Coal is a combustible black or brownish-black sedimentary rock with a high amount of carbon and hydrocarbons. Coal is classified into four main types, or ranks depending on the types and amounts of carbon present and on the amount of heat energy the coal can produce, including anthracite, bituminous, subbituminous, and lignite (highest to lowest ranked, pictured in Figure 1). For us to use the potential energy stored in coal, it first must be mined from the ground. This process in itself uses a great deal of resources and has its own environmental impacts. Coal then typically undergoes processing to make it suitable for use in coal-fire power plants. Finally, the processed coal is burned in these power plants, and the kinetic energy released from its combustion is harnessed for electricity generation or other purposes. We will investigate each of these steps individually below.

4.3.1: Coal Mining and Processing, and Electricity Generation

There are two primary methods of coal mining: **strip mining** and **underground mining**. Strip-, or surface-, mining uses large machines to remove the soil and layers of rock known as **overburden** to expose coal seams. It is typically used when the coal is less than 200 feet underground. **Mountaintop removal** is a form of surface mining where the tops of mountains are blasted with dynamite and removed to access coal seams. After the mining is finished, the disturbed area can be re-covered with topsoil, and the area is replanted. However, the topography of the mountain is permanently altered.

Underground mining, sometimes called deep mining, is used when the coal is several hundred feet below the surface. Some underground mines are thousands of feet deep, and extend for miles. Miners ride elevators down deep mine shafts and travel on small trains in long tunnels to get to the coal. The miners use large machines that dig out the coal.

Once mined, coal may go to a preparation plant located near the mining site where it is cleaned and processed to remove impurities such as rocks and dirt, ash, sulfur, and other unwanted materials. This process increases the amount of energy that can be obtained from a unit of coal, known as its **heating value**.

Finally, the mined and processed coal must be transported. Transportation can be more expensive than mining the coal. Nearly 70% of coal delivered in the United States is transported, for at least part of its trip, by train. Coal can also be transported by barge, ship, or truck. Coal can also be crushed, mixed with water, and sent through a slurry **pipeline**. Sometimes, coal-fired electric power plants are built near coal mines to lower transportation costs.

Once at the power plant, coal is first pulverized into a fine powder then mixed with hot air and blown into a **furnace**, allowing for the most complete combustion and maximum heat possible. Purified water, pumped through pipes inside a **boiler**, is turned into steam by the heat from the combustion of coal. The high pressure of the steam pushing against a series of giant **turbine** blades turns the turbine shaft. The turbine shaft is connected to the shaft of the **generator**, where magnets spin within wire coils to produce electricity. After doing its work in the turbine, the steam is drawn into a **condenser**, a large chamber in the basement of the power plant. In this important step, millions of gallons of cool water
from a nearby source (such as a river or lake) are pumped through a network of tubes running through the condenser. The cool water in the tubes converts the steam back into water that can be used over and over again in the plant. The cooling water is returned to its source without any contamination except at a higher temperature than when first extracted from the river or lake. Figure \(\PageIndex{2}\) below is a schematic diagram showing a typical layout of a coal-fire power plant. You can also watch a short video of a virtual tour of a coal power plant at the URL provided below.

Coal Power Plant Virtual Tour Video  [https://www.youtube.com/watch?v=2IKECl4Y3RI](https://www.youtube.com/watch?v=2IKECl4Y3RI)

Figure \(\PageIndex{2}\): Diagram of a typical steam-cycle coal power plant (proceeding from left to right). Image by US Tennessee Valley Authority – Public domain. www.tva.com

4.3.2: Impacts of coal mining and burning

**Impacts of coal mining on the environment**

A majority of the coal mined in the United States (about 66%) is from surface, or strip mines which leave highly visible impacts at the surface. Strip mining operations generally involve removing soils, rock, and other material to access shallow deposits of coal and therefore leave permanent scars on the landscape. It also involves the destruction of substantial amounts of forests and other ecosystems, destroying natural habitats and threatening biodiversity.

