Fossil Fuels: Facing the Issues

GRADE LEVELS	3rd-8th; California Content Standards for 6th and 8th
SUBJECTS	Earth Sciences, Physical Sciences
DURATION	Preparation: 10 minutes Activity: 90 minutes
SETTING	Classroom

Objectives

In these activities, students will:

1. learn about some of the environmental consequences associated with fossil fuel usage.
2. learn that fossil fuels are nonrenewable resources.
3. relate combustion reactions to fossil fuel burning.

Materials

Coal Mining
chocolate chip cookies – relatively hard cookies work best (1 per student)
toothpicks (1 per student plus a few extras)
plates (1 per student)
Coal Mining worksheets (1 per student)

Oil Spill
plastic tubs (1 per team of 4 or 5 students)
Dixie cups (1 per team of 4 or 5 students)
water
cooking oil
habitat items: rocks, sticks, feathers
cleaning items: sponges, cotton balls, spoons
Oil Spill worksheets (1 per student)

Air Pollution
candle (1 if doing a demonstration. 1 per group if older students are participating.)
glass jars or beakers (2-3 if doing a demonstration. 1 per group if older students are participating.)

Vocabulary

- fossil fuel: a hydrocarbon deposit, such as petroleum, coal, or natural gas, derived from living matter of a previous geologic time and used for fuel
- hydrocarbon: compound containing only hydrogen and carbon and often occurring in fossil fuels
- coal: a dark-brown to black solid substance formed naturally from the compaction and hardening of fossilized plants and used as a fuel primarily for electricity generation
- petroleum: naturally occurring mixture of gaseous, liquid, and solid hydrocarbons derived from remains of fossil plants and animals, especially in shallow marine environments, and separated into products such as gasoline, paraffin wax, asphalt, and many others

- natural gas: a mixture of hydrocarbon gases that occurs naturally beneath the earth's surface and is used as a fuel primarily for cooking and heating homes
- soot: the fine black particles, chiefly composed of carbon, produced by incomplete combustion of coal, oil, wood, or other materials
- renewable resource: a resource such as solar energy that is never used up or a resource that can be replaced
- nonrenewable resource: a resource that is not replaceable after its use such as oil or coal

Teacher Background

For many decades now, fossil fuels such as oil and coal have fueled the bulk of global energy production. These products were plentiful and inexpensive at the beginning of the industrial revolution and were widely adopted in industry, commerce, and transportation. However, energy is now becoming a critical topic of discussion as global supplies of cheap fossil fuels steadily decline and fossil fuel related greenhouse gases accumulate in the atmosphere. Due to increased concern about global climate change, as well as the uncertainties surrounding the import of foreign oil, many developed countries are now faced with the choice of continuing their fossil-fuel based energy, or developing new technologies that can reduce or eliminate the need for these products.

Although there is currently a surge in the use of alternative sources of energy, the vast majority of the world's energy continues to be produced by burning fossil fuels. In 2006, approximately 88% of the world's energy and 86% of the United States' energy was supplied by fossil fuels. Using fossil fuels has caused a number of environmental and human health effects. For example, burning fossil fuels is the number one contributor to human-induced climate change. Climate change is an important reason for people to reduce their fossil fuel consumption via conservation, efficiency measures, and switching to renewable energy sources. Although climate change is topmost in the list of concerns about fossil fuel usage, there are many other associated issues with our use of fossil fuels. The activities covered in this lesson will highlight three of the other problems associated with fossil fuel usage: extraction consequences, distribution problems, and air pollution. Specifically, these activities will illustrate the consequences of surface mining for coal, the challenges of cleaning oil spills, and the air pollution produced by burning fossil fuels. Although there are many other environmental consequences involved with burning fossil fuels, these three examples serve to illustrate the types of problems caused by our use of fossil fuels for energy.

Although fossil fuels (coal, oil, and natural gas) are all different in their properties and uses, they have some similarities. They all come from fossilized plant and/or animal material. They are all nonrenewable resources; they take millions of years to form and do not regenerate on the timescale of a human life. They also all go through similar processes on their path from being extracted from the ground to serving as fuels for human beings.

In order to extract coal, oil, and natural gas from underground, people have to mine or drill. This often has significant impacts on the surrounding land, plants, and animals. After these resources are extracted from the ground, they must be converted into useful energy currencies such as gasoline and electricity. This is done through refining, like when oil is refined to produce gasoline, or through burning the product to produce electricity, like when coal is burned at power

plants to produce electricity. These energy currencies are then distributed to people who use them for services such as transportation, heating, and lighting. The distribution of energy can be via pipes, trains, ships, or power lines. All of these steps (extraction, conversion, distribution, and end use) have impacts on the environment.

