ENVIRONMENTAL LITERACY TEACHER GUIDE SERIES

Energy Potential

A Guide for Teaching Energy in Grades 3 to 8

NATIONAL GEOGRAPHIC

2 Energy in Human Systems

by Ivan Salinas

Have you ever wondered how chemical energy in gasoline can become kinetic energy that moves cars on a road? Or how burning coal in a power plant provides electrical energy to our homes? Both may be mysterious for your students as well. Students see outlets in their homes and power lines running through their neighborhoods, but they may wonder where this electricity comes from. How did the power plant start with coal, uranium, or other resources, to make the electricity? Students also know that we put gasoline into our cars, but eventually the tank becomes empty and must be refilled. It is likely that they do not understand what actually happens to the gasoline to make the car run.

Energy in Our Lives

Engines and power plants will interest many of your students. Children are innately curious about how things work, especially in systems they come into contact with each and every day. Before introducing the internal workings of engines and power plants, consider reviewing several examples of energy transformations that students experience close to home. Ask students if they can think of any examples, such as eating food and then having more energy or plants converting solar energy into chemical energy to live and grow. Having a solid understanding of basic energy transformations can help lay the groundwork for understanding more complex human-engineered devices.

In Chapter 1, several forms of energy were presented (chemical potential, electrical, nuclear, kinetic, light, and heat). We utilize all of these everyday, often without even recognizing it. Many students may not know to look for these changes or have the language to describe them. The following list of examples may provide a starting point for your discussions on energy changes. These examples tap into some of the most common experiences that people, including children, have as they go about their everyday activities.

GRADE	STANDARD	EEI UNIT
Grade 3	3.1.a-d	
Grade 4	4.1.c-e 4.1.g 4.1.5	Reflections of Where We Live
Grade 5		
Grade 6	6.3.a-d 6.6.a-b	Energy: It's Not All the Same to You! Energy and Material Resources: Renewable or Not?
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Energy for Our Bodies. Students are naturally curious about how their bodies work. They grow up hearing that the human body is typically 98.6° Fahrenheit but may wonder why. They may wonder why we have "sugar highs" after consuming too many sweets or "sugar lows" after not eating for long periods of time. In order for our bodies to work properly, we need to have a steady stream of food and water. Water helps transport chemicals that are found in food, but water is not a source of energy for our bodies. Food is the ultimate source of chemical energy that our bodies use to function. When digested and **metabolized** in our bodies, food can be changed to kinetic energy (movement of fluids inside the body, as well as movement of body parts (such as a beating heart, a turning head or clapping hands), in the form of electricity (electrical impulses in the body's nervous system), or heat (to maintain a constant body temperature). When people consume more food than their energy needs demand, the body accumulates reservoirs of energy-rich substances from this food, such as fat, usually not immediately available to use but stored as chemical energy.

Illumination. The world at night is an amazing web of light. Europe and the East Coast of the United States light up in a fantastic display when viewed

CHAPTER OVERVIEW

From the engines in our cars to the power plants that supply our communities, people depend on energy for almost all of our daily needs. Yet how much do we know about where our electricity comes from? How much do we know about how our cars run on gasoline? We simply fill our gas tanks or flip a switch and things work as they should.

While Chapter 1 introduced different forms of energy, this chapter takes a closer look at how energy changes in human systems, from internal combustion engines to power plants. We will consider historical changes in engines, from steam engines to combustion engines to electric cars. All of these engines transform energy in different ways in order to transport people or goods around the globe. We are currently in the midst of a wave of changes, with the introduction of hybrid and electric engines. We may not know what the engines of our future will look like, but we can be certain they will transform energy resources to meet our transportation needs.

Additionally, this chapter outlines how energy is transformed in power plants. Electricity can be created from a variety of energy forms, including fossil fuels, nuclear energy, hydropower, biomass, geothermal energy, and more. This electricity is then transported to our homes, schools, and businesses through an extensive network of power lines—or power grid. Scientists and engineers are currently exploring ways to improve efficiency of our power distribution systems to conserve energy, with increasing attention to a move from nonrenewable energy to renewable energy.

from space. Thousands of years ago, light on Earth came only from the sun. Then we discovered fuels that we could use for fire, and later candles and lamps, and the devices that produce light proliferated. It is inconceivable for most Americans to imagine their activities stopping at night. There are many parts of the world today, though, that do not live with this 24-hour availability of light. Their activities are seriously curtailed when the sun sets. Some of your students may come from or have family still living in these conditions.

The light from both candles and electric lights result from energy transformations. The chemical energy from the wax or paraffin (fat) gives off light as it burns. In electric lights, electricity is transformed to light in an electrical resistor (the bulb filament). In both cases, heat is produced too, and often this heat is considered a waste product. Engineers are trying to design bulbs that give off the same amount of light, but use less electricity, and give off less heat (for example LED and CFL bulbs as described in Chapter 1). Giving off less heat means the bulb is more energy efficient.

Transportation. Transportation (movement from one location to another) requires energy to change forms. Even long ago, the chemical energy in food was changed to motion in our bodies to run, row boats, or ride horses. Machines that we use today for transportation, such as cars, trains, airplanes also undergo processes to change energy from one form into motion (kinetic) energy. In some cases, energy is transformed from an electrical source, such as in an electrical car, to kinetic energy. Chemical energy is transformed from fossil fuels in cars, trucks, and airplanes to kinetic energy as well. In all of these examples, some form of energy is changed to kinetic energy—the energy of movement—in order to transport people and goods all around the globe. We will take a closer look at these energy changes later in the chapter.

Teaching Tip

For a quick activity to illustrate heat emission, plug in two lamps—one with a compact fluorescent lightbulb (CFL), and one with a traditional, incandescent bulb. In a few minutes, students can measure the surface temperature on each bulb and note that the CFL has a lower temperature; less heat is being emitted. See **Chapter 6, Pictures of Practice: Energy Efficiency of Lightbulbs,** to watch this activity unfold in a fourth- and fifth-grade classroom, or view the following web link for information about CFL bulbs: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LB.

Drinking Water. Students may not realize that even getting water from their home's faucets requires energy to change forms. The water that comes out of the faucet is moving and is pressurized. This requires electrical- or gas-fueled pumps to move the water. There is also another type of pump that uses differences in height and gravity to change gravitational potential energy into kinetic energy.

Using water also uses energy. Water that comes to our homes is pressurized and requires an energy source.

Temperature Maintenance. Cold weather requires heating of home and work environments for both health and comfort. Hot weather requires cooling systems (such as refrigerators) to maintain food from rotting as well as for comfort and health in our homes in the forms of fans or air conditioning. In each case, energy changes several times. If a fire is lit, the chemical energy in wood is changed to heat and light. If a fan or air conditioner is turned on, it is likely that some form of energy was changed into electrical energy. What many of us overlook is that because heat is once again a by-product of energy transformation, it is produced and will have to be "pumped out" of air conditioners and refrigerators, also requiring energy.

Electrical Devices. Like heating and cooling systems, many appliances, instruments, and machines require electricity to work. We need kinetic energy and heat in dishwashers and laundry machines, we need light and sound for cell phones, televisions, and stereos. Making these appliances work involves several steps of energy transformations, often starting with the burning of a fuel in power plants to make electrical energy that eventually transforms into the energy we need (light, sound, kinetic, and heat).

Food. Plants undergo a process called photosynthesis, which changes light energy from the sun to chemical energy that is stored into plant structures such as stems, leaves, and fruits. In this way, plants are different from most other living things on Earth because plants make their own food. People and other animals then consume plants to meet their needs. When consumers eat the plants, that chemical energy can be transformed into many other forms: kinetic energy to move, stored chemical energy in the body, and heat. Energy is transferred up food chains. The energy that initially comes from the sun is the basis of our food chains, and almost every living thing on Earth depends upon subsequent energy transformations to survive. Because heat is often lost as a waste or byproduct of these transformations, the more transformations that occur, the more energy is lost, with less and less energy reaching the "final destination." This is often represented graphically as an energy pyramid, with the top consumers or predators dependent upon the energy of many transformations.

The previous examples capture experiences we have every day as energy changes forms. Although there are more energy transformations than the ones mentioned, these are examples that may be helpful to analyze with your students. They can provide a common experience for the class to discuss. Exploring answers to questions such as, "How does electricity make sound on my TV or stereo?" could tap into students' natural curiosity to explain the world around them.

Many of the transformations that happen in our human devices are truly a mystery to most students. Since the discovery and expansion of fossil-fuel-based power, scientists and engineers have revolutionized how energy is used in human activities. When students are asked what happens to gasoline in a car's gas tank, most will say that the gasoline disappears, turns into energy, or even evaporates into the air. All of these answers indicate that students need to know more about how our human systems—both engines and power plants—work in order to have a more complete understanding of energy in our lives. Following we take a closer look at the internal workings of human-engineered systems.

