OHIO GEOLOGY

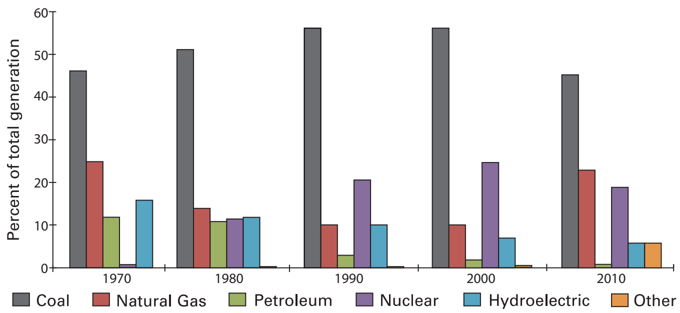
GEOFACTS No. 16

OHIO DEPARTMENT OF NATURAL RESOURCES • DIVISION OF GEOLOGICAL SURVEY

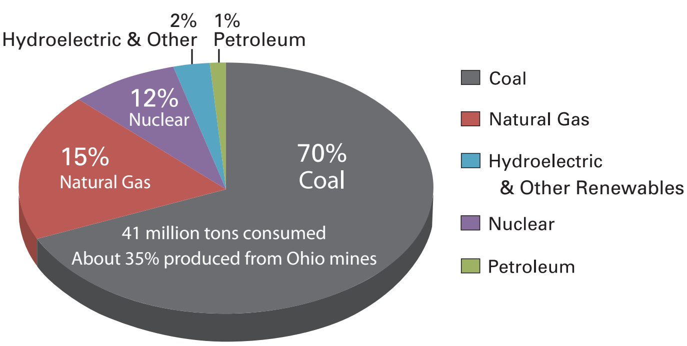
COAL AND ELECTRICITY

Coal is a black or dark brown, combustible sedimentary rock. It contains greater than 70% carbon-rich material by volume. Since the 1880s, coal has been burned to produce electricity, and today, the electric utility industry is the largest consumer of coal in the nation. The coal used in Ohio for electricity generation comes from a variety of sources including the Powder River Basin in Wyoming, northern and central Appalachia, the Illinois Basin, and Colorado. The specific blends of coal that each coal-fired power plant utilizes are a function of fuel cost, fuel cleanliness, and energy-generating potential. For example, coal mined from the Pittsburgh (No. 8) coal seam in Eastern Ohio may be inexpensive to transport and possess high energy potential per ton, but it has greater sulfur content that could make meeting regulatory standards more challenging.

Currently, 93% of nationwide and 90% of Ohio coal production is burned at power plants to produce electricity. In 2013, coal provided about 39% of electricity generated in the United States and 70% of electricity in Ohio.



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



Electric generation in Ohio by source in 2012 (data from U.S. Energy Information Administration)

The percentage of electricity generated by coal for the nation and Ohio is projected to decrease as coal consumption is expected to increase by less than 0.3% per year, and demand for electricity is projected to rise 0.9% per year through 2040. The U.S. Energy Information Administration (EIA) anticipates that demand for electricity will be fulfilled by increased natural gas production and non-hydroelectric renewable energy sources, such as wind or solar photovoltaics, though coal will remain the largest contributor for decades to come in Ohio.

CLEAN-COAL TECHNOLOGY

After it is mined, coal either is shipped directly to the user untreated or undergoes cleaning processes, depending on its impurities. Most Ohio coal contains impurities that include mine roof/floor rock, clay/shale partings, pyritic sulfur (FeS_2), organic sulfur, and mercury (Hg). When coal is burned, sulfur (S), carbon (C), and atmospheric nitrogen (N_2) react as gases with oxygen (O_2) to produce sulfur dioxide (SO_2), carbon dioxide (CO_2), and various nitrogen oxides (NO_x). Although volcanoes, automobiles, and factories emit significant quantities of these gases, electric power plants are the primary sources of emissions. Four types of clean-coal technology are used for reducing these emissions: pre-combustion, combustion, post-combustion, and conversion.