The extraction process is different for different fossil fuels, but drilling or mining for fossil fuels always impacts the land. Whether it is creating exploratory roads and drill sites or taking off the tops of mountains to look for coal, the land is altered by the extraction process. In this lesson, we will focus on one of the more destructive practices for fossil fuel extraction, surface mining for coal. Coal occurs in bands of various thicknesses, some of which are close to the earth's surface. Some coal is mined underground, but the majority is mined in surface mines, also known as strip mines. Strip mining involves removing the earth above a coal band in order to expose the coal. In an ideal situation, the excavated land would be refilled, but a lot of mines have been left without topsoil and with great risk of serious erosion. In these cases, the land can no longer support vegetation or wildlife. Today, United States federal law requires that people replace soil and replant vegetation. However even with these measures strip mined areas are heavily impacted and may not fully recover.

After extraction, fossil fuels need to be converted into useful forms. This includes burning coal and natural gas for electricity and converting crude oil into its byproducts such as gasoline. The conversion process is responsible for a large proportion of air pollution. But, air pollution is certainly not restricted to this step in the pathway. Air pollution also occurs in the end use step like when people burn gasoline in vehicles. Air pollutants are those substances added to the air by humans that have negative environmental and/or health consequences. Air pollutants include particulates (particles of solids in the air), sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, and more. In the United States, each year about 180 million tons of pollutants are released into the air from transportation, power plants, industrial processes and other sources. Air pollutants result in both environmental problems like acid rain and human health concerns like emphysema, bronchitis, and asthma.

In this lesson, we will show students how soot, fine black particulate matter, can be released when substances are burned. Combustion or burning involves a series of chemical reactions that produce heat and/or light. In complete combustion, a compound reacts with oxygen completely to produce a limited number of products. For example, when a substance composed entirely of hydrogen and carbon (a hydrocarbon) burns completely in pure oxygen, it will release only carbon dioxide and water. Incomplete combustion occurs more often than complete combustion. It occurs when there isn't enough oxygen for a complete burn or when combustion is interrupted. Incomplete combustion of hydrocarbons produces more products including carbon dioxide, water, carbon monoxide, soot, and various other compounds. This is the kind of combustion that occurs when we burn fossil fuels.

The distribution of energy resources can have negative environmental consequences. Distribution occurs both before and after energy conversion. For example, oil is transported to refineries, where it is converted to gasoline and other substances, which are in then distributed as well. This lesson will focus on one example of a distribution problem, an oil spill. Small oil spills occur all the time, as ships move around the oceans. Large oil spills, occur much less frequently,

but can be absolutely detrimental to the ecosystems in which they occur. The Exxon Valdez oil spill is one of the most infamous oil spills because it dumped a huge amount of oil, 10.9 million gallons, into Prince William Sound, a pristine area full of wildlife. The incident killed hundreds of thousands of birds, and damaged the local fisheries. It triggered the largest oil spill clean up in history, an effort that latest for many years. Some wildlife populations have recovered well, while others have not recovered. Closer to home, in November 2007, a container ship hit the San Francisco-Oakland Bay Bridge and spilled 58,000 gallons of oil, resulting in beach closures and dead and injured wildlife including seabirds and fish.

In exploring coal mining, oil spills, and air pollution, students will get a sense of a few of the problems associated with fossil fuels. Although fossil fuels have helped bring prosperity to many parts of the world by providing electricity, heating, cooling, and transportation, a decrease in fossil fuel usage is becoming more and more necessary for a host of reasons.

Activity

Preparation

1. Collect and organize all materials.
2. Print out all worksheets.

Introduction

Set the stage by discussing energy usage with your students. Ask them where we get the majority of the energy that we use. The answer is that we get the majority of our energy from fossil fuels. Discuss and describe the processes involved in taking fossil fuels from the ground to be used for fuel – extraction, conversion, distribution, and end use (see Teacher Background section).

Procedure

Cookie Mining

1. Tell students that they are going to become coal miners. Their job is to use the tool you give them to mine the land and find as much coal as possible while doing the least damage to the land.
2. Hand out the coal mining worksheets.
3. Tell students that they will each be getting a chocolate chip cookie. The cookie represents a parcel of land that is going to be mined for coal. The chocolate chips represent coal.
4. Tell students to draw their cookie first. Then give students time to mine for chocolate chips, draw their cookie again, and answer the questions at the bottom of the worksheet.
5. Ask students what happened to the land around the coal. Discuss what implications strip mining might have on local ecosystems. In general, surface mining takes away topsoil and vegetation and therefore destroys habitat for wildlife.
6. Ask students whether coal is a renewable or nonrenewable resource. Explain that fossil fuels are nonrenewable resources because they take millions of years to form and do not reform on the scale of a human lifetime. Explain that cookie

mining illustrated this fact because once they took the coal/chocolate out, there wasn't anymore to replace it.

