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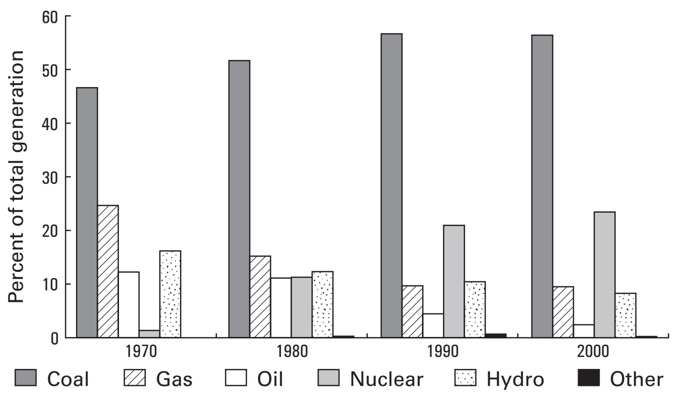
COAL AND ELECTRICITY

Coal is a black sedimentary rock that burns. It contains more than 70 percent carbonaceous matter by volume. Since the 1880's, coal has been burned to produce electricity. The electric utility industry is the largest consumer of coal in the nation. Currently, 80 percent of the nation's coal production and 90 percent of Ohio's coal production are burned at power plants to produce electricity. The degree to which the nation and Ohioans are dependent upon coal for the generation of electricity is indicated by the following: (1) coal provided more than 56 percent of the electricity generated by utilities in the United States in 2000; (2) 90 percent of the total electricity generated in Ohio in 2000 was from coal, 0.2 percent from gas and oil, and 9.8 percent from nuclear generation; (3) Ohio utilities in 2000 consumed almost 54 million tons of coal, of which about 33 percent was produced from Ohio mines; and (4) of the 22.5 million tons of coal produced in Ohio in 2000, all but about 14.4 percent, or about 3.2 million tons, were consumed by electric utility companies; the remaining 3.2 million tons were consumed by industry and domestic users. Coal consumption by electric utilities is likely to increase, as forecasters have predicted that the demand for electricity will increase by 1.8 percent per year through 2020.



Electric generation in the U.S. by source (data from Energy Information Administration).

CLEAN-COAL TECHNOLOGY

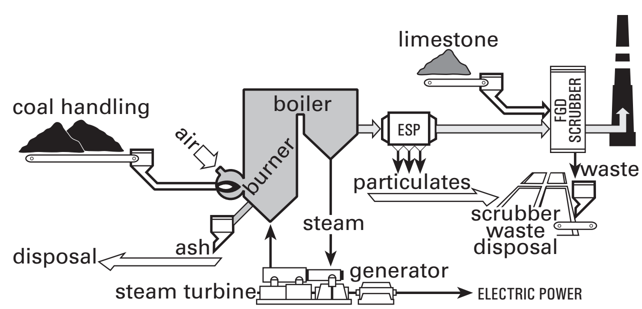
After coal is mined, it is either shipped directly to the user untreated, or it is cleaned before shipment because most of Ohio's coal contains impurities. These impurities include mine roof and/or floor rock, clay or shale partings, calcite ($CaCO_3$), pyritic sulfur (FeS_2), sulfate sulfur in the form of gypsum ($CaSO_4$), and organic sulfur. When sulfur-bearing coal is burned, the sulfur is volatilized (converted into a gas) and combines with oxygen (O_2) to produce sulfur dioxide (SO_2). Although volcanoes, automobiles, and factories emit significant amounts of SO_2, electric power plants are the primary sources of SO_2 emissions. There are four types of technology for cleaning coal to reduce the amount of SO_2 emissions: precombustion, combustion, postcombustion, and conversion.

Coal washing is a precombustion cleaning technology in which some of the impurities contained in coal are removed before the coal is burned. Modern coal-cleaning or coal-washing techniques are based on the principle that coal is lighter (less dense) than its associated rock and impurities. In coal-washing plants (also called preparation or prep plants), agitating liquids, high-velocity liquids, and magnetite-water suspensions in a variety of physical and chemical processes are used to separate impurities from crushed coal. This precombustion cleaning process can generally remove 30 to 50 percent of the pyritic sulfur and about 60 percent of the ash-forming minerals (residue left after coal has been burned). As a result of washing, the SO_2 emissions from burned coal can be reduced by almost 50 percent under ideal conditions.

Combustion cleaning technology is used to clean coal inside the furnace where the coal is burned. Fluidized-bed combustion is an example of this type of technology. In fluidized-bed combustion, pulverized coal is mixed with finely crushed limestone and is injected with hot air into the boiler. The mixture of coal and limestone is suspended on a bed of hot, injected air and resembles a boiling liquid. Because the mixture resembles a liquid, the process is called "fluidized." As the coal burns, sulfur is released and limestone acts like a chemical sponge to soak up or capture the sulfur before it can escape from the boiler. This technology can reduce the amount of SO_2 by more than 90 percent. In addition, the combustion temperature during this process remains between 1400°F and 1600°F, which is about half of the operational temperature of a conventional boiler. These lower temperatures are below the temperature threshold at which nitrogen pollutants form. As a result, fluidized-bed combustors can meet sulfur- and nitrogen-emission standards without additional pollution-control equipment.

