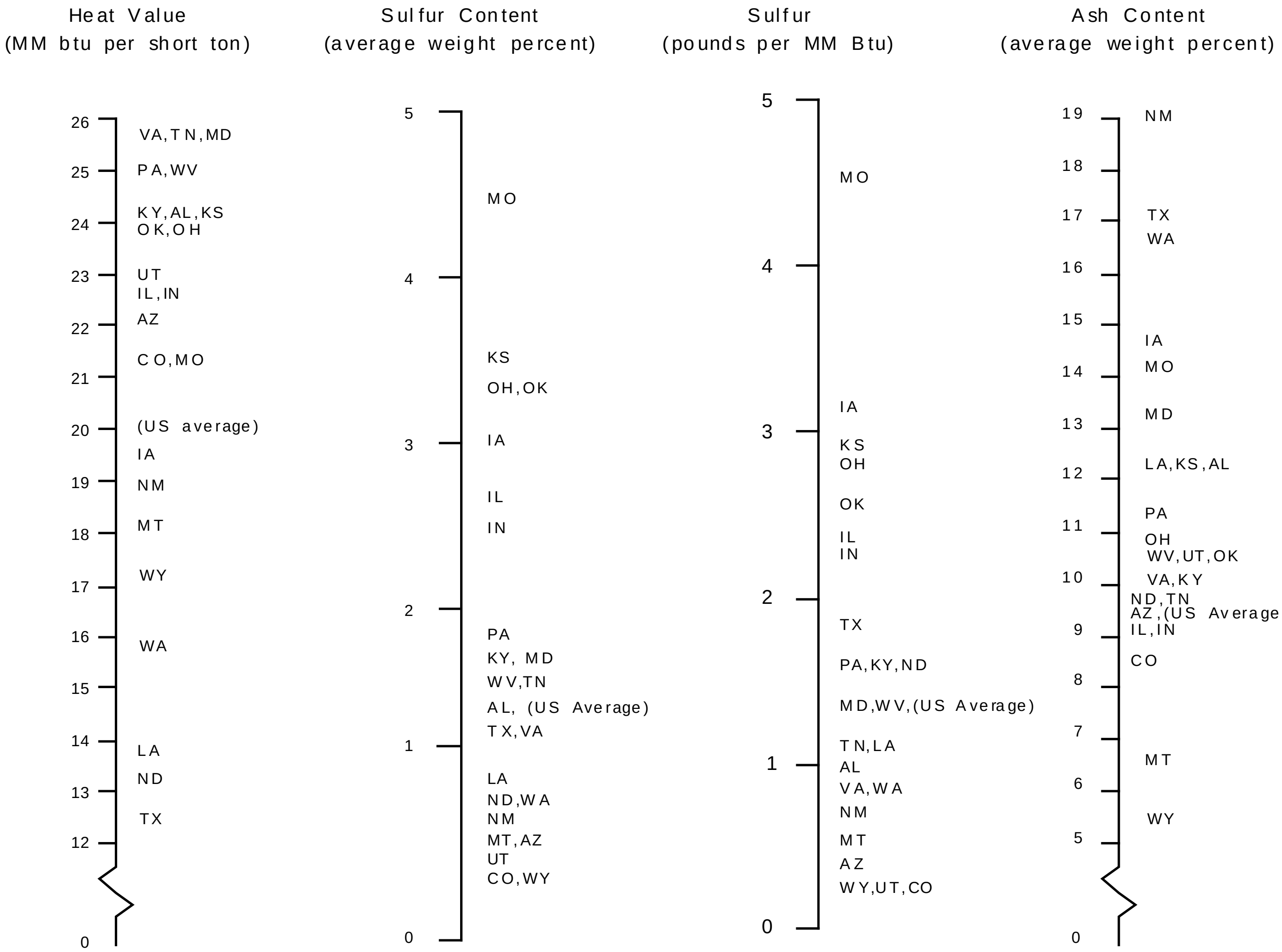


World coal production rose from about 4.2 billion tons in 1980 to a record 5.3 billion tons in 1989 and was about 5.0 billion tons in 1992. The United States is a major coal producer; it ranked first from 1980 through 1982 and again in 1984.

Note: Coal production in 1992 from countries that composed the former U.S.S.R. was as follows, in million short tons: Kazakhstan, 139; Russia, 372; Ukraine, 148.

Source: Energy Information Administration, *International Energy Annual 1992*, DOE/EIA-0219(92) (Washington, DC, January 1994).

Figure 37. Average Quality of Coal Produced for Power Plants by Producing State, 1993



Note: MMBtu = million British thermal units.
Source: Energy Information Administration, *Cost and Quality of Fuels for Electric Utility Plants 1993*, DOE/EIA-0191(93) (Washington, DC, July 1994).

Figure 38. Cost and Quality of Coal Shipped to Electric Utilities, by Origin, 1993

Lignite (LA, MT, ND, TX)

Btu/lb: 6,374
Sulfur:
Percent by Weight 0.94
Pounds per Million Btu 1.51
Ash, Percent by Weight: 14.43
Delivered Cost:
Per Million Btu $1.04
Per Short Ton $13.25
Quantity: 80.9 Million Short Tons

Western Region

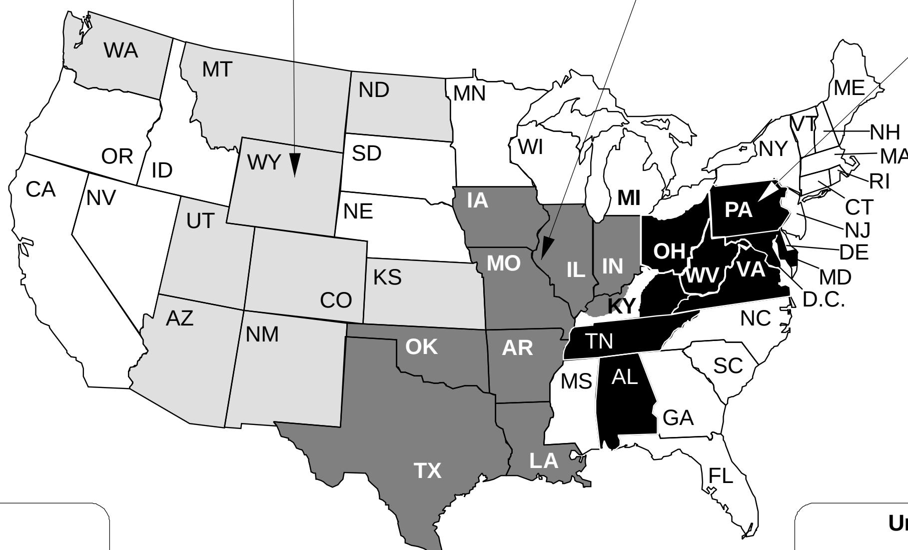
Btu/lb: 9,112
Sulfur:
Percent by Weight 0.43
Pounds per Million Btu 0.47
Ash, Percent by Weight: 7.42
Delivered Cost:
Per Million Btu $1.27
Per Short Ton: $23.23
Quantity: 312.6 Million Short Tons

