ENVIRONMENTAL LITERACY TEACHER GUIDE SERIES

Energy Potential

A Guide for Teaching Energy in Grades 3 to 8

NATIONAL GEOGRAPHIC
education

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Acknowledgements

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California Education and the Environment Initiative

California has always been a leader in environmental education and conservation, including the existence of environmental content in their academic standards.

Increasing California's impact on environmental education, Assembly Bill 1548 was passed into law in 2003 mandating the creation of a K–12 curriculum charged with incorporating more environmental education into the state's required academic content standards in Science and History/Social Science. The bipartisan law was supported by various state and nonprofit groups, and marked the beginning of the landmark Education and the Environment Initiative (EEI). The law helped solidify California's leadership role in improving national and international environmental education.

EEI Principles and Model Curriculum

With an emphasis on students' relationship with the environment, EEI aims to increase environmental literacy in a format familiar to California teachers. Critical environmental issues, such as climate change, freshwater, ocean, energy, and other topics, are addressed in the law.

"This nation-leading initiative will educate our next generation of workers in environmental preservation and protection and will help catapult California's growing green economy."

Former Governor Schwarzenegger

ENVIRONMENTAL PRINCIPLES AND CONCEPTS

1. **People depend on natural systems.**
2. **People influence natural systems.**
3. **Natural systems change in ways that people benefit from and can influence.**
4. **There are no permanent or impermeable boundaries that prevent matter from flowing between systems.**
5. **Decisions affecting resources and natural systems are complex and involve many factors.**

GRADE	STANDARD	EEI UNIT
Grade 3	3.3.a-e	Structures for Survival in a Healthy Ecosystem Living Things in Changing Environments
Grade 4	4.2.a-c 4.3.a-b	Plants: The Ultimate Energy Resource The Flow of Energy Through Ecosystems Life and Death With Decomposers
Grade 5		
Grade 6	6.5.a-e	Energy: Pass It On! Playing the Same Role
Grade 7	7.3.a 7.3.e	Shaping Natural Systems Through Evolution Responding to Environmental Change
Grade 8		

Each teacher guide chapter includes a table that aligns the content in the chapter to California state science and social studies academic standards, and to the EEI Model Curriculum.

Creation of this unprecedented curriculum began in 2004 with the development of the California Environmental Principles and Concepts (EP&C), which clearly highlights the relationship between humans and the environment. In addition to the Environmental Principles and Concepts, EEI also developed a Model Curriculum that was comprised of weeklong units for K–12 teachers to use in their own classrooms. Development of the Model Curriculum began in 2005, with a focus on aligning the unit content to California's academic standards. From 2006–2009, the California Environmental Protection Agency worked with partners, such as the California Department of Education, to create a curriculum that would be comprehensive and innovative, while continuing to teach academic content standards for Science and History/Social Science. More than 200 teachers and 600 students in 19 school districts across the state piloted the Model Curriculum units in 2007–2008 in order to test that the materials would be easily implemented in the classroom. Even more teachers and content experts independently reviewed the materials, making certain that the units fit with established classroom and assessment practices and would not burden teachers who would be using the curriculum. At the end, EEI developed 85 curriculum units spanning grades K–12, which were approved by the State Board of Education in Spring 2010.

The EEI Model Curriculum is poised to reshape how the environment is taught and presented to California's students. The California/Environmental Protection Agency (Cal/EPA), in partnership with the Department of Education, will be reaching out to inform teachers about how the curriculum can be used independently from, in conjunction with, or integrated into current instructional materials. The EEI curriculum will be made available electronically to school districts and teachers, free of charge, which will greatly increase the number of teachers who can easily access the materials. Find out more about the EP&C's and the EEI Model Curriculum at http://www.calepa.ca.gov/education/eei/.

Connecting EEI to the Teacher Guide Series

The hope of the EEI is to provide cutting-edge environmental content to students, while supporting them in achieving academic content standards. Given the environmental topics addressed by the units, professional development is needed so teachers feel confident and effective in delivering this content in their classrooms. Whether using the EEI Model Curriculum or other educational materials about the environment, teachers will need additional preparation to feel comfortable with teaching about the latest environmental issues.

The Environmental Literacy Teacher Guide Series responds to this need, providing both content background for teachers on these environmental issues, as well as providing information about concepts that likely will be challenging for students to learn. The Environmental Literacy Teacher Guide Series includes Climate Change, Ocean, Freshwater, and Energy guides. Each teacher guide is intended to prepare upper elementary and middle school teachers for instruction in these content areas.

The content and educational components of the teacher guides are aligned to both California Standards, as well as the units in the EEI Model Curriculum, allowing teachers to use specific chapters as resource when teaching those standards and units. While the goal of the teacher guide is not to prepare teachers for using a specific EEI unit, it is hoped that the information provided by the guide helps teachers feel more confident and prepared to teach about these topics in the classroom and to anticipate what their students will know and struggle with as they learn the EEI units or similar environmental curriculum.

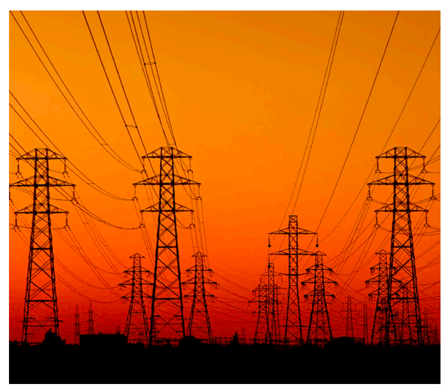
Why Is Energy Education Important?

The word *energy* is used so often, and in so many different contexts, we sometimes need to pause and think about exactly what it means. We use it in our everyday language to describe how much vigor we are feeling, the level of enthusiasm in a group, or even the spirit of a person. When scientists use the term *energy,* there are also a variety of definitions, but the commonly taught definition in school science is "the capacity to do work." What does this definition mean, and how does it help us think about our human energy systems? This teacher guide is designed to familiarize teachers with both the technical terminology about energy, and the energy-efficiency and conservation issues that have become so important in recent years. There are many ideas currently being discussed about sources of alternative energy and their relationship to energy efficiency as well as to the environment. Being armed with a greater understanding of energy allows us to make wiser choices in our personal lives as well as in our communities.

We have become familiar with the traditional scientific forms of energy as part of the regular school curriculum. We know that energy can exist in different forms: light, chemical, electrical, nuclear, thermal, and mechanical. We also know that energy can be transformed from one form to another. We know that there are renewable and nonrenewable forms of energy on our planet. Many of us are even aware of the laws of physics regarding the conservation of energy and energy degradation. These aspects of energy are not new to us, as they are commonly taught concepts in American schools. But do we know how combustion engines work to transform energy? Do we understand the inner workings of power plants? Can we trace our own energy use in the home back to its source? And how efficient are alternative energy sources? Even though we learn a great deal about energy already, many adults and students still have gaps in what they know about human energy systems, energy conservation, and energy efficiency.

In the last few years, energy has become a regular and an often contentious topic. We hear of blackouts, rising energy costs, oil spills, and concern about dependency on "foreign oil," as well as our over-dependence on oil and the environmental risks of drilling within our own borders. We are faced with the challenge of ferreting out the issues and exploring the pros and cons of each. This is an opportunity to blend the investigative process of science with the real-world approach of social studies in order to teach how energy is

Being armed with a greater understanding of energy allows us to make wiser choices in our personal lives as well as in our communities.



used in our human communities. There is much information to analyze and discuss, and the impacts of our decisions have a tremendous affect on both the environment and human communities.

Educating youth about energy and energy solutions will be necessary if future generations are going to help solve our energy problems. Yet, few resources are provided to educators to accomplish this goal. Many teachers and many states and local agencies have recognized the need for resources on environmental topics. Teachers have struggled to develop units on their own to help address the issues, while states have tried to rectify it through legislation. With the passage of Assembly Bill 1548, commonly referred to as the Education and the Environment Initiative (EEI), the state of California is attempting to bridge the gap between real-world and theoretical learning while connecting the concepts students are learning to their environment. This initiative calls for mastery of standards and curricula on environmental topics, through the use of EEI curriculum or comparable curriculum on environmental topics.

California is actually in a geographic position to consider many possibilities for alternative energy. The state has two operating nuclear reactors, wind turbine farms in both the northern and southern parts of the state, numerous hydroelectric dams, and great potential for harnessing solar energy. While there are obvious benefits to utilizing clean energy, many of these energy sources also have their trade-offs.

These trade-offs underscore the importance of conserving as much energy as possible and being as efficient as possible in the energy that we do use. In many municipalities, as well as our state and national governments, policy decisions and commitments regarding energy are being made. Although legislation is being debated, it is important not to make "knee-jerk" decisions but rather to look carefully at the trade-offs. As active consumers, it is crucial to be informed about what our governments are planning, as well as what is happening in our own communities and the choices we have as consumers and voters in those communities. Teachers are in the unique position to educate students with information about these topics while also educating students about their role as active participants in our democracy.

Being informed about energy allows us to use it more efficiently and even conserve what we have.

This guide was developed to support teachers in teaching topics with real-world context and provide them with the background to feel competent and comfortable when teaching about energy. It provides a solid introduction to energy in an accessible and reader-friendly manner. In addition to general information about energy, the guide includes numerous education features, such as teaching tips and student thinking, that help to connect the content to classroom practice.

The book describes our current understanding of energy resources, energy issues, and solutions.

Chapter 1 reviews basic concepts about energy—energy forms, energy transformations, and laws of thermodynamics. Students' common definitions of energy are compared to scientific definitions. Chapter 2 takes a closer look at energy transformations in combustion engines, electric cars, and in different types of power plants. Chapter 3 explores our reliance on fossil fuels, looking at energy use across time and the connection between fossil fuels and greenhouse gases. Chapters 4 and 5 look at impacts of energy use. Chapter 4 focuses on environmental impacts of energy extraction and use, while Chapter 5 looks at social issues, such as energy poverty and petropolitics. Chapter 6 presents solutions, innovations in alternative energies, and actions individuals can take to be more efficient and to conserve energy.

Teacher Guide Tour

Environmental Content

Environmental science includes a wealth of content that teachers may not learn as part of their professional preparation. Content pages provide teachers with an opportunity to learn this content alongside information about how students think about these topics. The content pages also reconsider fundamental science concepts in the context of environmental issues. Interesting and new concepts are in bold and defined in the accompanying glossary.

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?
Grade 7		
Grade 8	8.3.a 8.5.c	

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.

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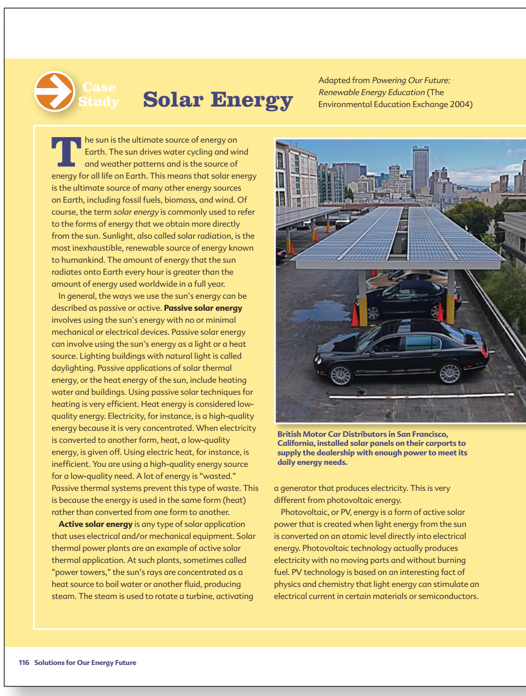
Standards Table

Chapters are aligned to California state science and social studies standards, as well as aligned to the Education and Environment Initiative (EEI) model curriculum units.



Case Study **Solar Energy**

Adapted from *Powering Our Future: Renewable Energy Education* (The Environmental Education Exchange 2004)

The sun is the ultimate source of energy on Earth. The sun drives water cycling and wind and weather patterns and is the source of energy for all life on Earth. This means that solar energy is the ultimate source of many other energy sources on Earth, including fossil fuels, biomass, and wind. Of course, the term *solar energy* is commonly used to refer to the forms of energy that we obtain more directly from the sun. Sunlight, also called solar radiation, is the most inexhaustible, renewable source of energy known to humankind. The amount of energy that the sun radiates onto Earth every hour is greater than the amount of energy used worldwide in a full year.

In general, the ways we use the sun's energy can be described as passive or active. **Passive solar energy** involves using the sun's energy with no or minimal mechanical or electrical devices. Passive solar energy can involve using the sun's energy as a light or a heat source. Lighting buildings with natural light is called daylighting. Passive applications of solar thermal energy, or the heat energy of the sun, include heating water and buildings. Using passive solar techniques for heating is very efficient. Heat energy is considered low-quality energy. Electricity, for instance, is a high-quality energy because it is very concentrated. When electricity is converted to another form, heat, a low-quality energy, is given off. Using electric heat, for instance, is inefficient. You are using a high-quality energy source for a low-quality need. A lot of energy is "wasted." Passive thermal systems prevent this type of waste. This is because the energy is used in the same form (heat) rather than converted from one form to another.

Active solar energy is any type of solar application that uses electrical and/or mechanical equipment. Solar thermal power plants are an example of active solar thermal application. At such plants, sometimes called "power towers," the sun's rays are concentrated as a heat source to boil water or another fluid, producing steam. The steam is used to rotate a turbine, activating a generator that produces electricity. This is very different from photovoltaic energy.

British Motor Car Distributors in San Francisco, California, installed solar panels on their carports to supply the dealership with enough power to meet its daily energy needs.

Photovoltaic, or PV, energy is a form of active solar power that is created when light energy from the sun is converted on an atomic level directly into electrical energy. Photovoltaic technology actually produces electricity with no moving parts and without burning fuel. PV technology is based on an interesting fact of physics and chemistry that light energy can stimulate an electrical current in certain materials or semiconductors.

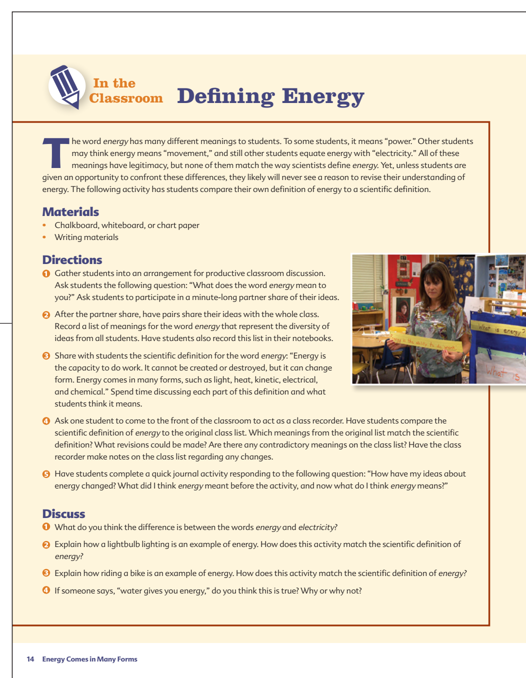
116 Solutions for Our Energy Future

Case Study

Case Studies offer an in-depth look at how concepts play out in particular locations or situations. Case studies provide real-life examples of how issues affect both natural and human communities today.

In the Classroom

In the Classroom features iconic or helpful classroom activities, as well as ideas for teaching topics. Details are provided to use the activity in the classroom, including materials lists and directions, as well as interesting discussion questions to ask your students. When possible, additional online resources are connected to the classroom activities.



In the Classroom **Defining Energy**

The word *energy* has many different meanings to students. To some students, it means "power." Other students may think energy means "movement," and still other students equate energy with "electricity." All of these meanings have legitimacy, but none of them match the way scientists define *energy*. Yet, unless students are given an opportunity to confront these differences, they likely will never see a reason to revise their understanding of energy. The following activity has students compare their own definition of energy to a scientific definition.

