Coal Energy

Lesson Plans and Resource Guide

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Lesson Plans

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Introduction

Coal, the most abundant fossil fuel in the U.S. and the world, has been used for thousands of years as a valuable natural resource. The U.S. has approximately 24% of all the world's known coal reserves. There are enough coal reserves worldwide to supply energy, at the current rate, for over 200 years. The interest in coal energy fluctuates due primarily to environmental concerns.

The objective of the following lesson plans is to educate elementary through high school students about the practices in developing this massive energy resource. The information, aligned with National Science Education Content Standards and Pennsylvania Academic Standards, will be presented in a hands-on, engaging manner. It will be balanced, coming from a variety of sources.

The lesson plans will investigate the following coal-related topics: formation and identification, mining, energy, environmental impacts and legislation. Also, they will explore advancements in the coal energy industry, including clean coal technologies, cogeneration, waste-coal usage and land reclamation.

Energy Resources

The necessities and luxuries in our everyday lives create the increasing demand for energy resources. The total world consumption of primary energy is approximately 460 quadrillion (one quadrillion = 1,000,000,000,000,000) Btu's annually. Btu's are British thermal units, which are a measure of heat energy. The heat produced by burning one wooden kitchen match is equal to about one Btu. The United States consumes over 100 quadrillion Btu's per year. Projections indicate that by the year 2025, the world will use 640 quadrillion Btu's annually.

Most of the energy consumed by the world comes from nonrenewable resources, which are limited in quantities and can be depleted. These resources are primarily fossil fuels: petroleum, coal and natural gas. Petroleum accounts for approximately 37% of the world's energy consumption. Coal and natural gas together supply approximately 48%. Uranium is another nonrenewable energy resource used in nuclear power plants. It is used for approximately 7% of the world's energy.

Renewable energy resources, of endless supply, account for approximately 8% of the world's energy consumption. Hydroelectric power, derived from running water, is the most widely used form of renewable energy. These resources also include biomass (from plants, garbage and agricultural waste), solar, geothermal (heat energy within the earth) and wind. Researchers continue to study other sources of energy among them nuclear fusion and a variety of hydrogen-based technologies.

Coal: A Fossil Fuel

Fossil fuels are derived from plant and animal matter. They formed naturally over millions of years. These energy-producing fuels are the remains of ancient life that have undergone changes due to heat and pressure. The primary fossil fuels are coal, petroleum and natural gas. Together they account for 85% of the world's energy consumption.

Coal is a dark, combustible material formed, through a process known as coalification, from plants growing primarily in swamp regions. Layers of fallen plant material accumulated and partially decayed in these wet environments to form a spongy, coarse substance called peat. Over time, this material was compressed under sand and mud, and heated by the earth to be transformed into coal. Some scientists refer to coal as sedimentary rock. Coal is primarily composed of carbon, hydrogen, oxygen and nitrogen.

There are several classifications of coal, which are rated according to their carbon content and heating value. The heating value of coal is expressed in BTUs per pound. A precursor to the formation of coal is peat. Peat, with a heating value of approximately 4,500 BTUs, contains up to 60% carbon when dried. Peat hardens over time and under pressure into lignite, a cheap brown coal, containing approximately 70% carbon. Lignite has a heating value of approximately 7,000 BTUs. Sub-bituminous coal, with an approximate heating value of 9,300 BTUs contains about 78% carbon. Bituminous coal is a more developed coal and the most common type. With a heating value that ranges from approximately 11,250 – 14,350 BTUs, it contains about 85% carbon. The hardest and most expensive coal, anthracite, has a heating value of approximately 13,600 BTUs. It contains 92-95% carbon.

Coal Mining

The two main types of coal mining are surface (strip) mining and underground mining. Strip mining involves the removal of coal deposits close to earth's surface (usually no more than 100 feet from the surface). Topsoil and rocks are removed from the surface to expose the coal deposits. Explosives and heavy machinery are used to break up and remove layers of coal.

Underground mining involves the removal of coal deposits, often hundreds of feet below the earth's surface. (Some mines may be close to 2,000 feet deep.) Shafts or tunnels are dug into the coal layers and widened to allow room for the miners and coal cars or conveyor belts. Additional shafts may be excavated to increase air ventilation for the miners.

The history of coal mining is rife with tragic occurrences. Mining accidents, methane gas explosions, violence fueled by labor strikes, and respiratory ailments - primarily Black Lung Disease- were common in the past. Over 100,000 miners have been killed in coal-mining accidents in the U.S. since 1900. The United Mine Workers of America Union was formed in 1890 to promote safer working conditions. Several health and safety acts were established in 1969 and 1977 setting stricter standards. The Miner Act of 2006 was created to significantly improve health and safety concerns. New technologies in mining and safety regulations have greatly improved conditions for miners.

Coal Uses

Coal is used to generate heat, produce electricity, and make steel and industrial products. It is used worldwide as a fuel, second only to petroleum as the most consumed energy resource.

Simple burning of coal produces heat for homes and industries. Coal is a major fuel for producing electricity. The coal is burned to turn water into steam. The steam turns the blades of a turbine, which drives a generator to produce electricity. Coal is used for approximately 50% of the U.S. electricity production and 40% of the world's electricity.