Interior Region (Excludes Lignite)

Btu/lb: 11,383
Sulfur:
Percent by Weight 2.72
Pounds per Million Btu 2.41
Ash, Percent by Weight: 9.86
Delivered Cost:
Per Million Btu $1.34
Per Short Ton: $30.60
Quantity: 98.5 Million Short Tons

Appalachian Region

Btu/lb: 12,451
Sulfur:
Percent by Weight 1.57
Pounds per Million Btu 1.27
Ash, Percent by Weight: 10.49
Delivered Cost:
Per Million Btu $1.54
Per Short Ton: $38.41
Quantity: 272.5 Million Short Tons



Imports

Btu/lb: 12,019
Sulfur:
Percent by Weight 0.65
Pounds per Million Btu 0.54
Ash, Percent by Weight: 6.78
Delivered Cost:
Per Million Btu $1.53
Per Short Ton $36.82
Quantity: 4.6 Million Short Tons

United States

Btu/lb: 10,315
Sulfur:
Percent by Weight 1.18
Pounds per Million Btu 1.11
Ash, Percent by Weight: 9.55
Delivered Cost:
Per Million Btu $1.38
Per Short Ton $28.58
Quantity: 769.2 Million Short Tons

Coal was mined in 26 States in 1993.

Source: Energy Information Administration, *Cost and Quality of Fuels for Electric Utility Plants 1993*, DOE/EIA-019(93) (Washington, DC, July 1994).

Table 48. U.S. Air Pollutant Emission Estimates from Coal Combustion as Compared with Total Emissions and Total Coal Consumption, Selected Years, 1970, 1980, 1990-1992
(Million Short Tons)

Emission/Source	1970	1980	1990	1991	1992
Sulfur Oxides Total	31.3	26.2	22.8	22.8	22.7
Coal	19.3	[a]	17.3	17.1	17.3
Nitrogen Oxides Total	20.9	23.7	23.6	23.4	23.1
Coal	4.3	6.1	7.3	7.3	7.3
Carbon Monoxide Total	118.7	129.0	92.4	90.7	87.2
Coal	0.7	0.3	0.3	0.3	0.3
Reactive Volatile Organic Compounds Total[b]	29.7	28.4	23.7	23.4	22.7
Coal	0.1	[c]	[c]	[c]	[c]
Particulates (PM-10) Total[d]	12.1[e]	7.0[e]	50.8	55.4	51.4
Coal	0.2	0.1	0.2	0.2	0.2
Coal Consumption	523.2	702.7	895.5	887.6	892.4
Electric Utilities (percent)	61.2	81.0	86.4	87.0	87.4

[a]Data not detailed for coal and other fossil fuels, but contained in aggregate estimate.
[b]These compounds along with nitrogen oxides contribute to the formation of ozone and other photochemical oxidants in the atmosphere.
[c]Less than .05 million short tons.
[d]Less than 10 microns in aerodynamic diameter.
[e]Excludes fugitive dust from sources such as agricultural tilling, construction activities, mining and quarrying, and wind erosion.
Notes: Estimate for 1990-1992 are preliminary. Emissions of lead from coal combustion totaled less than 100 short tons in recent years.
Sources: U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends, 1900-1992* (October 1993); and Energy Information Administration, *Annual Energy Review 1993*, DOE/EIA-0384(93) (Washington, DC, July 1994).

Table 49. U.S. Utility Coal Combustion Byproducts: Production and Use, 1992
(Million Short Tons)

Production/Use	Fly Ash	Bottom Ash	Boiler Slag	Flue Gas Desulfurization Material
Byproduct Production[a]	48.1	13.9	4.1	15.9
Byproduct Use				
External Markets				
Cement and Concrete Products	7.1	0.5	0.3	0
Structural Fill	0.8	0.3	0.2	0
Road Base/Subbase	1.2	0.4	[b]	[b]
Mineral Filler in Asphalt	0.2	0.2	0.1	0
Snow and Ice Control	0	0.5	0.3	0
Blasting Grit/Roofing Granules	0	[b]	2.0	0
Grouting	[b]	0	0	0
Coal Mining Applications	[b]	[b]	0	0
Wall Board	0	0	0	0.2
Waste Stabilization	0.5	[b]	[b]	[b]
Other	0.5	[b]	0	[b]
Subtotal	**10.4**	**1.9**	**3.0**	**0.3**
Internal Utility Applications				
Cement and Concrete Products	[b]	0	0	0
Structural Fill	1.3	0.1	[b]	0
RoadBase/Subbase	[b]	0.6	[b]	[b]
Snow and Ice Control	0	[b]	[b]	0
Other	1.4	1.2	[b]	0
Subtotal	**2.7**	**1.9**	[b]	[b]
Total	**13.1**	**3.9**	**3.1**	**0.3**

[a]Based on consumption of 779.8 million short tons.
[b]Less than 100,000 short tons.
Note: Totals may not equal sum of components because of independent rounding.
Source: American Coal Ash Association.

Table 50. Trace Elements in U.S. Coal: Highest Average Concentration by Rank and Widest Range by Region and Rank of Coal

Trace Element[a]	Chemical Symbol	Highest Average		Widest Range	
		Average (parts per million)	Coal Rank	Amount (parts per million)	Region and Coal Rank
Antimony	Sb	1.2	Bituminous	0.04-43	Rocky Mountain subbituminous
Arsenic	As	23	Lignite	0.2-420	Northern Plains subbituminous
Beryllium	Be	2.2	Bituminous	0.08-32	Rocky Mountain subbituminous
Cadmium	Cd	0.9	Bituminous	0.01-170	Interior bituminous
Chlorine	Cl	NA	NA	50-8,000	Appalachian bituminous
Chromium	Cr	47	Anthracite	1.5-220	Appalachian bituminous
Cobalt	Co	9.7	Bituminous	0.7-930	Appalachian bituminous
Fluorine	F	191	Lignite	20-1,900	Appalachian bituminous
Lead	Pb	14	Bituminous	0.78-590	Interior bituminous
Manganese	Mn	300	Lignite	1.4-3,500	Rocky Mountain subbituminous
Mercury	Hg	0.23	Anthracite	0.01-12	Northern Plains lignite
Nickel	Ni	28	Anthracite	0.87-580	Interior bituminous
Phosphorus	P	1,800	Lignite	<4-6,000	Appalachian bituminous
Selenium	Se	3.4	Bituminous	0.12-150	Appalachian bituminous
Thorium	Th	7.1	Lignite	0.04-79	Interior bituminous
Uranium	U	3.4	Lignite	0.06-76	Rocky Mountain subbituminous

[a]Elements identified as hazardous air pollutants by the Clean Air Act, as amended in 1990.

