Fossil Energy Study Guide:

WHAT IS COAL?

Coal looks like a shiny black rock. Coal has lots of energy in it. When it is burned, coal makes heat and light energy. The cave men used coal for heating, and later for cooking. Burning coal was easier because coal burned longer than wood and, therefore, did not have to be collected as often.

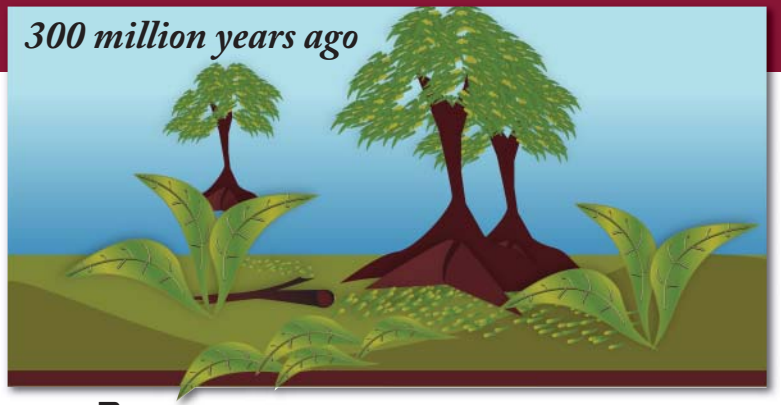
People began using coal in the 1800s to heat their homes. Trains and ships used coal for fuel. Factories used coal to make iron and steel. Today, we burn coal mainly to make electricity.

COAL IS A FOSSIL FUEL

Coal was formed millions of years ago, before the dinosaurs. Back then, much of the earth was covered by huge swamps. They were filled with giant ferns and plants. As the plants died, they sank to the bottom of the swamps.

Over the years, thick layers of plants were covered by dirt and water. They were packed down by the weight. After a long time, the heat and pressure changed the plants into coal. Coal is called a **fossil fuel** because it was made from plants that were once alive! Since coal comes from plants, and plants get their energy from the sun, the energy in coal also came from the sun.

The coal we use today took millions of years to form. We can't make more in a short time. That is why coal is called **nonrenewable**.



Before the dinosaurs, many giant plants died in swamps.

Over millions of years, the plants were buried under water and dirt.

Heat and pressure turned the dead plants into coal.

COAL IS OUR MOST ABUNDANT FUEL

The United States has more coal reserves than any other country in the world. In fact, one-fourth of all the known coal in the world is in the United States. The United States has more coal that can be mined than the rest of the world has oil that can be pumped from the ground. We have enough to last almost 300 years!

Currently, coal is mined in 26 of the 50 states.

Coal is used primarily in the United States to generate electricity. In fact, it is burned in power plants to produce more than half of the electricity we use. A stove uses about half a ton of coal a year. A water heater uses about two tons of coal a year. And a refrigerator, that's another half-ton a year. Even though you may never see coal, you use several tons of it every year!

Coal is not only our most abundant fossil fuel, it is also the one with perhaps the longest history.

1. Alabama
2. Alaska
3. Arizona
4. Arkansas
5. California
6. Colorado
7. Connecticut
8. Delaware
9. Florida
10. Georgia
11. Hawaii *(not shown)*
12. Idaho
13. Illinois
14. Indiana
15. Iowa
16. Kansas
17. Kentucky
18. Louisiana
19. Maine
20. Maryland
21. Massachusetts
22. Michigan
23. Minnesota
24. Mississippi
25. Missouri
26. Montana
27. Nebraska
28. Nevada
29. New Hampshire
30. New Jersey
31. New Mexico
32. New York
33. North Carolina
34. North Dakota
35. Ohio
36. Oklahoma
37. Oregon
38. Pennsylvania
39. Rhode Island
40. South Carolina
41. South Dakota
42. Tennessee
43. Texas
44. Utah
45. Vermont
46. Virginia
47. Washington
48. West Virginia
49. Wisconsin
50. Wyoming

KEY

States are listed alphabetically. Match the numbers to find where each state is located.

Those states with a coal cart beside their number are states where coal is mined.

A BRIEF HISTORY OF COAL

Coal is the most plentiful fuel in the fossil family and it has the longest and, perhaps, the most varied history. Coal has been used for heating since the cave man. Archeologists have also found evidence that the Romans in England used it in the second and third centuries (100-200 AD).

