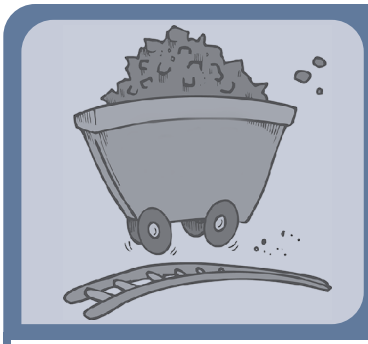


Digging for Coal

Students simulate the coal mining process using chocolate chip cookies.

Grade Level: K-4

Subject Areas: English Language Arts, Mathematics, Science, Social Studies

Setting: Classroom

Time:
Preparation: 40 minutes
Activity: One to two 50-minute periods

Vocabulary: Anthracite, Bituminous coal, Lignite, Reclamation, Subbituminous coal.

Major Concept Areas:

- Development of energy resources
- Consumption of resources
- Quality of the environment

Getting Ready: Obtain samples of coal from a science supply catalog or another source, possibly one of Wisconsin's electric utilities that burns coal to produce electricity (optional). Copy pictures of coal from books or other sources (optional).

Objectives

Students will be able to:

- describe how coal is formed;
- identify where coal deposits are found and show that they are unevenly distributed throughout the United States;
- identify how coal is used in Wisconsin and the United States;
- simulate coal mining and its effects using chocolate chip cookies; and
- state the benefits and problems associated with mining and using coal.

Rationale

By learning how coal is formed, where it is found, how it is mined, and how it is used, students gain an understanding of the important role it plays in providing energy to Wisconsin and the rest of the United States.

Materials

- Rectangular aquarium or glass loaf pan
- Fine-to-medium-grained sand
- Plant leaves, twigs, and grass
- Samples of coal (optional)
- Pictures of coal (optional)
- Butcher paper (optional)
- Large, soft cookies or muffins containing chocolate chips, raisins, berries, or nuts (one cookie or muffin for each student)
- Napkins (one for each student)
- Paper clips (one per student)
- Juice or milk (optional)
- Copy or display the graphics from ***Facts about Coal*** - U.S. Coal Deposits and Coal Production by State
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

See ***Facts about Coal***.

Procedure

Orientation

Ask students if they know how coal is used. They may answer based on previous knowledge or experience, or they may recount stories they've heard (the characters in Charles Dickens's A Christmas Carol use coal to heat their homes and workplaces; locomotives mentioned in a number of stories are powered by coal). List students' responses on the board.

Point out to students that nowadays coal is mostly used by power plants in Wisconsin and the United States to generate electricity. It is rarely used to heat homes or drive locomotives and ships anymore. Briefly mention other uses of coal (see ***Facts about Coal***).

Show students how coal is formed using the following demonstration. Fill the bottom of the aquarium (or glass loaf pan) with about 2 inches (5 cm) of fine-to-medium-grained sand. Add water, plant leaves, and twigs to create a "swamp." Then place another 2 to 3 inches (7.5 cm) of sand on top of the leaves and twigs. Repeat the following passage to students as you finish adding the top layer of sand:

"You take plants found in a swampy area, bury them under many layers of sand and silt, and compress the layers over millions of years until all but the layers on the top turn into rock. What do you get?"

Have students guess the answer. After students have guessed, show them a sample of coal (if available) or a picture of coal. If additional samples of coal are available, distribute them to students and have them describe the samples in terms of color, weight, and hardness. If you only have one or two pieces of coal available, have students pass the samples around. You may also have students look at the coal samples under a microscope in order to see the sedimentary layers. If known, tell students what type of coal they are looking at (anthracite, bituminous, etc.) and where it came from.

Steps

1. Review the different types of coal with students. Discuss how coal is mined out of the ground, and how it is used in Wisconsin and elsewhere in the United States. Tell students that they will be doing a coal mining simulation using chocolate chip cookies.
2. Place the ***Summary Table*** on the whiteboard or on a large piece of butcher paper posted on a wall.
3. Give each student a cookie, a napkin, and a paper clip. They are not to eat the cookies until the exercise is over.
4. Ask students to suggest what the whole cookie, the tan parts of the cookie, the chocolate chips, and the paper clip represent in the simulation. (Answers: cookie = country or state; tan parts of the cookie = Earth's crust; chocolate chips = coal; paper clip = mining machinery.)
5. Have students count how many visible chunks of coal are in their country or state. Students should count only the chips they can see on the top of the cookie. Record their responses on the ***Summary Table***.
6. Have students predict the total number of coal deposits in their country or state (the total number of chips they think the cookie has). Record this number for each student on the ***Summary Table***.
7. Students can begin "mining" their coal deposits. Make sure they understand that because the cookie represents the earth they can't pick it up.
8. Have students place their coal deposits in one pile and Earth's crust in another. Have students continue "mining" until most appear finished. When students finish, record the total number of coal deposits mined