Note: 100 parts per million = 0.01 percent; 1,000 parts per million = 0.1 percent. When coal is burned in a power plant, the trace elements are concentrated as follows: in fly ash—Sb, As, Be, Cd, Cr, Ni, Pb, and Se; in both fly ash and bottom ash—Co, Mn, Th, U, and probably P; as a vapor—Cl, F, and Hg.

NA = Not available.

Source: U.S. Department of Energy, Argonne National Laboratory, Environmental Assessment and Information Sciences Division, *Air Toxic Emissions from the Combustion of Coal: Identifying and Quantifying Hazardous Air Pollutants from U.S. Coals*, ANL/EAIS/TM-83 (Argonne, IL, September 1992).

Table 51. Classification of Coals by Rank

Coal Rank	Coal Group	Basis of Classification		
Coals Classified by Fixed Carbon		**Fixed Carbon Percentage[a]**		
		Equal to or Greater than	Less than	**Agglomerating Character**
I. Anthracite	1. Meta-anthracite	98	--	Non-agglomerating
	2. Anthracite	92	98	Non-agglomerating
	3. Semianthracite[b]	86	92	Non-agglomerating
II. Bituminous	1. Low-volatile bituminous	78	86	Commonly agglomerating[c]
	2. Medium-volatile bituminous	[d]69	78	Commonly agglomerating[c]
	3. High-volatile A bituminous	--	[d]69	Commonly agglomerating[c]
		Heat Content in Btu per Pound[e]		
Coals Classified by Heat Content		Equal to or Greater than	Less than	
II. Bituminous	4. High-volatile B bituminous	13,000	14,000	Commonly agglomerating[c]
	5. High-volatile C bituminous	11,500	13,000	Commonly agglomerating[c]
	6. High-volatile C bituminous	10,500	11,500	agglomerating
III. Subbituminous	1. Subbituminous A	10,500	11,500	Non-agglomerating
	2. Subbituminous B	9,500	10,500	Non-agglomerating
	3. Subbituminous C	8,300	9,500	Non-agglomerating
IV. Lignitic	1. Lignite A	6,300	8,300	Non-agglomerating
	2. Lignite B	--	6,300	Non-agglomerating

[a]Percentages are based on dry-mineral-matter-free coal. Volatile matter (not shown) is the complement of fixed carbon; that is, the percentages of fixed carbon and volatile matter sum to 100 percent. Therefore, as fixed carbon percentage decreases, volatile matter percentage increases by the same amount.

[b]If agglomerating, classify in low-volatile group of the bituminous class.

[c]There may be nonglomerating varieties in the bituminous class, most notable in the high-volatile C bituminous group.

[d]Coals having 69 percent or more fixed carbon are classified according to fixed carbon, regardless of Btu value. Coals with less than 69 percent fixed carbon, but with 14,000 or more Btu per pound, are classified as high-volatile A bituminous.

[e]Calorific values in Btu per pound, on a moist-mineral-matter-free basis.

Note: Terms in this table are defined in the Glossary.

Source: Adapted from American Society for Testing and Materials 1988, Standard Classification of Coal by Rank, ASTM Designation D388-84.

Table 52. Approximate Weights of Unbroken (Solid) Coal in the Ground

Coal Rank	Pounds per Cubic Foot	Tons per Acre-Foot	Tons per Square Mile-Foot
Anthracite	91.7	2,000	1,280,000
Bituminous Coal	82.4	1,800	1,150,000
Subbituminous Coal	81.1	1,770	1,130,000
Lignite	80.5	1,750	1,120,000

Notes: The weight of broken coal varies with the size of the coal. In general, a cubic foot of broken bituminous coal weighs 47 to 52 pounds and a cubic foot of broken anthracite weighs 52 to 56 pounds. (By comparison, a cubic foot of water weighs 62.4 pounds, and a cubic foot of limestone weighs about 165 pounds.) A ton of broken coal occupies approximately 40 cubic feet.

Source: U.S. Department of the Interior, U.S. Geological Survey, Bulletin 1412, *Coal Resources of the United States,* (Washington, DC, 1975).

Table 53. Representative Analyses of U.S. Coal

Classification by Rank	State/County	Bed	Type Sample[a]	Proximate Percent: Moisture	Volatile Matter	Fixed Carbon	Ash	Ultimate Percent[a]: Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calorific Value, Btu per pound
Meta-anthracite . .	Rhode Island	Middle	1	13.2	2.6	65.3	18.9	0.3	1.9	64.2	0.2	14.5	9,310
	Newport		2	--	2.9	75.3	21.6	0.3	0.5	74.1	0.2	3.1	10,740
			3	--	3.8	96.2	--	0.4	0.6	94.7	0.3	4.0	13,720
Anthracite	Pennsylvania	Clark	1	4.3	5.1	81.0	9.6	0.8	2.9	79.7	0.9	6.1	12,880
	Lackawana		2	--	5.3	84.6	10.1	0.8	2.5	83.3	0.9	2.4	13,470
			3	--	5.9	94.1	--	0.9	2.8	92.5	1.0	2.8	14,980
Semianthracite . .	Arkansas	Lower	1	2.6	10.6	79.3	7.5	1.7	3.8	81.4	1.6	4.0	13,880
	Johnson	Hartshorne	2	--	10.8	81.5	7.7	1.8	3.6	83.6	1.6	1.7	14,240
			3	--	11.7	88.3	--	1.9	3.9	90.6	1.8	1.8	15,430
Low-volatile Bituminous Coal	West Virginia	Pocahontas	1	2.9	17.7	74.0	5.4	0.8	4.6	83.2	1.3	4.7	14,400
	Wyoming	No. 3	2	--	18.2	76.3	5.5	0.8	4.4	85.7	1.3	2.3	14,830
			3	--	19.3	80.7	--	0.8	4.6	90.7	1.4	2.5	15,690
Medium-volatile Bituminous Coal	Pennsylvania	Upper	1	2.1	24.4	67.4	6.1	1.0	5.0	81.6	1.4	4.9	14,310
	Clearfield	Kittanning	2	--	24.9	68.8	6.3	1.1	4.8	83.3	1.5	3.0	14,610
			3	--	26.5	73.5	--	1.1	5.2	88.9	1.6	3.2	15,590
High-volatile A Bituminous Coal	West Virginia	Pittsburgh	1	2.3	36.5	56.0	5.2	0.8	5.5	78.4	1.6	8.5	14,040
	Marion		2	--	37.4	57.2	5.4	0.8	5.4	80.2	1.6	6.6	14,370
			3	--	39.5	60.5	--	0.8	5.7	84.8	1.7	7.0	15,180
High-volatile B Bituminous Coal	Kentucky	No. 9	1	8.5	36.4	44.3	10.8	2.8	5.4	65.1	1.3	14.6	11,680
	(Western field)		2	--	39.8	48.5	11.7	3.0	4.9	71.2	1.5	7.7	12,760
	Muhlenburg		3	--	45.0	55.0	--	3.4	5.5	80.6	1.7	8.8	14,460
High-volatile C Bituminous Coal	Illinois	No. 5	1	14.4	35.4	40.6	9.6	3.8	5.8	59.7	1.0	20.1	10,810
	Sangamon		2	--	41.4	47.4	11.2	4.4	4.9	69.8	1.2	8.5	12,630
			3	--	46.6	53.4	--	5.0	5.6	78.6	1.3	9.5	14,230
Subbituminous A Coal	Wyoming	No. 3	1	16.9	34.8	44.7	3.6	1.4	6.0	60.4	1.2	27.4	10,650
	Sweetwater		2	--	41.8	53.8	4.4	1.7	4.9	72.7	1.5	14.8	12,810
			3	--	43.7	56.3	--	1.8	5.2	76.0	1.5	15.5	13,390
Subbituminous B Coal	Wyoming	Monarch	1	22.2	33.2	40.3	4.3	0.5	6.9	53.9	1.0	33.4	9,610
	Sheridan		2	--	42.7	51.7	5.6	0.6	5.6	69.3	1.2	17.7	12,350
			3	--	45.2	54.8	--	0.6	6.0	73.4	1.3	18.7	13,080
Subbituminous C Coal	Wyoming	Wyodak	1	26.6	33.2	34.4	5.8	0.6	6.5	50.0	0.9	36.2	8,630
	Campbell		2	--	45.2	46.9	7.9	0.8	4.8	67.6	1.2	17.7	11,760
			3	--	49.1	50.9	--	0.9	5.0	73.3	1.3	19.5	12,780
Lignite	North Dakota	Unnamed	1	36.8	27.8	29.5	5.9	0.9	6.9	40.6	0.6	45.1	7,000
	McLean		2	--	43.9	46.7	9.4	1.4	4.5	64.3	1.0	19.4	11,080
			3	--	48.4	51.6	--	1.6	5.0	70.9	1.1	21.4	12,230