In the 1700s, the English found that coal could produce a fuel that burned cleaner and hotter than wood charcoal.

In North America, the Hopi Indians during the 1300s in what is now the U.S. Southwest used coal for cooking, heating and to bake the pottery they made from clay. Coal was later rediscovered in the United States by explorers in 1673.

The **Industrial Revolution** played a major role in expanding the use of coal. A man named **James Watt** invented the steam engine which made it possible for machines to do work previously done by humans and animals. Mr. Watt used coal to make the steam to run his engine.

During the first half of the 1800s, the Industrial Revolution spread to the United States. Steamships and steam-powered railroads were main forms of transportation, and they used coal to fuel their boilers.

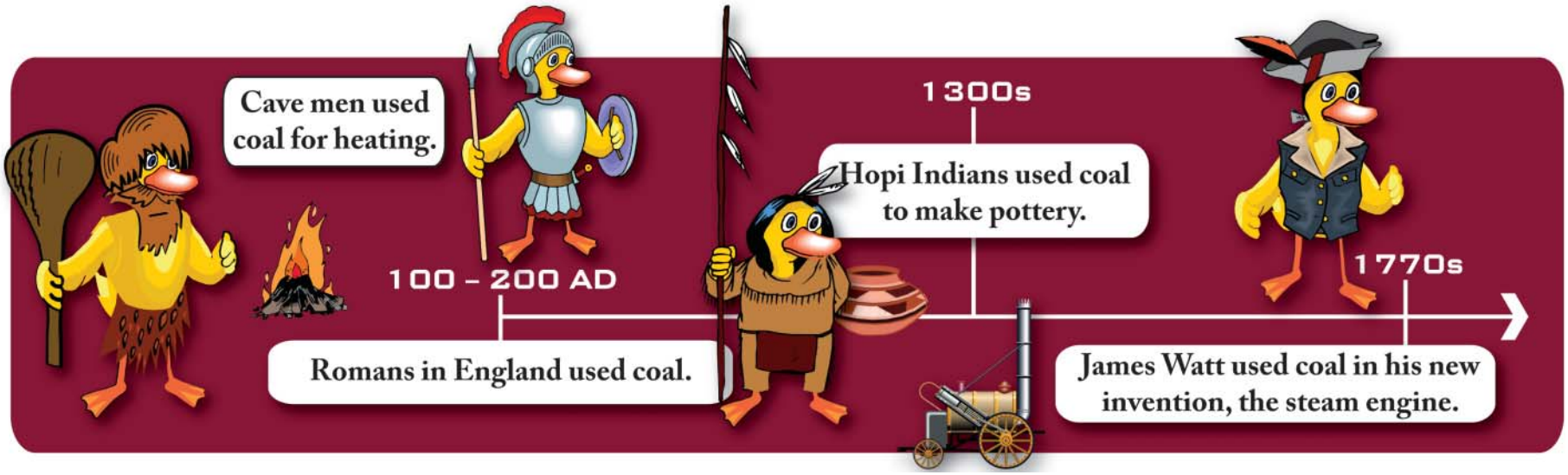
In the second half of the 1800s, more uses for coal were found.

During the Civil War, weapons factories were beginning to use coal. By 1875, **coke** (which is made from coal, and is not the same as Coca-Cola!) replaced charcoal as the primary fuel for iron blast furnaces to make steel.

The burning of coal to generate electricity is a relative newcomer in the long history of this fossil fuel. It was in the 1880s when coal was first used to generate electricity for homes and factories.

Long after homes were being lighted by electricity produced by coal, many of them continued to have furnaces for heating and some had stoves for cooking that were fueled by coal.

Today we use a lot of coal, primarily because we have a lot of it and we know where it is in the United States.



COAL MINING AND TRANSPORTATION

Most coal is buried under the ground. If coal is near the surface, miners dig it up with huge machines. First, they scrape off the dirt and rock, then dig out the coal. This is called **surface mining**.