Teaching Tip

Discuss energy transformations within the classroom as shown in Chapter 1, **In the Classroom: Watching Energy Flow.** For example:

- Is the class hamster running on the wheel (converting chemical energy to kinetic energy)?
- Are there solar calculators in which light energy is stored in the battery and then changed to electrical energy?

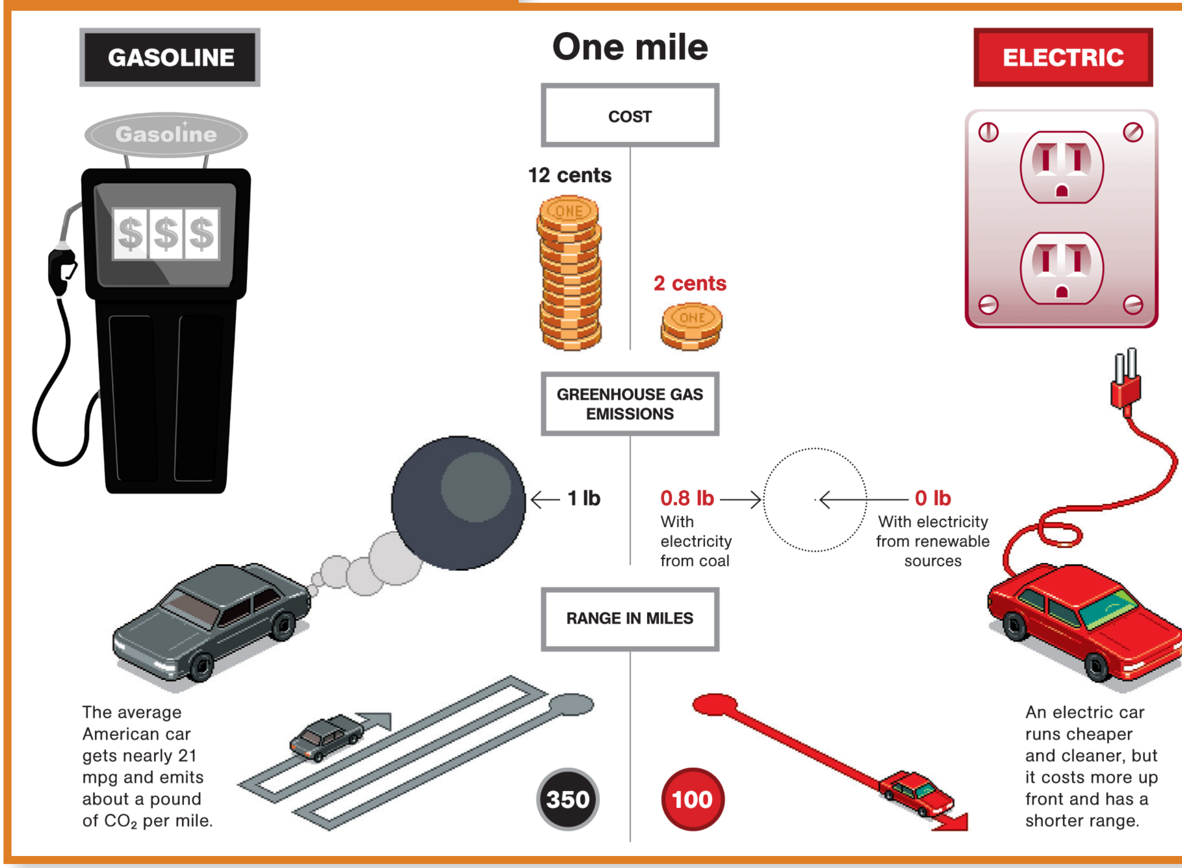
Model one or two of these examples for students, then ask students to walk around the classroom in pairs, taking notes of all the energy transformations they are witnessing in their very own classroom. Once students share their notes, develop a class list of these transformations. Ask students to find patterns in what they saw. For example, all the electrical appliances on the list likely show similar energy transformation patterns. Reminder: Every transformation has heat as an energy output.

What Happens in Engines?

The **Industrial Revolution,** during the 18th and 19th centuries, brought unprecedented advances in energy technologies. Until then, most everyday activities were carried out by animal or human power. Animals were used to pull carts and wagons and to help plow fields. Horses were widely used for transportation. The Industrial Revolution brought about the use of fossil fuels. Fossil fuels then powered transportation activities, as well as some agricultural practices, which replaced human and animal power. Fuel-based power allowed our communities to expand the production of goods by using energy resources differently. The widespread use of fossil fuels allowed engineers and scientists to build more efficient machines that took over traditional jobs. Two important inventions that changed how work was done—the steam engine and the combustion engine—both relied on the rich chemical energy found in fossil fuels.

Steam Engine. The steam engine was a marvel of its time. From agricultural uses to transportation, the steam engine changed the way we moved and produced goods around the globe, as well as labor distribution on our farms. Steam machinery requires a form of chemical energy. Burning wood fuel supplies energy to power the steam engine but requires a great deal of wood from forest to be cut and burned. When coal was available, steam engines used this rich source of energy. Whether coal-based or wood fuel-based, steam engines essentially used the heat created by burning fuel to heat water and produce steam. In the process of heating water, a phase change occurs, from liquid water

GASOLINE VERSUS ELECTRIC CARS



The graphic depicts a comparison between gasoline and electric vehicles in terms of cost, range, and emissions.

to water vapor. Continued heating of the water vapor causes increased pressure on the walls of its container. The pressure is used to mechanically move any device (usually a **piston**). Heated vapor can also be directed so that it spins a **turbine,** instead of using a piston. In this case the machinery is called a **steam turbine.** One of the features of a steam engine—whether it uses a piston or turbine—is that it transforms energy from chemical energy in the fuel to motion, or kinetic, energy.

The versatility of the steam engine for manufacturing goods led to a geographical concentration of activity around cities. These changes provoked the movement of people into the concentrated manufacturing locations, starting a growth of urban life and the well-documented migratory movements "from country to city." Steam engines were also widely used in rural areas, as agriculture began to use these engines to make farm labor more efficient.

Combustion Engine. The first combustion engines developed were called **external combustion engines** because the transformation of energy occurred outside the engine. Steam engines were examples of one type of external combustion engine. Combustion is the process in which the chemical energy in fuels is changed into another form of energy. For combustion to occur, two things are needed: a chemical source of energy (a fuel) and an oxidizer (usually oxygen).

As more designs were developed and a better understanding of combustion engines was gained, other designs became available. The **internal combustion engine** was an important development for manufacturing and transportation. In an internal combustion engine, combustion occurs inside the engine, in what is called a combustion chamber. The fuel used by an internal combustion engine is generally a fossil fuel, such as gasoline, diesel fuel, natural gas, or propane. The oxidizer is usually air. Valves are used to regulate the mix of fuel and oxidizer, which—by means of a spark—explode. Some mixtures are so explosive they do not need a spark; all that is needed is the pressure of mixing the fuel and the oxidizer in the chamber. This is the case with engines that run on diesel fuel. Once the fuel and air are mixed, the reaction creates a great deal of heat and pressure from gases given off by the reaction. This heat and pressure are used to move a piston, a turbine, or a nozzle, which is a form of kinetic energy. The gases are given off as waste products through the exhaust system.

Electric Cars. Electric cars work very differently from internal combustion engines. They use electric motors instead of combustion motors. In fact, electric vehicles were the preferred mode of transportation over internal combustion engines back in the 19th and early 20th centuries. This is because electric motors were cleaner and quieter than their combustion counterparts.

In electric motors there are different ways to generate the electricity needed by the motor. One common way to generate this electricity is by using stored chemical energy in batteries. The battery packs are rechargeable, hence the reason that electric cars must be plugged in overnight. An electric motor changes the electricity source into kinetic energy, just as combustion motors change chemical energy into kinetic energy.

There are numerous types of electric motors. General Motors produced an electric car in the 1990s called the EV1. This electric vehicle used an AC induction electric motor. This type of electric motor is composed of two key parts—the stationary stator and the moving rotor. The **stator** is a stationary electromagnet and the **rotor** is a rotating electromagnetic. A magnetic force is generated between the two. The current generated in the rotor conductors interacts with the magnetic field of the stator, which then causes the rotor to move. As this process is repeated, more electric energy is generated and stored and can then be converted into the energy of movement of the car.