Coke is a hard material produced when coal is heated without air at approximately 1000^{o} C (1832^{o} F). Coke (which is almost pure carbon) is used to smelt iron ore for the production of steel. Coal tar, a sticky black liquid derived from coke, is used for paving roads and tarring roofs. The extraction and distillation of coal tar into separate compounds produces a variety of products for making drugs, plastics, paints and synthetic fibers.

Coal gas, composed of methane and hydrogen, is a by-product of burning coal. Coal gas was used in the 1940s for residential lighting and cooking, but it was phased out because it was expensive. Today, coal gasification processes are being developed to be more cost effective. Methanol is now being developed and used as a fuel for engines.

Coal Energy: Environmental Impacts and Modern Technology

The mining and burning of coal has a long history of negative environmental impacts. Land, water and air pollution standards were not part of the coal industry's

early history. In 1955, the Air Pollution Control Act (Clean Air Act) was created. This legislation raised the nation's awareness of industrial coal pollution.

In 1977, the Surface Mining Control and Reclamation Act (SMCRA) was passed, requiring that coal-mining sites be restored to natural areas or productive land. By that time, there were over one million acres of abandoned coal mine sites in the United States, among them underground mines, strip-mining pits, acid mine drainage sites and coal refuse (culm) banks. These sites have had a detrimental effect on water quality, public health and safety, economics and aesthetics. Since the SMCRA, mine operators have been required to pay taxes. These taxes are placed into a fund that pays for reclamation of lands abandoned prior to SMCRA's enactment. The SMCRA also has mandated that today's coal companies pay directly for reclamation of lands affected by their own operations.

Regulations and environmental awareness have helped to improve the coal industry, but problems still exist. Newer operations have been employing positive environmental techniques including cogeneration, waste-coal usage, clean coal technologies, and land reclamation.

Cogeneration is a technology that has experienced resurgence beginning in the 1980's. Cogeneration plants (cogens) use coal as a fuel for both heat and power. In a traditional coal-fired plant, steam produced by the combustion process turns the turbine, which drives a generator to produce electricity. In a cogen plant, as the steam turns the turbine, it also provides direct heat to another user. Among the beneficiaries of the cogens' heat are prisons, fish farms and greenhouses.

Waste-coal-fired power plants utilize new methods to burn coal that, due to its low carbon content, could not have been used in traditional coal-fired plants. The coal is gathered from culm banks. Some of these toxic mounds are over 200 feet high. In order to combust the waste, many such plants use a fluidized circulating bed boiler.

Clean coal technologies (CCTs), encouraged by a government and industry initiative that began in 1984, help to reduce the emission of sulfur dioxide, nitrogen oxide, mercury, a host of other elements, and to a lesser extent, carbon dioxide. Sulfur dioxide and nitrogen oxide contribute to the formation of "acid rain," which can damage plant and animal life. Mercury is a health threat to people when they eat fish contaminated by polluted water. According to many scientists, carbon dioxide mixes with oxygen to cause global warming, a situation in which the earth's heat is trapped in the atmosphere, creating the "greenhouse effect."

Several modifications have been made to improve sulfur emissions from coal-fired power plants. First, washing the coal chunks before they are sent to a power plant removes some of the impurities. At some power plants, crushed coal is mixed and burned with limestone in a boiler of moving air, a "fluidized bed boiler." This process allows the limestone to combine with sulfur particles to form a compound, which is then extracted. Another method reduces sulfur dioxide gases after the coal is

burned. This process takes place in "scrubbers," or flue gas desulfurization units. A combination of water and crushed limestone is sprayed into the coal gases as they rise in the smokestacks. The limestone absorbs much of the sulfur dioxide before the gases are expelled into the environment. To decrease the emission of nitrogen oxide, coal is burned at lower temperatures. Together, these practices remove more than 95% of the pollutants caused by sulfur and nitrogen. Mercury is removed by calcium-based absorbents (sorbents). Other methods are being developed to further reduce mercury emissions.