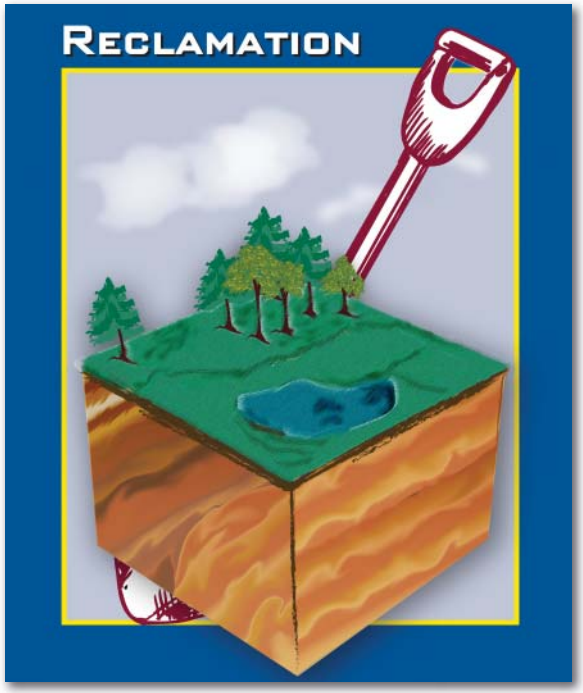
After the coal is mined, they put back the dirt and rock. They plant trees and grass. The land can then be used again. This is called **reclamation**.

If the coal is deep in the ground, tunnels called mine shafts are dug down to the coal. Machines dig the coal and carry it to the surface. Some mine shafts are 1,000 feet deep. This is called **deep mining**, or **underground mining**.

In the mine, coal is loaded in small coal cars or on conveyor belts which carry it outside the mine to where the larger chunks of coal are loaded into trucks that take it to be crushed (smaller pieces of coal are easier to transport, clean, and burn).

The crushed coal can then be sent by truck, ship, railroad, or barge. You may be surprised to know that coal can also be shipped by pipeline. Crushed coal can be mixed with oil or water (the mixture is called a **slurry**) and sent by pipeline to an industrial user.

We Dig for Coal



CONVERTING COAL INTO ELECTRICITY

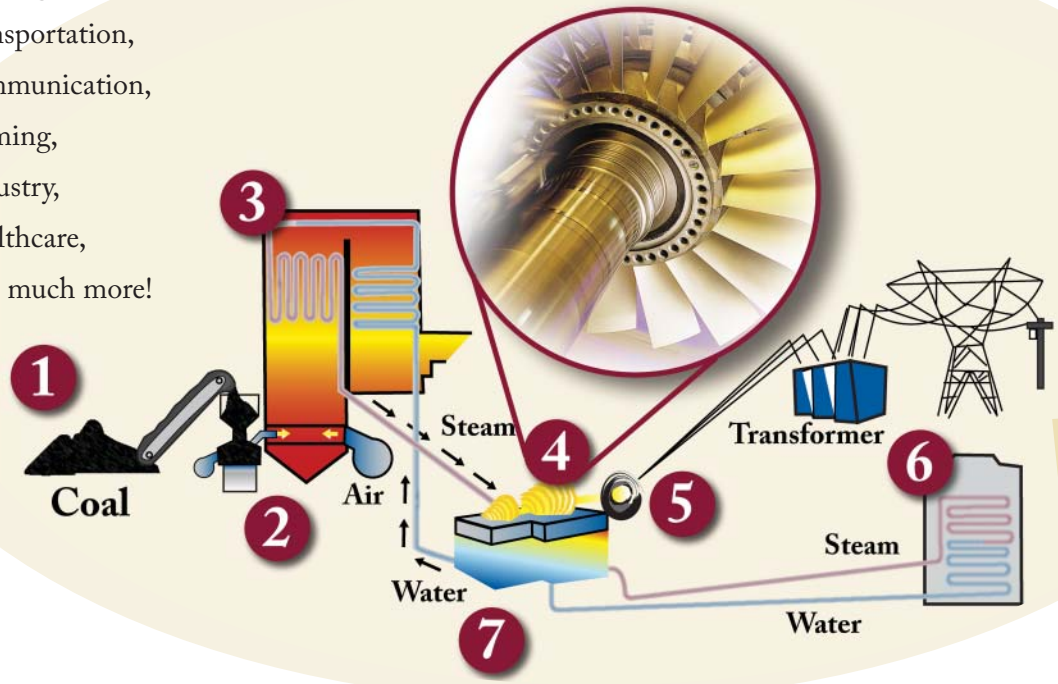
Nine out of every 10 tons of coal mined in the United States today are used to make electricity, and more than half of the electricity used in this country is **coal-generated electricity**.