Coal washing is a pre-combustion cleaning technology that removes some impurities contained in coal before it is burned. Modern coal-washing preparation plants rely on the principle that coal is less dense than its associated ash-forming minerals and impurities. Agitating liquids, high-velocity liquids, and magnetite-water suspensions are used to separate impurities from crushed coal. This process can remove 60% of the ash-forming minerals, including 30–50% of pyritic sulfur, which can reduce SO_2 emissions by up to 50%.

To generate electricity, most coal-fired power plants mix pulverized coal with hot air and then inject the fine particles into a boiler (a furnace lined with water-filled tubes) at temperatures of 2,800–3,200°F. Water is heated until it becomes steam, which spins a steam-turbine generator to produce electricity. Various combustion and post-combustion technologies are utilized to reduce or capture the gases and particulates emitted from the burned coal.

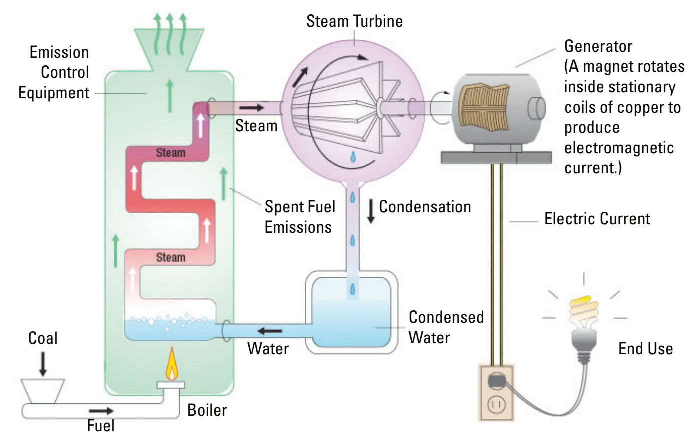


Diagram of how an electric power plant works (modified from EEI).

Combustion cleaning technology is used to clean coal inside the furnace where the coal is burned. For example, in fluidized-bed combustion, pulverized coal is mixed with finely crushed limestone and is injected into a boiler. The mixture is suspended on a bed of injected hot air and resembles a boiling liquid (i.e., fluidized). The limestone acts as a chemical sponge to capture the sulfur released during coal burning before it escapes the boiler. This technology can reduce SO_2 by more than 90%. In addition, this combustion process maintains a temperature about half that of conventional boilers, reducing NO_x emissions that form readily under hotter conditions.

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

Post-combustion scrubbers inject a slurry of finely ground limestone or lime into the flue gas as it exits the boiler. The SO_2 in the flue gas chemically reacts with the slurry to produce calcium sulfate ($CaSO_4$) and calcium sulfite ($CaSO_3$) precipitates and to reduce SO_2 emissions by 70–90%. Scrubbers are very expensive to implement and produce flue-gas-desulfurization (FGD) sludge that must be managed. Fortunately, FGD materials are widely used in the

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manufacturing of wallboard and concrete products. Nationwide, FGD gypsum accounts for over half of the total gypsum utilized and that number is even higher in Ohio. Coal-fired plants with scrubbers installed are able to burn high-sulfur coal and still meet strict air pollution control standards.

Carbon dioxide capture and storage (CCS) is a set of technologies being tested where up to 90% of CO_2 emissions from coal-fired plants are separated from other flue gases, captured, transported, and sequestered. Carbon dioxide is typically captured post-combustion using a solvent filter to trap the CO_2; this solvent is later heated to release water and leave behind concentrated CO_2. The CO_2 must be compressed to a supercritical phase—where it behaves like a liquid due to the high pressure—prior to being sequestered underground in geologic formations, such as oil-and-gas reservoirs, unmineable coal, or saline formations. These formations must have suitable pore space to store the high-pressure gas, a non-permeable cap rock present to keep the gas trapped, and be at least 2,500 feet underground, the minimum depth required to maintain the CO_2 in the supercritical phase.