To generate electricity, most coal-fired power plants mix pulverized coal with hot air and inject the fine particles into a boiler (a furnace lined with water-filled tubes). A conventional boiler operates at temperatures of 2800°F to 3200°F. Water is heated and steam from the boiling water spins a steam-turbine generator to produce electricity. The gases and particulates emitted from the burned coal are released into the atmosphere or are captured by postcombustion flue-gas cleaning devices such as electrostatic precipitators or scrubbers.

Electrostatic precipitators are filtering devices that use static electricity to capture dust-sized ash called fly ash. The fly ash is disposed of in landfills or is used as an additive (filler) in cement, plastics, and a variety of other products.



Flow diagram of flue-gas desulfurization technology (from Ohio Electric Utility Institute, p. 7). ESP = electrostatic precipitator; FGD = flue-gas desulfurization.

A scrubber is located between the boiler and the smoke stack. Scrubbing involves injecting a slurry of finely ground limestone or lime into the flue gas. The SO_2 in the flue gas reacts chemically with the slurry to produce calcium sulfite and calcium sulfate precipitates. Scrubber technology is capable of processing up to 1 million cubic feet of flue gas per minute and achieving 70 to 90 percent SO_2 reduction. However, over its lifetime, a 500-megawatt coal-fired power plant produces enough flue-gas-desulfurization (FGD) sludge to fill a 500-acre disposal pond to a depth of about 40 feet. Fortunately, there is growing interest in using FGD materials in the manufacture of wallboard and in concrete products. Scrubbers are very expensive to install and operate. The scrubber facility at the General James M. Gavin generating station at Cheshire, Ohio, cost an estimated $800 million to build. However, because of its scrubbers, the Gavin station can burn high-sulfur coal and meet strict air-pollution-control standards.

In conversion technology, coal is turned into a combustible gaseous or liquified fuel that can be cleaned. Combined-cycle coal gasification is an example of this type of technology. In this process, pulverized coal is gasified by a mixture of steam and air heated to 1500°F to 3000°F. The gaseous products from coal gasifi-

continued

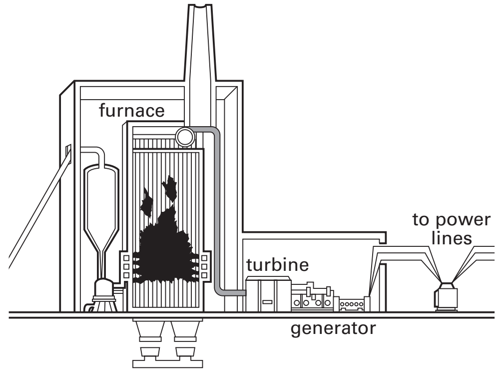
cation include hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), water (H_2O), ammonia (NH_3), hydrogen sulfide (H_2S), nitrogen (N_2), and methane (CH_4). The gas is scrubbed of its impurities to consist primarily of H_2, CO, CH_4, and N_2 and then is burned. The hot exhaust gas is routed through a gas turbine to generate electricity and the residual heat is used to boil water to power a conventional steam turbine to produce more electricity. The combined use of gas and steam to generate electricity accounts for the name "combined cycle." Combined-cycle gasification systems are among the cleanest clean-coal technologies available because the fly ash and most of the sulfur and nitrogen compounds are removed before the fuel is burned.

FEDERAL CLEAN AIR ACT

In 1970, the U.S. Congress passed acid-rain legislation in the form of the Clean Air Act, which placed stringent controls on the emissions from burned coal. In 1977, the U.S. Environmental Protection Agency (USEPA) set national ambient emission-control standards for SO_2, NO_x, particulate matter, and photochemical ozone. In 1979, the USEPA set a New Source Performance Standard of 1.2 pounds of SO_2 emitted per million Btu for new power plants. (Btu is the abbreviation for British thermal unit, the standard unit of measurement for heating value; 1 Btu equals the amount of heat required to raise the temperature of 1 pound of water 1ºF.) From 1970 to 1990, as a result of tightening emission controls, SO_2 emissions declined 24 percent nationally and 55.4 percent in Ohio. Despite this reduction in SO_2 emissions, in 1990 Congress passed the Clean Air Act Amendments (CAAA90), which imposed stricter emission standards on coal-fired utilities. Beginning in 2000, total nationwide SO_2 emissions from all electric power plants are capped at 8.9 million tons annually. In addition, all power plants larger than 25 megawatts (Mw) are required to keep their SO_2 emissions below 1.2 pounds per million Btu.