Summary Table

Student Name	Number of Chocolate Chips Found before Mining	Predicted Number of Chocolate Chips in the Cookie	Actual Number of Chocolate Chips Mined

in their country or state (the total number of chips found in the cookie) on the summary table.

9. Have students compare the number of coal deposits they predicted they would find to the actual number they "mined" in their country or state. Ask students how they arrived at their prediction, and whether or not their method was an accurate way to determine the number of coal deposits that were underground.

10. Before students are allowed to eat their cookie, instruct them to put their "Earth" back together. Encourage them to try, even if their cookie looks like a pile of crumbs.

11. Hand out copies of U.S. Coal Deposits and U.S. Coal Production by State from ***Facts about Coal***. Discuss with students the concept that coal deposits (as well as all fossil fuel resources) are unevenly distributed throughout the United States and the world. Relate this point to the lack of coal deposits in Wisconsin, and how we have to get coal from other parts of the nation to meet part of our energy needs.

Closure

Discuss the following points with the class and have students answer the questions.

- Compare the way chips were mined on the cookie's surface and interior with the process of surface and underground coal mining. In what ways are they the same? In what ways are they different? Also compare the effort it took to mine the chips inside the cookie to mining chips on the surface. What does this suggest about the energy needed to mine coal?
- Were students able to put their cookies back together? How difficult was it? How does this compare to the difficulty of reclaiming land after coal mining has taken place? Explain.
- Relate coal mining to the uses of coal. How do we use coal in Wisconsin and in other parts of the United States? What benefits do we get from using coal? What problems arise from using coal?

Assessment

Formative

- Can students explain how coal is used and how it is formed?
- How well did students perform the cookie mining exercise?

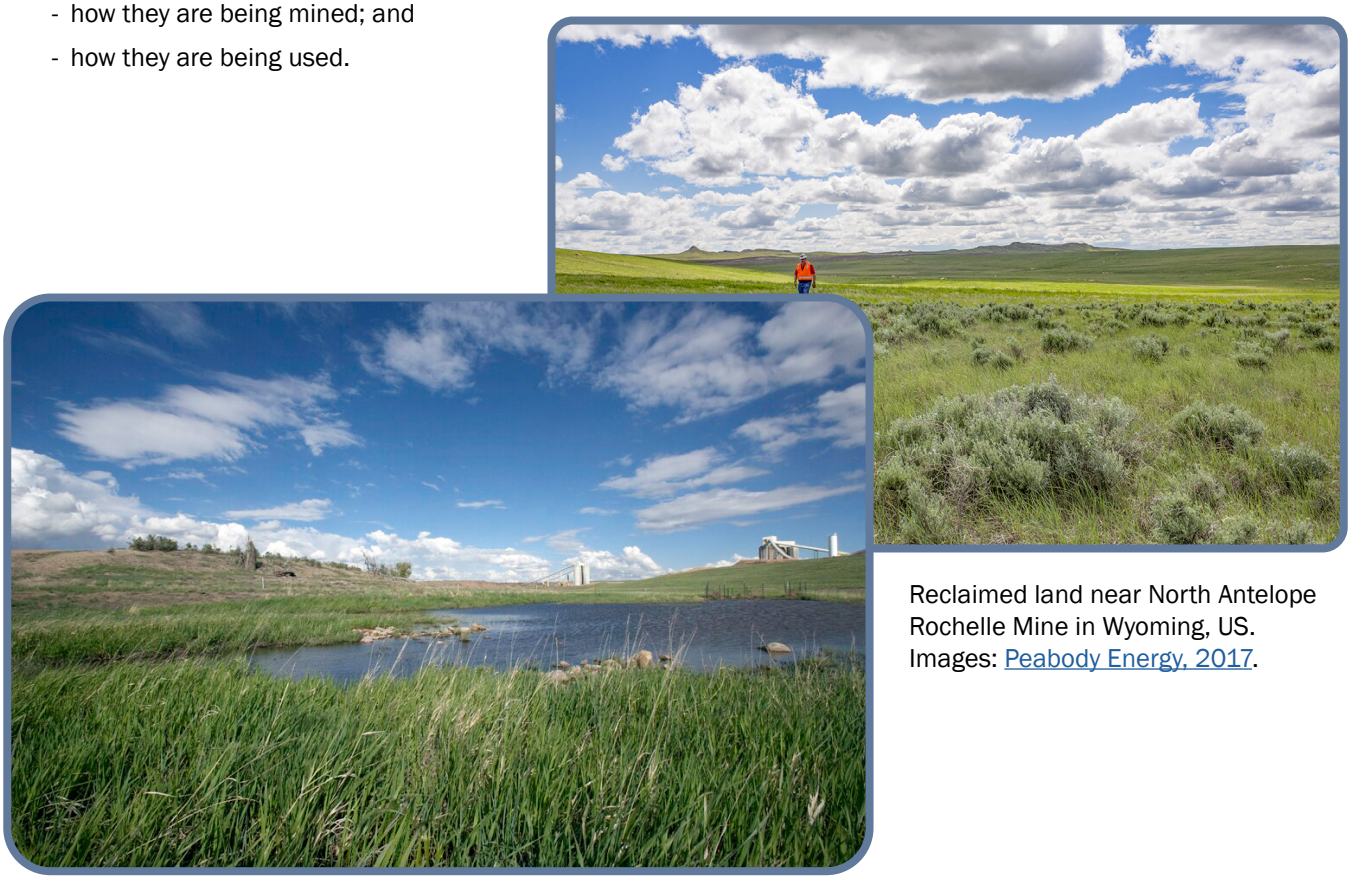
North Antelope Rochelle Mine in Wyoming, US. The mine was opened in 1983 by Peabody Energy and is one of the most productive mines in the world supplying the lowest sulfur coal in North America. Image: Peabody Energy, 2017.