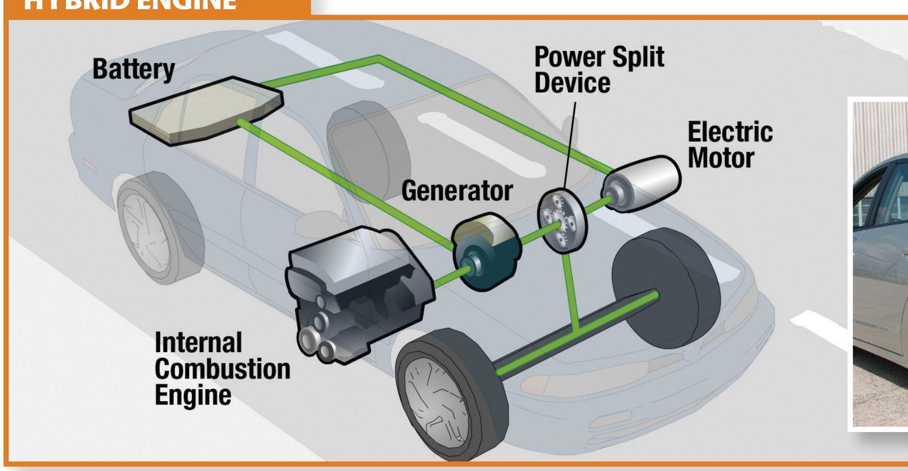
Hybrid Engines. As the name implies, hybrid engines use a combination of an internal combustion engine and an electric engine, with a **generator** between the two. There are many types of hybrid vehicles. The most popular of these vehicles is a full hybrid, like the Toyota Prius or Ford Fusion. Some key features of hybrid engines are 1) the use of regenerative braking, in which the kinetic energy from braking is changed into electrical energy that can be stored in batteries, and 2) the automatic shut off of the combustion engine when the car is stopped. That is why hybrid cars are more efficient in cities where braking and traffic stops are more frequent.

The hybrid vehicle usually has a device that helps to determine which power source to draw from. This is called the power split device. A hybrid can draw from stored electrical power from the batteries, from kinetic power generated by braking, or from chemical energy found in the combustion-fuel source. Depending upon the type of driving, a hybrid motor undergoes many energy transformations to result in kinetic energy.

While the different types of engines are complex, students can develop a basic understanding of ways energy changes forms in each type. Whether energy is changing from chemical energy to kinetic energy (traditional combustion), from kinetic energy to electrical energy (braking in a hybrid), or from electrical energy to kinetic energy (electric or hybrid), engines run by transforming one energy form into a usable energy form. More efficient engines get the same kinetic results while using less energy. This is what many automobile companies are currently working on—to create a new generation of transportation engines that rely on fewer fossil fuels, but still have competitive kinetic performance.

When discussing engines with students, help them keep matter and energy separate. When gasoline is used in engines, the gasoline is oxidized, giving off carbon dioxide and water. None of the matter that makes up the gasoline is lost or turned into energy. The atoms are simply rearranged into different molecules and released through the exhaust system. Likewise, energy is not created or destroyed in the engine; it simply changes form. Be attentive to how students describe energy in cars, as they often want to use the words *gasoline* (or *materials*) and *energy* interchangeably.

HYBRID ENGINE



Hybrid vehicles use a combination of the traditional internal combustion engine (gasoline engine) and an electric motor to produce better fuel economy. To learn more about how hybrid engine systems work, visit fueleconomy.gov or http://www.fueleconomy.gov/feg/hybridtech.shtml.

Student Thinking

Burning Gasoline

When students are asked to explain where matter goes during reactions in which it seems to disappear, they often invoke solid-solid or solid-liquid conversions instead of explaining the change of solids-liquids to gases. Students may use solid-liquid conversion to explain where the matter of a candle goes as it burns. Students describe the candle melting, but they may not grasp that the wax is being oxidized and transformed into gases that enter the air.

Scenario

Your students have just discussed what happens to propane in a barbeque grill and what happens to a candle as the wax burns. You are about to start an activity on gasoline in cars but want to assess how much your students will already know about this topic. You have your students free write in their journal about the following questions and then share as a whole group.

Question

Where does the gasoline go as it is used by a car? Is burning gasoline related to climate change?

Scientific Answer

An internal combustion engine uses gasoline through a reaction with air (oxidation), then compressing the mixture, after which the spark plug creates a small explosion. This creates force that propels the car and exhaust that is released through the tail pipe. Car exhaust not only releases carbon dioxide into the atmosphere, but also contains carbon monoxide, nitrogen dioxide, and sulfur dioxide, which all contribute to climate change.

Student Answers

Karin: All of the gas is sucked into the engine. The engine needs a combustible liquid or gas to push the pistons. The matter of gasoline turns into CO_2 (carbon dioxide). Too much CO_2 in the air can create a thicker layer of atmosphere, and when the sun's rays can't escape, the rays heat up the atmosphere.

Maria: The gas has been worn out and became energy. The gasoline produced smoke, which ruins the ecosystem and the ozone. Then the UV rays come in quicker.

Darian: I think the gas is burned and it evaporates into the air. Those gases are bad for the air and make the air hotter and glaciers melt.

Jessie: It goes into the air. I don't think it's related to global warming.

What Would You Do?

1. From the answers given, you decide Karin is starting off with a better-than-average understanding but that most students are not transferring what they already learned from the prior discussions of the candle and propane. Of the ideas mentioned previously, which concepts would you focus on teaching during your lessons on combustion in cars?
2. How would you address incorrect ideas about the topic through your instruction?

Pictures of Practice

Energy From Cars

In the United States, cars are the most widely used mode of personal transportation. This means that most students are familiar with traveling in cars and most likely have experience with watching their parents fill their cars with fuel. They also know that cars emit exhaust, and that car engines warm after the engine has been running. These experiences are ones that your students will share and can be used to help them build a more complete understanding of gasoline and energy in cars. What happens to fuel once inside the car can be mysterious to students. They often believe the fuel either evaporates or turns into energy. Many students, however, do connect fuel use with exhaust. Energy transformations inside a car engine are also a mystery. How does the energy in gasoline give us kinetic energy to move the car? This energy transformation deserves a closer look.

Students: Grades 4 and 5

Location: San Diego, California (a coastal community)

Goal of Video: The purpose of watching this video is to listen to students' ideas about what happens to energy in cars.

Classroom Context

This video clip shows students at a point when they are well into their energy unit. They seem more confident with identifying forms of energy and identifying simple transformations in their everyday world. In this lesson, Ms. Howard has her students learn more about transformations inside a car engine.

Video Analysis

During the pre-interviews, students are able to identify that gasoline is used to power the car, and they know that gases are given off by the car. However, the actual knowledge of how the car is moved and what kind of energy is created is not well understood yet. In the classroom, Ms. Howard begins the discussion by having her students make the connection between putting gasoline into the car and the car moving. Specifically, she talks about how chemical energy (gasoline) can change into motion (kinetic) energy and heat. The topic of heat is confusing for her students, and they talk about the air conditioning and engine before they get to the muffler, which also gets hot because of the waste, or exhaust, that is given off. An internal combustion engine uses gasoline through a reaction with air (oxidation). The oxidation ultimately causes pistons to move, propelling the car. Exhaust is released from the used materials (water vapor and carbon dioxide). Importantly, the most basic energy transformation is from chemical energy into kinetic energy and heat. Eventually the class realizes that gasoline travels from the tank, to the engine where it is used to create kinetic energy, and several students seem to understand that heat is a wasted energy product from cars.

Reflect

How would you teach about gasoline and energy in cars?

A car is such a familiar form of transport to students, but the complicated processes that occur in the engine can be confusing. What strategies would you use to help students understand the role of gasoline as energy in cars? How can you help students develop separate (but parallel) stories about how gasoline (matter) and energy change forms inside the engine?

What Happens in Power Plants

As with engines, students may have many questions about electricity. They use it every day but may never think about how it is available to them. Each day, students charge their cell phones and turn on televisions and computers. At school, we use lights, computers, as well as heating and cooling systems that use electricity. Electrical energy is working in our world day and night. As discussed in Chapter 1, students with limited understanding of energy may equate electricity with energy. Electrical energy is just one form of energy, albeit an important one in this modern world.

Electrical devices are so versatile that electricity has become the most common form of energy in many human communities. Electricity can come from multiple sources and is distributed through a vast energy grid, or a large network of wires that transmit this energy from power plants to our communities. Power plants, or power stations, are facilities responsible for transforming one form of energy into the electricity we can use. They send this electricity across power lines for domestic, commercial, and industrial use.