[a]1. Sample as received 2. Moisture-free 3. Moisture- and ash-free.

-- = Not applicable.

Notes: Source and analysis of coal were selected to represent the various ranks of the specifications for classification of rank adopted by the American Society for Testing and materials.

Sources: U.S. Department of the Interior, Bureau of Mines; and Wyoming State Geological Survey (Wyodak bed).

Table 54. Standard Anthracite Specifications

State	State Round Test Mesh (inches)	Percent				
		Undersize		Maximum Impurities[a]		
		Maximum	Minimum	State	Bone	Ash[b]
Broken	Through 4-3/8	--	--	1-1/2	2	11
	Over 3-1/4 to 3	15	7-1/2	--	--	--
Egg	Through 3-1/4 to 3	--	--	1-1/2	2	11
	Over 2-7/16	15	7-1/2	--	3	11
Stove	Through 2-7/16	--	--	2	3	11
	Over 1-5/8	15	7-1/2	--	--	--
Chestnut	Through 1-5/8	--	--	3	4	11
	Over 13/16	15	7-1/2	--	--	--
Pea	Through 13/16	--	--	4	5	12
	Over 9/16	15	7-1/2	--	--	--
Buckwheat No. 1	Through 9/16	--	--	--	--	13
	Over 5/16	15	7-1/2	--	--	--
Buckwheat No. 2 (rice)	Through 5/16	--	--	--	--	13
	Over 3/16	17	7-1/2	--	--	--
Buckwheat No. 3 (barley)	Through 3/16	--	--	--	--	15
	Over 3/32	20	10	--	--	--
Buckwheat No. 4	Through 3/32	--	--	--	--	15
	Over 3/64	30	10	--	--	--
Buckwheat No. 5	Through 3/64	No limit	--	--	--	16

[a]When slate content in the sizes from broken to chestnut, inclusive, is less than above standards, bone content may be increased by 1-1/2 times the decrease in slate content under the allowable limits, but slate content specified above shall not be exceeded in any event. A tolerance of 1 percent is allowed on maximum percentage of undersize and maximum percentage of content. Maximum percentage of undersize is applicable only to anthracite as it is produced at preparation plant. Slate is defined as any material that has less than 40 percent fixed carbon. Bone is defined as any material that has 40 percent or more, but less than 75 percent, fixed carbon.

[b]Ash determinations are on a dry basis.

Note: Standard anthracite specifications as approved and adopted by the Anthracite Committee, an agency of the Commonwealth of Pennsylvania, effective July 28, 1947, and amended July 20, 1953. Approximate size classification for bituminous coal are: Run-of-mine, 8 inches; lump, 5 inches; egg, 2 to 5 inches; nut 1-1/4 to 2 inches; stoker, 3/4 to 1-1/4 inches; slack, less than 3/4 inches.

-- = Not applicable.

Source: U.S. Department of the Interior, Bureau of Mines, “Anthracite,” *Mineral Facts and Problems*, Washington, DC, 1965.

Coal Terminology and Related Information

An electric drill prepares overburden for blasting by boring holes in a prescribed pattern, making it easier to excavate. The spoil pile in the background is overburden removed from another part of the mine.

Coal Terminology and Related Information

Acid Mine Drainage: This refers to water pollution that results when sulfur-bearing minerals associated with coal are exposed to air and water and form sulfuric acid and ferrous sulfate. The ferrous sulfate can further react to form ferric hydroxide, or *yellowboy*, a yellow-orange iron precipitate found in streams and rivers polluted by acid mine drainage.

Acid Rain: Also called *acid precipitation* or *acid deposition*, acid rain is precipitation containing harmful amounts of nitric and sulfuric acids formed primarily by nitrogen oxides and sulfur oxides released into the atmosphere when fossil fuels are burned. It can be wet precipitation (rain, snow, or fog) or dry precipitation (absorbed gaseous and particulate matter, aerosol particles, or dust). Acid rain has a pH below 5.6. Normal rain has a pH of about 5.6, which is slightly acidic. The term pH is a measure of acidity or alkalinity on a range from 0 to 14. Readings below 7, which is neutral, indicate increased acidity; readings above 7 indicate increased alkalinity.

As-Received Coal: Coal in the condition as received by the consumer or the laboratory analyzing the coal.

Bone Coal: Coal with a high ash content (25 to 50 percent, by weight); it is dull in appearance, hard, and compact.

Btu (British thermal unit): A measure of energy, the Btu is the amount of heat needed to raise the temperature of 1 pound of water (approximately 1 pint) by 1 degree Fahrenheit. The Btu is a convenient measure by which to compare the energy content of various fuels. One Btu of energy is approximately equivalent to the heat from one match tip. Heat available from coal, expressed as Btu per pound or ton, is a major factor in coal price.