Summative

- Have students mention three positive and three negative aspects of mining and using coal. What other energy resources or energy conservation strategies would they consider using to replace coal? What reasons can they give for their choices?
- Ask students to write a story or create a cartoon series where they pretend that they are a lump of coal. The story should include:
  - what type of coal they are;
  - how they were created millions of years ago;
  - how they were developed;
  - what region of the United States they come from;
  - how they are being mined; and
  - how they are being used.

Related KEEP Activities

Orient students to different energy resources through activities such as "Where Does It Get Its Energy?" and "Fueling Around." The use of coal in electricity generation can be integrated into the activity "Waterwheels, Windmills, and Turbines." Information about how coal and other fossil fuels and nuclear resources are imported into Wisconsin is found in the activity "Fuel That Power Plant." Issues associated with nonrenewable resources are further explored in "Energy Divide." Other energy resources are found in K–5 Energy Sparks: Theme II ("Introducing Energy Resources," "Introducing Renewable and Nonrenewable Energy Resources," "Fossil Fuel Products," "Sunvestigations," "Windy Wonders," and "Water Fun").



Reclaimed land near North Antelope Rochelle Mine in Wyoming, US. Images: Peabody Energy, 2017.

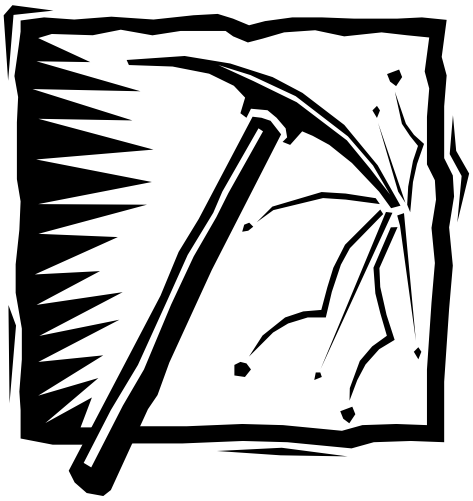
The Wisconsin K-12 Energy Education Program is supported through funding from

Wisconsin K-12 Energy Education Program (KEEP)
College of Natural Resources
University of Wisconsin-Stevens Point

Alliant Energy · WPPI energy The way energy should be · We · WPS · Xcel Energy RESPONSIBLE BY NATURE · MGE Madison Gas and Electric

Facts about Coal

Introduction



The United States has more coal than any other fossil fuel resource. Coal is the second most consumed fossil fuel in the world, behind petroleum, (which includes liquids from biomass, crude oil, coal, and natural gas).