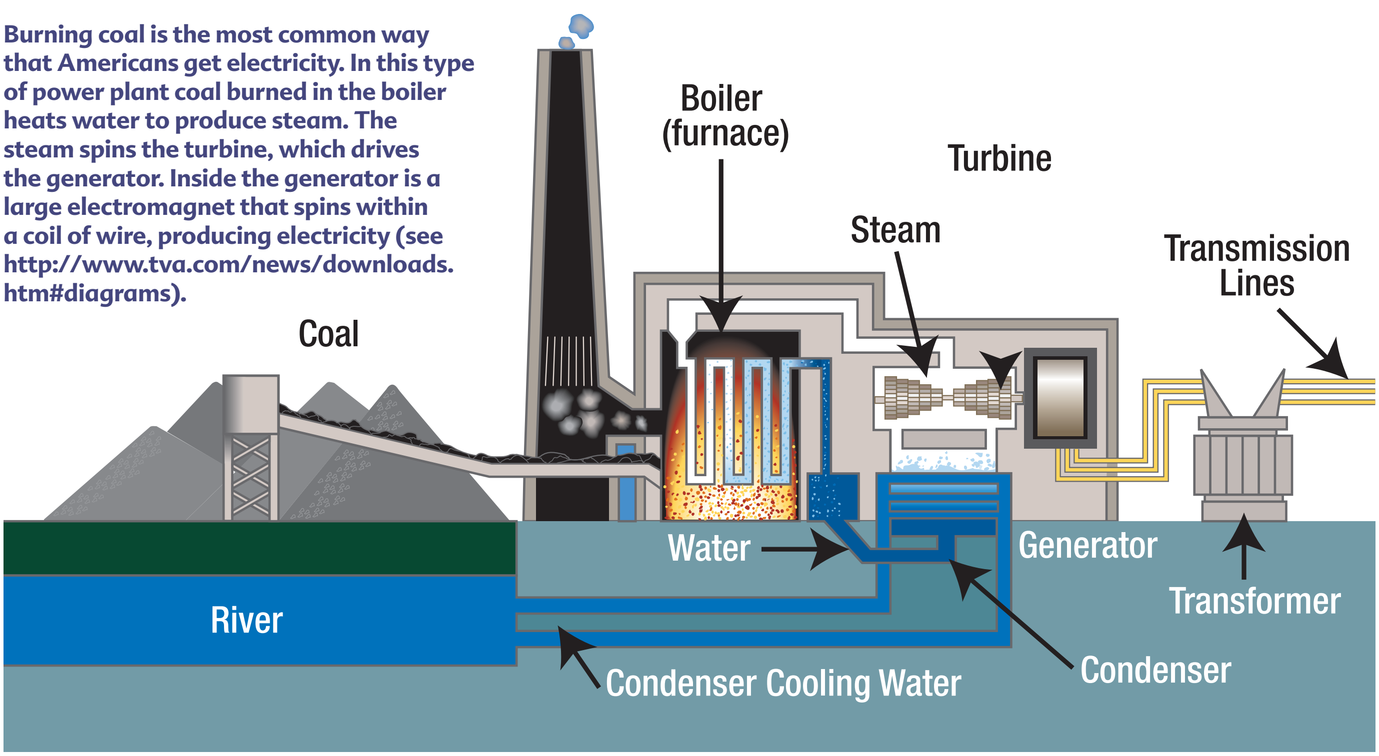
While power plants may not have a visible presence in your students' communities, power lines certainly do. Your students may wonder where these power lines start, how far they extend, and how they bring electricity into their homes.

Power plants are facilities composed of many specialized parts. Just like living cells have specialized organelles that work together to enable cell function, power plants have specialized components. Every power plant may have slight differences, but there are also common components that are shared. A power plant typically includes the following parts:

Turbines. A turbine is a blade arrangement that allows linear movement to become rotational movement by contact with a moving fluid (e.g., air, water), similar to a pinwheel or waterwheel. Turbines may look like fans, but the difference is that

Teaching Tip

Understanding the sequence of events that takes place in a power plant can be confusing and difficult for students to remember. This may be a good time to have students place the previous information into a graphic organizer that shows the sequence from turbine to generator and then transformer. Then, under each step, students can define the events taking place. For a website that contains graphic organizers or thinking maps, try: http://www.ascd.org/ASCD/images/publications/books/fisher2007_fig5.5.gif.



Burning coal is the most common way that Americans get electricity. In this type of power plant coal burned in the boiler heats water to produce steam. The steam spins the turbine, which drives the generator. Inside the generator is a large electromagnet that spins within a coil of wire, producing electricity (see http://www.tva.com/news/downloads.htm#diagrams).

Student Thinking

Electrical Energy

Power stations are facilities in which a variety of disciplines contribute to their functioning. Professionals working on a power station may include electrical engineers, architects, civil engineers, physicists, chemists, and optical engineers, among others. The jargon every discipline uses to communicate to the public may influence the way students think about energy changes in power plants. Students hold many misconceptions about electrical energy.

	Common Student Ideas	Scientific Concepts
Electrical energy: currents and voltage	The electricity made in power plants is just as strong, or the same strength, as electricity that reaches homes and businesses.	Currents and voltage depend on physical characteristics of the electrical conductor (i.e., the wires), as well as on different devices and mechanisms of voltage and current control.
Energy dissipation	All the electricity that is made in a power plant makes it to our homes.	Energy is dissipated as heat and lost in every step of a power plant, especially as electricity travels through power lines. In the United States, we lose an average of 6.5 percent of electricity generated. Electrical energy must be generated according to the demands to prevent high loss of energy.
Energy sources	Stuff or materials that are necessary for life (e.g., water, air, soil) are energy sources.	Energy sources are forms of energy that can be transformed into a usable form of energy (e.g., sources such as solar, geothermal, wind, water). Water and soil are not sources of energy.

Ask Your Students

1. What happens to electrical energy—at the power plant, as it travels, and inside our homes and businesses?
2. Not all the energy generated at a power plant makes it to homes and businesses. What happens to the energy that is not usable electricity? (Note: Some energy is lost as heat along the way.)
3. What types of energy are used to produce electricity in power plants? What are other energy sources?

Pictures of Practice

Where Does Electricity Come From?

Students: Grades 4 and 5

Location: San Diego, California (a coastal community)

Goal of Video: The purpose of watching this video is to listen to students talk about how electricity reaches homes and industry.

Power lines run through our communities and cross our landscapes, but how often do we think about where these lines originate? While electricity runs into and around our homes, the power grid is not well understood. Electricity itself can be an abstract concept. It runs through wires and powers our electronics, but what is electricity and how is it generated? There are many complicated steps that go into producing electricity, starting with the initial energy source (fossil fuels, wind energy, and so on) that creates movement in a turbine or piston, which ultimately rotates the rotor in the generator. The movement of the rotor and stator leads to an electrical current being produced. Power lines carry this current to our communities. Communicating these steps effectively and helping students to trace electricity from their homes to the source will make this system more visible to students.

Classroom Context

In prior lessons, students discussed the definition of energy and different forms of energy. In this lesson, Ms. Howard wants her students to learn more about electricity—what it is, how it is generated, and how to make appliances and lightbulbs more energy efficient. Ms. Howard begins the lesson with several appliances: a fan, a hot plate, and a radio. She asks students how each object changes energy (e.g., a radio changes electricity to sound and heat). This brings the class to a discussion of the energy source for each appliance (electricity from the powerstrip and outlet) and then into a further discussion of where electricity comes from.

Video Analysis

At the beginning of the energy unit, students demonstrate several misconceptions about electricity. Ezequiel describes electricity as being produced in "factories," and "volts" powering his electronics, but he cannot explain how electricity is brought to the outlet in his house. Martinez confuses power lines with "telephone vines." The difference between telephone wires and power lines can be hard to distinguish for students, but it is an important distinction to make. Consider showing your students the difference, using the power lines and telephone lines running into your school. Next, Ms. Howard begins a class discussion about electricity by talking about appliances in the room. She traces the electricity back through the cord and power strip and to the wall. She then leads students to point out power lines as an important step in between the power plant and consumer. After the discussion, Ms. Howard admits that after her class identified the power lines, they said that the next step was the sun. This misconception could stem from learning that the sun provides energy. In general, most electricity is produced at a power plant using a different form of energy (burning fuel, turning turbines using wind or water, and so on). However, with the advent of solar panels, electricity can be produced by energy from the sun, but there is still a human-made device that must generate the electrical flow. Students continue their discussion looking at the inner workings of power plants.

Reflect

How would you teach about electricity generation?

The complicated process of producing, transferring, and consuming electricity can be difficult to teach in the classroom. What method would you choose to help students understand each step of the process? How can you make the power grid more visible to students?

instead of the fan moving air, it is air (or another fluid) moving the turbine. No matter what the source (e.g., steam from burning fuels, **geothermal** activity, water from dam release, wind, and so on), turbines initiate the next step of the electricity generation.

Generators. A generator is the part of a power station in which the kinetic energy from the turbine's movement is transformed into electrical energy. This happens through the creation of a magnetic field that is transformed into an electric current. Most students will know that magnets have a positive and a negative "pole." This is due to an accumulation of positive or negative charges. As magnets are rotated, electrons (negative charge) begin to "flow," hence the generation of an electric current. To create the magnetic field, a generator has two parts: the rotor and the stator. The rotor spins from the turbine movement. The stator is stationary. The spinning of the rotor against the stator generates a magnetic field causing the flow of electrons. The electric current exits through cables that come out of the stator.