Combined-cycle coal gasification is a conversion technology where pulverized coal is gasified by a mixture of steam and 1,500–3,000°F air. The gaseous products from coal gasification are then scrubbed of CO_2, ammonia (NH_3), and hydrogen sulfide (H_2S), and the remaining hydrogen (H_2), carbon monoxide (CO), methane (CH_4), and nitrogen (N_2) gases are then burned. The exhaust gas is routed through a turbine to generate electricity, and the residual heat is used to power a conventional steam turbine. Combined-cycle gasification systems are among the cleanest clean-coal technologies because most impurities are removed prior to burning the fuel. However, the high initial setup price makes this option cost-prohibitive for many operations.

Organizations such as the Ohio Department of Natural Resources, Division of Geological Survey, the Ohio Coal Development Office, Battelle, and other state agencies are researching the best ways to utilize the state's coal reserves, as well as alternative and varied uses for coal in the future.

FEDERAL CLEAN AIR REGULATIONS

In 1970, the U.S. Congress passed the Clean Air Act, which placed stringent controls on the emissions from burned coal. In 1977 and 1979, additional emission-control standards for SO_2, NO_x, particulate matter, and photochemical ozone were introduced. From 1970 to 1990, SO_2 emissions declined 24% nationally and 55% in Ohio. In an effort to further curtail SO_2 emissions, Congress passed the Clean Air Act Amendments in 1990, capping nationwide SO_2 emissions from all electric power plants at 8.9 million tons annually. In 2011, the U.S. Environmental Protection Agency (USEPA) issued the Mercury Air Toxics Standards or MATS rule. The goal of this new standard was to reduce mercury emissions by 90%.

Under the Clean Air Act, the USEPA has set national air-quality standards for six criteria pollutants: carbon monoxide (CO), lead (Pb), nitrogen oxides (NO_x), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2). Since the 1970 Clean Air Act was signed into law, national air-quality levels nationwide have shown improvements. Between 1980 and 2012, emissions of all six criteria pollutants decreased: CO by 83%, Pb by 91%, NO_x by 60%, O_3 by 25%, PM by 87%, and SO_2 by 78%. These improvements in air quality occurred while consumption of coal by electric utilities increased 60%.

National and international environmental focus on emissions from burning coal began to shift from acid-rain issues to climate change issues during the late 1980s with an emphasis on greenhouse gases, which include CO_2, methane (CH_4), and nitrous oxide (N_2O). Carbon dioxide accounts for most of the anthropogenic greenhouse gases emitted worldwide. In 2012, emissions of CO_2 increased 5%, N_2O increased 3%, and CH_4 decreased 11% from 1990 levels. As of 2012, proposed greenhouse gas legislation would limit new electric-generating utilities to less than 1,100 lb of CO_2/MW-hr, which is difficult for coal-fired plants to meet without CCS technology.

W. H. Sammis Power Plant, Stratton, Ohio. Coal-fired power plant operated by FirstEnergy.

Ohio has 16 coal-fired power plants, which have 57 operating boilers. Since 1988, no new coal-fired power plants have been built; in 1991, the Zimmer plant near Cincinnati converted from nuclear power to coal. In 2016, the Avon Lake power plant plans to convert from coal to natural gas, and the Muskingum River and Picway coal-fired plants are scheduled for retirement.

The future of Ohio's coal-fired electric-utility industry is uncertain, but coal will unquestionably play a substantial role in Ohio's power generation for years to come. Nationally, the demand for electricity is expected to increase by 0.9% per year through 2040. To meet this growing need for electricity, the generation from natural gas and non-hydroelectric renewables is expected to increase. Although the share of electric generation by coal nationally is expected to drop from 39 to 32%, the consumption of coal is expected to increase by 0.3% per year through 2040. Over half of Ohio's coal-fired boilers are greater than 50 years old and many are slated for retirement by 2020 due to age, economic, and regulatory factors. The EIA anticipates that boilers utilizing natural gas will gradually replace these coal units due to cost and stricter environmental policy. Ohio has over 11 billion tons of recoverable coal reserves. At a rate of 26 million tons of coal produced in 2012, Ohio has about a 400-year supply of fuel for electric power generation and future alternative uses. Despite the anticipated shift from coal to natural gas for electricity generation, coal will continue to be a significant source of power in Ohio.

FURTHER READING

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• This GeoFacts compiled by J. D. Stucker • Revised March 2015 •

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