# Coal Fact Sheet

## Overview

Coal is a combustible sedimentary rock with a high amount of carbon, and the United States has the largest coal reserves in the world. In 2022, almost 92 percent of coal use in the United States was in the power sector, where coal-fired generation represents 22 percent of the electricity we use. Industry represents about 8 percent of coal consumption, with 3 percent of coal consumption used to produce coke for iron and steel production. Other industrial uses of coal include using coal tar pitch to create the carbon anodes needed for aluminum production and using the gypsum (voluminous byproduct of wet scrubbers used for removal of sulfur oxides from coal-derived flue gas) for wallboard products. A small amount of coal is used in domestic chemical production to produce activated carbons.[1] In 2022, 14 percent of domestic coal production was exported to more than 70 countries.[2] Coal is mined in 22 states, but over 80 percent comes from just seven states.[1] Coal is one of the largest users of rail transport as coal is often shipped from the producing states across the nation by train.

## Coal Type (or Ranks)[3]

There are four main types (or ranks) of coal: anthracite, bituminous, subbituminous, and lignite. Most of the coal used in the United States is bituminous coal (46 percent) from West Virginia, Illinois, Pennsylvania, and Kentucky, or subbituminous coal (46 percent) from Wyoming or Montana. Lignite production is primarily in North Dakota. There is only a small amount of anthracite coal, which is produced in Northeastern Pennsylvania. In general, the ranking reflects the carbon content and heat energy the coal can produce. However, coal is a heterogenous material, with large variations in composition even within coal type for some properties. For example, sulfur varies more by region than by type, so samples from the same state and type (e.g., West Virginia bituminous A) will have large ranges that overlap with the ranges of coal samples from a different state and type (e.g., Wyoming sub-bituminous B). The table shown in Figure 1, developed using data from the U.S. Geological Survey (USGS) COALQUAL database, illustrates typical compositions of different coal types.

Figure 1: COALQUAL median and standard deviation of coal samples by state and rank[4]

| | Moisture % | | Volatile Matter % | | Fixed Carbon % | | Nitrogen % | | Sulfur % | | BTU (calorific value)/lb | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | STDEV | Median | STDEV | Median | STDEV | Median | STDEV | Median | STDEV | Median | STDEV |
| Pennsylvania Anthracite | 3.06 | 1.06 | 4.46 | 0.71 | 81.70 | 4.43 | 0.80 | 0.28 | 0.65 | 0.60 | 12743 | 716 |
| West Virginia Volatile A Bituminous | 2.50 | 1.16 | 33.10 | 3.55 | 54.40 | 5.85 | 1.40 | 0.21 | 0.80 | 0.89 | 13280 | 1224 |
| Illinois Volatile B Bituminous | 4.50 | 1.41 | 35.35 | 2.45 | 49.70 | 4.07 | 1.20 | 0.17 | 2.85 | 1.81 | 11990 | 748 |
| Wyoming Sub-bituminous B | 19.41 | 3.10 | 31.89 | 2.91 | 41.96 | 5.51 | 1.10 | 0.37 | 0.60 | 0.77 | 9685 | 863 |
| North Dakota Lignite A | 34.45 | 4.68 | 27.70 | 1.64 | 30.60 | 3.11 | 0.70 | 0.07 | 0.50 | 1.13 | 6962 | 415 |

1 Use of coal - U.S. Energy Information Administration (EIA)

2 Coal imports and exports - U.S. Energy Information Administration (EIA)

3 Coal Rank is the process of plant matter becoming coal, the “metamorphism” while type represents the mineral properties. They are used interchangeably by the EIA and USGS, but there are more ranks (variations of coals with different type/location combinations) than four types.

4 COALQUAL Database (usgs.gov)

## Coal-fired Power Plants

The combustion of coal produces a flue gas containing carbon dioxide ($CO_2$), carbon monoxide, unburned hydrocarbons, water, nitrogen, oxygen, halogens, sulfur dioxide, sulfur trioxide, nitrogen oxides, hydrochloric acid, mercury, and entrained fly ash particles. When fluidized bed combustion technology is used, nitrous oxide production is also increased.[5] The higher-ranking coals, per short ton upon combustion, produce more $CO_2$ and other air pollutants. These pollutants can cause smog, acid rain, haze, respiratory illnesses, and lung disease. Mercury and other heavy metals have been linked to both neurological and developmental damage in humans and other animals. However, modern coal plants have pollution control devices that capture well over 90 percent of these air pollutants. Selective catalytic reduction catalysts, wet scrubbers, electrostatic precipitators, fabric filter baghouses, and injection of activated carbon will dramatically reduce emissions of sulfur dioxide, sulfur trioxide, nitrogen oxides, hydrochloric acid, particulates, and mercury.