Coal is formed from plant matter that decayed in swamps and bogs millions of years ago. Geological processes compressed and altered these plant remains into a solid material made of carbon and other substances, such as hydrogen, oxygen, nitrogen, and sulfur, in other words, it's packed with energy.

There are four main types of coal, which are classified by how much carbon they contain. Anthracite is the hardest and contains the most carbon per pound. Anthracite is followed by bituminous and subbituminous coal. Lignite, a soft coal, has the lowest amount of carbon per pound. The energy content of coal is approximately related to its carbon content. The energy content of coal is measured in Btu (British thermal units) or quads (1,015 Btu).

The table below summarizes the different types of coal in terms of energy, carbon and sulfur content, and percent of known U.S. Reserves.

Coal Types

Type of Coal	Average Energy Content (Btu per lb.)	Carbon Content (%)	Sulfur Content* (%)	Percentage of Known U.S. Reserves (%)
Anthracite	12,500	86–98	0.4–1.9	1.5
Bituminous	12,000	50–86	0.8–5.0	51.0
Subbituminous	9,000	40–0	0.6–1.8	38.0
Lignite	7,000	40	1.6	9.5

* For selected samples of coal types. Numbers may not cover the complete range of sulfur contained in a given type of coal.

Reserves

As of 2014, the U.S. had 480 billion short tons of known coal reserves. Of this, about 256 billion short tons (53 percent) are mineable. Most known coal reserves are in Wyoming, followed by West Virginia, Kentucky, Pennsylvania, and Illinois. Wisconsin has no known coal deposits. (See ***U.S. Coal Deposits***). Based on U.S. coal production in 2013 at 984.8 million short tons, the U.S. estimated recoverable coal reserves would last about 261 years. The actual number of years that those reserves will last depends on changes in production and reserves estimates.

Some refer to the U.S. as the "Saudi Arabia of coal" because it has more than one-fourth of the world's mineable reserves. Current known world coal reserves are estimated to be 861 billion tons. The biggest mineable reserves can be found in China, the U.S., India, Indonesia, and Russia.

Facts about Coal

Mining

Coal is extracted from underground and from surface mines (sometimes called strip mines). Since coal is deposited in broad layers or seams, between 40 and 60 percent of the coal from underground mines must be left behind as pillars to prevent cave-ins and collapse of the surface. Most underground mines are located in the eastern United States.

Coal seams within 300 feet of the surface can be surface mined. Most of the coal produced in the U.S. comes from surface mines, which are often found in the central and western U.S. To mine the coal, the ground above the seams, called overburden, is first removed. After mining, the land is reclaimed; the overburden is put back and the surface is graded to match the original shape of the land (although it will be somewhat lower in elevation) and replanted with the same type of vegetation.

Production

The United States produced 984.8 million short tons of coal in 2013. About 47.8 percent of which is bituminous coal, which is mined mostly in West Virginia, Kentucky, and Illinois. About 44.1 percent is sub-bituminous, mined principally in Wyoming, and 7.8 percent is lignite which is mined chiefly in Texas, North Dakota, and Louisiana. Anthracite is mined only in northeastern Pennsylvania and makes up about 0.2 percent of the US coal production.

In 2013, Wyoming produced most (40 percent) of the nation's coal, providing 388 million tons. West Virginia was the second highest producer at 11 percent while Kentucky produced eight percent. These three states account for 59 percent of total U.S. coal production.

In 2013, world coal production was around 7,823 million tons. China is the highest producer, and together, China and the US produce more than half of the world's coal. Other large coal producers include India, Indonesia, Australia, Russia, South Africa, Germany, Poland, and Kazakhstan.

Processing and Transportation

Coal requires little processing to be used as fuel. Processing includes washing impurities from the coal and then grinding it into fine particles at electric power plants to improve burning.

Sixty-seven percent of US coal is transported either partially or completely by rail in the United States. The balance is moved by river barge, truck, and--for power plants located at the coal mine--by conveyor. Coal slurry, a mix of finely ground coal and water, can also be transported by pipelines, although this is rare.

In Wisconsin, coal shipments are handled at several of the state's ports along the Mississippi River and the Great Lakes. Most of the coal consumed in Wisconsin arrives by rail from Wyoming, and almost all of it is used by the electric power sector to generate electricity. The remaining coal is used by the industrial sector, with only about 0.1 percent being consumed by the commercial sector.