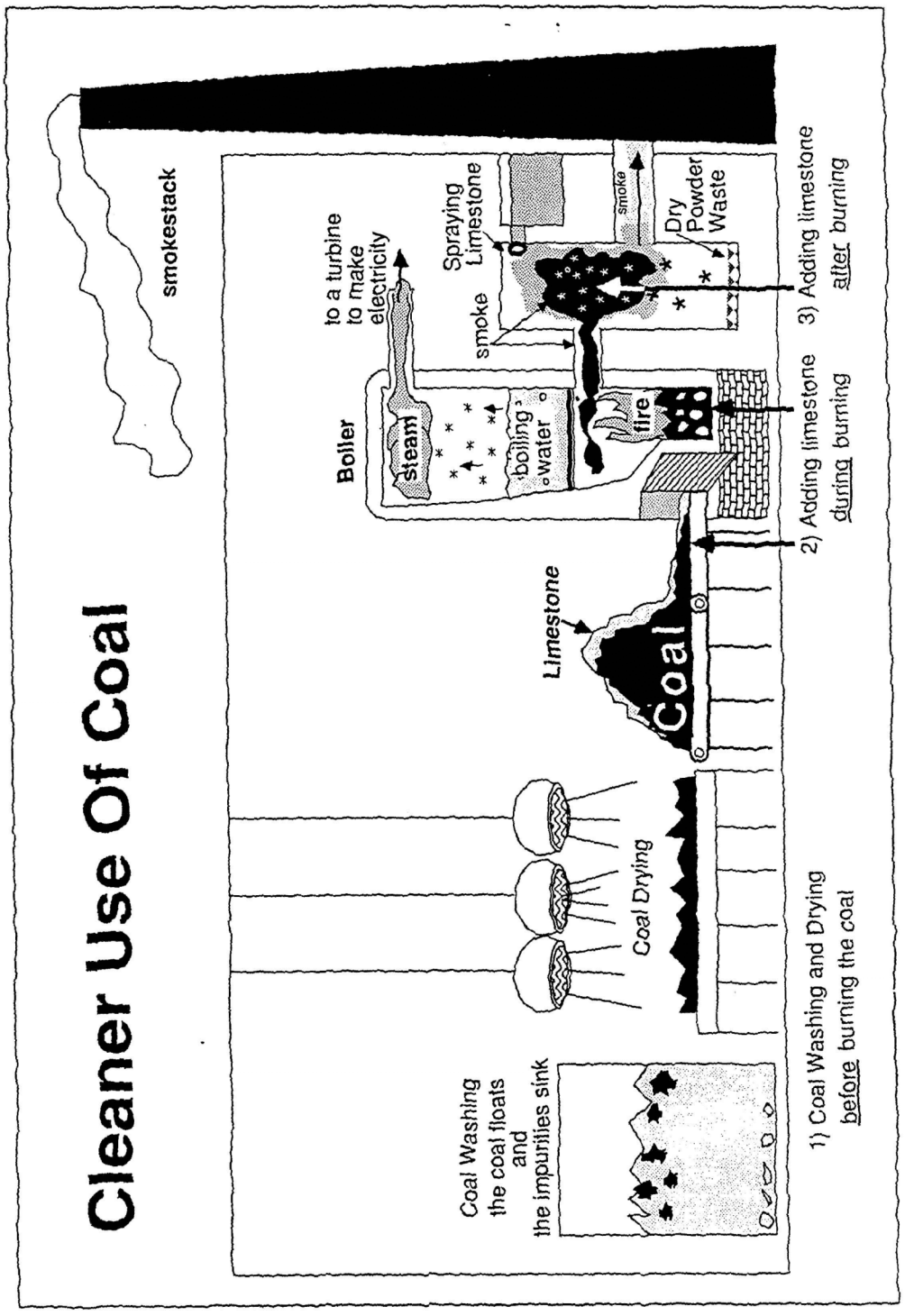
Coal gasification, is an advanced clean coal technology, which uses a coal conversion process. Coal, combined with steam and oxygen, is heated at high temperatures. This process changes it into synthesized gas. By using this process, 99% of the sulfur content can be removed from the coal. Carbon monoxide and hydrogen gases can be collected to make useful products. Methanol fuel, produced in coal-gasification plants, can be used as a fuel for vehicles. Many such plants use an integrated gasification combined-cycle process (IGCC) to further reduce pollution and waste. Hot coal gases are used to run a gas turbine for producing electricity, and the residual heat is used to boil water for a traditional steam generator and to produce electricity.

A number of other CCTs exist. Some of these, while not in widespread use at this time, are being broadly researched. One of them, coal liquefaction is a conversion technique in which coal is changed into a liquid. The U.S. Department of Energy and a network of state, federal and private sectors are currently investigating carbon sequestration and carbon capture and storage technologies. The realization of these technologies would greatly reduce carbon dioxide emissions. Due to economic and technologic constraints, carbon dioxide emissions continue to cause significant problems in many traditional and waste-coal-fired plants.

Even as new CCTs are being studied, efforts are being made to reclaim land and water damaged by the coal industry. Land reclamation programs funded by government sources, coal operators, and private organizations are many and varied. In one example, waste-coal processing facilities use the alkaline ash, (residue from the combustion process) to fill surface mine and underground mine sites. After surface mines are filled, the land is restored. Meadows, forests, recreational sites, and areas for development are rising out of the ashes.

In other examples, water pollution issues are being addressed. In an attempt to neutralize acid mine drainage into nearby water sources, the water is being treated with limestone in order to increase its alkalinity. Also, runoff holding areas are being built for the acid waters so that smaller amounts move into nearby streams. In other cases, lands are being regraded to approximate their original routes so that dried-up streams, cut off from their sources by coal mines, can flow once again.

Over the past twenty years, the coal industry has made substantial progress. Even as aggressive efforts are being put forth to research new clean coal technologies, coal energy proponents and opponents abound.



Courtesy of U.S. Department of Energy: Office of Fossil Energy

Coal Energy
Elementary Lesson Plans

National Science Education Content Standards: F
PA Academic Standards: 3.8, 4.2
Subject Areas: Science, Social Studies, Language Arts

Unit Objectives
Students will:

1. Define “energy” and identify various energy resources.
2. Recognize and identify the characteristics of coal.
3. Classify coal as a fossil fuel.
4. Explain and demonstrate how coal is formed.
5. Observe and conclude that coal is combustible.
6. Research and describe coal as a major energy resource.
7. Compare and contrast environmental impacts of the coal industry before and after the advent of clean coal technologies.