Transformers. A **transformer** changes the voltage of an electrical current by means of a process called **induction.** Usually, power lines transmit "high tension" or "high voltage" electrical current that has accumulated. A transformer is used to give a suitable voltage for household use. The transformer is used to "step-down" voltage that enters homes or "step-up" the voltage that needs to be transmitted across long distances.

Different Types of Power Plants

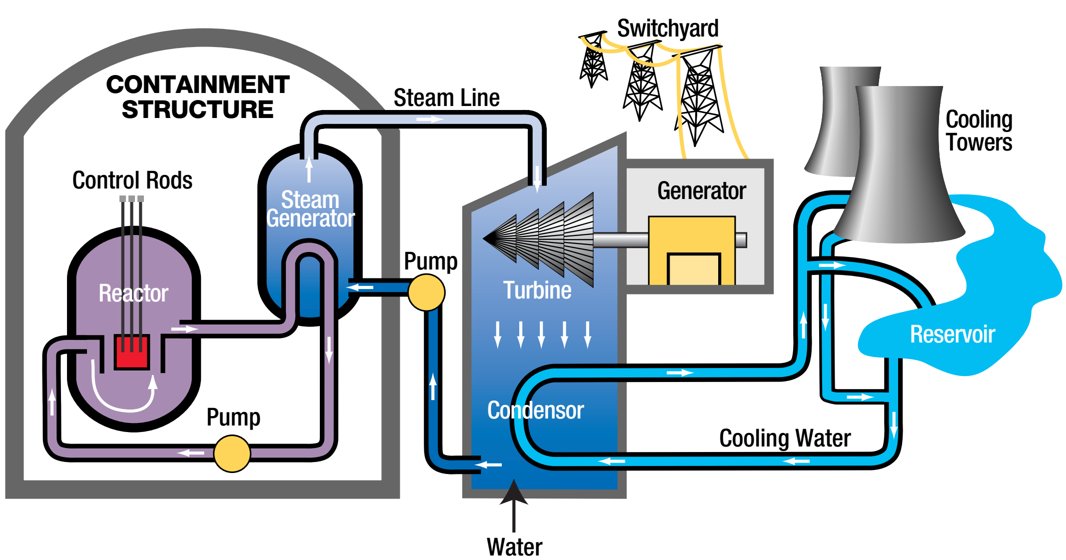
Most differences in power plants are related to the source of energy turning the turbine. Students may know that there are different kinds of power plants but may not realize how similar these power plants are in terms of their internal parts.

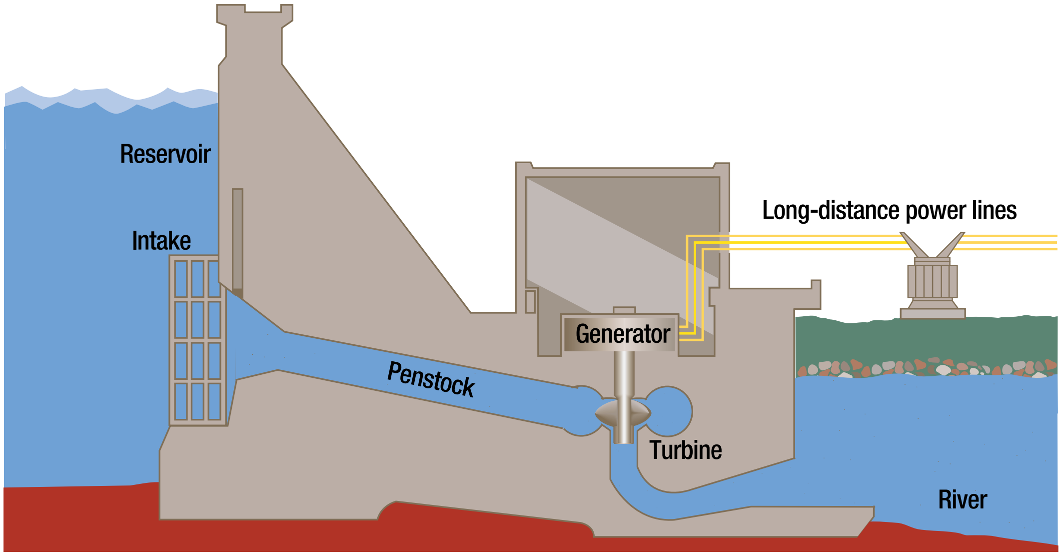
Fuel Power Plants. Fuel power stations take energy-rich materials, such as coal or natural gas, and transform their chemical energy into electrical energy. The chemical energy found in fuels is burned (oxidized) to create heat energy. This heat energy is then transformed into kinetic energy, or turbines and rotors, and eventually leaves the power plant as electrical energy.

There are many types of fuel-based power plants: coal-powered, gasoline-powered, natural gas-powered, or **biofuel**-powered (the burning of **biomass**—or living matter, such as manure or wood—to make fuels such as ethanol or biodiesel). In the United States, most of these power plants use either coal or natural gas. Combustion of fuels produces emissions of carbon dioxide and other potentially toxic gases into our atmosphere (some of which create acid rain). Carbon dioxide is also called a **greenhouse gas** because of its ability to trap heat within the atmosphere. Because of the emissions from fuel power plants, many energy companies are looking for cleaner, more efficient ways to burn fossil fuels to release less greenhouse gases. For example, to produce the same energy output, burning natural gas releases fewer greenhouse gases compared to burning coal.

Nuclear Power Plants. Nuclear power plants use nuclear reactions (fission or fusion) to create heat energy, which is then transferred to a fluid—mostly water. The heat causes the water to vaporize, and the heated vapor flows through a turbine, making the rotor

The most common nuclear power system in the United States is the pressurized-water reactor as shown in the figure. The other type of reactor is the boiling-water reactor. Water is heated through the splitting of uranium atoms in the reactor core. The water, held under high pressure to keep it from boiling, produces steam by transferring heat to a secondary source of water. The steam is then used to generate electricity (see http://www.tva.com/news/downloads.htm#diagrams for more examples).





Water from the reservoir rushes through the penstock into the powerhouse. The water spins the turbine, which drives the generator. Inside the generator is a large electromagnet that spins within a coil of wire, producing electricity (see http://www.tva.com/news/downloads.tm#diagrams).

of the generator spin. After that, the water vapor is cooled and condensed, and then reused in a cycle. The general changes in energy follow this sequence: nuclear energy to heat energy through a nuclear reaction; heat energy to kinetic energy in the fluid; kinetic energy in the turbine and rotor to electrical energy as a product.

Nuclear power makes up a relatively small but important portion of our energy resources. Nuclear power does not emit greenhouse gases like the burning of fossil fuels, but nuclear power plants must be careful about other potential impacts, such as the disposal of nuclear wastes and the discharge of heated wastewater into our waterways and ocean. Some aquatic and marine ecosystems are affected when heated water is released into the system.

Geothermal Power Plant. **Geothermal energy** utilizes thermal energy, mostly coming from Earth's internal heat (under Earth's crust). This heat is transported to Earth's surface in the form of geysers, hot springs, or other sources of heated fluid such as lava. These phenomena occur mainly near the boundaries of tectonic plates, oftentimes in earthquake and volcanic zones. As a result, most of the geothermal power plants in the United States are located on the West Coast or in Hawaii. In geothermal power plants, the stages of energy transformation are similar to other power plants. Water or steam coming from geysers is either directed toward a turbine or used to heat another fluid with a lower boiling point than water, and then directed toward a turbine. The spinning turbine makes the rotor of the generator spin, which then generates electrical energy.

Hydropower Plants. Hydropower uses the **gravitational potential energy** of water accumulated at a greater height that then cascades to a lesser height. A dam is built to raise the water level. Water on top of the dam is directed toward a turbine, which makes the rotor of a generator spin, provoking the conversion from motion to electrical energy just like other power plants.

Hydropower is a relatively clean source of energy because no waste products are produced from power generation. Furthermore, dams also control the flow of water throughout a region and across time, so they serve multiple purposes beyond power generation. Like all power plants, hydropower is not without fault. Dams break up the natural flow of a river and can disrupt migration patterns for aquatic life. Dams also have relatively short life spans, and many older dams are now being dismantled in order to restore natural flows to their rivers.

Wind Power Plants. Wind power plants use airflow to move a turbine. Before the technology of electricity production was developed, wind was used for grinding grain (e.g., Bale Mill near Calistoga in northern California is one example), for pumping or draining water (used extensively in low-lying terrains seen in Holland), and for propelling sailing ships Most people refer to air motion energy as wind energy. In a zone of high-energy winds, wind farms may be built to generate electric energy for communities. Wind farms are arrangements of many wind turbines, which are high towers that usually have three blades.