Materials

- Chalkboard, whiteboard, or chart paper
- Writing materials

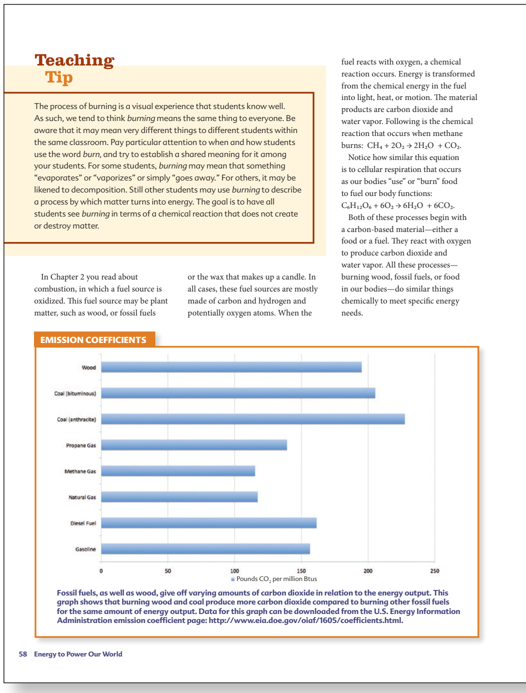
Directions

1. Gather students into an arrangement for productive classroom discussion. Ask students the following question: "What does the word *energy* mean to you?" Ask students to participate in a minute-long partner share of their ideas.
2. After the partner share, have pairs share their ideas with the whole class. Record a list of meanings for the word *energy* that represent the diversity of ideas from all students. Have students also record this list in their notebooks.
3. Share with students the scientific definition for the word *energy*: "Energy is the capacity to do work. It cannot be created or destroyed, but it can change form. Energy comes in many forms, such as light, heat, kinetic, electrical, and chemical." Spend time discussing each part of this definition and what students think it means.
4. Ask one student to come to the front of the classroom to act as a class recorder. Have students compare the scientific definition of *energy* to the original class list. Which meanings from the original list match the scientific definition? What revisions could be made? Are there any contradictory meanings on the class list? Have the class recorder make notes on the class list regarding any changes.
5. Have students complete a quick journal activity responding to the following question: "How have my ideas about energy changed? What did I think *energy* meant before the activity, and now what do I think *energy* means?"

Discuss

1. What do you think the difference is between the words *energy* and *electricity*?
2. Explain how a lightbulb lighting is an example of energy. How does this activity match the scientific definition of *energy*?
3. Explain how riding a bike is an example of energy. How does this activity match the scientific definition of *energy*?
4. If someone says, "water gives you energy," do you think this is true? Why or why not?

14 Energy Comes in Many Forms



Teaching Tip

The process of burning is a visual experience that students know well. As such, we tend to think *burning* means the same thing to everyone. Be aware that it may mean very different things to different students within the same classroom. Pay particular attention to when and how students use the word *burn,* and try to establish a shared meaning for it among your students. For some students, *burning* may mean that something "evaporates" or "vaporizes" or simply "goes away." For others, it may be likened to decomposition. Still other students may use *burning* to describe a process by which matter turns into energy. The goal is to have all students see *burning* in terms of a chemical reaction that does not create or destroy matter.

In Chapter 2 you read about combustion, in which a fuel source is oxidized. This fuel source may be plant matter, such as wood, or fossil fuels or the wax that makes up a candle. In all cases, these fuel sources are mostly made of carbon and hydrogen and potentially oxygen atoms. When the fuel reacts with oxygen, a chemical reaction occurs. Energy is transformed from the chemical energy in the fuel into light, heat, or motion. The material products are carbon dioxide and water vapor. Following is the chemical reaction that occurs when methane burns: $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$.

Notice how similar this equation is to cellular respiration that occurs as our bodies "use" or "burn" food to fuel our body functions: $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$.

Both of these processes begin with a carbon-based material—either a food or a fuel. They react with oxygen to produce carbon dioxide and water vapor. All these processes—burning wood, fossil fuels, or food in our bodies—do similar things chemically to meet specific energy needs.

EMISSION COEFFICIENTS

Fossil fuels, as well as wood, give off varying amounts of carbon dioxide in relation to the energy output. This graph shows that burning wood and coal produce more carbon dioxide compared to burning other fossil fuels for the same amount of energy output. Data for this graph can be downloaded from the U.S. Energy Information Administration emission coefficient page: http://www.eia.doe.gov/oiaf/1605/coefficients.html.

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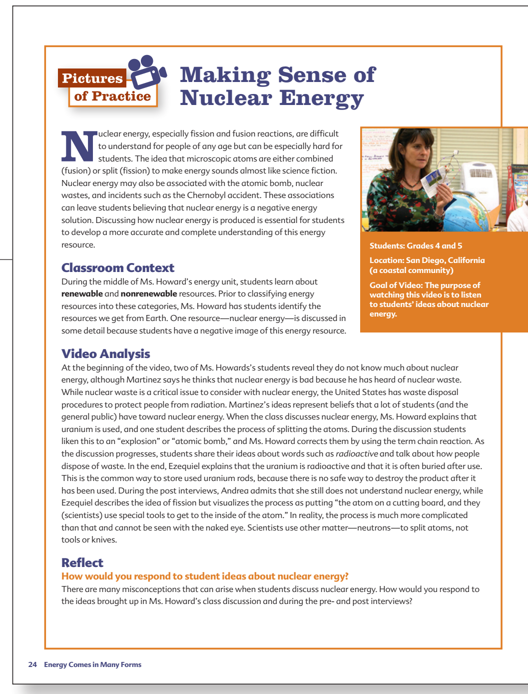
Teaching Tip

Throughout the content pages, **Teaching Tips** connect the content to classroom practice. Teaching Tips suggest practical activities and resources to consider when teaching about a particular topic. When available, Teaching Tips direct teachers to additional online resources.

Pictures of Practice

Classroom video is a valuable resource for reflecting on practice. **Pictures of Practice** are videos, about two to five minutes in length, focusing on student ideas. The purpose of these videos is to capture everyday classroom life and to provide real-life examples of how students learn and think about these topics. The focus of the videos is on student participation and ideas, as opposed to the teacher and instructional style. Reading the video activity prior to watching the video will help prepare you to get the most out of the videos.



Pictures of Practice

Making Sense of Nuclear Energy

Nuclear energy, especially fission and fusion reactions, are difficult to understand for people of any age but can be especially hard for students. The idea that microscopic atoms are either combined (fusion) or split (fission) to make energy sounds almost like science fiction. Nuclear energy may also be associated with the atomic bomb, nuclear wastes, and incidents such as the Chernobyl accident. These associations can leave students believing that nuclear energy is a negative energy solution. Discussing how nuclear energy is produced is essential for students to develop a more accurate and complete understanding of this energy resource.

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 nuclear energy.

Classroom Context

During the middle of Ms. Howard's energy unit, students learn about **renewable** and **nonrenewable** resources. Prior to classifying energy resources into these categories, Ms. Howard has students identify the resources we get from Earth. One resource—nuclear energy—is discussed in some detail because students have a negative image of this energy resource.

Video Analysis

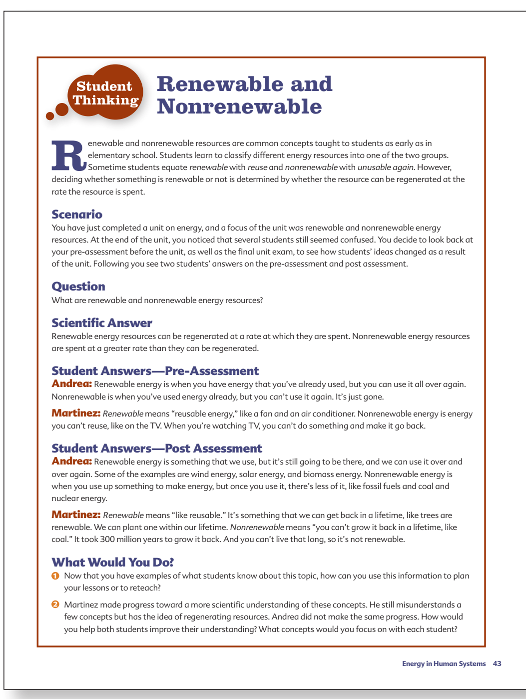
At the beginning of the video, two of Ms. Howards's students reveal they do not know much about nuclear energy, although Martinez says he thinks that nuclear energy is bad because he has heard of nuclear waste. While nuclear waste is a critical issue to consider with nuclear energy, the United States has waste disposal procedures to protect people from radiation. Martinez's ideas represent beliefs that a lot of students (and the general public) have toward nuclear energy. When the class discusses nuclear energy, Ms. Howard explains that uranium is used, and one student describes the process of splitting the atoms. During the discussion students liken this to an "explosion" or "atomic bomb," and Ms. Howard corrects them by using the term chain reaction. As the discussion progresses, students share their ideas about words such as *radioactive* and talk about how people dispose of waste. In the end, Ezequiel explains that the uranium is radioactive and that it is often buried after use. This is the common way to store used uranium rods, because there is no safe way to destroy the product after it has been used. During the post interviews, Andrea admits that she still does not understand nuclear energy, while Ezequiel describes the idea of fission but visualizes the process as putting "the atom on a cutting board, and they (scientists) use special tools to get to the inside of the atom." In reality, the process is much more complicated than that and cannot be seen with the naked eye. Scientists use other matter—neutrons—to split atoms, not tools or knives.

Reflect

How would you respond to student ideas about nuclear energy?

There are many misconceptions that can arise when students discuss nuclear energy. How would you respond to the ideas brought up in Ms. Howard's class discussion and during the pre- and post interviews?

24 Energy Comes in Many Forms



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?

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Student Thinking

The purpose of **Student Thinking** features is to help you prepare for the challenges students may face as they learn about these topics. Common student ideas are compared alongside scientific concepts or are situated in real-life classroom scenarios. Provided quotes come from real students. Suggestions for questions to ask your students are also provided. Accessing student ideas through formative assessment is a great way to learn about your students' knowledge and pique your students' interest in learning more about a topic. Students love to share what they know! You can use what you learn to help guide your teaching. You may find that you need to provide experiences for students that help them confront their existing ideas and begin to develop more scientific conceptions.

1 Energy Comes in Many Forms

by Ivan Salinas

Energy is responsible for the world as we know it. It runs our homes, our cars, our bodies, and is virtually changing forms every moment of every single day. The sun is our constant supply of energy, as solar radiation allows plants to grow, water to evaporate, and wind to move. Today, our human communities are so intimately tied to energy resources we could hardly imagine a world without them. What was life like just a few hundred years ago when most relied only on wood for fuel and a few luxuries of charcoal and wax? What was the world like just a few thousand years ago, when only the wood was available?

Energy resources have become the cornerstone of our society. Almost everything we do in our daily lives depends upon energy. Even the water we drink from our faucets and the plastic and glass containers used to store our leftover foods, require energy. While plant-based energy resources dominated the energy landscape just hundreds to thousands of years ago, we now have a myriad of energy options. The potential for our energy future is great. The time for discovering new and innovative energy technologies is now.

We talk about energy every day. Some people are said to spend energy in their work, to recover energy after a night's sleep, or to conserve energy by turning off lights. The pros and cons of all energy sources, renewable and nonrenewable, are debated by politicians and citizens alike and are often the subject of discussion on news networks. But what does *energy* mean to scientists, the people who define and study energy?

This chapter takes a closer look at what *energy* means and how this meaning is similar and different from our everyday use of the word. Basic concepts of energy and energy forms are reviewed as well as the laws that govern the way energy flows through our world. Lastly, energy resources will be classified as renewable and nonrenewable, a common concept taught in schools. In fact, many of the basic concepts discussed in this chapter

GRADE	STANDARD	EEI UNIT
Grade 3	3.1.a-d	
Grade 4	4.1.g	
Grade 5	5.2.f-g	
Grade 6	6.3.a-d 6.4.a-b 6.5.a 6.6.a-b	Energy: It's Not All the Same to You! Energy and Material Resources: Renewable or Not?
Grade 7	7.1.d	
Grade 8	8.3.a 8.5.c	

receive repeated attention in our schools and, therefore, deserve special attention in any study of energy. These concepts are the foundation for additional study on energy resources in our human communities.

What Is Energy?

Think about a magazine that describes an artist as focusing her "creative energy" from one activity, such as painting, to another, such as a sculpture. This use of the word *energy* implies that energy is stored in a person's mind. We commonly refer to energy as something we have stored inside our bodies. We say, "I don't have any more energy to finish this test," or "I'll have more energy tomorrow to finish my homework." Such a view of energy depicts it as something we gain or lose. Think about all the meanings of the word *energy* that your students encounter in a single school day!

Saying that someone or something "has" energy is a metaphor. It is the everyday meaning we give to the word *energy.* This metaphor is particularly problematic for science, because while scientists look at energy as a "capacity," they do not describe energy as something that can be "shared," "used," "spent," or "possessed." A very important concept to remember is that energy is not created; rather, energy is just transformed, from one form to another. Our experiences of energy are simply us witnessing energy flowing from form to form, happening every day in almost everything we do.

When we describe energy in this way, it is different from the scientifically accepted definition, which says that *energy* is the "capacity of doing work" (*work* being defined as "the force exerted through a distance"). The science definition of *energy,* while sometimes easy for students to remember in science class, does not readily give meaning to their everyday experiences. Students must relearn everyday words such as *work, force,* and *energy,* for science class that do not match the way they commonly use these words outside of school. As a consequence, teaching the concept of energy can be a challenge for many teachers.

In the scientific definition of *energy,* there are four concepts that need to

CHAPTER OVERVIEW

Energy is a difficult concept to define but one that we experience every moment of every day. Energy comes in several basic forms, and most of our experiences of energy can point to one of these forms—movement, light, heat, electricity, and so on.

Energy forms can be classed into two basic types: kinetic or potential. Potential energy may be chemical energy or gravitational energy. Kinetic energy is the energy of motion, such as the movement of wind or water or a person running. One interesting form of energy is heat. Heat, while sometimes useful, is not a useable energy resource. Oftentimes heat is considered a waste product. In science we use several laws—laws of thermodynamics—to help us understand the dynamics of energy in our world.

In this chapter we review forms of energy and how energy transforms following laws of thermodynamics.

Kicking a soccer ball is a change from potential energy to kinetic energy.

be clarified: energy, work, force, and distance (or position). Let's take a closer look at these concepts in an example. Think of a soccer ball standing on a field or a playground. If someone kicks the ball, the ball will move. The ball is no longer standing on the field, but rather moving through the air. Thus, the position of the ball is not the same before and after someone kicked it. The change in the position happened because a person exerted a force on the ball when kicking it. Even though the force was exerted over a small distance (the kick), it was enough to change the ball's position.

Kicking the soccer ball is actually a change in energy—a change from **potential energy** to **kinetic energy** in the kicker, then to kinetic energy of the ball moving. **Heat** was probably given off along the way.

Another illustration of energy can be seen when shopping in a supermarket and using a shopping cart. When you get to the supermarket, you grab a cart and move it along the aisles while you shop. If it were not for you pushing the cart, the cart would not move. You exert a force on the cart so it changes its position. You have the capacity to do work. As an option for people with disabilities, supermarkets may have electric carts, which do the same thing; they move along the aisles while a person shops. The difference is that the person is not exerting the force. The cart has an electric motor that has the capacity to do work.

In both of these examples, energy is changing forms. We call this energy transformation. While your students may remember the definition of *energy* in science class, *energy transformations* will be what helps students connect the scientific definition to their real-world experience.