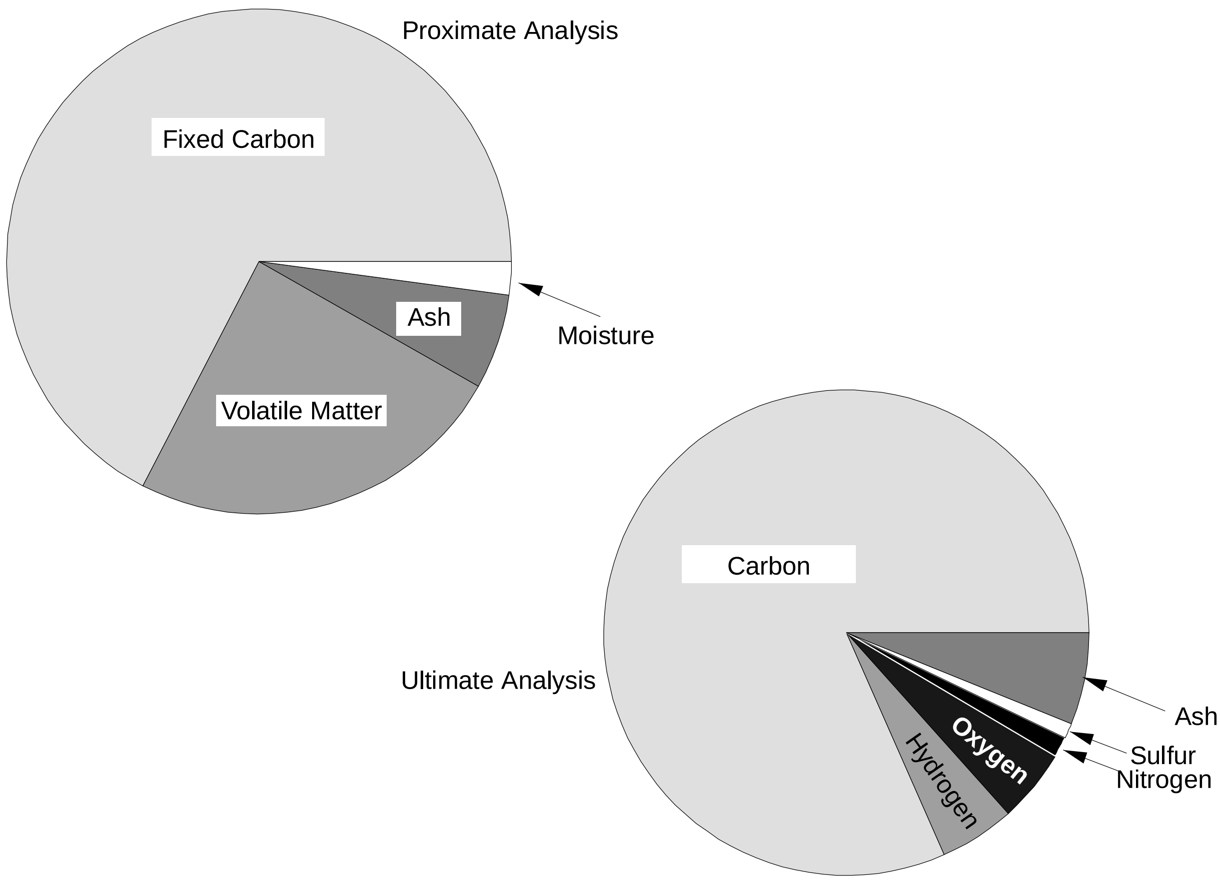
Captive Coal: This refers to coal produced and consumed by the mine operator, a subsidiary, or the parent company (for example, steel companies and electric utilities).

Coal Analysis: This determines the composition and properties of coal so it can be ranked and used most effectively.

Proximate analysis determines the behavior of a coal when burned. It measures (in percent) the moisture content, volatile matter (gases released when coal is heated, principally hydrogen, carbon dioxide, carbon monoxide, and various compounds of carbon and hydrogen), fixed carbon (solid combustible residue remaining after the volatile matter is driven off—principally carbon, but may contain sulfur, hydrogen, nitrogen, and oxygen), and ash (incombustible matter consisting of silica, iron, alumina, and other material similar to ordinary sand, silt, and clay). The moisture content affects the ease with which coal can be handled and burned. Volatile matter and fixed carbon provide guidelines for determining the intensity of the heat produced (volatile matter influences the ignitability and overall combustion of a coal and contributes about 25 to 40 percent of the heat; fixed carbon, 60 to 75 percent). Ash increases the weight of coal, adds to the cost of handling, and can cause fuel bed and furnace problems due to the formation of clinkers (fused ash) and slag (melted ash that sticks to furnace walls). Proximate analysis may be reported in several ways, such as "as received," "dry," and "dry, mineral-matter-free (dmmf)." Proximate analysis is commonly used in industrial applications, such as in the purchase of coal for electricity generation.

Ultimate analysis determines the percentage of carbon, hydrogen, oxygen, nitrogen, sulfur, and ash. It may be reported in several ways, such as "as received," "dry," and "dry, mineral-matter-free (dmmf)." Ultimate analysis is used for a more thorough scientific investigation of coal.

Heating value, or *heat content*, is determined in terms of Btu, both on an as-received basis (including moisture) and on a dry basis. It is the amount of heat released by the complete combustion of a specified quantity of coal (usually 1 pound or 1 short ton) as carbon and hydrogen combine with oxygen in the air to produce carbon dioxide and water. *Higher heating value (HHV), or gross heat content*, includes the amount of energy used to transform the water into steam. *Lower heating value, or net heat content,* excludes the energy used to vaporize the water and is generally calculated to be 93 to 97 percent of the gross heat value. EIA conversion factors typically represent gross heat content.



Two different types of analyses of a bituminous coal.

Agglomerating refers to coal that softens when heated and forms a hard gray coke; this coal is called *caking coal*. Not all caking coals are coking coals. The agglomerating value is used to differentiate between coal ranks and also is a guide to determine how a particular coal reacts in a furnace.

Agglutinating refers to the binding qualities of a coal. The agglutinating value is an indication of how well a coke made from a particular coal will perform in a blast furnace. It is also called a *caking index*.

Other analyses include the determination of the ash-softening temperature, the ash-fusion temperature (the temperature at which the ash forms clinkers or slag), the free-swelling index (a guide to a coal's coking characteristics), the Gray-King assay (determines the suitability of coal for making coke), and the Hardgrove Grindability Index, or HGI (a measure of the ease with which coal can be pulverized as compared with a "standard" coal with a 100 HGI value; the lower the index, the harder to grind and vice-versa). In a *petrographic analysis*, thin sections of coal or highly polished blocks of coal are studied with a microscope to determine the physical composition, both for scientific purposes and for estimating the rank and coking potential.

Coal Blending: The process of combining two or more coals with different characteristics to obtain coal with a certain quality, such as a low sulfur content.

Coal Chemicals: Coal chemicals are obtained from the gases and vapor recovered from the manufacturing of coke. Generally, crude tar, ammonia, crude light oil, and gas are the basic products recovered. They are refined or processed to yield a variety of chemical materials.