Electricity Production

Coal currently provides 40 percent of the world's electricity needs. Most of the coal produced in the United States is burned in power plants to generate electricity. Wisconsin's electric power plants consume 94 percent of all coal delivered to the state, dominating electricity generation in Wisconsin. In 2013, coal provided 62 percent of the state's net electricity generation.

Facts about Coal

Other Uses

Coal is used as a source of energy by industries that manufacture cement, chemicals, paper, and metals. Coal can also be used to produce methane using a process called gasification. There are several gasification plants in the United States.

One percent of the coal consumed in the United States is used for heating homes and commercial businesses. In Wisconsin, virtually no homes (out of more than two million) are still heated with coal. Coal is used to produce coke, a material used to make steel. Roughly 70 percent of global steel production is dependent on coal. Manufacturers also use coal as an ingredient to create photographic film, electrodes, varnishes, perfumes, and inks.

Consumption

During 2013, Americans consumed 924 million short tons of coal. Total coal consumption in Wisconsin was more than 25 million short tons; 94 percent of this was burned in power plants to generate electricity. World consumption of coal was 4,762 million tons. The global coal demand is projected to reach 9 billion tons by 2019.

Effects

The mining and transportation of coal provide jobs. However, conflicts between miners and mine owners and managers have led to numerous strikes throughout the past century and caused supply disruptions within the United States. Underground mining is hazardous because of cave-ins, methane gas explosions, and dust inhalation. Surface mining is safer, although accidents and noise may cause problems. Mine safety has greatly improved during this century.

Coal use has serious environmental drawbacks. Mining can scar the land unless it is carefully reclaimed. Groundwater may become polluted. Surface collapse above old underground mines, called subsidence, is also a potential problem.

Mercury, a toxic, heavy metal, is released into the air when coal is burned. The airborne mercury attaches to water and dust particles and enters lakes and streams in rain, snow, and runoff. Fish absorb mercury through their gills or by ingesting contaminated smaller organisms. Humans may get mercury poisoning by eating contaminated fish. Serious neurological damage, especially to children, has been linked to mercury poisoning.

Compared to other fossil fuels, coal produces the greatest amount of carbon dioxide and solid particles per pound when burned. Carbon dioxide contributes to climate change. Coal burning also produces sulfur dioxide (which leads to acid rain) and nitrogen oxides. Large amounts of ash remain after burning coal and must be disposed of. Some of these air pollutants can be reduced using scrubbers and other pollution control devices. To reduce sulfur dioxide emissions, many electric utilities, including those in Wisconsin, have switched to burning low-sulfur subbituminous coal mined in Wyoming and other western states.

Carbon Capture and Storage (CCS)

Carbon Capture and Storage (CCS) is a technology that can capture up to 90 percent of the carbon dioxide (CO_2) emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere. There have been some positive efforts to build more efficient plants, retrofit old plants, and decommission the oldest, least efficient plants. Carbon capture and storage (CCS) is the most promising technology to reach near-zero CO_2 emissions from large CO_2 sources.

Facts about Coal

Outlook

At current rates of use, the nation's known mineable coal reserves should last hundreds of years. In the future, coal may be converted into gaseous and liquid fuels, thus supplementing finite supplies of natural gas and oil. However, coal-derived fuels will likely be more expensive. Environmental drawbacks such as acid rain and climate change, along with mining restrictions on protected lands, may limit future coal use.

References

Carbon Capture & Storage Association: ccsassociation.org

International Energy Agency: Coal: iea.org/topics/coal

Institute for Energy Research: instituteforenergyresearch.org/topics/encyclopedia/coal

U.S. Department of Energy: Fossil Energy: energy.gov/fe/office-fossil-energy

U.S. Energy Information Administration: Coal: eia.gov/coal

Wisconsin Office of Energy Innovation. Wisconsin Energy Statistics Book: psc.wi.gov/Pages/Programs/OEI/WisconsinEnergyStatistics.aspx