Energy changing forms is so common that we can find these transformations anywhere at any time, including when reading these pages! There is an energy transformation in your brain that helps your eyes move to scan the pages. There may be a lamp that illuminates your environment, changing electrical energy into light and heat energy. When we start looking at events happening in the world through the lens of energy transformations, it becomes easier to help students find meaning and connections between energy in science class and energy in their world outside of school.

Teaching Tip

Help your students better understand the basics behind energy transformation by trying the following activity. Have each student put a pencil at the edge of his or her desk so it is not moving. Explain how the pencil is exhibiting one type of energy as it is not moving (potential). Next, have students push their pencils off their desks and onto the floor. Ask students if the type of energy has changed from when it was still. This moving pencil now exhibits kinetic energy. Also discuss the role of students prior to pushing the pencil off of the desk. Where do students get energy from? Students should respond that they get energy to do everyday activities from food they consume. Discuss with students how the energy changed, or transformed, from one type (potential) to another (kinetic) during this exercise.

Student Thinking

Explaining Energy

Numerous studies have looked at student ideas about energy. Educators know that students describe energy in countless ways, but that some interpretations of energy are more common than others. Following are a few examples of the most common conceptions about energy.

	Common Student Ideas	Scientific Concepts
Energy as an agent	Energy causes things to happen. It makes an activity happen and can be stored inside a person or an object.	Energy does not cause events to happen. However, when events happen such as a ball rolling down a hill, there is always a change of energy to another form.
Energy as an action	Energy is an action or activity like burning, bubbling, running, and bouncing.	Actions are visible experiences that energy is changing forms. Running, for example, is the change of chemical energy (food) into kinetic energy (movement).
Energy as an ingredient or a product	Energy is an ingredient to help plants grow, people move, and cars run.	At the beginning of a chemical reaction, energy starts in one form; however, during the reaction, energy changes into another form.
Energy as a technical appliance	Energy is *electricity* or something that relates to electrical appliances and power lines.	There are many different forms of energy and electrical energy is an example of one of these forms. Electrical energy is the form of energy that powers many of our appliances by causing positive and negative charges to move.
Energy as a property of life	Energy is useful for humans or other living things. For example, we need energy to grow and live. Only living things have energy, but dead things do not.	Sunlight is necessary to power plant **photosynthesis.** Chemical energy is necessary to power other metabolic processes. During these processes, we do not "use up" energy but rather change energy forms. For example humans change chemical energy (food) into kinetic energy (motion). All "things," living and nonliving, have some energy associated with them.

Ask Your Students

1. What is the first word you think of when you hear *energy*?
2. How would you define *energy*? How does this compare to the way scientists define *energy*?
3. How are electricity and energy different?

In the Classroom Defining Energy

The word *energy* has many different meanings to students. To some students, it means "power." Other students may think energy means "movement," and still other students equate energy with "electricity." All of these meanings have legitimacy, but none of them match the way scientists define *energy*. Yet, unless students are given an opportunity to confront these differences, they likely will never see a reason to revise their understanding of energy. The following activity has students compare their own definition of energy to a scientific definition.

Materials

- Chalkboard, whiteboard, or chart paper
- Writing materials

Directions

1. Gather students into an arrangement for productive classroom discussion. Ask students the following question: "What does the word *energy* mean to you?" Ask students to participate in a minute-long partner share of their ideas.
2. After the partner share, have pairs share their ideas with the whole class. Record a list of meanings for the word *energy* that represent the diversity of ideas from all students. Have students also record this list in their notebooks.
3. Share with students the scientific definition for the word *energy*: "Energy is the capacity to do work. It cannot be created or destroyed, but it can change form. Energy comes in many forms, such as light, heat, kinetic, electrical, and chemical." Spend time discussing each part of this definition and what students think it means.
4. Ask one student to come to the front of the classroom to act as a class recorder. Have students compare the scientific definition of *energy* to the original class list. Which meanings from the original list match the scientific definition? What revisions could be made? Are there any contradictory meanings on the class list? Have the class recorder make notes on the class list regarding any changes.
5. Have students complete a quick journal activity responding to the following question: "How have my ideas about energy changed? What did I think *energy* meant before the activity, and now what do I think *energy* means?"

Discuss

1. What do you think the difference is between the words *energy* and *electricity?*
2. Explain how a lightbulb lighting is an example of energy. How does this activity match the scientific definition of *energy?*
3. Explain how riding a bike is an example of energy. How does this activity match the scientific definition of *energy?*
4. If someone says, "water gives you energy," do you think this is true? Why or why not?

What Is Energy?

Pictures of Practice

Classroom activities on energy are numerous and diverse. One of the most iconic activities to do with students is to complete a comparison of student definitions of *energy* with scientific definitions. Like many words in science, people commonly use the word *energy* outside of the classroom; thus, most students have developed a meaning for the word *energy* that does not match what science teachers say in their classrooms. You can imagine how ingrained these everyday meanings for *energy* are compared to scientific definitions that students encounter intermittently in their science classrooms. Developing a shared meaning of the word that is directly related to how students commonly talk about it is a necessary step prior to engaging in a larger unit on energy.

Students: Grade 5

Location: San Diego, California (an urban school)

Goal of video: The purpose of watching this video is to hear student ideas about *energy* before and during a classroom activity defining *energy*.

Classroom Context

Lynn Howard is an elementary school science teacher. She teaches science to most students at Encanto Elementary in San Diego, California. The benefit of her position is that she can develop her curriculum across several years of instruction, as opposed to teaching within a single given year. Thus, her students have experienced several lessons on energy in school years prior to fifth grade, and Ms. Howard knows what was taught and how she taught it. Most students have learned about simple circuits, conducted experiments with circuits, and learned about compact fluorescent lightbulbs (CFLs). However, students are still using everyday definitions of energy, and before starting the fifth-grade energy unit, Ms. Howard decided that the first lesson would focus on developing a shared definition and understanding of the concept.

Video Analysis

Ms. Howard conducts a classroom lesson similar to **In the Classroom: Defining Energy.** Students generate a list of ideas about energy and then compare those to a scientific definition. In science, *energy* means "the capacity to do work," and energy is governed by a set of principles, or laws. Energy is not created or destroyed but instead transforms between many different forms. There is always a loss of heat during energy transformations. This is not considered a loss of energy, because the heat is actually released into space. In the video, you will see students describe their ideas about energy prior to the classroom activity. Their ideas focus on power and movement. The video then shows segments from a classroom activity in which students generate a class list of meanings for the word *energy* and then compare that list to scientific ideas about energy. At the end of the video, Ms. Howard shares that she believes students still lack a strong understanding of energy that is aligned to scientific definitions, but students definitely seem to make progress on what they know about energy.

Reflect

How would you teach the concept of energy?

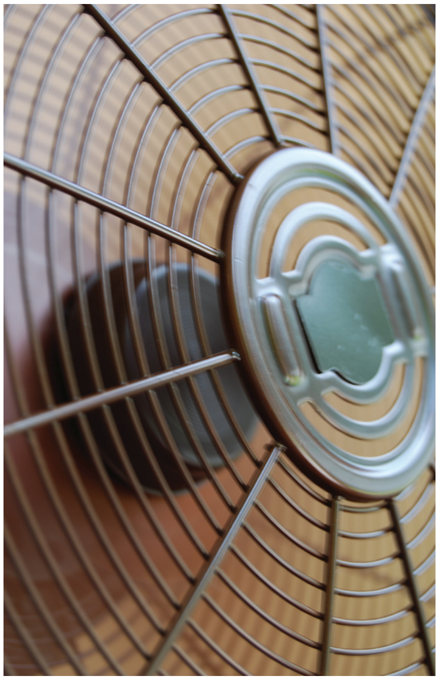
Given that students bring incorrect ideas about energy to your class prior to instruction on the topic, how would you construct a set of lessons to directly address these incorrect ideas? What everyday misconception would you target, and how would you work with students to improve their understanding?

Forms of Energy

A regular car cannot move without gasoline, an electric fan cannot work without electricity, and it is hard to move our bodies without food. Yet, there are some cars that do not use gasoline and fans that spin using the wind. The same is true for heating: There are electrical as well as gas heaters, and we can also heat our bodies by exposing them to sunlight or when covering our bodies with electric blankets. While each of these are sometimes trying to accomplish the same goals, they may be transforming energy in different ways. Helping students to see patterns in energy transformations is one step toward a better understanding. For example, how is an electric fan more similar to a toaster than to a wind turbine? How is using gasoline in cars more similar to people eating food, than to the workings of an electric car? Sometimes these similarities and differences are not immediately obvious.

There are two overarching categories of energy that are common concepts taught in schools. These are kinetic energy and potential energy. Kinetic energy is the energy of movement. It is visible and easy for students to identify in many situations. When a yo-yo moves up and down, it is exhibiting kinetic energy. Potential energy is a form of "accumulated" energy that is transformed when an object can move. There are different sources of potential energy. Before the yo-yo is released from the hand, when it is still, it has potential energy.

Additionally, kinetic energy and potential energy have an interesting relationship. An object that is at the top of a mountain, such as a bicycle, has more possibilities of increasing its kinetic energy than the same object does at sea level. Scientists refer to the object on the mountaintop as having more potential gravitational energy than the object at sea level. The kinetic energy of an object becomes increasingly greater as the potential energy of the object diminishes.



A wind turbine harnesses kinetic energy of wind into electrical energy, while an electric fan uses electrical energy to get kinetic energy in the air it blows.

Light Energy. The presence of light is what allows us to see things in our daily lives. Additionally, plants transform light from the sun into chemical energy in glucose. In doing this, a complex mechanism of energy absorption and storage works in the leaves of most plants. Theories about the nature of light say that light is a phenomenon of particles and also a phenomenon of waves. If we consider light as particles (**photons**), we may think of these particles as "hitting" the plant leaves to move "things" inside the plant, in the same way objects could be used to move others by a physical contact (e.g., the balls on a billiard table). If we look at light from the perspective of waves, we might envision

Teaching Tip

Ask students to illustrate potential and kinetic energy using their own experiences. For example, students might draw a sled or skateboard at the top of a hill and then sliding down the hill. Students should indicate that the sled has more potential energy at the top of the hill, but more kinetic energy while in motion. As an alternative, ask students to spend a week journaling examples of any energy in their everyday life at school or at home. Have students compare their list to lists generated by classmates. Identify the most common experiences of energy that everyone in the class shares as well as interesting or unique examples that students brainstormed.

An incandescent lightbulb (left) uses more energy than other bulbs that produce the same amount of light. A light-emitting diode (LED) bulb (middle) is the most efficient bulb, but it is more expensive than the compact fluorescent lightbulb (CFL) shown on the right.

a wave starting at one end (the source) of a long slinky and traveling to the other end (the receptor of the wave). The energy is transferred from one side to the other by "traveling" through a medium, in this case the slinky. The sunlight ultimately drives metabolic processes in plants to help them build energy-rich glucose molecules.

Another iconic example of light energy happens in a lightbulb, which is a change of electrical energy running through the lightbulb into light energy and heat. Have you ever touched an incandescent lightbulb after it's been on for a long time? These lightbulbs can become incredibly hot. New compact fluorescent lightbulbs (CFL's) are said to be energy efficient because less of the original electrical energy is lost as heat. These bulbs use less electrical energy to give off the same amount of light.

Chemical Energy. One type of potential energy is chemical energy. Humans and other living things use chemical energy stored in plants for different purposes. Recall that plants transform light energy from the sun to make chemical energy found in glucose and other complex carbohydrates. When living things eat plants, they obtain the chemical energy. Animals eat plants and other animals in order to obtain energy for growing and moving. Energy is then transformed in an animal's body from chemical energy in the food to motion, or kinetic energy. Also, chemical energy is transformed into heat in order to maintain our bodies at a constant temperature, which averages 98.6° Fahrenheit.

Another example of chemical energy is that found in fuels. When we burn wood, which used to be part of a plant, energy is transformed from the chemical energy to heat and light energy. When ancient plants and animals were trapped underneath Earth's surface, given enough time, pressure, and heat, the materials were transformed into **fossil fuels,** such as coal, oil, and natural gas. Like burning wood, burning fossil fuels changes chemical energy into heat, light, kinetic energy, or ultimately, into electrical energy in power plants.

Engineered devices, including **combustion** engines, are one way people have learned to use the energy in fossil fuels. For example, most of today's vehicles use fossil fuel (gas or diesel) by mixing it with oxygen and having the fuel explode under controlled conditions that make vehicles move. During this chemical reaction, chemical energy changes to kinetic energy. In addition, heat energy is always a product of this process, which is why car engines become so hot after running for awhile. Some scientist consider heat from cars, or other lost heat, as waste because the energy "is lost," or dissipated.

Wood has chemical energy that changes to light and heat when burned.

Electrical Energy. The easiest way to think about electrical energy is to think of electricity we use every day, whether we plug electric cords into power computers or hair dryers. Electrical energy is probably the most widely used form of energy in our societies today. One common mistake made by students is to equate energy with electricity. Be particularly attentive when you hear students talking about electrical energy to make sure they understand that this is just one of many forms of energy. *Electricity* is referred to as any flow of electrical power or charge.

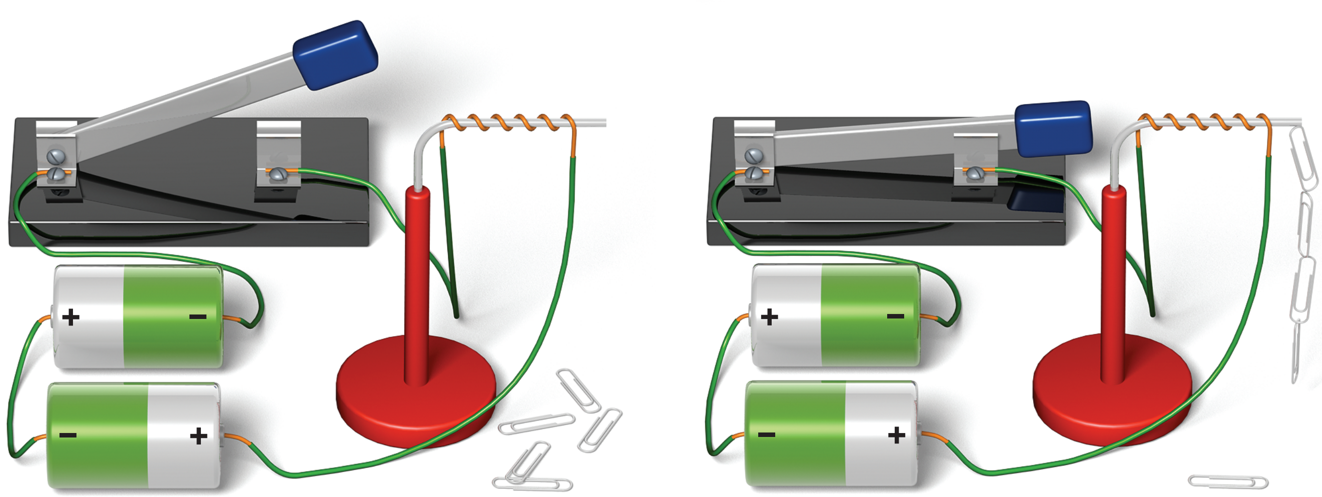
The use of the word *electricity* comes from the Greek *elektron*, which means "materials that are 'amber-like.'" The Greek people discovered that rubbing some fabrics over amber or glass had attractive and repulsive effects on some objects. Scientists now explain this as electrostatic phenomena, or **static electricity.** Students will be familiar with static electricity if they have ever felt a shock when touching something or someone. Static electricity occurs when attractive forces are the result of interactions between different types of charge, whereas **repulsive forces** are interactions between charges of the same type. Rubbing two objects together causes charge exchange, and both the objects become charged with one of the two types of charges (positive or negative). The flow of charge goes from a positively charged object to a negatively charged object.