Coal Classification: In the United States, coals are classified by rank progressively from lignite (least carbonaceous) to anthracite (most carbonaceous) based on the proximate analyses of various properties (fixed carbon, volatile matter, heating value, and agglomerating character), following methods prescribed by the American Society for Testing and Materials. The International Coal Classification of the Economic Commission for Europe recognizes two broad categories of coal, "brown coal" and "hard coal." In terms of U.S. coal classification, the international classification of brown coal includes lignite and lower-ranked subbituminous coal, whereas hard coal includes all higher rank coals.

Coal Face: This is the exposed area from which coal is extracted.

Coal Fines: Coal with a maximum particle size usually less than one-sixteenth inch and rarely above one-eighth inch.

Coal Grade: This classification refers to coal quality and use. The classification includes the following categories:

Briquettes are made from compressed coal dust, with or without a binding agent such as asphalt.

Cleaned coal or *prepared coal* has been processed to reduce the amount of impurities present and improve the burning characteristics.

Compliance coal is a coal, or a blend of coal, that meets sulfur dioxide emission standards for air quality without the need for flue gas desulfurization.

Culm and silt are waste materials from preparation plants. In the anthracite region, culm consists of coarse rock fragments containing as much as 30 percent small-sized coal. Silt is a mixture of very fine coal particles (approximately 40 percent) and rock dust that has settled out from waste water from the plants. The terms culm and silt are sometimes used interchangeably and are sometimes called refuse. Culm and silt have a heat value ranging from 8 to 17 million Btu per ton.

Low-ash coal contains less than 8 percent ash by weight; *medium-ash coal*, 8 percent to less than 15 percent by weight; *high-ash coal*, more than 15 percent ash by weight.

Low-sulfur coal contains 1 percent or less sulfur by weight. For air quality standards, "low-sulfur coal" contains 0.6 pounds or less sulfur per million Btu (equivalent to 1.2 pounds of sulfur dioxide per million Btu). *Medium-sulfur coal* contains more than 1 percent to less than 3 percent sulfur by weight; 0.61 to 1.67 pounds of sulfur per million Btu. *High-sulfur coal* contains more than 3 percent sulfur by weight; more than 1.67 pounds of sulfur per million Btu.

Metallurgical coal (or coking coal) is a coal that can be converted into coke. It must have a low ash and sulfur content and form a coke that is strong enough to support the weight of iron ore and limestone in a blast furnace. A blend of two or more bituminous coals is usually required to make coke.

Pulverized coal is coal that has been crushed to a fine dust in a grinding mill. It is blown into the combustion zone of a furnace and burns very rapidly and efficiently.

Slack coal usually refers to bituminous coal one-half inch or smaller in size.

Steam coal refers to coal used in boilers to generate steam to produce electricity or for other purposes.

Stoker coal refers to coal that has been crushed to specific sizes (but not powdered) for burning on a grate in automatic firing equipment.

Coal Preparation (Cleaning/Beneficiation/Processing) Processes:
Dense (heavy) medium processes use a thick solution, usually a mixture of magnetite and water, to separate coal from impurities by gravity separation.

Flotation processes treat fine-sized coal with an oil-based reagent that attracts air bubbles in a liquid medium; the coal floats to the surface as a froth, leaving the refuse below.

Hydraulic processes use currents of water to separate coal from impurities.

Pneumatic processes use currents of air to separate coal from impurities.

Coal Rank: This classification is based on the fixed carbon, volatile matter, and heating value. It is an indication of the progressive alteration, or coalification, from lignite to anthracite. Rank can also be determined by measuring the *reflectance of vitrinite,* one of the several organic components (macerals) of coal.

Lignite, the lowest rank of coal, is brownish black and has a high moisture content, sometimes as high as 45 percent. It tends to disintegrate when exposed to weather. The heat content of lignite ranges from 9 to 17 million Btu per ton as received and averages about 14 million Btu per ton. The ignition temperature is approximately 600 degrees Fahrenheit. Lignite is mined in California, Louisiana, Montana, North Dakota, and Texas, and is used mainly to generate electricity in power plants that are relatively close to the mines. The term “lignite” is used interchangeably with “brown coal” in other countries.

Subbituminous coal, or *black lignite,* is dull black and usually contains 20 to 30 percent moisture. The heat content of subbituminous coal ranges from 16 to 24 million Btu per ton as received and averages about 18 million Btu per ton. Subbituminous coal, mined in western coal fields (notably the Powder River Basin), is used mostly for generating electricity.

Bituminous coal, or *soft coal,* is the most common coal. It is dense, black, often with well-defined bands of bright and dull material. Its moisture content usually is less than 20 percent. The heating value ranges from 19 to 30 million Btu per ton as received and averages about 24 million Btu per ton. The ignition temperature ranges from about 700 to almost 900 degrees Fahrenheit. Bituminous coal is mined chiefly in Appalachian and interior coal fields. It is used for generating electricity, making coke, and space heating.

Anthracite, or *hard coal,* is the highest rank of economically usable coal. It is jet black with a high luster. The moisture content generally is less than 15 percent. Anthracite contains approximately 22 to 28 million Btu per ton as received and averages about 25 million Btu per ton. Its ignition temperature is approximately 925 to 970 degrees Fahrenheit. Virtually all of the anthracite mined is from northeastern Pennsylvania. It is used mostly for space heating and generating electricity.

Meta-anthracite, the highest rank of coal, is a low-quality fuel. It is dull gray or black, and has a high ash content. It was intermittently mined in the Narragansett Basin of Rhode Island and Massachusetts. The last mine, at Cranston, Rhode Island, closed in 1959. Coal from the area averaged about 19 million Btu per ton as received.

Coal Sulfur: *Coal sulfur* occurs in three forms: *organic, sulfate,* and *pyritic.* Organic sulfur is an integral part of the coal matrix and cannot be removed by conventional physical separation. Sulfate sulfur is usually negligible. Pyritic sulfur occurs as the minerals pyrite and marcasite; larger sizes generally can be removed by cleaning the coal.

Coal Type: This classification is based on physical characteristics or microscopic constituents. Examples of coal types are *banded coal, boghead coal, bright coal, cannel coal,* and *splint coal.* The term is also used to classify coal according to heat and sulfur content. (See Coal Grade.)

Coalbed Degasification: This refers to the removal of methane, or *coalbed gas,* from a coal mine before or during mining.

Coalbed Methane: Methane is generated during coal formation and is contained in the coal microstructure. Typical recovery entails pumping water out of the coal to allow the gas to escape. Methane is the principal component of natural gas. Coalbed methane can be added to natural gas pipelines without any special treatment.

Coke: Coke is a combustible residue consisting of residual ash and fixed carbon made from bituminous coal (or blends of bituminous coal) from which the volatile constituents are driven off by baking in an oven at temperatures as high as 2,000 degrees Fahrenheit. The process is called *carbonization.* Coke is hard and porous, has a gray, submetallic luster, and is strong enough to support a load of iron ore in a blast furnace. It is used chiefly as a fuel and reducing agent in smelting iron ore in a blast furnace. Coke has a heat value of about 25 million Btu per ton.