In the late 1980's, national and international environmental focus on emissions from burning coal began to shift from acid-rain issues to climate-change issues. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was convened to assess the available information on climate change. In 1992, the Framework Convention on Climate Change was adopted by the United Nations to return worldwide emissions of greenhouse gases to 1990 levels. In 1997, the Kyoto Protocol established targets for greenhouse gas emissions for developed nations, including the United States, relative to their emission levels in 1990. These targets are to be achieved on average between 2008 and 2012. The United States signed the Kyoto Protocol, but has yet to ratify it and intends to develop alternatives to the Kyoto Protocol, including the National Climate Change Technology Initiative. In 1995, the IPCC reported that greenhouse gas emissions could cause a 2º to 6ºF rise in temperature during the next century, if atmospheric levels are not reduced. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Carbon dioxide accounts for most of the manmade greenhouses gases emitted worldwide, and manmade CO_2 is attributed almost entirely to the burning of fossil fuels (coal, oil, and natural gas). Since 1990, emissions of CO_2, CH_4, and N_2O increased 11 percent, 2 percent, and 10 percent, respectively (USEPA, 2000a).

Under the Clean Air Act, the USEPA has set national air-quality standards for six principal pollutants (also referred to as criteria pollutants): carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2). Because ozone is not emitted directly into the air, but is a product of photochemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOC), emissions of NO_x and VOC are measured. Ground-level ozone forms readily in the atmosphere, usually during hot summer weather. Since the 1970 Clean Air Act was signed into law, national air-quality levels nationwide have shown improvements. Between 1970 and 1999, emissions of five of the six criteria pollutants decreased: CO by 29 percent, Pb by 98 percent, VOC by 43 percent, PM by 77 percent, and SO_2 by 40 percent (USEPA, 2000b). However, the emissions of NO_x increased 17 percent. These improvements in air quality occurred while the consumption of coal by electric utilities increased 180 percent.



Cross section of conventional coal-fired power plant (from Ohio Electric Utility Institute, p. 3).

Ohio has 26 coal-fired power plants, which have 89 operating boilers. Seventy-nine of these boilers are larger than 25-Mw generating capacity; the remaining boilers have less than 25-Mw capacity. Since 1988, no new coal-fired power plants have been built; in 1991, the Zimmer plant near Cincinnati converted from nuclear power to coal-fired power. In November 2001, a 600-Mw coal-fired power plant was proposed for Ashtabula County. Between 1990, when CAAA90 was passed into law, and September 2001, 92 new electric-generating units have been built in Ohio. Most of these are peaking units, less than 25-Mw capacity, and all except one are powered by either natural gas or oil. (Peaking units are small electric generators that are activated only during periods of high or peak demand.)

What is the future for Ohio's coal-fired electric-utility industry? Ninety percent of Ohio's electricity is generated from burning coal. Nationally, the demand for electricity is expected to increase by 1.8 percent per year through 2020. To meet this growing need for electricity, the generation from natural gas and coal are expected to increase. Although the share of electric generation by coal nationally is expected to drop from 52 percent to 46 percent, the consumption of coal is expected to increase by 1.2 percent per year through 2020. The direction that Ohio's coal-fired electric industry will take should become clear over the next 10 years. By 2010, more than 60 percent of Ohio's 89 coal-fired boilers will be more than 50 years old and in need of replacement. It is anticipated that boilers using clean-coal technologies will replace these aging boilers. The U.S. Senate and U.S. House versions of President Bush's 2001 National Energy Policy call for $200 million a year commitment over a 10-year period for coal research, such as coal gasification, carbon sequestration, and other clean-coal technologies. This kind of commitment to clean-coal technology, coupled with a growing demand for electricity, may promote Ohio's coal as a least-cost fuel for Ohio's electric utilities. Ohio has over 9 billion tons of mineable coal. At a rate of 22 million tons of coal produced in 2000, Ohio has about a 400-year supply of fuel for electric power generation.

FURTHER READING

Crowell, D. L., 1995, History of the coal-mining industry in Ohio: Ohio Division of Geological Survey Bulletin 72, 203 p.

_______ 1997, History of coal mining in Ohio: Ohio Division of Geological Survey GeoFacts 14.

_______ 1997, Coal: Ohio Division of Geological Survey Educational Leaflet 8.

Ohio Electric Utility Institute, undated, To fuel our dreams, the promise of clean coal technology: 13 p.

U.S. Environmental Protection Agency, 2000a, Inventory of U.S. greenhouse gas emissions and sinks: 1990-1998: U.S. Environmental Protection Agency, EPA 236-R-00-001, 217 p.

_______ 2000b, Latest findings on National air quality: 1999 status and trends: U.S. Environmental Protection Agency, EPA-454/F-00-0002, 30 p.

Wolfe, M. E., 2001, 2000 Report on Ohio mineral industries: Ohio Division of Geological Survey, 153 p.

• This GeoFacts compiled by Douglas L. Crowell • Revised March 2002 •

The Division of Geological Survey GeoFacts Series is available on the World Wide Web: http://www.ohiodnr.com/geosurvey/