Electrical energy provokes the movement of charges. When that movement flows using engineered devices, we can transform this electrical energy into other kinetic forms, such as when we use appliances at home that move (e.g., fans), illuminate (lightbulbs), make sound (kinetic energy in radio speakers), or toast a slice of bread (heat energy in a toaster), just to name a few devices.

Scientists have discovered that various types of materials are able to facilitate the flow of electrical energy, while other materials are not good facilitators. Students likely know that metals allow electrical energy to flow well, but that rubber (such as the rubber encircling a power cord) does not allow electricity to flow. Materials that facilitate electric flow are called **conductors,** whereas the ones that do not are called **insulators.** Electrical lines in our homes are metallic cables (conductors) covered with a rubber film (insulator).

Another important concept related to electrical energy is **electromagnets.** Scientists have discovered that magnets spinning inside a spiral made with an insulated conductor can create an electric flow. This is one of the principles that govern the construction of power plants. Different sources of energy can be used to make the magnets spin, such as chemical sources (coal or fossil fuels), gravitational potential sources (water falling in engineered dams), and nuclear energy, among others. These sources can be used to ultimately generate electrical energy for our homes using an electromagnet at the core of the power plant, which will be discussed in more detail in Chapter 2.

ELECTROMAGNETS



An electromagnet can be made using a iron or steel object (e.g., nail) and a coil of wire. This creates a magnetic field when electricity flows through the coil. Building electromagnets in class can be fun for students and help explain the concept in a hands-on way. See an example activity by the California Energy Commission at Energy Quest: http://www.energyquest.ca.gov/projects/electromagnet.html.

Nuclear Energy. Nuclear energy is one of the most mysterious forms of energy, as well as one of the most powerful sources. Students may believe nuclear energy is bad because they associated the word *nuclear* with nuclear weapons, bombs, or disasters. Yet, nuclear energy is an important form of energy we depend upon to meet our energy needs.

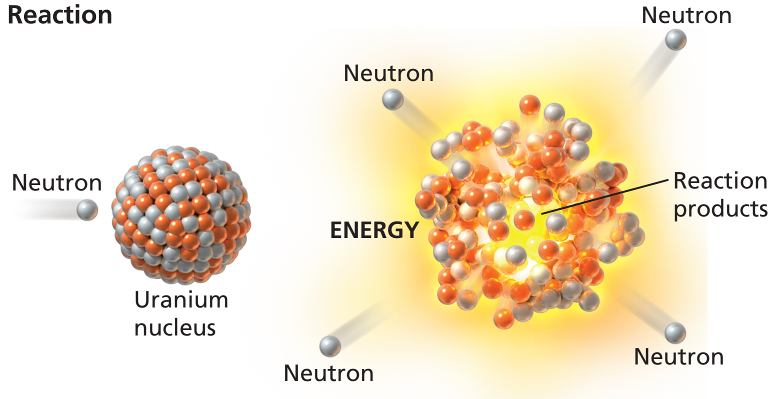
Nuclear energy is generated through the **nuclear fusion** or **nuclear fission** of atoms. Fusion involves combining atoms, while fission refers to the splitting of atoms. Atoms that have a heavy nucleus (more protons and neutrons) present are said to be **radioactive.** A radioactive atomic nucleus, or a radioactive substance, emits different forms of **radiation,** which are beams of high-energy that can have charged particles as well as neutral ones and also energetic beams that are not particles but waves.

Scientists have found that heavier nuclei are more prone to becoming radioactive, especially when they are unstable. Nuclei are unstable because the number of protons and neutrons are in higher quantities than nonradioactive or stable elements. In "searching for stability," a nucleus will emit a radiation wave or particle, changing the number of protons and neutrons until reaching a quantity that characterizes stability. The concentration of unstable radioactive atoms can trigger a powerful reaction that releases huge amounts of energy. In controlled facilities, the energy released by radioactive nuclei can be transformed into electrical energy, which is what occurs in nuclear power plants. In uncontrolled settings, atomic energy can have disastrous consequences.

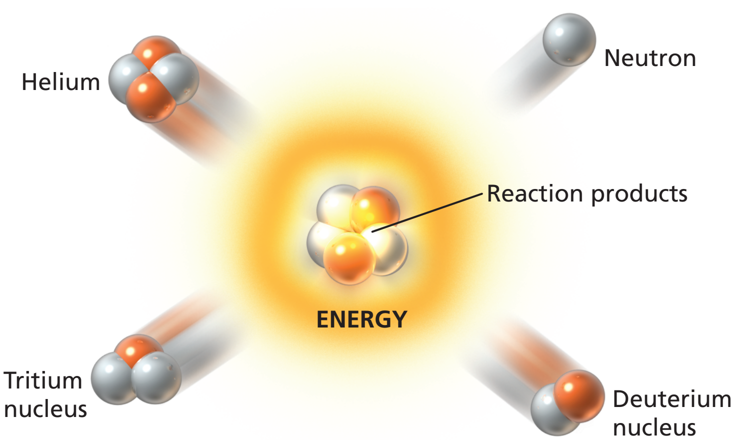
Nuclear radiation phenomena are not just related to heavy nuclei. Small nuclei can collide to form more heavy ones, also releasing radiation, or nuclear energy. That can happen when nuclei have enough kinetic energy to collide. For example, the sun is a host for those processes in which heat triggers the movement of small atoms, such as hydrogen and helium, and their collision gives raise to radiation waves that travel in the form of light and heat to all places, including Earth's surface.

FISSION AND FUSION

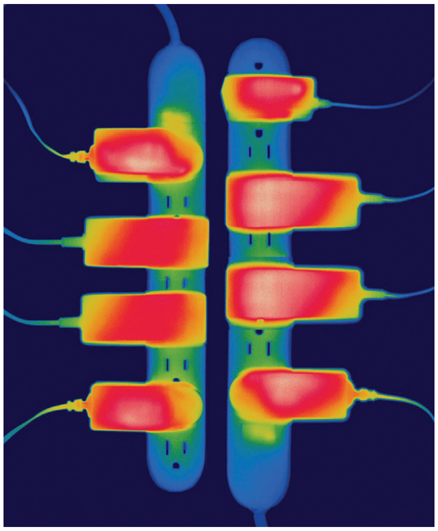
Fission Reaction



Fusion Reaction



Nuclear fission is the splitting of atoms, while nuclear fusion is the combining of atoms. In a controlled facility, these reactions can produce great amounts of energy that we can harness for electricity production. However, once fission or fusion has occurred, the waste products from the reactions are radioactive and must be stored in a place that will minimize harmful radiation from these materials. Because of the by-products of nuclear reactions and the difficulty of storing waste materials, nuclear energy use is still debated.



A thermal image shows plugs for hard drives and cell phones in a power strip giving off heat.

Heat Energy. We receive many forms of energy from the sun, a small percentage of which is within the visible spectrum and is what we typically refer to as light. When incoming visible light and infrared radiation interact with molecules in our atmosphere and the land surface, the radiation is absorbed and then gives off infrared radiation, also known as heat energy. It is this incoming and outgoing radiation that is responsible for heating our planet.

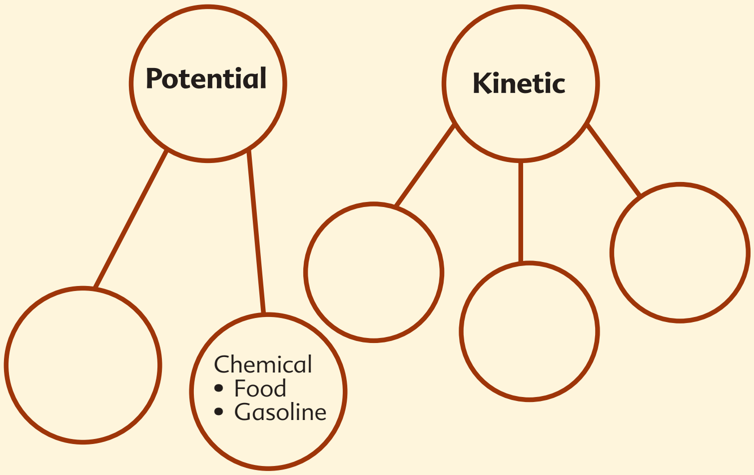
In our human systems today, heat energy is often considered a waste product, and energy engineers are looking for ways to reduce heat lost to make energy more efficient. The reason heat is considered a waste is because it is often an unusable form of energy that dissipates and is eventually lost into space.

Thermodynamics

Energy simply does not flow around our world in chaotic, unpredictable patterns. While energy is changing forms around us all the time, there are patterns in the way this happens. **Thermodynamics** is the name of the discipline that has come to govern much of what we know about energy and the physical sciences.

Teaching Tip

After you have finished discussing the various types of kinetic and potential energy, now may be a good time to have students place all of this information into a graphic organizer, such as a double-bubble map. Have students create their own organizer, starting out with two different bubbles, each that contains one type of energy, either potential or kinetic. Next, students will add bubbles below each type of energy that will include examples. You can also have students use a Venn diagram to show differences and similarities between the two types of energy. The following link provides a variety of different organizers or thinking maps: http://www.ascd.org/ASCD/images/publications/books/fisher2007_fig5.5.gif.



From this discipline comes the **laws of thermodynamics.** The first law of thermodynamics states that energy cannot be created or destroyed but can change forms. This law is also known as the conservation of energy principle.

In addition to the principle of conservation of energy, there are additional laws that describe how energy flows. One of the laws is known as the zero law of thermodynamics. This law establishes that heat will always transfer from a body of high temperature to a body of lower relative temperature, until reaching the **thermodynamic equilibrium,** or the same temperature. As heat is energy, it is possible to say that energy transfers from hot bodies to cooler bodies. This energy transfer happens through three different mechanisms: **conduction, convection,** and radiation.

Conduction. When a body conducts heat, it requires direct contact. For example, if a person with warm hands rubs the cold hands of another person, the cold hands will be warmed. Warm body heat is transferred to colder body heat. Another common example is when someone touches the hot metal handle of a pot on a stove. The heat from the pot is transferred to the person's hand, burning it.

Convection. In convection, heat is transferred within a fluid, such as a liquid or gas, by the motion of its molecules. The light of a flame is also an example of convection, in which most

ENERGY TRANSFER

Convection, conduction, and radiation are ways that energy transfer occurs.

of the heat is directed to the top of the flame and provokes the motion of air. Another example is placing a pinwheel over the flame, and the pinwheel starts to spin because of the movement of air around the flame. A liquid convection example would be a pot of water heated by placing it over a flame. The water moleucles move from the warmer bottom of the pot toward the top, where the water is relatively cooler.

Radiation. Finally, radiation is another form of heat transfer. In radiation, hot and cooler bodies do not need to be in contact for heat to be transferred. **Electromagnetic waves** (infrared spectrum) are released from the body of highest temperature into the surroundings in all directions. An example of radiation is the heat we receive when sitting next to a fire in a fireplace. We are not in contact with the fireplace, but we still warm up through radiation of heat.

These three forms of energy transfer (conduction, convection, and radiation) occur mostly at the same time, and it is difficult to isolate them from each other. Thus, when heating water in a pot on an electric stove, there is conduction from the stovetop to the metal pot, convection in the water receiving heat from the heated metal and the air receiving heat from the whole system, and radiation is also present all around the pot.

Another law of thermodynamics that governs energy states that in any energy transformation, the total amount of energy being transformed into useful forms (e.g., kinetic, chemical, light, and so on) will not equal the original energy input because heat will always be released. For example, a lightbulb connected to a power line will transform electrical energy into light energy, but heat will be released and "lost" during this process. So the electrical energy made available to the lightbulb turns into both light energy and heat. As mentioned before, efficient lightbulbs are ones that reduce the amount of heat lost, so less electricity is needed to get the same amount of light energy.

When heat is given off it does not mean that energy is destroyed. Energy is simply lost into space in a form of energy that we can no longer use. Energy is always conserved, but this is why we use the common saying in schools, "Matter cycles, while energy flows" because ultimately all energy turns to heat and dissipates out into space.

Teaching Tip

Have students "experience" conduction for themselves by taking them outside the classroom on a warm day when the sun is shining brightly. When you are outside, first have the student press the palm of their hand against their cheek to notice the temperature. Next, have students place one of their palms against a surface, such as a school wall or pavement, that receives direct heat from the sun. Keep the palms on this surface until they start to feel warmer, and then remove them. Finally, place the palm against the cheek again and notice the difference in temperature from before the hand was placed against the warm surface.

Questions to ask your students after this activity:

1. How does the temperature of your palm compare with the first time you touched your cheek?
2. What process is taking place to warm your palm?

In the Classroom

Watching Energy Flow

Energy changes all around us. Almost everything we experience, from reading a page to walking in the school hallway to turning on a light, involves energy changing forms. Training students to be more observant about these forms of energy provides a new lens for students to see energy in their everyday life. This involves teaching students about different forms of energy and then identifying everyday energy transformation. The following activity uses everyday energy transformations to demonstrate these changes (adapted from Environmental Literacy Project materials).

Materials

- Notebooks
- Labels
- Crank flashlight or radio
- Solar powered model car

Directions

1. Prior to the lesson, identify at least 8 to 10 energy transformations in your own classroom. These might be a lightbulb, overhead projector, computer, fan, plant, class pet, lighter or candle, and so on.
2. Label each object with a number to represent a "station." If possible, add a crank flashlight and/or solar-powered model car to the list of stations to visit. These objects are fun for students to play with and also represent interesting examples of energy transformations.
3. Prepare a worksheet for students or have students use their science notebooks when they visit each station. If students use their notebooks, have students label the page with the number of stations and construct simple diagrams like the one shown in number 5.
4. In groups of two or three, have students visit each station to record the energy transformation. Ask students to discuss each situation and make note of areas in which they disagree.
5. When students visit a station, they should record the energy input and output for the station. Students can use the following diagram as one way to record their ideas.

   Electrical Energy → **LIGHTBULB** → **Light Energy and Heat**

6. After students visit each station, conduct a whole-class discussion in which students share their results.
7. In almost every situation, heat should be an energy output. After the class has generated a class list of results, ask students if they notice a pattern. Circle all the "heat" outputs. With older students this is an opportunity to connect to energy laws or other energy concepts, such as energy pyramids.

Discuss

1. Can you think of other instances in your everyday life that show energy transformations?
2. How do energy transformations show that energy is not created or destroyed? Thinking back to each station, do any of these situations show energy being created or destroyed?

Student Thinking

Confusing Energy Concepts

Energy is an abstract concept that in everyday language becomes confused with other ideas. The meanings given to words in everyday speech are the product of social exchanges. Common ideas about certain words can be problematic for students learning science, a subject in which certain terms, such as *energy* or *evolution,* have very specific definitions. The following table contrasts some conceptions that are problematic as students understand the scientific concept of energy.

	Common Student Ideas	Scientific Concepts
Water and air are sources of energy to living organisms.	Water and air provide energy for people and plants to stay alive.	Water and air do not “have” chemical energy. Organisms cannot use these materials to meet their energy needs, because water and air cannot be chemically changed to supply energy. Food has chemical energy that is transformed when people consume it. Water and air are necessities for life but not as an energy source.
Heat and temperature are the same thing.	Heat rises. Temperature is related to objects’ materials and is not measurable but is qualitatively expressed as hotness or coldness.	Temperature is measurable and gives information about the amount of internal energy a body has. Heat is a form of energy and can be sensed when there is a temperature difference between two bodies.
Energy is the same as power.	Appliances connected to electrical outlets, or bulbs connected to batteries, are connected to power lines.	Electricity is the manifested phenomenon of electrical energy. Power is the amount of energy that is transformed in a given amount of time. Appliances that use more power “spend” more energy in less time.
Energy can be replenished by resting.	People have energy to act on things, and when they get tired, they recover energies by resting.	Energy is transformed by people to move and to maintain a constant body temperature. To transform energy into usable forms, a potential source of energy is needed, which—in the case of animals and people—is given by chemical energy “stored” in food.
Energy cycles.	Energy cannot be created or destroyed, so it cycles on Earth between living things.	Matter cycles and energy flows. While energy cannot be destroyed, it does dissipate as heat and is lost into space. We cannot recapture that lost energy.