Coke Battery: A series of adjacent coke ovens, usually 45 or more, sharing coal charging and byproduct control equipment.

Coke Breeze: The term refers to the fine sizes of crushed coke that will pass through a ½-inch or ¾-inch screen opening. It is commonly used for sintering (agglomerating) iron ore, a process in which fine ore is mixed with coke and ignited to produce semifused lumps of ore.

Coke Button: A button-shaped piece of coke resulting from a standard laboratory test that indicates the coking or free-swelling characteristics of a coal; expressed in numbers and compared with a standard.

Coke Oven: An individual coking chamber made of silica brick walls and ranging from 4 to 14 feet in height, 30 to 45 feet in length, and 1 to 2 feet in width. *Byproduct ovens* contain a series of long, narrow chambers arranged in rows and heated by flues in which are burned a portion of the combustible gases generated by the coking of coal. All the volatile products are collected as ammonia, tar, and gas, and may be further processed into other byproducts.

Coke-Oven Gas: This by-product of coke production is used as fuel for heating coke ovens, generating steam, and producing heat for other purposes.

Fossil Fuel: Fuel such as coal, crude oil, or natural gas, formed from the fossil remains of organic material.

Foundry Coke: This is a special coke, generally 3 inches and larger in size, that is used in furnaces to produce cast and ductile iron products. It is a source of heat and also helps maintain the required carbon content of the metal product. Foundry coke production requires lower temperatures and longer times than blast furnace coke.

Fuel Ratio: The ratio of fixed carbon to volatile matter in coal.

Gob: This refers to the caved area of broken rock in an underground mine. A *gob pile* is a heap of waste from preparation plants.

Interburden: The material that separates the coalbeds of a surface deposit.

Middlings: In coal preparation, this material, also called *mid-coal,* is neither clean coal nor refuse; due to their intermediate specific gravity, middlings sink only partway in the washing vessels and are removed by auxiliary means.

Open-Market Coal: Coal that is sold on the commercial market, in contrast to captive coal.

Overburden: Any material, consolidated or unconsolidated, that overlies a coal deposit. *Overburden ratio (stripping ratio)* refers to the amount of overburden that must be removed to excavate a given quantity of coal. It is commonly expressed in cubic yards per ton of coal, but is sometimes expressed as a ratio comparing the thickness of the overburden with the thickness of the coalbed. *Spoil* is the overburden removed in gaining access to a coalbed in surface mining. *Swell factor* is the ratio of the increase in volume, normally expressed as a percentage, that occurs in the overburden material when it is excavated and deposited in a loose state.

Parting: A layer of rock within a coalbed that lies roughly parallel to the coalbed and has the effect of splitting the bed into two divisions.

Peat: Peat is partially decomposed plant debris, and is considered an early stage in the development of coal. Peat is distinguished from lignite by the presence of free cellulose and a high moisture content (exceeding 70 percent). The heat content of air-dried peat (about 50 percent moisture) is about 9 million Btu per ton. Most U.S. peat is used as a soil conditioner. The first U.S. electric power plant fueled by peat began operation in Maine in 1990.

Raw Coal: Coal that has received no preparation other than possibly screening.

Round Test Mesh: A sieving screen with round holes, the dimensions of which are of specific sizes to allow certain sizes of coal to pass through while retaining other sizes.

Run-of-Mine Coal: Coal as it comes from the mine prior to screening or any other treatment.

Screenings: The undersized coal from a screening process, usually one-half inch or smaller.

Solvent Refined Coal (SRC): A tar-like fuel produced from coal when it is crushed and mixed with a hydrocarbon solvent at high temperature and pressure.

Spontaneous Combustion, or Self-Heating, of Coal: A naturally occurring process caused by the oxidation of coal. It is most common in low-rank coals and is a potential problem in storing and transporting coal for extended periods. Factors involved in spontaneous combustion include the size of the coal (the smaller sizes are more susceptible), the moisture content, and the sulfur content. Heat buildup in stored coal can degrade the quality of coal, cause it to smolder, and lead to a fire.

Surface Mining Equipment:
An *auger machine* is a large horizontal drill, generally 3 feet or more in diameter and up to about 100 feet long. It can remove coal at a rate of more than 25 tons per minute.

A *bucket-wheel excavator* is a continuous-digging machine equipped with a boom that has a rotating wheel with buckets along its edge. The buckets scoop up material, then empty onto a conveyor leading to a spoil bank. This excavator is best suited for removing overburden that does not require blasting. It is also used in combination with conveyors to move topsoil from areas to be mined to storage.

A *bulldozer* is a tractor with a movable steel blade mounted on the front. It can be used to remove overburden that needs little or no blasting.

A *carryall scraper* (or *pan scraper*) is a self-loading machine, usually self-propelled, with a scraper-like retractable bottom. It is used to excavate and haul overburden.

A *continuous surface miner*, used in some lignite mines, is equipped with crawlers, a rotating cutting head, and a conveyor. It travels over the bed, excavating a swath up to 13 feet wide and 2 feet deep.

A *dragline excavator* removes overburden to expose the coal by means of a scoop bucket that is suspended from a long boom. The dragline digs by pulling the bucket toward the machine by means of a wire rope.

A *walking dragline* is equipped with large outrigger platforms, or walking beams, instead of crawler tracks. It "walks" by the alternate movement of the walking beams.

A *drilling rig* is used to determine the amount and type of overburden overlying a coal deposit and the extent of the deposit, to delineate major geologic features, and to drill holes for explosives to fragment the overburden for easier removal.

A *front-end loader* is a tractor with a digging bucket mounted and operated on the front. It is often used to remove overburden in contour mining and to load coal.

A *hydraulic shovel* excavates and loads by means of a bucket attached to a rigid arm that is hinged to a boom.

A *power shovel* removes overburden and loads coal by means of a digging bucket mounted at the end of an arm suspended from a boom. The shovel digs by pushing the bucket forward and upward. It does not dig below the level at which it stands.

A *thin-seam miner* resembles an auger machine but has a drum-type cutting head that cuts a rectangular cross section.

Surface Mining Methods:

An *auger mine* recovers coal through the use of a large-diameter drill driven into a coalbed in the side of a surface mine pit. It usually follows contour surface mining, particularly when the overburden is too costly to excavate. (See also *punch mine,* a type of underground mine.)

Area mining is practiced on relatively flat or gently rolling terrain. It recovers coal by mining long strips successively; the material excavated from the strip being mined is deposited in the strip pit previously mined.

A *bench* is a ledge in a surface mine that forms a step from which excavation will take place at a constant level.

A *box cut* is the first cut made to remove the overburden from the coal where no open side exists; this results in a highwall on both sides of the cut. The overburden is placed on unmined land, normally outside the area to be mined.