Activity 1: Introduction to Energy

Objective
Students will define "energy" as the ability to do work.
Students will identify different energy resources.

Materials
“Background Information,” encyclopedias or internet access, magazine pictures, poster board or large construction paper, glue, scissors

Procedure
Direct students to use resources available (encyclopedias, Internet) to define “energy," in simple terms. (Energy is the ability to do work.)
Review: Work is done when something moves or changes. Potential energy is stored energy or the energy an object contains. Kinetic energy is energy in motion or doing work.

Discuss the forms of energy: heat, mechanical, electrical, chemical, light and nuclear. Have students list where these kinds of energy are used. Heating homes, running cars and electrical appliances require energy to work.

Introduce the fuels or resources needed to produce energy. Relate how our bodies use food as fuel to help us function or give us energy. As a class, list types of energy resources or fuels used to produce energy: coal, petroleum, natural gas, wind, water, solar, wood, etc. Have students classify and group the list of energy resources as renewable or nonrenewable. (See “Background Information.”)

Evaluation

Assignment: Instruct children to make a collage, with magazine pictures or illustrations, depicting the use of different energy resources. Have students label the fuel used to produce energy in each picture.

Activity 2: Coal Characteristics

Objective

Students will recognize and identify the characteristics of coal.

Materials

"Background Information," Bituminous or soft coal samples (available from coal distributors, science catalogs and geological agencies), drawing/writing paper

Procedure

Distribute coal samples and ask students if they can identify them. Have students work with partners to describe and list characteristics of coal samples: texture, color, luster, smell and hardness.

Review as a class and list characteristics of coal. Identify samples as "coal" and brainstorm to determine students' knowledge of coal. Have students share knowledge or experiences they have had with coal. See "Background Information" to introduce coal lessons.

Evaluation

Students draw their coal samples and list observable characteristics.

Activity 3: Coal: A Fossil Fuel

Objective

Students will classify coal as a fossil fuel.

Students will explain and demonstrate how coal is formed (coalification).

Materials

"Background Information," coal sample, ice cream sandwiches, wax paper (approximately 30 cm. or 12 inches), construction paper, rolling pin, oil or nonstick spray, plant matter: leaves and small twigs, clear 2-liter milk carton, scissors, pie plate, sand, soil, encyclopedias, resource books and/or Internet.

Procedure A

Review *Coal: A Fossil Fuel* in "Background Information."

Simulate how coal is formed: On a display table, place a sheet of construction paper on wax paper. Set 3 ice cream sandwiches on top of each other, then place on the construction paper. Explain that the ice cream represents moisture and the

dark wafers represent compressed plant matter. Press the ice cream sandwiches together with an oiled rolling pin. Ask students how this represents the formation of coal. Continue pressing ice cream sandwiches to a depth of approximately 1 cm. Discuss observations.

Define coal as a fossil fuel. (It is a sedimentary rock formed by the burial and compression of accumulated plant material.)

Allow pressed ice cream sandwiches to dry out for several days. Observe changes. (The wafers should be compressed into a dry, firm mass.) Discuss observations and have students relate activity to the formation of coal, a fossil fuel.

Compare and contrast the following fossil fuels: coal, petroleum and natural gas. Divide students into groups and assign research on fossil fuels.

Evaluation

Students research and report on fossil fuels with a concentration on coal energy.

Enrichment

Instruct students to create a diorama depicting how coal is formed. (Students could design a swampy landscape with fallen vegetation being buried.)

Procedure B

Demonstrate how coal is formed: Cut a 2-liter soda bottle in half. Coat the inside of the bottle with oil or nonstick spray. Place approximately 50 ml. of water on bottom. Add layer (4-5 cm.) of sand and soil. Add layer (5-6 cm.) of leaves and small twigs. Cover with layer of soil and sand (fill to top of bottle). Poke ten or more holes near bottom of soda bottle. Over the next few days, instruct volunteer to press down material in bottle with palm of hand or flat surface. (This will press out excess water.) Allow to set for several days. Invert bottle on pie pan and have students make observations. Facilitate class discussion comparing activity to the coal formation process.

Evaluation

Students write and illustrate steps of activity and compare to coalification.

Activity 4: Coal is Combustible

Objective

Students will observe and determine that coal is combustible.

Materials

dictionary, lignite coal sample (if unavailable, charcoal may be used), candle or Bunsen burner, matches, pie pan, needle-nose pliers or forceps with insulated handles, tissue paper (or thin paper that easily ignites)

Procedure

Have students define the term "combustible" and give a synonym for it (flammable). Use dictionaries, if needed.

Set up experiment: Place tissue paper in pie pan. Light candle. Secure coal sample with forceps and set in flame for 1-2 minutes. Coal should absorb heat, glow and give off its own heat. Allow time for observations. Extinguish candle flame and display glowing coal for observations. Reheat coal sample until it glows, then place coal on paper in pie pan. Ask students to explain observations. (The coal absorbs heat and combusts. It then transfers heat to the paper and the paper ignites.) Discuss how coal may be useful because it is combustible and gives off heat.

Evaluation

Students illustrate and describe their observations.