Ask Your Students

1. Why are these ideas so confusing to students? Can you think of some examples of ways in which erroneous ideas are perpetuated in everyday life?
2. What activities could you plan to help students see differences among the terms contrasted in the table?

Pictures of Practice

Making Sense of Nuclear Energy

Nuclear energy, especially fission and fusion reactions, are difficult to understand for people of any age but can be especially hard for students. The idea that microscopic atoms are either combined (fusion) or split (fission) to make energy sounds almost like science fiction. Nuclear energy may also be associated with the atomic bomb, nuclear wastes, and incidents such as the Chernobyl accident. These associations can leave students believing that nuclear energy is a negative energy solution. Discussing how nuclear energy is produced is essential for students to develop a more accurate and complete understanding of this energy resource.

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 nuclear energy.

Classroom Context

During the middle of Ms. Howard's energy unit, students learn about **renewable** and **nonrenewable** resources. Prior to classifying energy resources into these categories, Ms. Howard has students identify the resources we get from Earth. One resource—nuclear energy—is discussed in some detail because students have a negative image of this energy resource.

Video Analysis

At the beginning of the video, two of Ms. Howards's students reveal they do not know much about nuclear energy, although Martinez says he thinks that nuclear energy is bad because he has heard of nuclear waste. While nuclear waste is a critical issue to consider with nuclear energy, the United States has waste disposal procedures to protect people from radiation. Martinez's ideas represent beliefs that a lot of students (and the general public) have toward nuclear energy. When the class discusses nuclear energy, Ms. Howard explains that uranium is used, and one student describes the process of splitting the atoms. During the discussion students liken this to an "explosion" or "atomic bomb," and Ms. Howard corrects them by using the term chain reaction. As the discussion progresses, students share their ideas about words such as *radioactive* and talk about how people dispose of waste. In the end, Ezequiel explains that the uranium is radioactive and that it is often buried after use. This is the common way to store used uranium rods, because there is no safe way to destroy the product after it has been used. During the post interviews, Andrea admits that she still does not understand nuclear energy, while Ezequiel describes the idea of fission but visualizes the process as putting "the atom on a cutting board, and they (scientists) use special tools to get to the inside of the atom." In reality, the process is much more complicated than that and cannot be seen with the naked eye. Scientists use other matter—neutrons—to split atoms, not tools or knives.

Reflect

How would you respond to student ideas about nuclear energy?

There are many misconceptions that can arise when students discuss nuclear energy. How would you respond to the ideas brought up in Ms. Howard's class discussion and during the pre- and post interviews?

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Watts, D. M. "Some alternative views of energy." *Physics Education* 18 (1983): 213–217.

Teaching Resources

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

Jason Project Infinite Potential curriculum: http://www.jason.org/public/WhatIs/CurrOIPIndex.aspx

National Geographic My Wonderful World energy resources: http://www.mywonderfulworld.org/educators_welcome.html

U.S. Department of Energy lesson plans: http://www1.eere.energy.gov/education/lessonplans/

U.S. Energy Information Administration resources for kids: http://www.eia.doe.gov/kids/index.cfm

U.S. Energy Information Administration energy laws for kids: http://www.eia.doe.gov/kids/energy.cfm?page=about_laws_of_energy-basics

NOAA's energy resources from the ocean: http://oceanexplorer.noaa.gov/okeanos/edu/lessonplans/media/09oceansofenergy.pdf

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?
Grade 7		
Grade 8	8.3.a 8.5.c	

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).

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.

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.

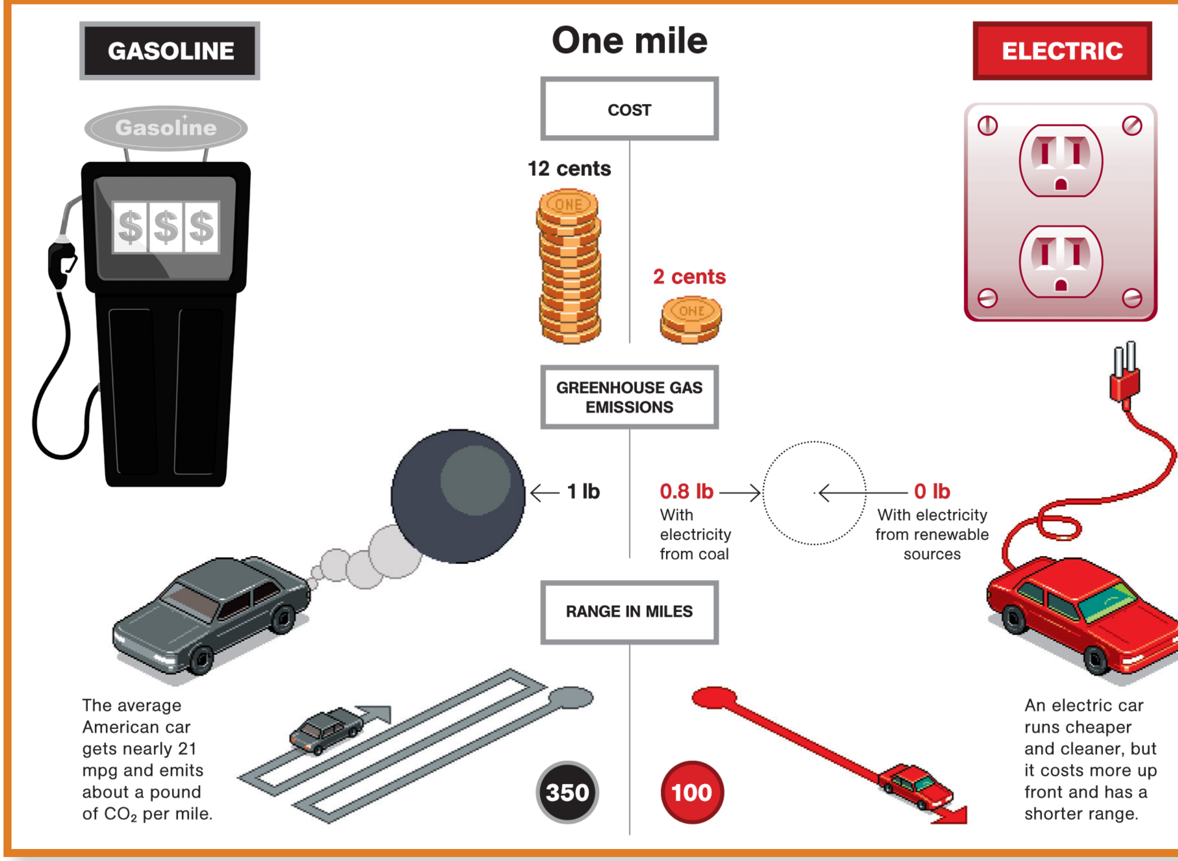
Many of the transformations that happen in our human devices are truly a mystery to most students. Since the discovery and expansion of fossil-fuel-based power, scientists and engineers have revolutionized how energy is used in human activities. When students are asked what happens to gasoline in a car's 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.

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.

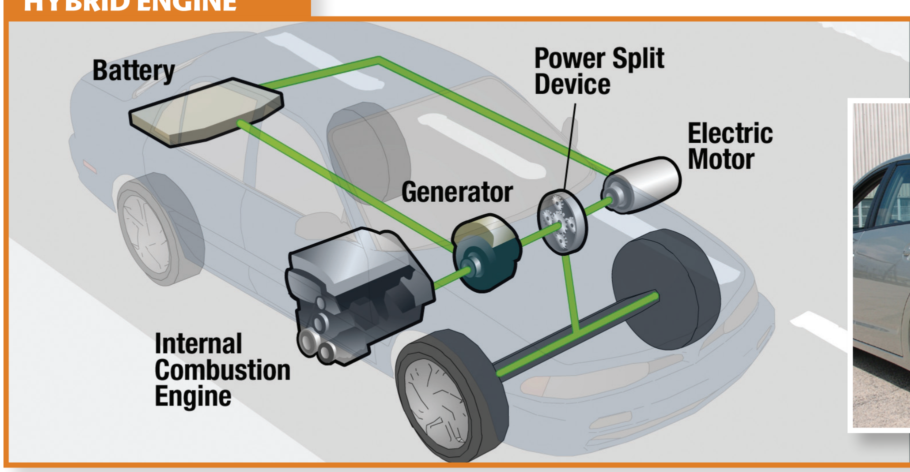
Hybrid Engines. As the name implies, hybrid engines use a combination of an internal combustion engine and an electric engine, with a **generator** between the two. There are many types of hybrid vehicles. The most popular of these vehicles is a full hybrid, like the Toyota Prius or Ford Fusion. Some 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.

Teaching Tip

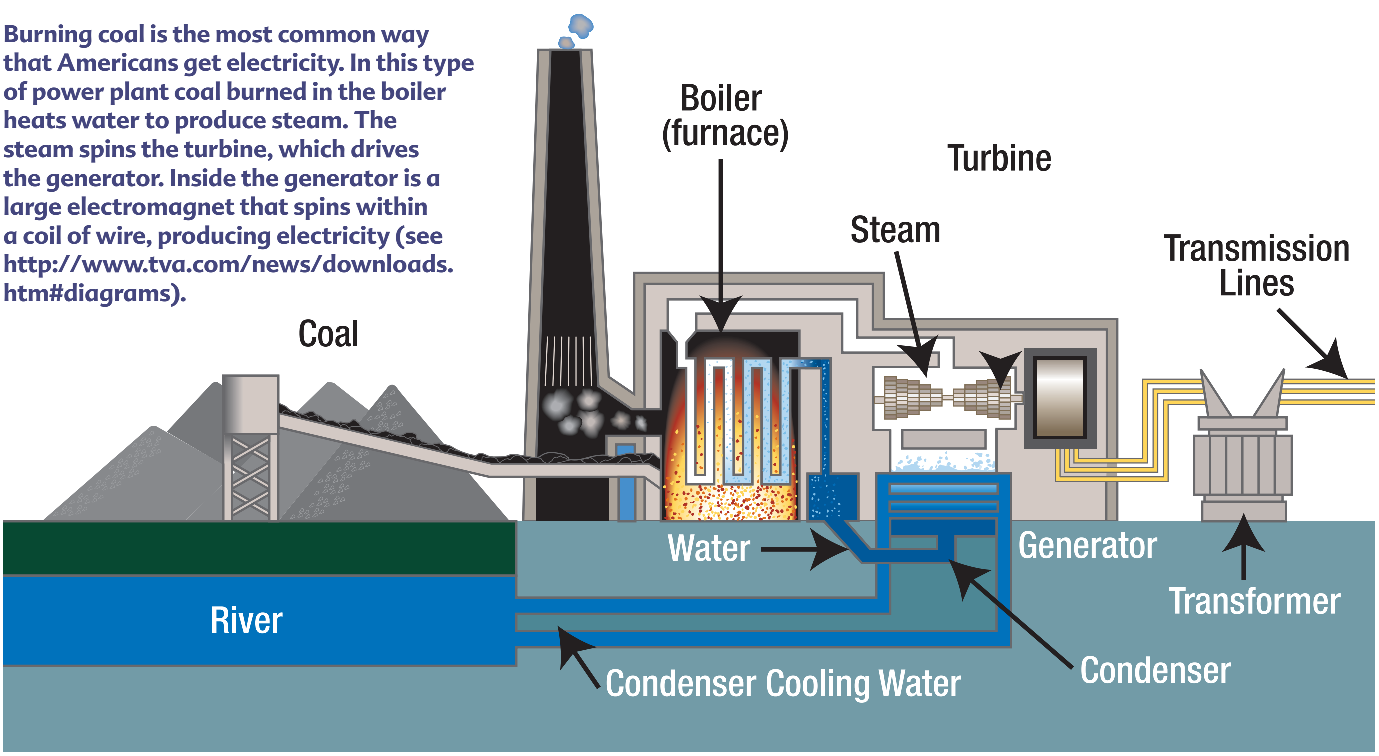
Understanding the sequence of events that takes place in a power plant can be confusing and difficult for students to remember. This may be a good time to have students place the previous information into a graphic organizer that shows the sequence from turbine to generator and then transformer. Then, 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.

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

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?

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.

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.

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

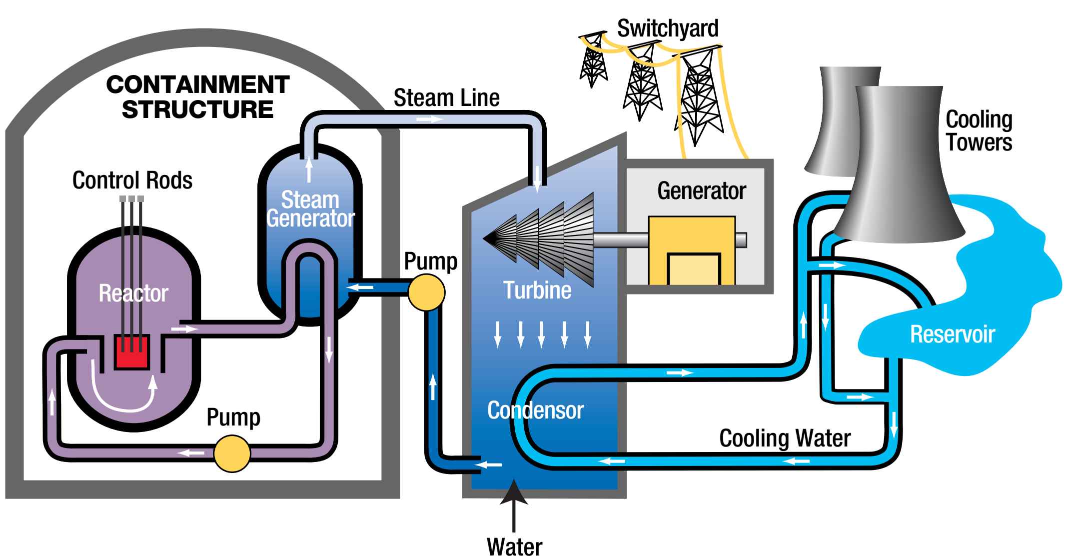
Most differences in power plants are related to the source of energy turning the turbine. Students may know that there are different kinds of power plants but may not realize how similar these power plants are in terms of their internal parts.