Mountaintop removal, the extreme form of strip mining, has affected large areas of the Appalachian Mountains in West Virginia and Kentucky. The tops of mountains are removed using a combination of explosives and mining equipment and the material is deposited into nearby valleys. This technique not only alters the landscape (Figure \(\PageIndex{3}\)) but affects the health and quality of nearby streams by depositing rocks, dirt, and pollutants that can harm aquatic wildlife. While mountaintop removal mining has existed since the 1970s, its use became more widespread and controversial beginning in the 1990s. U.S. laws require that dust and water runoff from areas affected by coal mining operations be controlled, and that the area be **reclaimed**, and returned to close to its original condition.
One of the largest environmental impacts of underground mining may be the methane gas that must be vented out of mines to make the mines a safe place to work. Methane is a greenhouse gas, meaning that it enhances the greenhouse effect naturally occurring in our atmosphere, and contributes to global warming and global climate change. Its global warming potential, or relative capacity to produce the greenhouse effect, is higher than that of carbon dioxide (see chapter 7). Other impacts of underground mining include ground collapse above mine tunnels and draining of acidic water from abandoned mines into nearby streams. Acidic water lowers the pH (resulting in increased acidity), which is detrimental to aquatic organisms. This acid mine drainage is an environmental impact associated with both underground mining and strip mining.

Impacts of coal burning on the environment and human health

In the United States and most of the world, most of the coal consumed is used as a fuel to generate electricity. Burning coal produces emissions such as sulfur dioxide (SO$_2$) and nitrogen oxides (NO$_x$) that are associated with acid rain (more on this in chapter 6). Carbon dioxide (CO$_2$), another emission resulting from burning coal, is a major greenhouse gas that is associated with global warming (see chapter 7).

Ash (including fly ash and bottom ash) is a residue created when coal is burned at power plants. In the past, fly ash was released into the air through the smokestack, where it would contribute to particulate matter air pollution (see chapter 6). Laws now require that much of the fly ash now must be be captured by pollution control devices, like scrubbers. In the United States, fly ash is generally stored at coal power plants or placed in landfills. Pollution leaching from ash storage and landfills into groundwater and the rupture of several large impoundments of ash are environmental concerns.

Burning coal produces emissions that also impact human health. Emissions such as sulfur dioxide (SO$_2$), nitrogen oxides (NO$_x$) and particulates contribute to respiratory illnesses. Particulates also contribute to a condition among coal miners and other coal workers known as coal workers’ pneumoconiosis (CWP) or black lung disease, which results from long exposure to coal dust. Inhaled coal dust progressively builds up in the lungs and is unable to be removed by the body; this leads to inflammation, fibrosis, and in worse cases, tissue death (necrosis).

Coal is the largest source of mercury and also a source of other heavy metals, many of which have been linked to both neurological and developmental problems in humans and other animals. Mercury concentrations in the air usually are low and of little direct concern. However, when mercury enters water, either directly or through deposition from the air, biological processes transform it into methylmercury, a highly toxic chemical that accumulates in fish and the animals (including humans) that eat fish.
4.3.3: Reducing the environmental impacts of coal use

Regulations such as the **Clean Air Act** and the **Clean Water Act** require industries to reduce pollutants released into the air and water. Below are some actions that have been taken to reduce the negative impacts of coal on human and environmental health:

- **Clean coal technology**: Industry has found several ways to reduce sulfur, NO\textsubscript{x}, and other impurities from coal before burning.
- Coal consumers have shifted toward greater use of low sulfur coal.
- Power plants use **scrubbers**, to clean SO\textsubscript{2}, NO\textsubscript{x}, particulate matter, and mercury from the smoke before it leaves their smokestacks. In addition, industry and the U.S. government have cooperated to develop technologies that make coal more energy-efficient so less needs to be burned.
- Research is underway to address emissions of carbon dioxide from coal combustion. **Carbon capture & sequestration** separates CO\textsubscript{2} from emissions sources and recovers it in a concentrated stream. The CO\textsubscript{2} can then be sequestered, which puts CO\textsubscript{2} into storage, possibly underground, where it will remain permanently (see chapter 7)
- Reuse and recycling can also reduce coal's environmental impact. Land that was previously used for coal mining can be reclaimed and used for airports, landfills, and golf courses. Waste products captured by scrubbers can be used to produce products like cement and synthetic gypsum for wallboard.