Electricity from coal is the electric power made from the energy stored in coal. Carbon, made from ancient plant material, gives coal most of its energy. This energy is released when coal is burned.

We use coal-generated electricity for:

- heating,
- cooling,
- cooking,
- lighting,
- transportation,
- communication,
- farming,
- industry,
- healthcare,
- and much more!

Turning Coal into Electricity



The process of converting coal into electricity has multiple steps and is similar to the process used to convert oil and natural gas into electricity:

1. A machine called a **pulverizer** grinds the coal into a fine powder.
2. The coal powder mixes with hot air, which helps the coal burn more efficiently, and the mixture moves to the **furnace**.
3. The burning coal heats water in a **boiler**, creating steam.
4. Steam from the boiler spins the blades of an engine called a **turbine**, transforming heat energy from burning coal into mechanical energy that spins the turbine engine.
5. The spinning turbine is used to power a **generator,** a machine that turns mechanical energy into electric energy. This happens when magnets inside a copper coil in the generator spin.
6. A **condenser** cools the steam moving through the turbine. As the steam is condensed, it turns back into water.
7. The water returns to the boiler, and the cycle begins again.

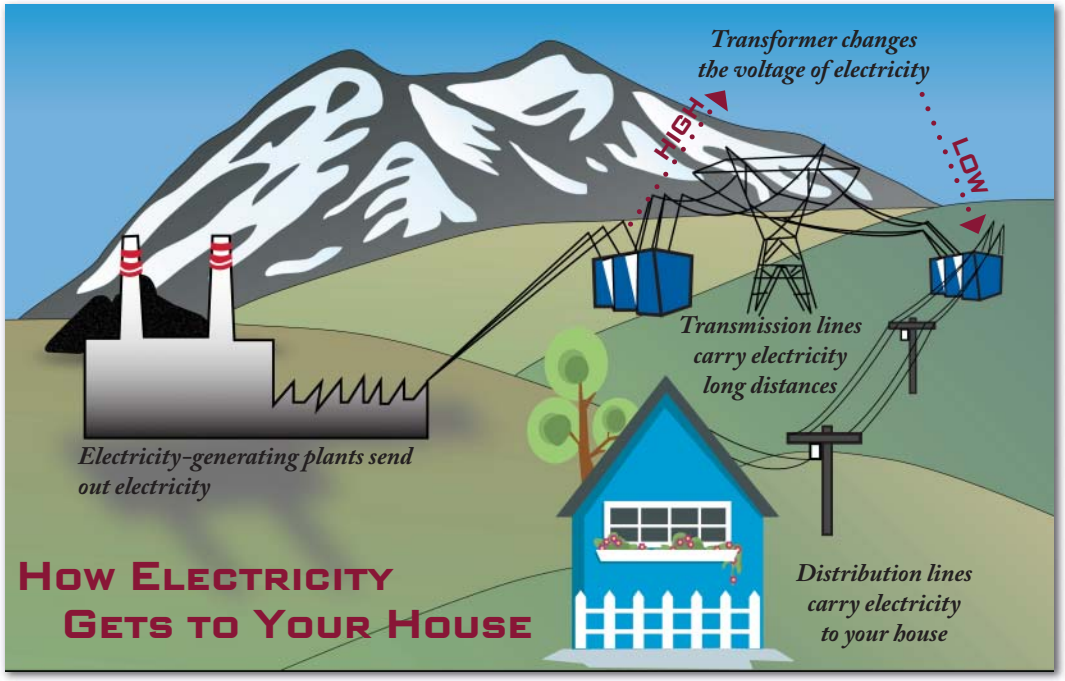
The steps for converting coal into electricity are shown here, and described above. An actual photo of a turbine is shown in the circle. Turbines have fan-like blades attached to a shaft that spin to generate power. Practically every form of electric power is generated by a turbine. Even the Space Shuttle uses a gas turbine!

DELIVERING ELECTRICITY

Electricity-generating plants send out electricity using a **transformer**, which changes the electricity from low voltage to high voltage. This is an important step, as it gives electricity the *jolt* it needs to travel from the power plant to its final destination. Voltages are often as high as 500,000 volts at this point.