Enrichment

Take a small sample of the dried plant matter from Activity 3 and hold with forceps. Place sample in the flame of a candle and observe combustion. (This matter can be compared to peat.) Discuss observations.

Activity 5: Coal: A Major Energy Resource

Objective

Students will research and describe coal as a major energy resource.

Materials

"Background Information," internet access, resource books, 3 x 5 index cards, string, hangers or dowel rods, magazine pictures, construction paper

Procedure

Introduce coal as a fuel for producing energy. See "Background Information." List energy uses: produces electricity, powers train engines, supplies heat for homes and industries, and produces steel and other products.

Have students research coal energy uses and write information on index cards. Review together as a class discussion.

Instruct students to create a mobile illustrating coal energy uses: Magazine pictures and brief descriptions on index cards can be hung by string to a hanger or crisscrossed dowel rods. Display mobiles in classroom.

Evaluation

Students complete mobiles illustrating coal energy examples and present to class.

Activity 6: Cleaning Up Coal

Objective

Compare and contrast environmental impacts of the coal industry before and after the advent of clean coal technologies.

Materials

"Background Information," internet access, resources materials (including current information), plastic gloves, small coal samples or crushed coal, white paper towels, darker paper towels, magnifying lenses and/or hand-held illuminated microscopes

Procedure A

See "Background Information." Discuss historic ecological impacts of mining coal in relation to land, water and air pollution. Introduce term “clean coal technology. “ List improvements and new technologies:

- Washing coal before sending it to the plant.
- Mixing crushed coal with limestone and water.
- Spraying coal gases with water and crushed limestone in the smokestacks.
- Gasifying or liquefying coal.
- Reclaiming mining sites.

Procedure B

Demonstrate simple coal washing to lessen emissions:
Pass out plastic gloves, small coal samples or crushed coal, white paper towels, darker paper towels and magnifying lenses or microscopes. Students observe coal texture and examine particles with magnifiers. Have students rub coal on paper towels and observe different color particles with magnifiers (dark carbon laced with lighter particles).

Have students place crushed coal in plastic container 2/3 full of water and shake. Students remove coal from water, dry and observe closely again with magnifiers. (Some tiny loose particles have been washed away.) Discuss changes in coal samples. Review simple washing of coal helps remove some sulfur and other particles, making the coal "cleaner."

Divide class into groups and assign research on environmental impacts and changes in the coal industry. Students should indicate if and where new technology is being used. (Each group should specify contributions of each member.) Groups can present their information with creative visuals, role-playing, class participation, etc.

Evaluation

Using creative visuals, role-playing, class participation, etc., groups present their information, describing and comparing environmental impacts and changes in the coal industry.

Coal Energy
Middle School Lesson Plans

National Education Content Standard: F
PA Academic Standards: 3.8, 4.2
Subject Areas: Science, Social Studies, Language Arts

Unit Objectives

Students will:

1. Review coal as a fossil fuel and illustrate how coal is formed.
2. Observe the combustibility of coal and recognize it as an energy fuel.
3. Research and report on the different methods of coal mining.
4. Create a timeline illustrating historic changes and advances in the coal industry. Include changes in methods of mining, plant production processes, safety measures and environmental impacts.
5. Compare and contrast the use of coal energy to other energy sources in regard to health and safety, efficiency, environmental impacts and cost.
6. Recognize that waste coal can be a usable fuel.

Activity 1: Reviewing Coal as a Fossil Fuel

Objective

Students will review coal as fossil fuel.
Students will describe and illustrate how coal is formed.

Materials

"Background Information," Elementary Activities 2 and 3, ice cream sandwiches, wax paper, construction paper, rolling pin, nonstick spray or oil, forceps, candle, matches

Procedure

See "Background Information." Conduct "Review and Brainstorm Session" to determine students' knowledge of coal as a fossil fuel. Review concepts if needed:

-Coal is a major energy resource in the world. It is used for heating, producing electricity, and making various products.

-The formation of coal is due to the accumulation of plant matter, which has undergone changes due to pressure and heat.

-Coal is composed primarily of carbon, hydrogen, oxygen and nitrogen.

-There are different rankings of coal determined by their carbon content, hardness and heat content.

Using Elementary Activity 3, review how coal is formed. Have student volunteer demonstrate and explain the process of coal formation. (Pressing ice cream sandwiches together with rolling pin represents coal layers being compressed into a solid mass.) Discuss observations.

Evaluation

Assign creative coal formation project. Students explain in writing and illustrate with models or diagrams, the process of coal formation.

Enrichment

Plan a field trip to collect fossils. Coal regions are common sites for fossil collecting, primarily fern fossils**.** (This also reinforces the fact that coal is formed from plant matter.) A rock and mineral club or geological agency may be of assistance**.**

Activity 2: Coal Combustion and Energy Use

Objective

Observe the combustibility of coal and recognize it as an energy fuel.

Materials

small coal samples (1-3 cm. size), votive candles, votive candle holders, aluminum foil, matches, forceps or needle-nose pliers with insulated handles, goggles, thermometers, water, small beakers, "Background Information."

Procedure

Review that heat is a form of energy; and things that give off heat are an energy source. Introduce activity to recognize coal as an energy fuel.