The amount of emissions and other pollutants in untreated flue gas is related to the thermal efficiency of the coal-fired power plants. The more efficient the plant, the less coal is needed to deliver the same amount of electricity, achieving a proportionate reduction in emissions and pollutants. The average coal-fired power plant in the United States operates around 33 percent efficiency (compared to the world's most efficient coal plant that achieves a net efficiency of 49.37 percent[6]). Research and development to improve the efficiency of coal plants continues in markets like China, Japan, and Germany. These technologies will improve the efficiency and performance of coal power plants and their ability to work with wind and solar by enabling the plants to quickly ramp up or down to complement the variable nature of wind and solar electricity production.

The fly ash and bottom ash residues created when power plants burn coal are typically stored in impoundments near the power plants.[7] A significant portion of the fly ash currently produced by coal-fired power plants is beneficially used for making concrete. There are over 1,000 impoundments containing coal ash and other power plant byproducts and over 1,000 impoundments containing waste coal scattered across the United States.

### Carbon Capture for Coal-fired Power Plants

For the last 15 years, the U.S. Department of Energy's (DOE) Point Source Carbon Capture Program has supported research, development, and large demonstrations of technology to capture $CO_2$ emissions from coal-fired generation. Carbon capture technologies can also reduce pollution beyond $CO_2$ emissions, as they often require co-pollutants such as sulfur oxides and nitrogen oxides to be removed from the flue gas prior to capturing the $CO_2$. DOE recognizes the risk of amine (organic compound derived from ammonia) degradation in the solvents used for carbon capture and is developing monitoring approaches to stay ahead of the risks, as well as investing in a broad suite of capture technologies that do not require amines, such as solid sorbents, membranes, and cryogenic separation.

## Coal Mining

The environmental impact of coal depends on the mining method. Surface mining is often used when coal is less than 200 feet underground. In surface mining, large machines remove the topsoil and layers of rock known as overburden to expose coal seams. A form of surface mining, mountaintop mining, is where the tops of mountains are removed, allowing for almost complete recovery of coal seams. Underground (deep) mining is used when the coal is more than 200 feet below the surface. Some underground mines are thousands of feet deep, with tunnels that may extend out from the vertical mine shafts for miles. Access to these mines is limited, requiring miners to travel by elevator and mine train to dig for coal. Surface mines make up about two-thirds of the nation's 548 mines. Surface mining is less labor intensive and considered safer for miners than underground mining, avoiding mine shafts and inhalation of coal mine dust that causes "black lung disease."

5 https://www.sciencedirect.com/science/article/abs/pii/0378382093900618

6 China's Pingshan Phase II Sets New Bar as World's Most Efficient Coal Power Plant - ICSC (sustainable-carbon.org)

7 Coal and the environment - U.S. Energy Information Administration (EIA)

However, surface mining, particularly mountaintop mining, can be more destructive to the landscape and release more pollutants into the surrounding air and watersheds.[8]

Methane, which accounts for approximately 30 percent of current anthropogenic climate change, is also released during coal mining. Active underground mines release methane through degasification systems (drainage system methane) and ventilation systems (ventilation air methane or VAM). Surface mines emit less methane than underground mines, but because surface mines produce large volumes of coal, methane emissions can remain high. The methane emissions from coal mining and abandoned coal mines accounted for about 8 percent of total U.S. methane emissions in 2019.[9]

The mining of coal also produces significant waste streams. One ton of hard coal produces 0.4 tons of extractive waste materials, including coal washery rejects, tailings, and waste rock. There have been environmental issues caused by coal-waste dumps and tailings storage facility failures, runoff water pollution, and spontaneous combustion incidents.[10] For example, when ground water comes in contact with coal mining activity, drinking water can become contaminated with acid mine drainage (AMD), the formation and movement of highly acidic water rich in heavy metals. The coal mining industry is working to reduce the environmental impact of operations by improving processes and deploying digital technologies to reduce how much energy and manpower is used, reducing waste, and increasing the use of renewable energy to power site operations.