Electricity flows along transmission lines to **substation transformers**. These transformers reduce the voltage for use in the local areas to be served.

From the substation transformers, electricity travels along distribution lines, which can be either above or below the ground, to cities and towns. Transformers once again reduce the voltage—this time to about 120 to 140 volts—for safe use inside homes and businesses. The delivery process is instantaneous. By the time you have flipped a switch to turn on a light, electricity has been delivered.



COAL'S ROLE IN OUR ELECTRICAL SUPPLY

Natural gas and oil are also used to make electricity. How does coal compare to these other fossil fuels? In terms of supply, coal has a clear advantage. The United States has nearly 300 billion tons of recoverable coal. That is enough to last about 300 years if we continue to use coal at the same rate as we use it today.

But what about costs? The mining, transportation, electricity generation, and pollution-control costs associated with using coal are increasing, but both natural gas and oil are becoming more expensive to use as well. This is, in part, because the United States must import much of its oil supply from other countries. It has enough coal, however, to take care of its electricity needs, with enough left over to export some coal as well.

The cost of using coal should continue to be even more competitive, compared with the rising cost of other fuels. In fact, generating electricity from coal is cheaper than the cost of producing electricity from natural gas. In the United States, 23 of the 25 electric power plants with the lowest operating costs are using coal. Inexpensive electricity, such as that generated by coal, means lower operating costs for businesses and for homeowners. This advantage can help increase coal's competitiveness in the marketplace.

CLEANING UP COAL

Coal is our most abundant fossil fuel. The United States has more coal than the rest of the world has oil. There is still enough coal underground in this country to provide energy for the next 200 to 300 years.

But coal is not a perfect fuel.

Trapped inside coal are traces of impurities like **sulfur** and **nitrogen**. When coal burns, these impurities are released into the air.

While floating in the air, these substances can combine with water vapor (for example, in clouds) and form droplets that fall to earth as weak forms of sulfuric and nitric acid. Scientists call it "acid rain."

There are also tiny specks of minerals—including common dirt—mixed in coal. These tiny particles don't burn and make up the ash left behind in a coal combustor. Some of the tiny particles also get caught up in the swirling combustion gases and, along with water vapor, form the smoke that comes out of a coal plant's smokestack. Some of these particles are so small that 30 of them laid side-by-side would barely equal the width of a human hair!

Also, coal like all fossil fuels is formed out of carbon. All living things—even people—are made up of carbon. (Remember—coal started out as living plants.) But when coal burns, its carbon combines with oxygen in the air and forms **carbon dioxide**. Carbon dioxide is a colorless, odorless gas, but in the atmosphere, it is one of several gases that can trap the earth's heat. Many scientists believe this is causing the earth's temperature to rise, and this warming could be altering the earth's climate.

Sounds like coal is a dirty fuel to burn. Many years ago, it was. But things have changed. Especially in the last 20 years, scientists have developed ways to capture the pollutants trapped in coal before they can escape into the air.

We also have new technologies that cut back on the release of carbon dioxide by burning coal more efficiently.

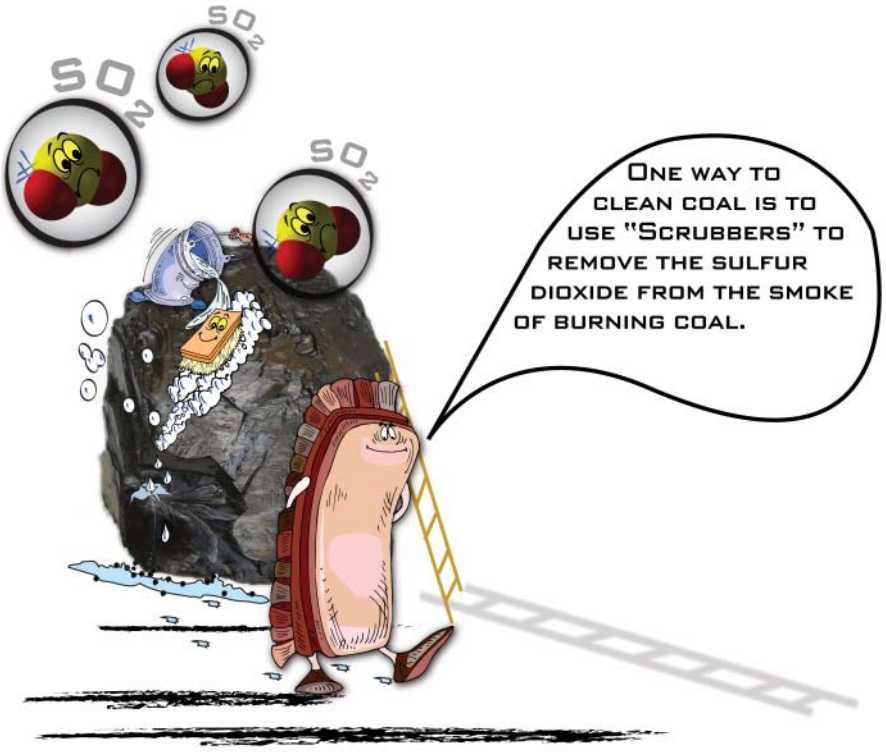
Many of these technologies belong to a family of energy systems called "**clean coal technologies**."