*This lesson can be structured as a teacher demonstration or as a student hands-on project. Teachers should use their discretion.

Have students work with partners to share materials. Distribute materials, except for matches. Students put on goggles. They place candles on aluminum foil, place thermometers in bottom of beaker, and fill beaker with just enough water to cover base of thermometer (25-50 ml.). Students note temperature of water at room temperature. Teacher lights one candle for each group. Using forceps or pliers, students hold coal pieces in the flame for one minute. Students observe glowing coal, place coal in beaker and record water temperature immediately. (Coal samples are difficult to keep burning, but the absorbed heat is measurable.) Discuss observations.

Facilitate class discussion on conclusions of experiment.

Evaluation

Students write procedure, data and conclusions of science lab, and diagram lab set-up.

Activity 3: Coal Mining Investigation

Objective

Students will research and report on the different methods of coal mining.

Materials

"Background Information," internet access, resource books, resource people

Procedure

See "Background Information." Introduce basic methods of coal mining: surface mining and underground mining.

Types of surface mining:
-Area or mountain top mining is done in relatively flat locations. Coal is removed in one location at a time with large machines such as draglines.
-Contour mining is done where coal is located in hills or mountains. Coal is excavated in circular tracks around the landscape.

Types of underground mining:
-Longwall mining is used to remove most of the coal in an area underground. A longwall mining machine cuts wide tunnels with rotating disks of steel teeth. Large steel jacks must be used to support the roof to prevent it from collapsing.
-Room and pillar mining involves removing part of the coal in an underground site. Much coal is left untouched to support the roof of the tunnels. This underground excavation looks like rectangular rooms, divided by coal pillars.

Assign research to investigate mining practices, both past and present. Topics should include the basic process of excavating coal, efficiency of operations, health and safety of miners, economic ramifications and environmental impacts. Land reclamation issues should be included. (Specific dates indicating changes in the industry should be collected for next lesson.) Encourage students to use a variety of resources to gather information, which may include personal interviews of miners.

Facilitate class discussion on research findings.

Evaluation

Students complete research on mining in written report with references cited.

Enrichment

Instruct students to create two models comparing land devastation of past strip-mining methods to modern land reclamation practices. Two shoeboxes lined with plastic may be used to model excavated land and reclaimed land.

Activity 4: Coal Industry Timeline

Objective

Students will create a timeline illustrating historic changes and advances in the coal industry. They will include changes in the methods of mining, plant production processes, safety measures and environmental impacts (related to land, air and water pollution; clean coal technologies; and land reclamation).

Materials

Students' research from last lesson, current coal news articles, pictures downloaded from Internet, poster boards or large roll paper, blackboard, "Background Information"

Procedure

Divide students into three or more groups to discuss research data from last lesson. Instruct students to gather and list specific events and dates relevant to changes in the coal industry. For reference, teachers may use the timeline below and "Background Information."

Instruct students to include current changes in federal or state regulations, which may strengthen or weaken the coal industry in regard to public health and safety, efficiency, the environment and the economy.

As a class, list specific dates and briefly describe on board. Assign each group a time period to come up with rough draft of pictures illustrating the events:

Coal-Energy Legislation

1890- United Mine Workers of America formed
1891- First Federal Mine Safety statute
1910- United States Bureau of Mines founded
1941- The U.S. Coal Mine and Health Safety Act
1948- US Water Pollution Control Act
1952- Federal Coal Mine Safety Act
1955- Federal Air Pollution Control Acts began
1965- Federal Water Pollution Control Administration was created.
1969- The U.S. Coal Mine Health and Safety Act
1970- First Clean Air Act enacted
1973- Mining Enforcement and Safety Administration (MESA) founded
1977- Federal Mine Safety and Health Act
-The Surface Mining Control and Reclamation Act
1984- Clean Coal Technology Program instituted
1990- Clean Air Act amended
2002- Clear Skies Initiative proposed
2006- The Mine Improvement and New Emergency Response Act (Miner Act)
-New legislation related to coal technology

Evaluation

Each group of students completes a timeline of their specific time period with small illustrations. All students should contribute a section of the timeline. To allow most students to work simultaneously, a few may draw illustrations to be glued to timeline while several are writing. Each group's section can be pieced together to form one long timeline.

Enrichment

Have students listen to several coal-mining songs:
www.fortunecity.com/tinpan/parton/2/mines.html

Discuss the role that music has played in our world (e.g., people can express their emotions, rally support for a cause and provide historical information for future generations).

Activity 5: Comparing Energy Resources

Objective

Students will compare and contrast the use of coal energy to other energy resources in regard to safety, efficiency, environmental impact and cost.

Materials

Students' research, internet access, current resources: books, periodicals, etc.

Procedure

Discuss various renewable and nonrenewable energy resources:
Renewable resources, of endless supply, include hydroelectric, solar, geothermal, biomass and wind power.
Nonrenewable resources, which are limited in quantities, include petroleum, coal, natural gas, and uranium (used in nuclear power plants).

Divide class into groups and assign different energy resources to be researched and compared to coal energy. Students should include topics of safety, efficiency, environmental impacts and cost.

Evaluation

Students compare and contrast coal energy to other sources of energy in a report, an oral presentation or a debate.