Contour mining is practiced when the coal is mined on hillsides. The mining follows the contour of the hillside until the overburden becomes uneconomical to remove. This method creates a shelf, or bench, on the hillside. Several variations of contour mining have been developed to control environmental problems. These methods include *slope reduction* (overburden is spread so that the angle of the slope on the hillside is reduced), *head-of-hollow fill* (overburden is placed in narrow V-shaped valleys to control erosion), and *block-cut* (overburden from current mining is backfilled into a previously mined cut).

Explosives casting is a technique designed to blast up to 65 percent of the overburden into the mine pit for easier removal. It differs from conventional overburden blasting, which only fractures the overburden before it is removed by excavating equipment.

A *highwall* is the unexcavated face of exposed overburden and coal in a surface mine.

Mountaintop mining, sometimes considered a variation of contour mining, refers to the mining of a coalbed that underlies the top of a mountain. The overburden, which is the mountaintop, is completely removed so that all of the coal can be recovered. The overburden material is later replaced in the mined-out area. This method leaves large plateaus of level land.

Open-pit coal mining is essentially a combination of contour and area mining methods and is used to mine thick, steeply inclined coalbeds. The overburden is removed by power shovels and trucks.

Tipple: Originally, the place on the surface where mine cars were tipped or emptied of their coal, but now expanded to include the place where trucks, railroad cars, or conveyors hauling coal from a mine dump the coal. Sometimes applied to the surface structures of a mine, including the preparation plant and loading tracks.

Underground Mining Equipment:
An *armored face conveyor* is used to transport coal from the face of a longwall operation and also to support the shearing machine or plow.

A *coal-cutting machine* is used in conventional mining to undercut, topcut, or shear the coal face so that coal can be fractured easily when blasted. It cuts 9 to 13 feet into the bed.

A *continuous auger machine* is used in mining coalbeds less than 3 feet thick. The auger has a cutting depth of about 5 feet and is 20 to 28 inches in diameter. Continuous auger mining usually uses a conveyor belt to haul the coal to the surface.

A *continuous-mining machine,* used during *continuous mining,* cuts or rips coal from the face and loads it into shuttle cars or conveyors in one operation. It eliminates the use of blasting devices and performs many functions of other equipment such as drills, cutting machines, and loaders. A continuous-mining machine typically has a turning "drum" with sharp bits that cut and dig out the coal for 16 to 22 feet before mining stops so that the mined area can be supported with roof bolts. This machine can mine coal at the rate of 8 to 15 tons per minute.

Conveyor systems consist of two types. A *mainline conveyor* is usually a permanent installation that carries coal to the surface. A *section conveyor* connects the working face to the mainline conveyor.

A *face drill* is used in conventional mining to drill shotholes in the coalbed for explosive charges.

A *loading machine* is used in conventional mining to scoop broken coal from the working area and load it into a *shuttle car,* which hauls the coal to mine cars or conveyors for delivery to the surface.

A *mine locomotive,* operating on tracks, is used to haul mine cars containing coal and other material, and to move personnel in specially designed "mantrip" cars. Large locomotives can haul more than 20 tons at a speed of about 10 miles per hour. Most mine locomotives run on electricity provided by a trolley wire; some are battery-powered.

A *plow* is a longwall-mining machine with a blade that has fixed bits or a saw-toothed edge.

A *ram car,* or *shuttle ram,* is a rubber-tired haulage vehicle that is unloaded through the use of a movable steel plate located at the back of the haulage bed.

A *roof-bolting machine,* or *roof bolter,* is used to drill holes and place bolts to support the mine roof. Roof bolting units can be installed on a continuous-mining machine.

A *scoop* is a rubber-tired haulage vehicle used in thin coalbeds.

A *shearer* is a longwall-mining machine with one or two rotating cutting drums.

A *shield* is a movable roof support used in longwall mining.

A *shortwall-mining machine* generally is a continuous-mining machine used with a powered, self-advancing roof support system. It shears coal from a short coal face (up to about 150 feet long). The broken coal is hauled by shuttle cars to a conveyor belt.

A *shuttle car* is a rubber-tired haulage vehicle that is unloaded by a built-in conveyor.

Underground Mining Methods:
A *cross cut* in an underground mine is a short tunnel connecting two parallel entries.

Development refers to the mining needed to provide access to the area to be produced. It includes driving shafts and slopes.

A *drift mine* is driven horizontally into coal that is exposed or accessible in a hillside.

An *entry* in an underground mine is a tunnel-like passage, usually driven entirely within the coalbed and rectangular in cross section, typically about 6 feet high and 20 feet wide. The number of entries is determined by the requirements for ventilation, haulage, escapeways, and mine services such as power, water, and drainage.

In a *hydraulic mine,* high-pressure water jets break the coal from a steeply inclined, thick coalbed that would be difficult to mine with the usual underground methods. The coal is then transported to the surface by a system of flumes or by pipeline. Although currently not in commercial use in the United States, hydraulic mining is used in western Canada.

In *longwall mining,* a panel, or block, of coal generally about 700 feet wide and often over 1 mile long is completely extracted, leaving no pillars to support the mined-out area. The working area is protected by a movable, powered roof support system. The caved area (gob) compacts and, after initial subsidence, supports the overlying strata. Longwall mining is used where the coalbed is thick and generally flat, and where surface subsidence is acceptable.

A *portal* is the surface entrance to an underground mine. It is the point where the main haulage and ventilation entries of the mine intersect the earth's surface.

A *punch mine* is a type of small drift mine used to recover coal from strip-mine highwalls or from small, otherwise uneconomical, coal deposits.

Rock dusting, sprayed in an underground coal mine, reduces the possibility of coal dust explosions. Rock dust is a very fine noncombustible material, usually pulverized limestone.

Roof bolting is the principal method of supporting the mine roof. In roof bolting, long bolts, 2 to 10 feet long with an expansion shell or with resin grouting, are placed in the mine roof. The bolts reinforce the roof by pulling together rock strata to make a strong beam, or by fastening weak strata to strong strata.

In a *room-and-pillar mining system,* the most common method, the mine roof is supported mainly by coal pillars left at regular intervals. Rooms are places where the coal is mined; pillars are areas of coal left between the rooms. Room-and-pillar mining is done either by (1) *conventional mining,* which involves a series of operations that require cutting the working face of the coalbed so that it breaks easily when blasted with explosives or high-pressure air, and then loading the broken coal or (2) *continuous mining,* in which a continuous mining machine extracts and removes coal from the working face in one operation. When a section of a mine has been fully developed, additional coal may be extracted by mining the supportive pillars until the roof caves in; this procedure is called *room-and-pillar retreat mining.*

A *shaft mine* is driven vertically to the coal deposit.

A *shortwall mining system* generally refers to room-and-pillar mining in which the working face is wider than usual but smaller (less than 150 feet) than that in longwall mining.

A *slope mine* is driven at an angle to reach the coal deposit.

Ventilation, accomplished with large fans, is essential to supply fresh air and to remove gases and dust from the mine.

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