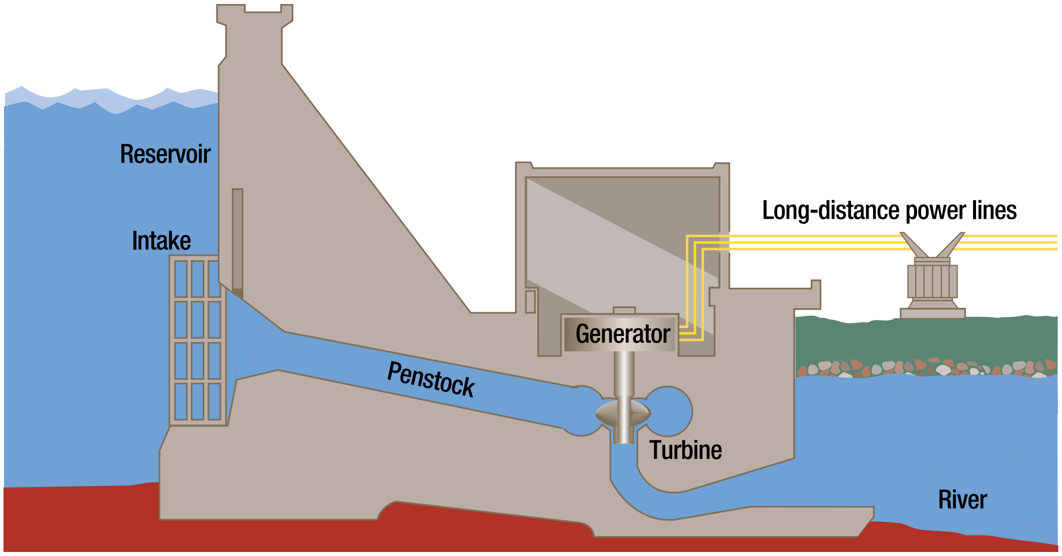
Fuel Power Plants. Fuel power stations take energy-rich materials, such as coal or natural gas, and transform their chemical energy into electrical energy. The chemical energy found in fuels is burned (oxidized) to create heat energy. This heat energy is then transformed into kinetic energy, or turbines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

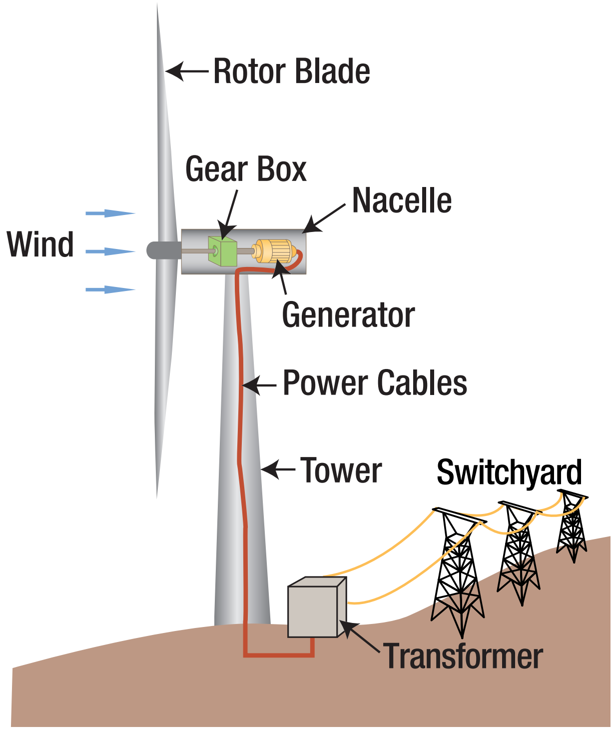
Marine Power Plants. Marine, or ocean, power plants are recent developments in energy production. In marine power stations, movement of water is used to make a rotor of a generator spin. Tidal power stations use the regular movement of tides to spin turbines located underwater. Wave power stations use 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

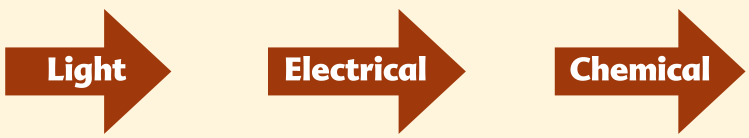
Power plants share many features, such as turbines and generators, but they can be contrasted by the source of energy used to turn the turbines. This is typically the key difference between types of power plants. In addition, power plants are also contrasted by the environmental impact they may cause, 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.

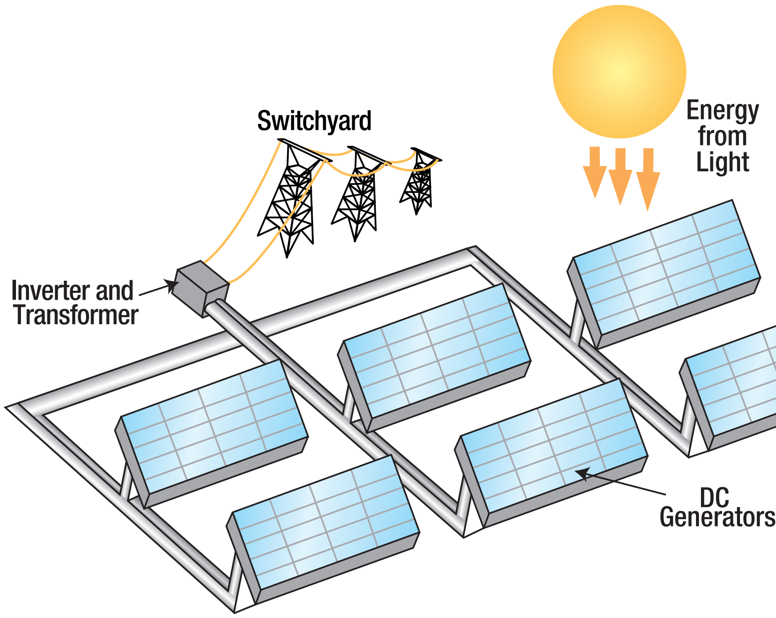
3. Ask students to develop one summary sentence about differences and similarities between power plants. Then ask students to brainstorm other things coming out of the power plants that may be harmful to the environment. For example, nuclear power needs water to cool reactors, coal and natural gas emit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

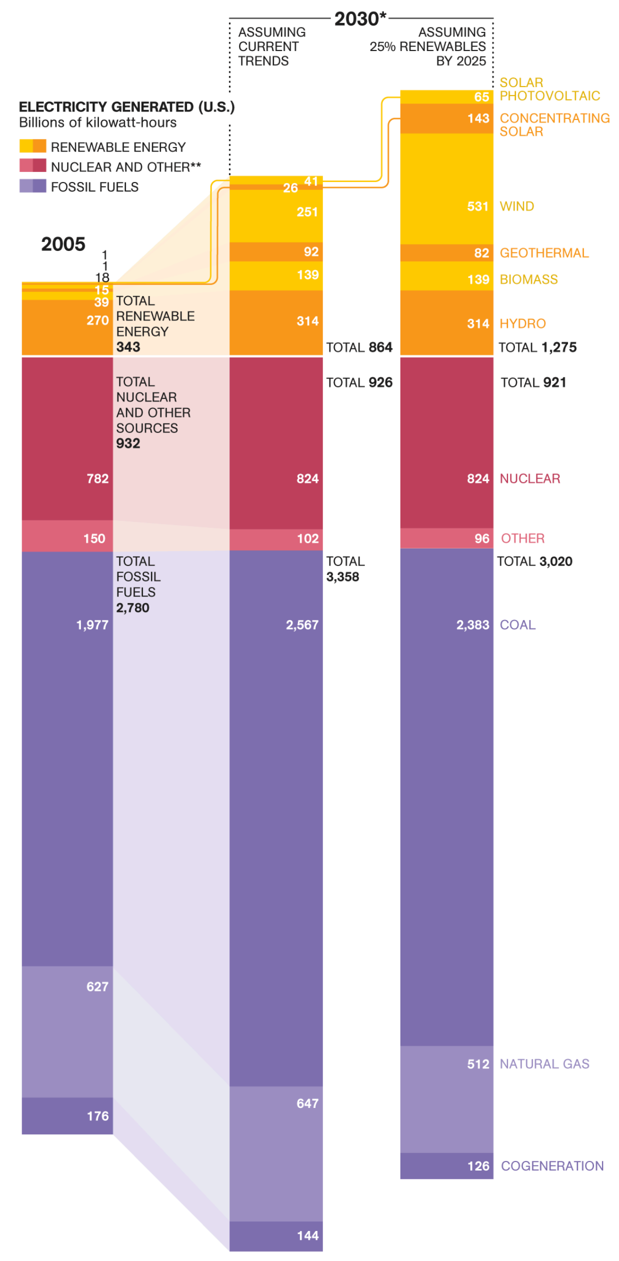
1. Now that you have examples of what students know about this topic, how can you use this information to plan your lessons or to reteach?
2. Martinez made progress toward a more scientific understanding of these concepts. He still misunderstands a few concepts but has the idea of regenerating resources. 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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Levine, Ira *Physical Chemistry.* Boston, MA: McGraw-Hill, 2002.

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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

3 Energy to Power Our World

by Nicole D. LaDue and Lindsey Mohan

Before the discovery of fossil fuels, our ancestors relied primarily upon wood and other plant materials for fuel. Every day, people had to collect enough burnable material for cooking, heating homes, and fueling fires to make tools. In developing countries, some populations still live this way. Since the 1800s, however, industrialized nations have greatly developed the capacity of fossil fuels to provide power for many human activities.

Today, industrialized nations use carbon-based fossil fuels such as coal and petroleum for heat and power. These fuels make our way of life possible. We use gasoline to drive to work and school, and much of the electricity we use to run our homes and businesses comes from burning coal or natural gas. We also use petroleum fuel to ship goods around our nation and the globe. Other fuel sources, such as nuclear, hydroelectric, wind, and solar provide energy to our electricity grid, but most of our energy comes from burning fossil fuels.

In this chapter, we will discuss how our energy use has changed over time, especially since the Industrial Revolution. We will take a closer look at how fossil fuels form in order to understand what makes these materials so energy-rich and discuss how the burning of these fuels has contributed to anthropogenic (human-caused) climate change. Finally, we'll examine scientific data on carbon dioxide emissions from different activities we engage in everyday.

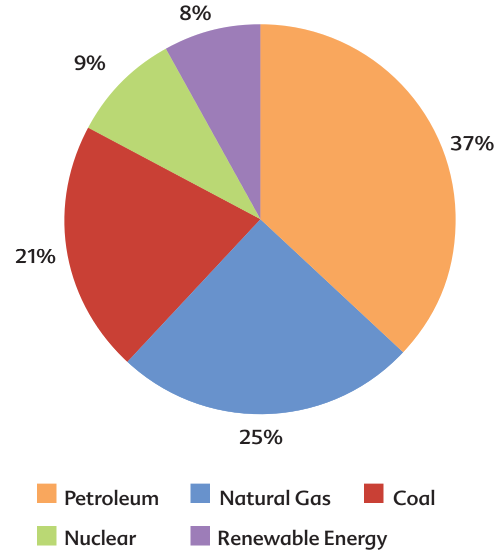
Energy Portfolios

An **energy portfolio** describes the types and amounts of energy used by a society. A well-developed and desirable energy portfolio is often described as a diverse portfolio. Centuries ago, people did not have many options for fuel, so energy portfolios were not diverse. They likely consisted of wood or other plant and animal-based products, such as charcoal. Wind energy from windmills was harnessed by some societies. In the mid-1800s, as humans started to use coal and water power to run newly invented machines, energy portfolios

GRADE	STANDARD	EEI UNIT
Grade 3	3.1.2 3.5.1-3	The Geography of Where We Live California's Economy—Natural Choices
Grade 4	4.1.5	Reflections of Where We Live
Grade 5		
Grade 6	6.3.b 6.6.a-c	Energy: It's Not All the Same to You! Energy and Material Resources: Renewable or Not? Made From Earth
Grade 7		
Grade 8	8.6.1 8.12.1 8.12.5	Agricultural and Instustrial Development in the United States Industrialization, Urbanization, and the Conservation Movement

EXAMPLE ENERGY PORTFOLIO

Primary Energy Use in U.S., by Source (2010)



The example energy portfolio presented here shows a portfolio for an industrialized country today. This portfolio shows that the only 8 percent of the energy used in the United States comes from renewable sources.

became more diverse. Today, our energy portfolios are even more diverse, using both fossil fuels and alternative energy sources, such as nuclear, solar, or wind energy.

Energy portfolios are represented in a variety of ways, but oftentimes we see these portfolios as pie charts with percentages showing different energy sources.

Energy in the United States

Energy usage in the United States has changed dramatically over its relatively short history. Before the 1850s, most of

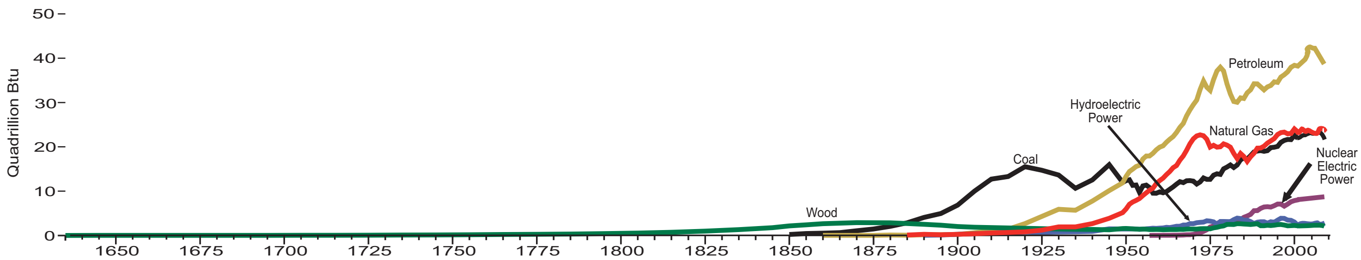
CHAPTER OVERVIEW

The technology we have today requires a great deal of energy to keep our societies functioning. Most of this energy comes from fossil fuels, whereas just a few centuries ago, this energy came primarily from wood and other plant-based materials. Today, our energy needs are met mostly with fossil fuels we extract from deep underground, but we also use other sources of energy by harnessing wind, solar, hydroelectric, and nuclear power, to name only a few.

Energy portfolios are a way societies represent their energy sources. Some countries have more diverse portfolios compared to other countries. Energy use in the United States relies predominantly on fossil fuels, but use of these fuels is different. For example, coal and natural gas are primarily used to power homes, while petroleum is used for transportation. The use of fossil fuels in the United States and Canada dwarfs use by other industrialized nations. Fossil fuels are ancient plant-and-animal materials buried millions of years ago and, through time and pressure, transformed into the energy-rich hydrocarbons we burn today.

The chapter explores how energy needs have been met over time and takes a closer look at the discovery and use of fossil fuels in modern times.

UNITED STATES ENERGY OVER TIME



Energy use in the United States has grown dramatically since the 19th century. Today, energy resources are more diverse, but Americans still rely mostly on fossil fuels to meet energy needs.

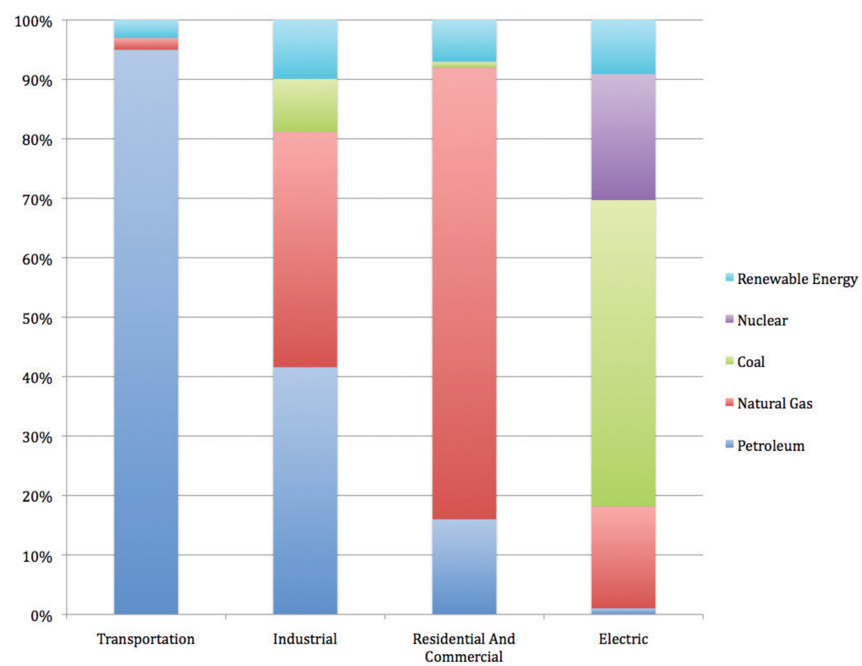
the forest east of the Mississippi River was cleared as humans used the trees for energy and building materials. The energy we use today comes from a more diverse mix, including fossil fuels, nuclear power, and renewable energy sources such as biofuels and wood products, plus hydroelectric, solar, and wind power.