World Coal Association: Coal Statistics: worldcoal.org/resources/coal-statistics

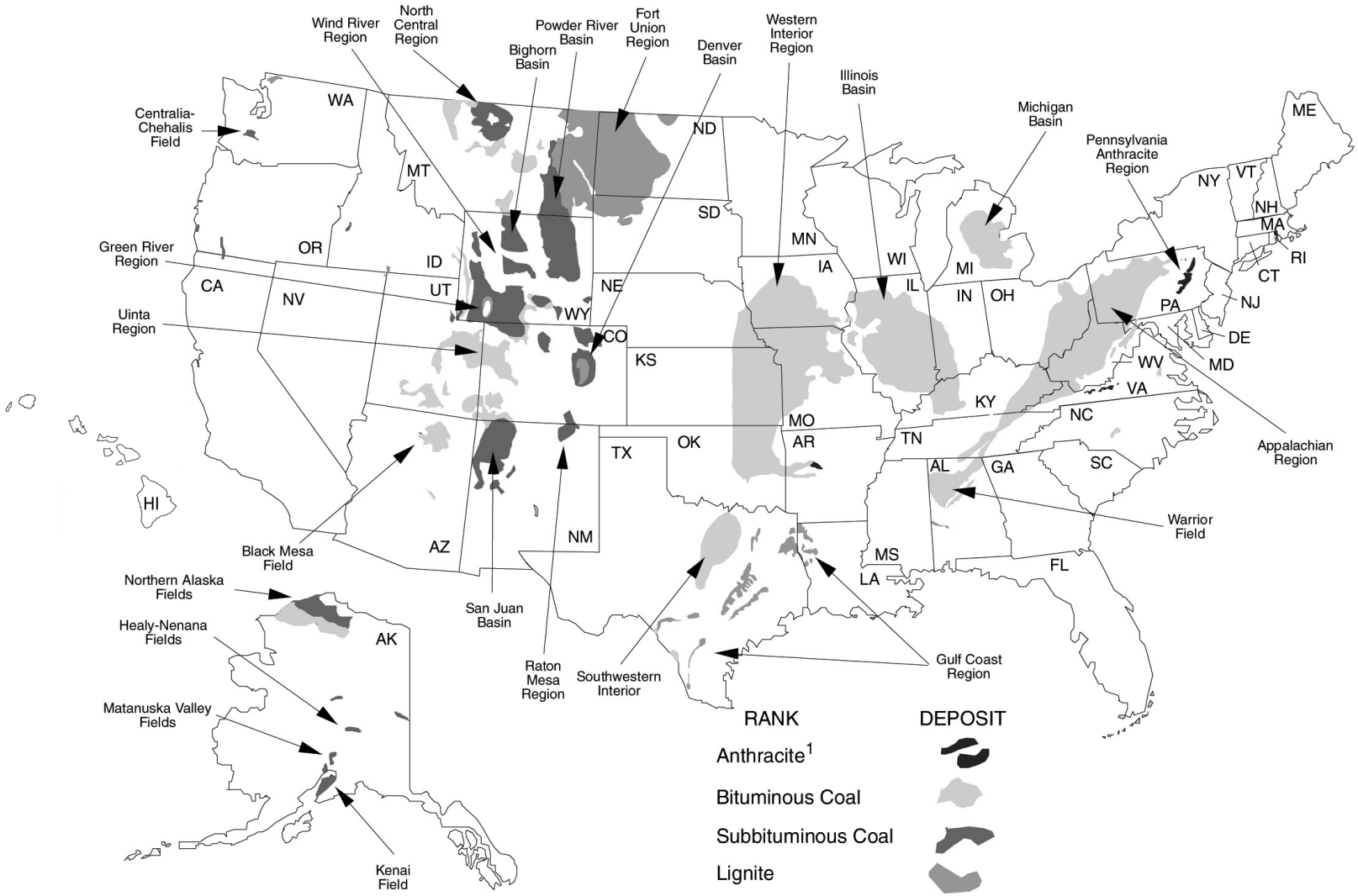
Wyoming State Geological Survey: Wyoming Coal: wsgs.wyo.gov/energy/coal

The Wisconsin K-12 Energy Education Program is supported through funding from

Wisconsin K-12 Energy Education Program (KEEP)
College of Natural Resources
University of Wisconsin-Stevens Point

Alliant Energy · WPPI energy The way energy should be · We · WPS · Xcel Energy RESPONSIBLE BY NATURE · MGE Madison Gas and Electric