Activity 6: Using Waste Coal in the Fluidized Bed Boiler

Objective

Students will recognize that previously discarded coal refuse can be a usable fuel.

Materials

crushed coal, pestle and mortar set (if needed to crush larger coal pieces), pulverized limestone (or powdered lime available from lawn and garden centers), tumbler (from Bingo game or rock tumbler), or 3 plastic jars with lids (e.g., peanut butter jars), plastic gloves

Procedure

See "Background Information." Discuss changes related to abandoned coal mining, and coal power production sites:
The older mining sites often were left in unstable conditions creating serious environmental and safety hazards. The Surface Mining Control and Reclamation Act of 1977 instituted laws that require the restoration of coal-mining sites to ecologically sound or productive use. The Public Utility Regulatory Policies Act mandates that power plants buy power from cogens and designated waste-coal plants.

Technology now enables power plants to make use of refuse coal in a fluidized bed boiler combustion system. Previously discarded waste coal or culm, high in ash content and low BTU output (which cannot be burned in conventional coal boiler utilities) is now economically feasible. Coal is used in many cogen plants, producing electricity and heat energy.

Simulate circulating fluidized bed boiler system:

*Note: Remind students that limestone (calcium carbonate) absorbs sulfur particles during the burning of coal. In a power plant, the amount of limestone to be added is adjusted according to the sulfur content in the coal. This simulation gives the students a visual representation of the process.

Set tumbler above picture or model of flame source. Fill one plastic jar with crushed coal and the other with lime (similar to pulverized limestone) and have students identify each. Place crushed coal in tumbler or other plastic container until 1/3 full. (If crushed coal is not available, crush with mortar and pestle.) Add approximately 10% lime, close lid and turn crank of tumbler or swirl container briskly. (Be careful to keep lime dust away from students because it is caustic.) Have volunteer explain the process of limestone mixing with the coal during the burning of coal. Facilitate class discussion about why the reduction of sulfur emissions is an important environmental issue.

Review: The burning of coal causes water to turn to steam. The steam turns the blades of a turbine, which drive a generator to produce electricity. In cogens, the steam also is used as a source of direct heat.

Evaluation

Have students complete a project of personal interest:

-Research the Surface Mining and Reclamation Act of 1977. Students may determine how funds are allocated and for what specific ventures.

-Design a model illustrating the use of refuse coal.

Enrichment

Plan a field trip to a coal power plant, which uses clean coal technology.

Coal Energy
High School Lesson Plans

National Science Education Content Standards: E, F
PA Academic Standards: 3.8, 4.2
Subject Areas: Science, Social Studies, Language Arts

Unit Objectives

Students will:

1. Review and list uses of coal.
2. Research supply and demand for coal and graph statistics.
3. Recognize and describe peat and different classifications of coal: lignite, bituminous and anthracite.
4. Experiment and compare energy emitted from different coal samples.
5. Investigate new technologies in the coal industry using multiple resources. Include impacts on public health and safety, efficiency, environmental impacts and the economy.
6. Investigate and determine if new clean coal technologies are mandated and enforced by laws.

Activity 1: Coal Uses

Objectives

Students will review and list uses of coal.

Materials

internet access, computer, graph-making software, "Background Information."

Procedure

Brainstorm to determine students' knowledge of coal uses: as a fuel for heat and electricity; and as an ingredient in making steel, iron, chemicals and other products. Assign investigations into less common coal applications: cement, medicines, paint and fertilizers.

Evaluation

Students present their unique coal use information in a visual display, pamphlet or brief presentation with props.

Activity 2: Supply and Demand of Coal

Objective

Students will research the supply and demand of coal and graph statistics.

Materials

"Resource Guide," Internet access:
www.eia.doe.gov Energy Information Administration
www.fossil.energy.gov U.S. Department of Energy

Procedure

Review basic concepts of supply and demand. Facilitate discussion on how supply and demand of a product affects pricing.

Instruct students to research the supply and demand ratios of coal. They should use most current data in regard to major coal supplies available from different countries and the coal consumption by countries.

Evaluation

Students complete research of coal supply and demand and create several graphs showing production and consumption of coal by major countries. An additional graph can be designed to show statistics of specific states or regions where coal is produced.

Activity 3: Comparing Types of Coal

Objective

Students will describe and recognize peat and different ranks of coal: lignite, bituminous and anthracite.

Students will experiment and compare energy emitted from different coal samples.

Materials

"Background Information," goggles, peat samples (available in garden supply centers), coal samples approximately 1-2 cm. size: lignite, bituminous and anthracite (available from coal distributors, science catalogs and geological agencies), votive-style candles or Bunsen burners, needlenose pliers, small beakers filled with approximately 50 ml. of water, data sheet with peat and coal samples listed, matches

Procedure

Distribute peat and coal samples to lab groups. Using "Background Information," review characteristics of peat and coal samples. Have students identify each sample.

Pass out remaining materials for lab investigation. Ask students how they would test and compare energy emitted from samples, using materials provided.

Pass out data-collecting sheets and proceed with experiment.
Students place thermometers in 3 or 4 beakers of water (depending on number of coal samples) and record temperature. Students put on goggles, heat peat and coal samples for 1 minute, then gently drop samples in different beakers of water.