Around 1890, coal surpassed wood as the dominant source of fuel in the United States. Despite some fluctuations in the early half of the 20th century, coal use has grown fairly steadily since about 1960. Today, petroleum is our dominant fuel source, followed by natural gas and coal. Alternative energies such as nuclear and hydroelectric power supply just a fraction of the total energy used in the United States.

Energy sources are valued for their energy output. The **British thermal unit (Btu)** is one measure of energy output. A Btu is the amount of energy required to heat one pound of water one degree Fahrenheit. This is about the amount of energy released when burning a match. The energy content of various fuel sources is usually described by Btus. We also use this unit of measurement to describe the capacity of appliances to heat or cool. For example, furnaces and barbeque grills usually indicate their capacity with a Btu rating. The reason that some fuels are highly valued and used more than other fuels is often due to the energy output we can obtain from those fuels. Fossil fuels, for example, provide a great deal of energy compared to other sources such as solar energy.

Currently, we burn fossil fuels to produce more than 85 percent of the total energy used in the United States. Of our total energy use, however, different sources supply different uses. For instance, of all the energy used to power transportation in the United States, 95 percent of it comes from petroleum. Just more than half

ENERGY USE BY SECTOR



In the United States we use our energy resources in different ways. Coal is used to produce electricity for homes and businesses. Natural gas is used predominantly in homes, while petroleum dominates the transportation sector.

(51percent) of the electricity used by appliances in homes and businesses comes from burning coal.

Energy Use Around the World

The United States uses approximately 21.1 percent of global energy consumed each year (Annual Energy Review, EIA 2006). Considering that the country has only 4.6 percent of the world's population, Americans consume, on average, more than any other country, except Canada.

Consider how much energy Americans use by comparing the United States to China. Both countries have about the same land area and use approximately the same amount of energy, but China's population is four times that of the United States. Also, we might think that American lifestyles are similar to those of Europeans, but people who live in the United States use almost twice as much energy per person as people living in Germany, France, or the United Kingdom.

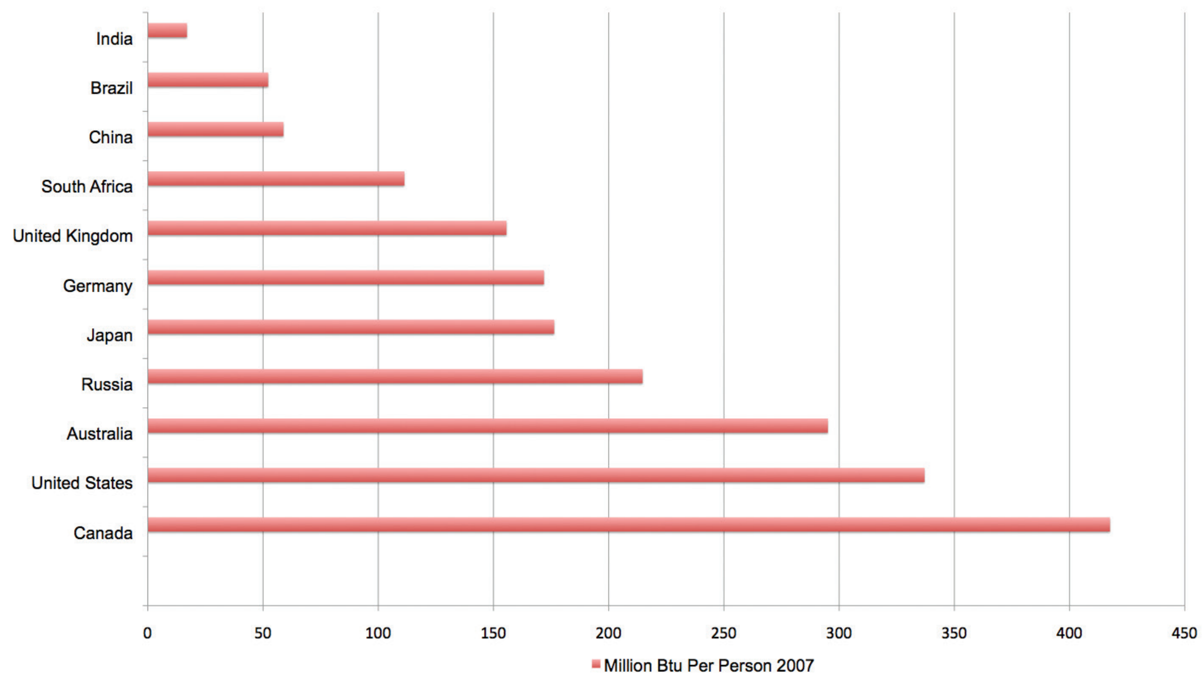
City lights of Toronto, Canada, shine brightly in the night.

Fossil Fuels

Most students have likely heard the term *fossil fuel* in some capacity or another. They may know that we use fossil fuels in our cars, and they might associate these fuels with factories or power plants. Given the high level of attention that climate change and fossil fuels have had in the media, even early elementary students may have some knowledge about fossil fuels.

However, few students have any real idea how dependent their everyday experiences are on the use of fossil fuels. Even if students can name some fossil fuels and know that they come

ENERGY USE PER CAPITA



The U.S. Energy Information Administration (EIA) monitors national and global energy use. In 2007, EIA calculated that American citizens consumed an average of 337 million Btu compared 172 Btu per German citizen and 156 Btu per British citizen. Data can be downloaded from EIA's International Energy Statistics website: http://www.eia.doe.gov/emeu/international/contents.html

from the days of dinosaurs, they are not likely to know what makes them such ideal energy sources, or how they revolutionized our energy system.

What Are Fossil Fuels? Coal, natural gas, and crude oil (the raw material from which gasoline and other petroleum products are derived) form from organic material that has been buried and compacted by natural Earth processes over millions of years. Fossil fuels were once plant and animal materials, but chemical reactions that take place under heat and pressure transformed them into different substances. At an atomic level, all fossil fuels contain hydrogen and carbon atoms that are bonded together into molecules called **hydrocarbons.** The history of heat and pressure changes on the original organic material and the way the carbon and hydrogen atoms are bonded together is different for coal, oil, and natural gas.

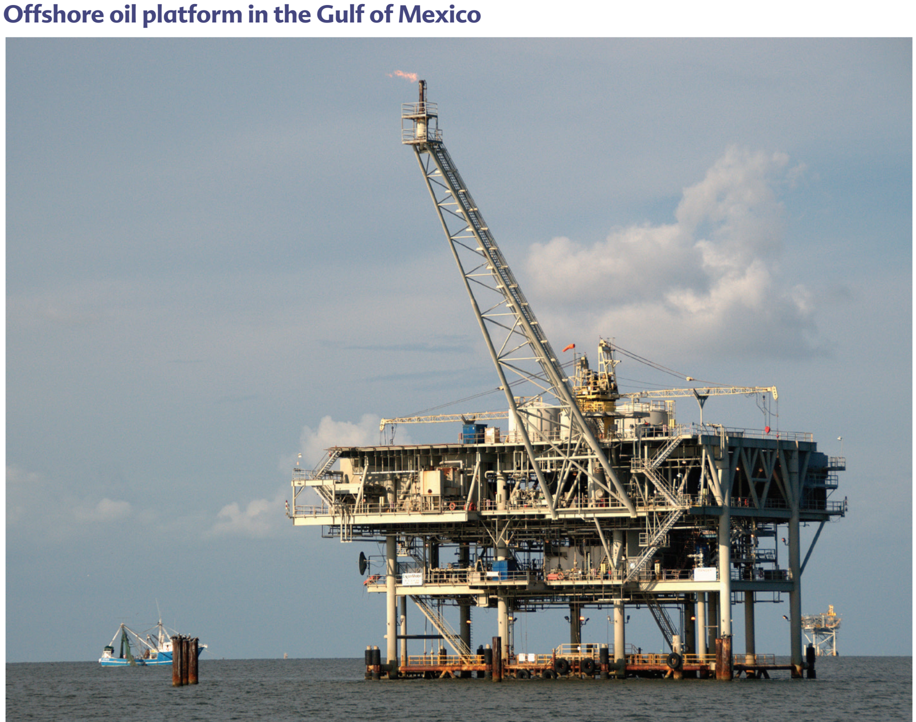
Natural Gas. The most common type of natural gas is methane, which has a chemical formula of CH_4. When methane and oxygen gases are together, a small amount of energy (such as a spark) can start a chemical reaction between the two substances. This reaction is known as *combustion,* or burning. In the combustion of a hydrocarbon such as methane, the bonds between carbon and hydrogen atoms break apart to form new bonds with the oxygen atoms. The formation of new chemical bonds with oxygen releases energy—the same amount of energy that it took to bond hydrogen and carbon together through photosynthesis when the plant material was alive. The formation of new carbon-oxygen bonds and hydrogen-oxygen bonds releases more energy than it takes to break the original carbon-hydrogen bonds, so overall, the combustion reaction releases energy.

The chemical equation for the combustion of methane is $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$ (+ energy). This means that for each methane molecule that chemically combines with two oxygen molecules in a combustion reaction, two molecules of water and one molecule of carbon dioxide plus a specific amount of energy will be produced. Thus, carbon dioxide is one of the products of burning methane. Similarly, other types of natural gas also result in the production of carbon dioxide.

Natural gas plant in Texas

Oil. Crude oil is a combination of liquid hydrocarbon molecules that can be separated into products such

Offshore oil platform in the Gulf of Mexico

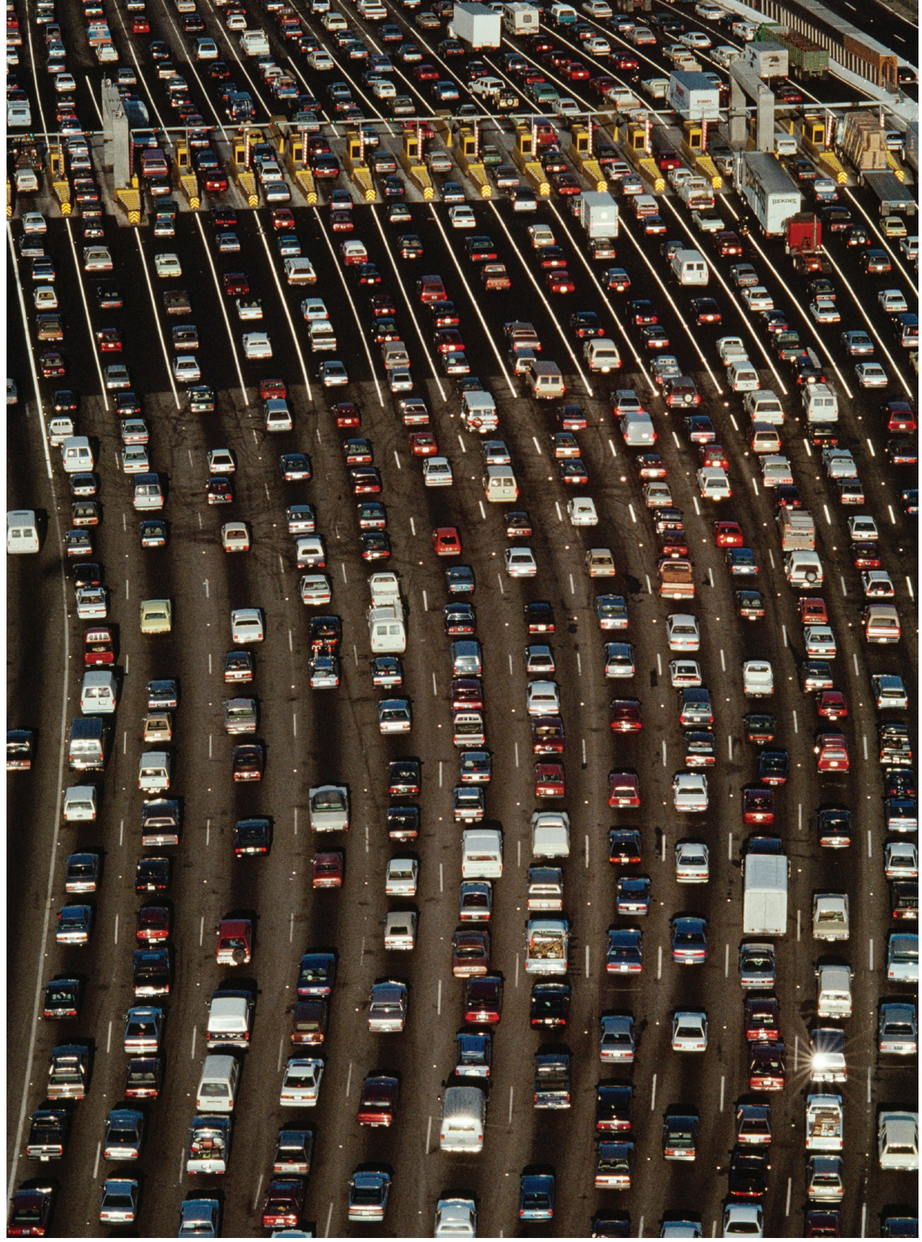


as gasoline, heating oil, and asphalt. To separate the black crude oil into its component parts, petroleum refineries raise the temperature of the mixture and capture the products that boil out of it at different temperature ranges. As the temperature is raised, increasingly larger molecules boil out of the mixture and then condense; they can be collected with other similarly sized molecules.

The molecules in gasoline are typically hydrocarbon chains with 4 to 12 carbon atoms per molecule; diesel fuel contains hydrocarbon chains with about 8 to 21 carbon atoms per molecule. When these petroleum products are combusted inside the engine of a car or truck, they produce energy and a molecule of carbon dioxide for every carbon atom involved in the reaction.

Coal. Coal is made mostly of carbon, but it also contains varying amounts of hydrogen, oxygen, nitrogen, sulfur, and other elements. Coal is solid because its carbon atoms are bonded together into strong ring–shaped molecules rather than existing as the hydrocarbon chains found in liquid oil. Coal is classified by the amount of carbon it contains. Coal that has the highest amount of carbon, typically more than 90 percent of the total weight, has the highest potential for producing energy through combustion; this high-grade coal is called **anthracite.** Grades of coal that have progressively lower amounts of carbon are called **bituminous** coal, lignite, and peat. When coal is burned to release energy, the reaction releases carbon dioxide. Burning coal also releases pollutants such as sulfur dioxide, nitrogen oxide, particulates, and mercury compounds. Coal is considered the “dirtiest” fossil fuel for the environment.

How Do Fossil Fuels Form? Fossil fuels have the name *fossil* because they form from the remains of plants and animals that were once alive.



Cars line up at tollbooths during rush hour on the San Francisco-Oakland Bay Bridge.

Though many people associate the term *fossil* only with solid bones or shells, it also refers to any remnants or traces of once-living material.

In general, fossil-fuel deposits represent regions that had abundant life, with swamps and shallow seas dominating the landscape. Over millions of years, natural geologic processes covered these areas with layers of mud and sand. The decaying organic matter was buried and compacted, eventually forming coal, oil, and natural gas.

All fossil fuels represent energy that was originally captured from the sun through photosynthesis. Plants use water, energy, and carbon dioxide to make sugar, converting the solar energy to chemical energy.