Oil Spills

1. Ask students if they have heard about oil spills in the ocean.
2. Remind students of some oil spills in history. See the Teacher Background section for information.
3. Tell students that sometimes ships transporting oil accidentally spill oil into the oceans and that the results can be really harmful for marine ecosystems.
4. Tell students they are going to become part of an oil spill clean up crew.
5. Divide students into groups of four or five.
6. Give each group a plastic tub filled a few inches with water, a small cup with a few tablespoons of cooking oil, and a set of habitat and cleaning items.
7. Tell students to put their habitat items in the tub.
8. Have student pour the oil into the tub.
9. Have students experiment with the various cleaning items.
10. Hand out the worksheets and tell students to record their observations on the Oil Spill worksheet as they experiment with cleaning up the oil spill.
11. After students have finished filling out their worksheets, lead a discussion about how each of the objects interacted with the oil. Then ask students what they think this demonstration can tell us about real world oil spills.
12. There are a few key lessons to point out. It is hard to separate oil and water, so clean up processes can take a long time and a lot of effort. Oil sticks to feathers and is hard to remove, which implies that birds are affected during oil spills. In fact, oil can hamper a bird's ability to stay warm. When oil coats feathers, the feathers are no longer waterproof. The birds thus get wet and cold, which can lead to death.

Candle Pollution

1. Tell students that they will get to see one component of air pollution.
2. Light a candle.
3. Let it burn for a few seconds.
4. Then, put the bottom of a glass jar or beaker above the flame so that the glass touches the top of the flame.
5. Soot will immediately develop on the glass.
6. You can do this with a few glass jars and then pass it around so that students can touch the soot if they want.
7. Ask students what soot is. It is fine black particles, chiefly composed of carbon, produced by incomplete combustion.
8. Ask students what the candle burning represents. It represents the burning of fossil fuels. Most candles are made with paraffin wax, which is derived from oil. It is a hydrocarbon and so burns like other hydrocarbons such as fossil fuels.
9. Spend a few minutes explaining to students why soot was created. Depending on the level of your students, you can go into more or less detail about combustion reactions.

Complete Combustion of Paraffin Wax:
$C_{25}H_{52} + 38O_2 \leftrightarrow 25CO_2 + 26\ H_2O$
Paraffin Wax + Oxygen ↔ Carbon Dioxide + Water

If complete combustion were to occur as in the equation above, the only products formed would be carbon dioxide and water. Most combustion is incomplete however. This means that only a portion of the paraffin is converted into carbon dioxide and water. Some of the carbon from the paraffin is released as soot. This is what you saw on the glass that was held in the flame. Soot and other air pollutants are released when humans burn fossil fuels.

Incomplete Combustion of Paraffin Wax
Paraffin Wax + Oxygen ↔ Carbon Dioxide + Water + Carbon Particles

Wrap-Up
Discuss with the students:

- What are some of the problems associated with using fossil fuels for energy? *(mining damages ecosystems, air pollution can harm ecosystems and human health, oil spills, climate change)*
- What are some things that we can do to lessen these problems in our world? *(conserve energy, use more efficient technology that consumes less energy, encourage the use of renewable energy sources)*

Resources

Airnow. A cross-agency U.S. Government Web site. http://airnow.gov.

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Correlated California Content Standards

Grade Six

Earth Sciences: Resources

6a. Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

6b. Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.

Grade Eight

Physical Sciences: Reactions

5a. Students know reactant atoms and molecules interact to form products with different chemical properties.

Coal Mining: Mining for Chocolate Chips

Name: _____

Date: _____

Draw a picture of your cookie here.

Draw a picture of your cookie after mining here.

1. How many chocolate chips did you extract? What do the chocolate chips represent?

2. What does the land look like after mining? What do you think this means about coal mining in the real world?

Oil Spill Clean Up

Name:_____

Date:_____

Use this table to document how natural materials interact with oil.

Natural Object	Reaction with oil	What does this mean for real oil spills?
Rock		
Stick		
Feather		

Use this table to document how cleaning materials interact with oil.

Cleaning Object	Reaction with oil	What does this mean for real oil spills?
Sponge		
Cotton Ball		
Spoon		