Temperature changes should be recorded. Students discuss, compare and evaluate results. ((The harder coal absorbs more heat.)

Evaluation

Students complete lab investigation, comparing heat emitted from peat and coal samples. Have students write up lab investigation using the Scientific Method:

Problem or Question
Research
Hypothesis
Materials
Procedure
Data or Results
Conclusion

Activity 4: Coal Technology

Objective

Students will use multiple resources to investigate new technologies in the coal industry.

Students will evaluate the impact the technologies may have on efficiency, public health and safety, the environment and the economy.

Materials

"Background Information," "Resource Guide," periodicals, Internet access:

www.wci-coal.com	World Coal Institute (WCI)
www.fossil.energy.gov	U.S. Department of Energy
www.acaa-usa.org	Advancing the Management and Use of Coal Combustion Products

Procedure

Review "Background Information" and introduce new coal technologies. Review that the major environmental concern with the coal industry is carbon dioxide emissions. Facilitate class discussion about various clean coal technologies and list on board:

·Coal Gasification
·Coal Liquefaction
·Fluidized Bed Boilers
·Carbon Sequestration and Carbon Capture and Storage

Divide students into groups to research new technologies in the coal industry using multiple resources. Have students determine the impact of these technologies on public health and safety, efficiency, the environment and the economy. Students should determine if and how the new technologies reduce pollutants in the water and air. Acid rain, (caused by sulfuric and nitric gases combining with water molecules) and the "greenhouse effect," (believed to be caused by substantial carbon dioxide gases) need to be addressed.

As a class, have students share their information and note any additions to their data.

Evaluation

Students research and report on new coal technologies with a creative presentation.

Enrichment

Do Middle School Activity 6: Using Waste Coal in the Fluidized Bed Boiler.

Activity 5: "Clean Coal" and Environmental Laws

Objective

Students will investigate and determine if clean coal technologies (CCTs) are being mandated and enforced by law.

Materials

internet access, current periodicals, "Resource Guide," contact information for State Representatives' Offices and State Department of Environmental Protection

Procedure

Review research collected from last lesson and "Background Information" related to clean coal technologies. Ask students how they can determine if CCTs are being used throughout the coal industry.

Instruct students to investigate federal and state laws that hold coal-mining and coal-energy-producing sites accountable for pollution control standards. Encourage students to study the most current and proposed legislative changes relating to air, land, and water quality control. Students should evaluate such changes in regard to the environmental impacts. In addition, have students research to determine how existing laws are being enforced. Share findings as a class discussion.

Evaluation

Students evaluate their research and present their conclusions in small groups. A spokesperson for each group shares the general consensus of his/her group stating to what extent clean coal technology is used and enforced.

Enrichment

Have students write a letter stating their own opinions either agreeing or disagreeing with recent legislative proposals or changes relating to the coal industry. (Students may choose to send their letters to state representatives and other officials.)

Academic Standards

PA Academic Standards for Science and Technology:

Science, Technology and Human Endeavors	3.8

PA Academic Standards for Environment and Ecology:

Renewable and Nonrenewable Resources	4.2

www.pde.state.pa.us

National Science Education Content Standards:

Science and Technology	E
Science in Personal and Social Perspectives	F

www.nsta.org/publications/nses.aspx

Resources

Books

Baker, Julie. *Up Molasses Mountain. New York*: Random House, Inc., 2002.
Historical Fiction: Explores a West Virginia mining town during a strike in 1953. (upper elementary)

Bartoletti, Susan Campbell. *Growing Up in Coal Country.* New York: Houghton Mifflin, 1996.
Non-Fiction: Examines coal mining in Northeastern Pennsylvania at the turn-of-the-century. (upper elementary)

Earth's Resources, The. Grolier Educational. Connecticut: Atlantic Europe Publishing Company, Inc., 2000. (elementary)
An introduction to rocks and minerals, including coal and coal-mining techniques.

Websites

Advancing the Management and Use of Coal Combustion Products (American Coal Ash Association: ACAA)
www.acaa-usa.org

American Coal Foundation: Teacher Resources
www.teachcoal.org

American Council for Energy Efficient Economy (ACEEE)
www.aceee.org

PA Department of Environmental Protection (DEP): Energy -Coal
www.dep.state.pa.us

EFMR Monitoring Group, Inc.: Lesson Plans
www.efmr.org

Energy Information Administration
www.eia.doe.gov

Energy Quest: Energy Education
www.energyquest.com

FortuneCity: Songs from the Mines
www.fortunecity.com/tinpan/parton/2/mines.html

U.S. Department of Labor: Mine Safety and Health Administration (MSHA): Statistics and current information on coal-mining.
www.msha.gov

Mineral Information Institute (MII): Teacher Resources
www.mii.org

National Resources Defense Council: Environmental action group for environmental legislation.
www.nrdc.org

National Science Teachers Association: National Science Education Standards
www.nsta.org/publications/nses.aspx

Pennsylvania Department of Education: Academic Standards
www.pde.state.pa.us

U.S. Department of Energy: Office of Fossil Energy
www.fossil.energy.gov

World Coal Institute (WCI)
www.wci-coal.com

Special thanks to:
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