Several wind farms are already generating electrical energy in the American West, especially in Texas and California. These farms harvest wind energy in locations where wind flow is strong and reliable, such as in gaps between mountains that create natural wind tunnels and in open prairies. Several examples include Altamont Pass east of San Francisco, Tehachapi southeast of Bakersfield, and San Gorgonio near Palm Springs. While wind farms are a clean source of energy, they face the challenge of reducing bird and bat fatalities that occur as birds and bats migrate using the same wind currents that the wind farms seek to harvest.

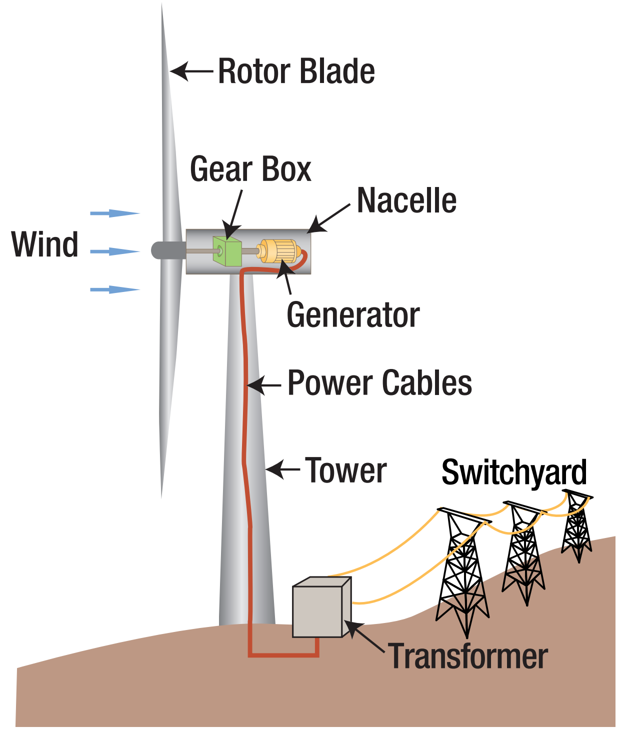
Marine Power Plants. Marine, or ocean, power plants are recent developments in energy production. In marine power stations, movement of water is used to make a rotor of a generator spin. Tidal power stations use the regular movement of tides to spin turbines located underwater. Wave power stations use ocean waves to move pistons that compress a fluid. The compressed, or pressurized, fluid is then directed toward a station to spin a turbine. In both cases, the movement of water is ultimately transformed into movement of pistons or generators to then transform into electrical energy.

These sources of energy are among the newest to arrive on our energy landscape. Like with wind farms and hydropower, there is some concern about disrupting the natural marine ecosystems. For example, some scientists worry that ocean energy structures (such as underwater turbines) may affect migrations of marine species, especially whales. Because this technique is relatively new, we still know little about the amount of energy that can be harnessed from our ocean, and the impacts this type of power plant will have on the local environment.

Solar Thermal Power Plants. In solar thermal power plants, sunlight can be used in one of two ways: Sunlight can be directed by using mirrors or lenses to a focal point in which a fluid is boiled and used to spin a turbine, or sunlight can be used to warm up massive amounts of air (also a fluid), which is directed through a turbine. Solar thermal technology has existed for decades, but recently major advances have substantially improved its efficiency. The technology is expected to continue to improve, and the number of solar thermal facilities is also increasing. We have been taking advantage of solar heating for many years. For example, sunrooms are designed to maximize the passive solar heat that can be captured just from utilizing incoming sunlight.

Solar Photovoltaic Power Plants. In contrast to the power stations discussed previously, **photovoltaic** systems work on a different principle than the magnetic generation of an electrical flow. Photovoltaic solar cells use the properties of some materials **(semiconductors)** that react to solar light by activating electrons and creating a charged electrical field. The basic structure of a solar photovoltaic cell (the basic unit of a solar photovoltaic power arrangement) is two external conductors that are connected. If you have ever seen a solar-powered home, you will have seen these panels on top of the roof. Like a sandwich, the two conductors enclose two layers of semiconductors (usually silicon-based): one called an *n*-layer (negative layer) that faces sunlight and the other called a *p*-layer, which is underneath the *n*-layer. When sunlight hits the *n*-layer, negatively charged electrons are activated and migrate through the external conductor

Wind turbines generate electricity inside their hub, or nacelle. A turbine and gear box are mounted in the nacelle, and rotor blades are attached to the turbine. The turbine localizes the energy of the turning rotor blades in a single rotating shaft that generates electricity (see http://www.tva.com/news/downloads.htm#diagrams).



Teaching Tip

Introduce students to the sources of electricity in your community. Are your power plants coal-fired, powered by wind farms, or a result of nuclear reactions? Discuss the idea that the energy transformations occur long before the electricity travels to our homes and schools. What are the pros and cons of the type of energy used in your local area? What other types are available? For example, if you live on a coast, have marine power plants been considered?

In the Classroom

Comparing Power Plants

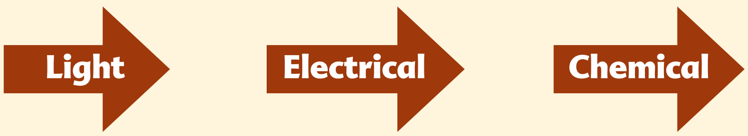
Power plants share many features, such as turbines and generators, but they can be contrasted by the source of energy used to turn the turbines. This is typically the key difference between types of power plants. In addition, power plants are also contrasted by the environmental impact they may cause, such as wastewater, heat, **pollution** and carbon dioxide, and toxic waste. Notably many types of power plants, such as hydroelectric, geothermal, solar, and wind, are solely transforming energy, while other types of power plants, such as coal or natural gas, transform both matter and energy. Taking a closer look at how power plants transform energy can help students develop an understanding of what makes each type different.

Materials

- Power plant card set, teacher generated
- Arrows with energy labels, teacher generated

Directions

1. Prior to the lesson, prepare enough packets of cards and arrows so that teams of two to four students can complete the activities. Each packet should include a small card (3 x 5 inch) image of different types of power plants. Include solar panels, hydropower, nuclear, coal, natural gas, and wind turbines (see www.energy.ca.gov/index.html for images that could be used). Create small labeled arrows for forms of energy: Light, kinetic, gravitational potential, nuclear, electrical, heat, and chemical. Each packet should have a complete set of arrows for each form of energy. See examples.



2. Pass out packets to teams. Tell students that their task is to identify the form of energy that is the original source of power for each power plant. They should then place that arrow so it "goes into" the image of the power plant on the card. Have students then identify energy outputs coming out of the power plant. Note: Energy outputs should always be electrical energy and heat.

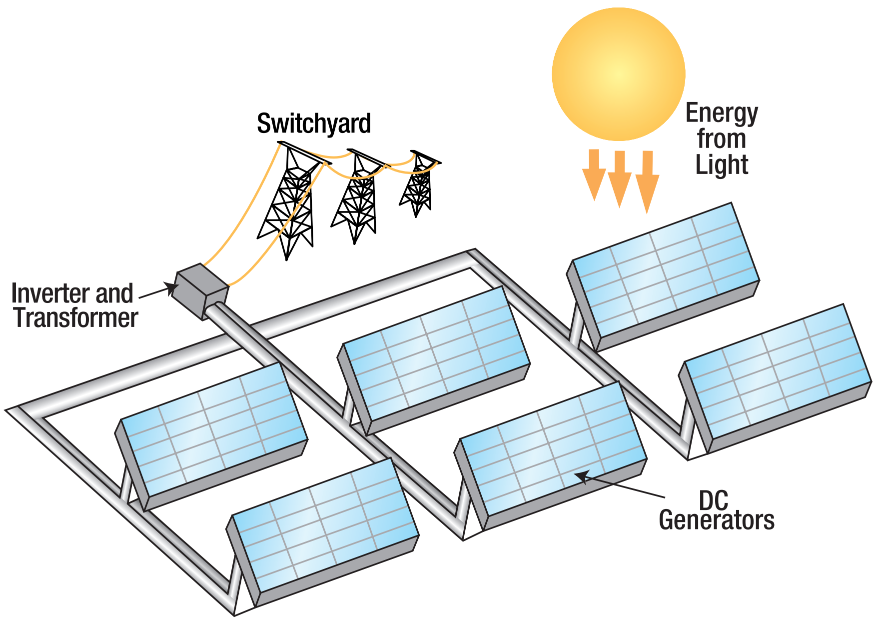
3. Ask students to develop one summary sentence about differences and similarities between power plants. Then ask students to brainstorm other things coming out of the power plants that may be harmful to the environment. For example, nuclear power needs water to cool reactors, coal and natural gas emit carbon dioxide and other potentially harmful gases, and so on.

Discuss

1. Where does our electricity come from? What is the energy input and energy output for the local power plant? Are there other outputs that could be potentially harmful?

2. Heat is an energy output, but one we do not use. Why is heat waste a problem for power plants? (Guide students toward thinking about energy efficiency.)