U.S. Coal Deposits

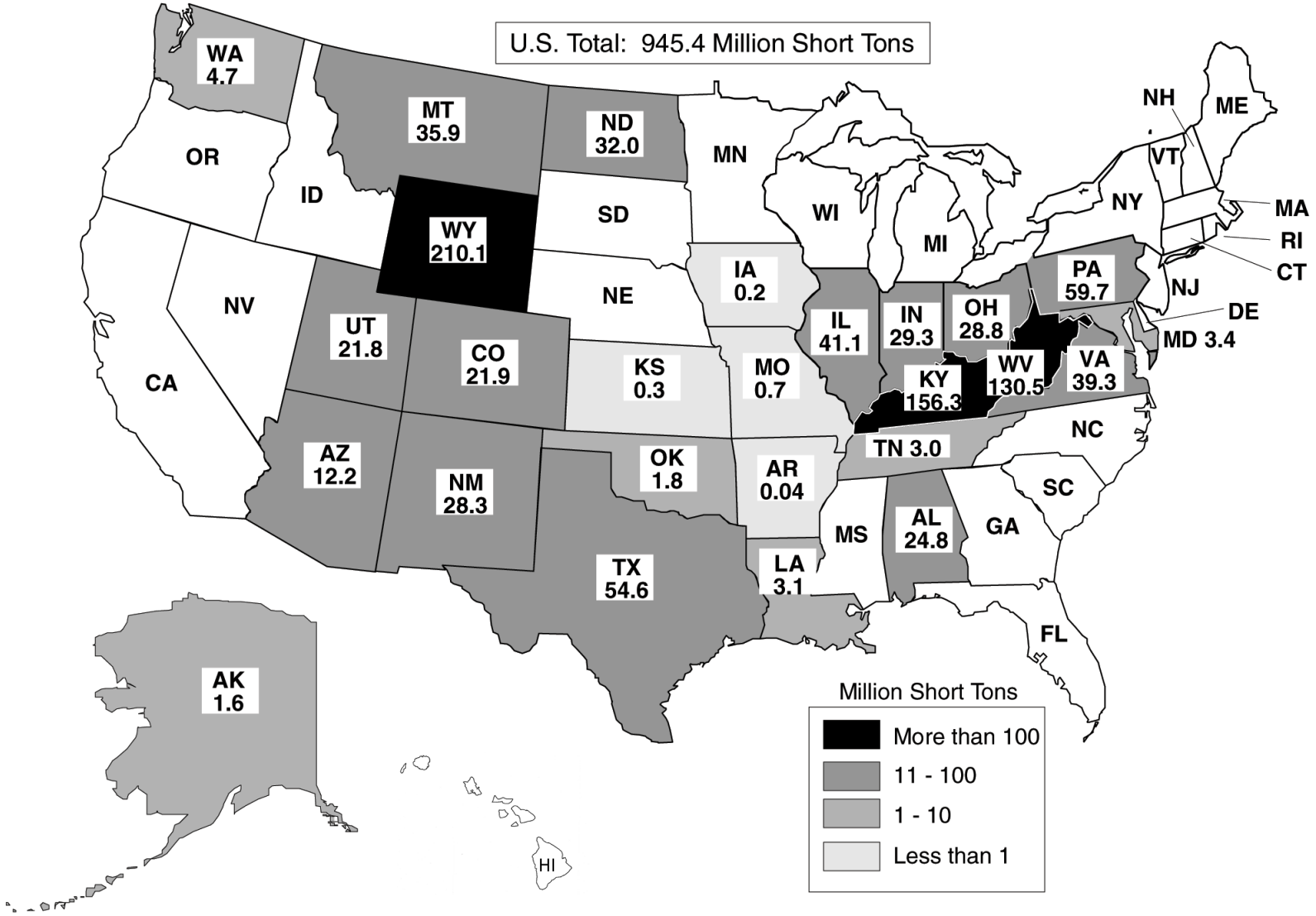


*Principal anthracite deposits are in Pennsylvania. Small deposits occur in Alaska, Arkansas, Colorado, Massachusetts-Rhode Island, New Mexico, Utah, Virginia, Washington, and West Virginia.

NOTE: Alaska and Hawaii not to scale of conterminous United States. Small fields and isolated occurrences are not shown.

Source: U.S. Department of Energy, Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels. "U.S. Coal Deposits." p. 7 in *Coal Data: A Reference*. Washington, D.C., February 1995. DOE/EIA-0064 (93).

U.S. Coal Production by State



Source: Energy Information Administration, *Annual Coal Report 2013*, U.S. Department of Energy, Washington, DC, April 2015.