HOW DO YOU MAKE COAL CLEANER?

Actually there are several ways.

One way is to clean the coal before it arrives at the power plant. This is done by simply crushing the coal into small chunks and washing it.

Another way is to use "**scrubbers**" that remove the sulfur dioxide (a pollutant) from the smoke of coal-burning power plants.



HOW DO SCRUBBERS WORK?

Most scrubbers rely on a very common substance found in nature called "**limestone**." We literally have mountains of limestone throughout the United States. When crushed and processed, limestone can be made into a white powder. Limestone can be made to absorb sulfur gases under the right conditions—much like a sponge absorbs water.

In most scrubbers, limestone (or another similar material called lime) is mixed with water and sprayed into the coal combustion gases (called "**flue gases**"). The limestone captures the sulfur and "pulls" it out of the gases. The limestone and sulfur combine with each other to form either a wet paste (it looks like toothpaste!), or in some newer scrubbers, a dry powder. In either case, the sulfur is trapped and prevented from escaping into the air.

THE CLEANEST COAL TECHNOLOGY—A REAL GAS!

We can even turn coal into a gas—using lots of heat and water—in a process called **gasification**. When coal is turned into a gas, we can burn it and use it to spin a gas turbine to generate electricity. The exhaust gases coming out of the gas turbine are hot enough to boil water to make steam that can spin another type of turbine to generate even more electricity. But why go to all the trouble to turn the coal into gas if all you are going to do is burn it?

A big reason is that the pollutants in coal—like **sulfur, nitrogen** and **carbon dioxide**—can be almost entirely cleaned up when coal is changed into a gas. In fact, scientists have ways to remove 99.9% of the sulfur and small dirt particles from coal gas. Gasifying coal is one of the best ways to clean pollutants out of coal.

Another reason is that the coal gases don't have to be burned. They can also be used as valuable chemicals. Scientists have developed ways to turn coal gases into everything from liquid fuels for cars and trucks to plastic toothbrushes!

COAL AND CLIMATE CHANGE

Carbon dioxide (CO_2) is a colorless, odorless gas that is produced naturally when humans and animals breathe. The main source of man-made CO_2 emissions, however, is the burning of fossil fuels (oil, natural gas and coal) for energy production. Carbon dioxide is important for plants and animals, but if too much of it is produced, it can build up in the air and trap heat near the earth's surface. This is called the **greenhouse effect**.

To clean CO_2 from power plants, scientists have been studying how to capture the CO_2 coming up a power plant's smokestack before it gets into the air. The CO_2 is then gathered, transported and eventually stored underground or in the ocean, where it's supposed to sit for a long, long time. Scientists are even studying ways to recycle the CO_2 into new materials. The technical name for this process is **carbon storage**, or **carbon sequestration**.

It is expected that coal and other fossil fuels will remain a major energy source for years to come. Many environmentalists believe that capturing and storing CO_2 from power plants, combined with other efforts, could help fight climate change.

Scientists continue to research and develop carbon sequestration technologies. It is important to make sure these new processes are environmentally acceptable and safe. For example, scientists must determine that CO_2 will not escape from under the ground, or contaminate drinking water supplies. Carbon capture and storage is an exciting area of research and development for today's scientists.