## Critical Minerals and Materials from Coal, Coal By-products, and Coal Waste

The United States has more than 4.4 billion tons of coal waste scattered across many sites throughout the nation.[11] Almost the entire periodic table of elements can be found in coal, so coal, coal by-products, and coal waste can provide the critical minerals and materials used for batteries, wind turbines, semiconductors, electrolyzers, and other technologies needed to reach the nation's clean energy goals and provide for our national defense. Since 2014, DOE's Office of Fossil Energy and Carbon Management (FECM) has worked to develop and advance technologies needed to produce critical minerals and materials from coal, coal by-products, and coal waste, along with other mining and energy waste streams. In May 2022, FECM presented a *Recovery of Rare Earth Elements and Critical Materials from Coal and Coal Byproducts* report to Congress. This report outlines the achievements in realizing opportunities and resolving challenges for the separation, extraction, and recovery of rare earth elements and other critical materials from coal, coal byproducts, and coal waste, validating the resource potential and technical feasibility.

Depending on the type and properties of the coal (refer to Figure 1), the concentration of critical minerals and the ease of extraction will vary. A significant benefit of using coal waste streams is facilitating the clean-up of waste coal and coal by-product impoundments. FECM's Critical Mineral Sustainability Program is focused on accelerating domestic critical minerals and materials production while remediating sites.

### Critical Mineral Recovery

Two coal waste streams can serve as feedstocks for the recovery of rare earth elements and critical minerals.[12]

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8 Surface coal mining and public health disparities: Evidence from Appalachia - ScienceDirect

9 About Coal Mine Methane | US EPA

10 Coal wastes: handling, pollution, impacts, and utilization - ScienceDirect

11 Carbon Ore Processing | netl.doe.gov

12 NAE Website - Domestic Wastes and Byproducts: A Resource for Critical Material Supply Chains

### *Coal Ash*

There is approximately 2 billion tons of coal ash stored in over 1,000 impoundments scattered across the United States. The combustion process in coal-fired power plants serves to concentrate many critical elements that are present within coal. Extractability of the elements of interest is also an important factor for the economics of resource recovery, and some metals may be more easily recovered from the waste coal impoundments than other metals or from other types of coal. For example, extracting rare earth elements from lignite coal has shown the most promise in multiple pilot projects when compared to other critical minerals and/or other coal sources.

**Potential Supply in U.S. Legacy Coal Ash, at Current Rates of Consumption**

| Critical Metal | Estimated Mass | Potential Supply (Years) |
|---|---|---|
| Nd | 172,000 tons | 40 |
| Dy | 62,000 tons | 14 |
| Li | 288,000 tons | 130 |
| Co | 110,000 tons | 15 |
| Ni | 252,000 tons | 1.1 |
| Ir | 40 tons | 15 |
| Pt | 600 tons | 15 |
| Ga | 20,000 tons | 1,100 |
| Ge | 30,000 tons | 3,900 |

### *Acid Mine Drainage*

The AMD produced from mining activity often has high concentrations of heavy metals. Recovering these metals has the additional benefit of addressing water pollution risks of AMD. AMD also includes solid wastes, such as acidic sentiments, tailings, and waste rock. The oxidation of sulfides present in coal produces waste sulfuric acid. The sulfuric acid formed will often leach valuable metals such as manganese, nickel, and cobalt from the surrounding environment. DOE is sponsoring pilot-scale research on the recovery of these metals, and rare earths from abundant AMD and AMD solid wastes.

## Coal to Carbon Products

Coal can be used to produce materials needed to support clean energy technologies, such as graphite for carbon electrodes widely used in batteries. Coal carbons have been found to outperform other carbons and metal oxides in electronics because of lower cost fabrication methods, improved device-to-device reproducibility, and better long-term device stability. Coal materials are being developed into porous carbons and nanoporous membranes, that can be used in energy storage, chemical processing, and filtration applications.

The Carbon Ore Processing Research Program at DOE's National Energy Technology Laboratory supports research and development to transform coal and coal wastes into value-added carbon products. This research and development covers an entire spectrum of products and includes projects that are developing building products, cement additives, silicon carbide, graphite for electrochemical applications, activated carbons, carbon fibers and foams, conductive inks, and nano-materials such as graphene and quantum dots.

Synthetic graphite is typically produced by heating carbonaceous materials such as coal or petroleum coke to extraordinarily high temperatures of 5,400 – 7,200°F (3,000 – 4,000°C), often for long periods of time, in an energy intensive and polluting process. Methods for producing synthetic graphite from waste coals at significantly lower temperatures and shorter residence times have been developed through the Carbon Ore Program. These technologies will be more environmentally friendly and use much less energy than the current state-of-the-art technologies. Research has also shown potential in using a carbon silicon electrode derived from waste coal that can rival the performance of graphite in lithium-ion batteries.

## Learn More

To learn more about the Office of Fossil Energy and Carbon Management, sign up to receive email updates and follow us on X, Facebook, and LinkedIn.