3. What power plants would be the best-suited sources of energy for our local community? How do they take advantage of local resources? Which power plants may not be wise choices for the local community? Why?



Photovoltaic (PV) systems use semiconductor cells that convert sunlight directly into electricity. Direct current (DC) from the PV cells, which are arrayed in flat panels, flows to inverters that change it to alternating current (see http://www.tva.com/news/downloads.htm#diagrams).

toward the positively charged *p*-layer to maintain the neutrality of the whole system. This movement of charges provokes an electrical flow that is harnessed as electric energy.

The solar panels are expensive to build, and some materials used to build them may present constraints, which can be costly. Demand for these photovoltaic cells has increased for both residential and commercial use.

Quest For Energy

All of the examples of power plants described previously represent efforts to convert energy from different forms to electricity. To distribute this huge amount of energy, it is necessary to develop systems of distribution from power plants to the main users: homes, commerce buildings, and industrial facilities.

Does all the energy generated at power plants make it to users? Definitely not! In fact, a relatively small amount of the original energy source, whether coal, nuclear, or wind power, will actually reach the end of the generator. For example, only about 35 percent of the energy available in the coal or 26 percent at wind farms is converted to electricity (ABB, 2007; U.S. Energy Information Administration 2010). Some forms of energy, such as hydropower, have a higher percentage. One way to improve generational efficiency is to use cogeneration plants, where heat waste is used to heat the power station buildings or for other purposes.

Immediately after the electricity leaves the power stations, it goes to the exit substations that regulate the voltage of the electric flow to direct it to appropriate power lines. Power lines are towers that support long metal cables that ensure the flow of electricity to cities and other centers of consumption. Substations transform the voltages to what can be sent to homes. In U.S. residential homes this is 110 volts (110V). During the transmission of electricity, 6.5 percent of the energy generated is lost as heat! (EIA 2009). This percentage may seem small but, when combined across major cities, represents a large amount of energy. One of the major goals for making an energy-efficient nation is to reduce the energy lost during the transmission and distribution process.

There is a difference between electric transmission and electric distribution. Transmission involves the high-voltage power lines and towers that can be seen along major highways and closer to power stations. Electricity that is transmitted across the lines dissipates as heat loss, especially over long distances. That loss depends on the current that is transmitted as well as the materials used as conductors. This transformation process continues as the energy transmitted in high-voltage power lines is changed into low-voltage power lines for consumer use. These are the lines that you often see in neighborhoods and around local schools and homes. While it is estimated that 6.5 percent of the electricity generated in a power plant is lost before it reaches a power outlet in a home, individual states and local communities have different rates of loss. Check out your state's energy profile at http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html.

Of the total energy consumed in the United States, only 28.5 percent is used in transportation, 21.1 percent in industrial activities, and 10.4 percent in residential and commercial facilities. It is surprising for most people to learn that 40 percent of the total energy consumed in the United States is used to produce electricity: It takes energy to make electricity. In order to generate electricity, we use petroleum (2 percent), natural gas (17 percent), renewable energy sources (9 percent), nuclear energy (21 percent), but mostly we use coal (51 percent). It is almost unbelievable to learn that 91 percent of coal used in the United States is destined for power stations!

Power Sources: Renewable and Nonrenewable

We often look at power plants in terms of whether their original source of energy is renewable or nonrenewable. Resources that can regenerate by natural processes at a rate similar to the rate they are used (or spent) are called renewable resources. For example, wind energy and sunlight are renewable resources. We harness a very small fraction of the energy that is created from wind and sunlight, so the rate at which they are spent is far less than what is available. Wood or other plant-related products can be considered renewable resources because trees and plants can be grown quickly enough to replace what is used. However, we spend them at a greater rate than they grow. Wind, solar, hydropower, geothermal, and ocean power are renewable resources.

Most of the electricity we generate comes from nonrenewable resources. When we transform chemical potential energy to usable forms we generally use nonrenewable resources—those not recovered at the same rate as they are used. Nonrenewable sources of chemical energy widely used in the world include petroleum or oil, natural gas, and coal; all of these are naturally occurring but take hundreds of millions of years to produce. This is why fossil fuels are considered nonrenewable energy sources. Fossil fuels are formed when the remains of organisms are, over geologic time, subjected to intense heat and pressure resulting in their transformation into high-energy carbon compounds. Uranium, a metal found in rocks, which is used as a fuel for nuclear energy, is also a nonrenewable resource.

There is great concern about the use and exhaustion of nonrenewable energy resources. We also need to be aware of the potential negative environmental consequences of using them. The combustion of fossil fuels transforms large amounts of organic (carbon-based) matter into gases that are now contributing to global climate change. When burned, some of these fossil fuels give off less carbon dioxide, but ultimately burning any of them will contribute to some carbon dioxide entering our air. The use of nuclear energy poses questions for safe disposal of nuclear waste and opportunities for recycling nuclear fuel sources.

The 2011 accident in Japan's Fukushima nuclear power plant following the devastating earthquake and tsunami illustrate nuclear power's potential dangers. Japan is expected to spend more than $100 billion decontaminating areas near the plant that were evacuated and will likely remain uninhabitable for several decades. While the human health effects from this accident are expected to be few overall, radioactivity has been detected in food products including beef, spinach and milk (Caracappa, 2011). Nuclear power plants, when operating properly, are relatively safe for workers and the public. Coal mining experiences many disasters worldwide every year, for instance, 29 miners lost their lives in a 2010 West Virginia mining accident. The environmental consequences of different energy resources will be discussed in Chapter 4.

Energy efficiency of power systems is still a major area for research. Your students may be the ones to discover how to make our transportation and power systems more efficient for a cleaner and more sustainable energy future.

Teaching Tip

You may want to consider doing a week-long activity with your students so they can trace the resources they use every day. Give students a list of activities that use renewable and nonrenewable resources and them tally in a table every time they use a resource. At the end of the week, discuss the results with the class. If there is time, have students research various forms of alternative energy so they can find ways to decrease their use of nonrenewables and take advantage of any of the local renewable energy resources.

Activities	Renewable	Nonrenewable	How Many Times You Used
Driving car		✓	1111111
Drying clothes on line	✓		1
Drying clothes in dryer		✓	0
Turning on A/C		✓	11111
Opening windows	✓		11

Student Thinking

Renewable and Nonrenewable

Renewable and nonrenewable resources are common concepts taught to students as early as in elementary school. Students learn to classify different energy resources into one of the two groups. Sometime students equate *renewable* with *reuse* and *nonrenewable* with *unusable again*. However, deciding whether something is renewable or not is determined by whether the resource can be regenerated at the rate the resource is spent.

Scenario

You have just completed a unit on energy, and a focus of the unit was renewable and nonrenewable energy resources. At the end of the unit, you noticed that several students still seemed confused. You decide to look back at your pre-assessment before the unit, as well as the final unit exam, to see how students' ideas changed as a result of the unit. Following you see two students' answers on the pre-assessment and post assessment.

Question

What are renewable and nonrenewable energy resources?

Scientific Answer

Renewable energy resources can be regenerated at a rate at which they are spent. Nonrenewable energy resources are spent at a greater rate than they can be regenerated.

Student Answers—Pre-Assessment

Andrea: Renewable energy is when you have energy that you've already used, but you can use it all over again. Nonrenewable is when you've used energy already, but you can't use it again. It's just gone.

Martinez: *Renewable* means "reusable energy," like a fan and an air conditioner. Nonrenewable energy is energy you can't reuse, like on the TV. When you're watching TV, you can't do something and make it go back.

Student Answers—Post Assessment

Andrea: Renewable energy is something that we use, but it's still going to be there, and we can use it over and over again. Some of the examples are wind energy, solar energy, and biomass energy. Nonrenewable energy is when you use up something to make energy, but once you use it, there's less of it, like fossil fuels and coal and nuclear energy.

Martinez: *Renewable* means "like reusable." It's something that we can get back in a lifetime, like trees are renewable. We can plant one within our lifetime. *Nonrenewable* means "you can't grow it back in a lifetime, like coal." It took 300 million years to grow it back. And you can't live that long, so it's not renewable.

What Would You Do?

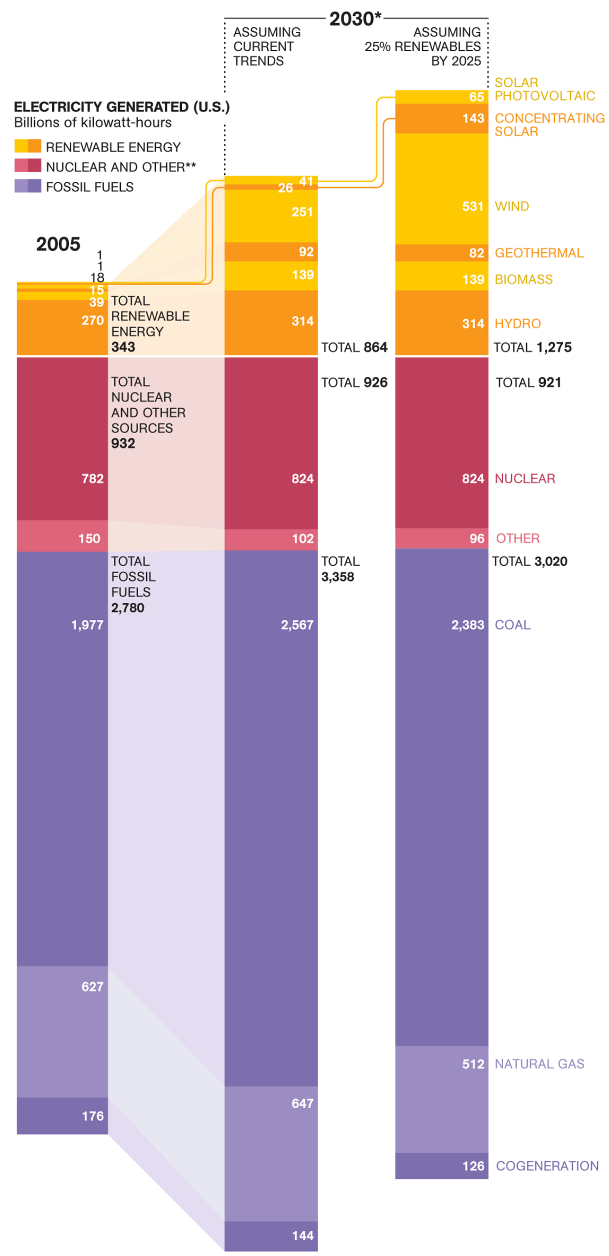
1. Now that you have examples of what students know about this topic, how can you use this information to plan your lessons or to reteach?
2. Martinez made progress toward a more scientific understanding of these concepts. He still misunderstands a few concepts but has the idea of regenerating resources. Andrea did not make the same progress. How would you help both students improve their understanding? What concepts would you focus on with each student?

Case Study: Support for Renewables

As previously described, 40 percent of the total energy consumed in the United States is actually used to produce electricity! Finding energy resources to meet our electricity needs is a critical issue for the United States and for other countries around the world.

The renewable energy graph shown to the right represents two potential forecasts for the year 2030: One forecast based on current trends (and ratio) of fossil fuels to renewable energy sources as of 2005; the other forecast is based on the assumption that 25 percent of our energy will come from renewables by the year 2025. Assuming that nuclear power use remains roughly the same, the 25 percent renewable projection will decrease our dependence on all three fossil fuel resources—coal, oil, and natural gas. Both forecasts are based on assumptions about the future of energy. For example, the renewable forecast assumes that both solar and wind power are ready to take on a larger piece of the energy resource landscape now. Other renewables, such as biomass and hydropower, may not expand. Another assumption is that tidal or wave energy from our ocean will not play a significant role in our renewable energies in the next 20 years.

Although interesting projections can be made regarding renewable energy sources, as of yet, renewables still play a relatively small role in our power generation compared to fossil fuels. As technology advances, renewables will likely play increasingly important roles. The projections shown in the graphic are also based on the assumption that commitment and support for renewables given by governments and private citizens will continue. For example, California has invested in renewable energy far more than most other U.S. states. Whether altruistic or based on necessity, Californians have ample reasons to explore the possibilities and probabilities of developing alternate sources of energy.



How much will people depend on renewable energy in the future? Renewable energy will likely be key for meeting our energy needs, but how much depends upon support from government and citizens.

California has a population of approximately 37 million, according to the U.S. Census Bureau (the most populous state in the union and more than many countries). This population is distributed in several concentrated metropolitan areas and also in mountain, desert, valley, and coastal communities—each with its unique energy demands and challenges. Given the large population, the demands for energy in the state and, in fact, across the nation, are daunting.

Recognizing the potential for an energy crisis, an amalgam of California legislators, the California Energy Commission, investor-owned utilities (IOUs), and others, began to look into alternatives. In 2002, the California State Legislature passed Senate Bill 1078 calling for 20 percent of California's energy to be from renewable sources by 2017. In 2003, the State's Energy Action Plan I called for 20 percent renewables by 2010, accelerating the commitment to renewables earlier than the 2002 legislation. Both set ambitious goals for energy reform. Established in 2004, an alliance between IOUs and both the University of California and California State University systems pooled their resources and expertise to develop a best-practices model to save energy and reduce costs. So far more than 80,000 metric tons of carbon dioxide equivalent has been saved. While California was already doing well in its commitment, in 2005, Energy Action Plan II recommended additional renewables, from 20 percent up to 33 percent by 2020. Additionally, in 2006, the California Legislature passed Assembly Bill 32, the Global Warming Solution Act, that set the 2020 greenhouse-gas emissions reduction goals, which outlined specific actions to be taken by industry, municipalities, and individuals. In early 2011, a bill was passed to increase California's Renewable Portfolio Standard (RPS) from its current 20 percent to 33 percent in 2020. This legislation means that renewable energies must comprise 33 percent of utility companies' retail sales by that time.

As of 2009, three of California's largest energy providers served customers with electricity generated from a notable amount of renewables (Southern California Edison generated 17.4 percent of electricity from renewables, Pacific Gas and Electric generated 14.4 percent from renewables, and San Diego Gas and Electric generated 10.5 percent from renewables). Clearly, statewide motivation and momentum is present.

As mentioned earlier in the chapter, California is fortunate to have geographic features that offer promising solutions to the staggering demand for energy. Much of California has abundant sunshine throughout the year. Because of this, many residential and commercial residents have installed the photovoltaic cells necessary to generate energy. Some are even able to produce enough energy to "sell back" energy to the municipal suppliers. The state has encouraged solar power by offering a system of rebates and tax credits. Wind farms in both northern and southern California have been supplying energy for several years, and owners are working on ways to ameliorate the mills' negative impact on birds and bats. Geysers in Napa and Sonoma counties have been supplying energy from geothermal plants since the 1960s. There are currently about a dozen preliminary permits to develop tidal energy from coastal waters. With all of these renewable projects in development or already supplying energy, there are environmental issues that need to be studied and addressed.

The need for creative solutions to our energy crunch is apparent. Californians are working to address the challenges on many levels.

In the Classroom

Generating Electricity

This classroom activity requires some materials and is an extended project for students to work on over the course of several weeks. Students will brainstorm and get hands-on experience on how to bring electricity to homes, using models in the classroom. The conceptual focus for students is to learn that in order to spend energy, we must first consider how to get energy, how to transport it to the places we need it, and the consequences of energy generation.

Materials

- Batteries
- Wires
- Small light bulbs
- Rubber bands
- Battery clips
- Small blocks or models of houses (or materials to build them)
- Cardboard
- Markers

Directions

1. Direct students to build a neighborhood using small-scale models of houses and/or streets, and to light the streets and houses.
2. As students work, ask questions such as: Where should we put lights in the houses/streets? How can we get light into the models? Students may come up with different locations to put lights and different materials to be needed (batteries, cables, little bulbs). The locations and materials should raise questions such as How should we illuminate different locations in the model? How should we connect lights together? The idea is to give students questions that would have them think of how to build a system of illumination that considers resources, such as a usable energy source (e.g., a battery), a transmission line (cables), and devices that spend energy for our purposes (e.g., bulbs for the purpose of illuminating).
3. Next, students should consider energy resources. As the battery may not be able to provide more energy, students can be asked to build another source of energy—an "energy plant." The details to build it can be found on the Internet (e.g., http://www.energyquest.ca.gov/projects/index.html)
4. Finally, relate the activity to real life by discussing how this model is similar to and different from reality.

Discuss

1. How do energy stations work? What is necessary for them to produce electricity?
2. What would happen if a power station stops functioning? How do we deal with this in real life?
3. What types of energy are used to produce electricity in real life?

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Teaching Resources

California Education and the Environment Initiative: http://www.calepa.ca.gov/education/eei/

EIA Electricity Resources for Kids: http://www.eia.doe.gov/kids/energy.cfm?page=electricity_home-basics

Energy Resources for Students: http://www.energy.gov/forstudentsandkids.htm

Energy Story: http://energyquest.ca.gov/story/index.html

Fossil Fuels: http://fossil.energy.gov/education/energylessons/index.html

How to Build an Electromagnet: http://www.sciencenetlinks.com/lessons.php?BenchmarkID=4&DocID=428

Nuclear Energy: http://www.nrc.gov/reading-rm/basic-ref/students.html

Tennessee Valley Authority power plant schemes: http://www.tva.com/news/downloads.htm#diagrams

U.S. Department of Energy frequently asked questions about energy systems: http://www.oe.energy.gov/information_center/faq.htm

Wind Power: http://www.windpoweringamerica.gov/schools_teaching_materials.asp

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