If a plant is exposed to air after it dies, oxygen reacts with sugars in the plant matter, breaking the bonds between carbon atoms. Aided by a variety of bacteria and fungi that ingest and digest the sugars, the plant eventually decomposes. However, if dead plant material is buried under layers of mud at the bottom of a swamp, no oxygen or decomposers can reach the decaying plant matter. In this case, the organic material will not decompose completely, and the carbon it contains is preserved. If additional layers of mud and rocks eventually cover the buried organic matter, the weight can squeeze out any water left in the material. Pressure,

Coal is the most abundant fossil fuel in the United States, and coal mining has been an influential industry for more than a century.

heat, and the absence of water can result in plant sugars ($C_6H_{12}O_6$) slowly transforming into hydrocarbons as the relatively unstable oxygen atoms are removed through slow chemical reactions.

Coal generally forms from buried plant material that grew in swamps and bogs on land. Conversely, deposits of oil and natural gas are formed from the remains of microscopic marine organisms. Small life forms, such as algae and plankton, thrive in shallow ocean waters where they can capture sunlight through photosynthesis or ingest other plankton. When these microscopic organisms die, they fall to the sea floor, taking the carbon-hydrogen-oxygen compounds they built with the sun's energy with them. Great accumulations of these dead organisms can eventually be buried and squeezed by thick layers of sand and rocks. Given the right conditions of heat and pressure over millions of years, the organic material is transformed into liquid oil. Because it is less dense than rocks and water, the oil moves generally upward through **permeable** layers of rocks, such as sandstone, until it is trapped by an **impermeable** layer of rock, such as clay.

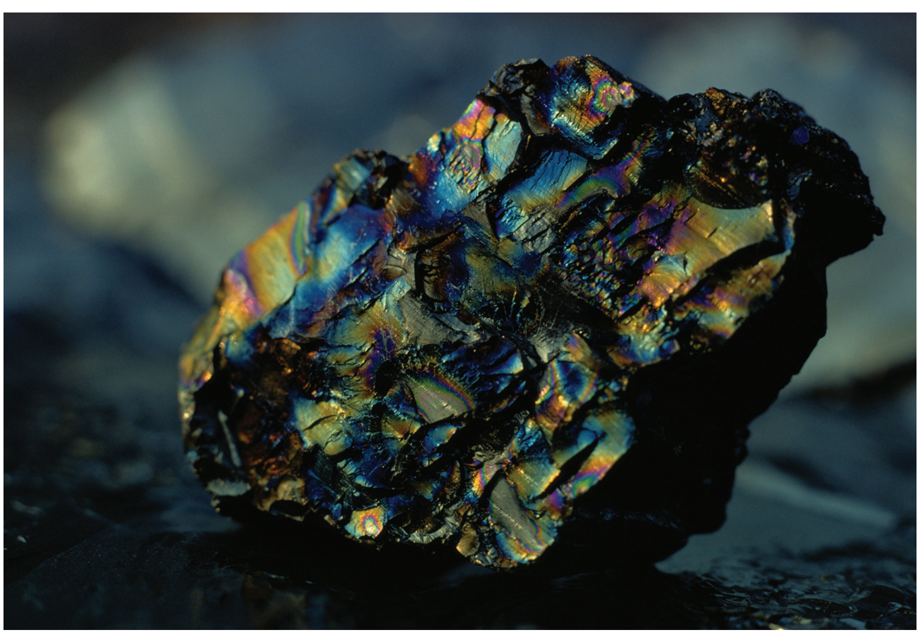
In general, the deeper a deposit of marine organisms is buried, the higher the temperature and pressure it will experience. Heat and pressure can break some of the bonds of the hydrocarbon chains, releasing small molecules such as methane to bubble upward as natural gas. In most cases, as an oil deposit heats, it releases a larger proportion of natural gas and preserves a smaller proportion as oil. Shallower oil deposits that don't experience extreme heat will usually have a lower proportion of natural gas and a higher proportion of oil.

Fossil fuels are highly concentrated sources of energy. Imagine the difference in the potential energy content between a mass of organic material that was squeezed and heated for millions of years compared to a tree of the same size that is cut down for firewood.

Fossil fuels are incredibly energy-rich in terms of the molecular bonds that hold them together. A great deal of energy is released when hydrogen and carbon molecules combine with oxygen.That energy is transformed into heat energy in car engines and then into kinetic energy (motion) as the heat energy turns the wheels of a car. Fossil fuels can also be transformed into electrical energy to power the appliances in our homes.

The energy of fossil fuels started out as solar energy and was transformed into chemical energy through photosynthesis in plants and the animals that consumed the plants. Burial of these plants and animals preserved this chemical energy, and the materials transformed into fossil fuels. Now, after humans mine and drill these fuels from Earth, they transform the chemical energy into light, heat, motion, and electricity that we use to power our everyday activities.

Anthracite coal has the highest carbon count (more than 90 percent). It has less impurities and is more valuable than ordinary bituminous coal.



Student Thinking

What Are Fossil Fuels?

When asked where fossil fuels come from, many students will likely describe something related to dinosaur bones as opposed to plant materials. The word *fossil* immediately creates some confusion among most students.

Ancient plant *Lycopodium squarrosum*, a major source of European coal.

Scenario

Today you teach the class about the formation of fossil fuels. The following question is asked as the starting discussion question to assess what your fifth-grade students already know, and you also use it to end the day's lesson as review.

Question

What is a fossil fuel?

Scientific Answer

A fossil fuel is an energy-rich material, such as coal, natural gas, or crude oil. A fossil is accurately described as any remains from ancient plants or animals, including bones, plant material, imprints, or any other evidence of an ancient living thing. Fossil fuels are created when heat and pressure are applied by natural Earth processes to fossil remains over millions of years, and fossil fuels are actually made mostly from plant material from long ago.

Student Answers (Before Instruction)

Ezequiel: Fossil fuels are fossils, which are found long ago in the era of dinosaurs and ancient plants. And over time, those plants and dinosaurs were covered in mud and turned into fossils.

Martinez: Fossil fuels are natural things like oil and gasoline. Because we get coal from log lost dead dinosaurs. Then we melt it to make oil.

Andrea: Well, when an animal dies, its fossils get broken down into the earth, and after thousands and thousands of years, we found them and we start using them to make energy for our cars.

Student Answers (After Instruction)

Ezequiel: Before I thought fossil fuels were dinosaur fossils and trees, but now I know it's not dinosaur bones, but trees and oils from back then and gases that were trapped underground because of all the pressure.

Martinez: Fossil fuels are made by like dead trees that have fallen. Then the bark, it gets decomposed and turns into coal. Or dead grass or dead plants that got decomposed and make oil.

Andrea: Fossil fuels are made by plants and trees that were pressurized down by sediment and heat. And the plants and the trees got fossilized, and then we're starting to use them to make liquid for our gas and oil.

What Would You Do?

1. Given students' pre-instruction ideas, what concepts seem to be the most important to focus on when teaching fossil fuels?
2. Given students' post-instruction ideas, what would you do next to improve their understanding?

Pictures of Practice

Fossil Fuels and Carbon

When asked to name fossil fuels, many students are able to list coal, oil, and natural gas. However, many students have trouble understanding where fossil fuels come from. In addition to this confusion, students may have trouble linking the carbon that was originally in the ancient living things to the carbon in fossil fuels. The idea that the carbon used now in fossil fuels also existed millions of years ago is a difficult concept for students to wrap their minds around. It may also be hard for students to understand how long it takes fossil fuels to form. Long periods lose meaning for children as numbers begin to exceed thousands to millions of years.

Students: Grade 6

Location: South Gate, California (a coastal community)

Goal of Video: The purpose of watching this video is to see students discuss what fossil fuels are and how they relate to carbon.

Classroom Context

Ms. Walker's sixth-grade science class discussed fossil fuels during their unit on global warming. Most of Ms. Walker's students already learned to name fossil fuels, and most students associate these fuels with global warming. Many students already know that burning fuels releases carbon dioxide (or "bad" gas and pollution) into the air, and that this release of carbon dioxide is bad for the environment.

Video Analysis

In the video, you see that Ms. Walker's students can name fossil fuels. Fossil fuels include coal, natural gas, and crude oil, all of which take about 300 million years to form, with their origins being plant-based materials, not dinosaur bones. During a preinterview, Eliazar describes fossil fuels as coming from dinosaurs and taking only a few hours to form. Eliazar's explanation represents what many of Ms. Walker's students believed about fossil fuels prior to additional instruction. Ms. Walker wanted her student to move beyond the idea that fossil fuels come from dinosaurs, so she approached the question in a different way. Because students knew that carbon dioxide comes from burning fossil fuels, Ms. Walker decided to have her students explain where the carbon in the carbon dioxide comes from. When she asked this question, most of her students were confused, but Emily explained that the carbon was originally in plants and animals before it became fossil fuels. The discussion about carbon continued beyond Emily's explanation, and students heard about how carbon bonds in fossil fuels are strong, making them good energy sources. After this discussion, many students were still confused, although they seemed to realize that fossil fuels come mostly from ancient plants (not just dinosaurs). You will see one student, Samantha, mention carbon in her explanation of fossil fuels, during a post interview. Yet, Samantha admits that she does not understand fossil fuels even after the discussions.

Reflect

How can you help students better understand fossil fuels?

Think about why fossil fuels are challenging for students to comprehend. How would you approach teaching this topic? What is the benefit of focusing on carbon that helps students move beyond explaining fossil fuels as coming from dinosaurs and dinosaur bones?

Carbon Emissions

Just as energy is transformed through photosynthesis and burning, matter involved in these processes is also transformed. The ancient plants and animal materials that became fossil fuels were fundamentally different materials from the coal, oil, and natural gas they became. Chemical reactions changed the starting substance into a different material.

When we burn fossil fuels and convert them to a form of energy we can use (light, motion, heat, and electricity), that material is also changed. Though we know that matter cannot be created or destroyed, it can be confusing to fill a car's tank with gas and have it "disappear" as we drive the car. The discrepancy can be understood when we know that the primary products of combustion are invisible gases. Combustion changes the location of carbon that has been buried beneath Earth's surface for millions of years, releasing it into our atmosphere.

Because of the increasing concentration of carbon dioxide in Earth's atmosphere, people point to the negative impact from fossil fuels. Further, people question whether fossil fuels can continue to supply our demand for energy for many years to come. Today we find ourselves in a conundrum. On the one hand, fossil fuels revolutionized our societies and made our current lifestyles possible. Our success as a nation is inextricably linked to what we have accomplished by using fossil fuels. However, we also know that these amazing energy sources are limited in quantity, and we know that our systems for extracting them cause environmental damage. We also know that we are sending large amounts of carbon dioxide into the atmosphere when we burn them, resulting in amplification of the **Greenhouse Effect** and leading to climate change.

Through combustion of fossil fuels, such as coal, carbon dioxide and water are released into the air.

One of our biggest concerns today is figuring out how the world can meet our demands for energy in a way that reduces our use of fossil fuels.

Combustion of Fuels. The burning of fossil fuels releases the carbon that was originally stored in plant and animal matter as carbon dioxide. Some countries have vast amounts of underground coal available to them. Coal can be mined, processed, and burned relatively cheaply and often does not need to be transported great distances. These factors make coal an inexpensive energy source. As countries expand economically and develop their industries, they often burn more coal. While the United States underwent this transition to coal-based power in the 1800s, other countries, such as China, are in the process of building new coal-fired power plants for electricity generation today.

The amount of CO_2 that is produced from each energy source varies. Common gasoline releases less CO_2 for the energy we recover compared to coal products. Burning natural gas for energy produces even less CO_2 per unit of energy produced than either gasoline or coal.

Surprisingly, burning wood produces almost the same amount of carbon dioxide as an equal amount of energy produced from some forms of coal.

The United States currently produces approximately 6 billion metric tons of carbon dioxide per year. Our present carbon emissions come from petroleum (primarily used for transportation needs), coal (primarily used for electricity production) and natural gas (primarily used for commercial/residential heating).

Students may have heard about carbon emissions or carbon dioxide, but their understanding of combustion of fuel to produce carbon dioxide is probably not well developed. When asked to explain where the gasoline has gone when a car's gas tank has gone from full to empty, many students respond that the gasoline turned into energy or evaporated into the air. More recently, students are starting to recognize that the gasoline reacts with oxygen to form gases that enter the air, but they can still lack a solid understanding of how liquid gasoline becomes gaseous carbon dioxide and water vapor.

Teaching Tip

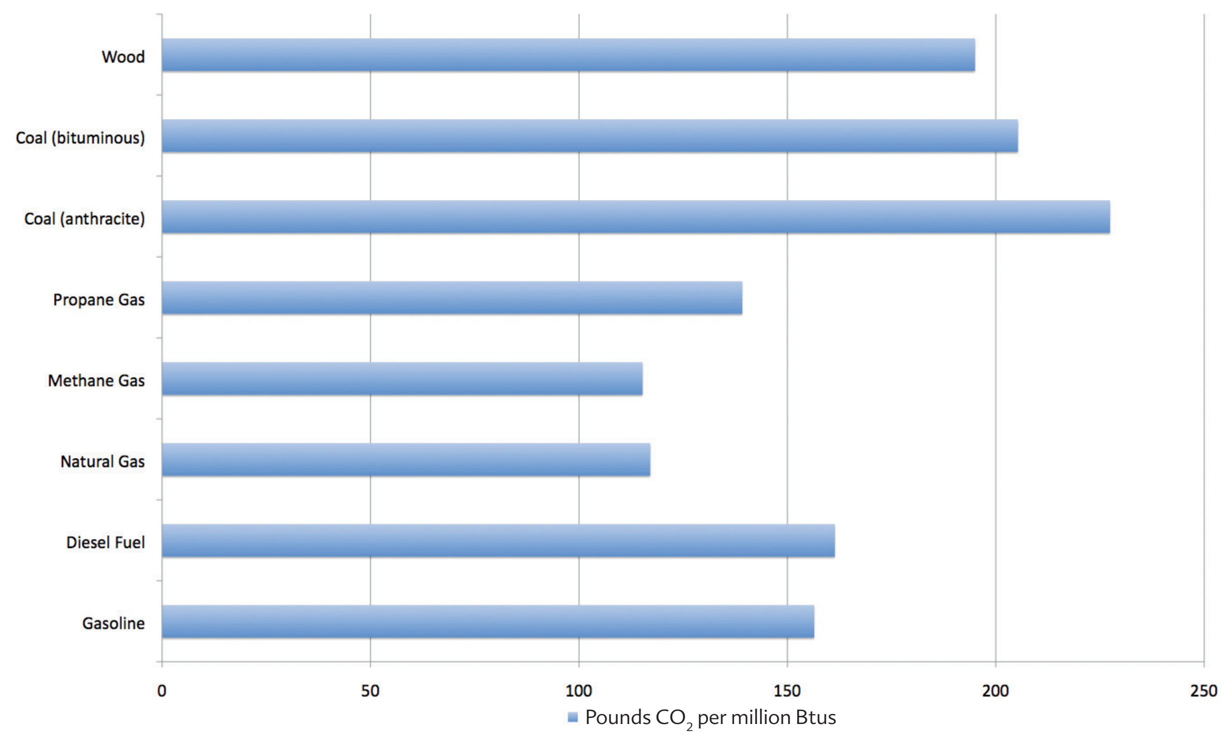
The process of burning is a visual experience that students know well. As such, we tend to think *burning* means the same thing to everyone. Be aware that it may mean very different things to different students within the same classroom. Pay particular attention to when and how students use the word *burn,* and try to establish a shared meaning for it among your students. For some students, *burning* may mean that something "evaporates" or "vaporizes" or simply "goes away." For others, it may be likened to decomposition. Still other students may use *burning* to describe a process by which matter turns into energy. The goal is to have all students see *burning* in terms of a chemical reaction that does not create or destroy matter.

In Chapter 2 you read about combustion, in which a fuel source is oxidized. This fuel source may be plant matter, such as wood, or fossil fuels or the wax that makes up a candle. In all cases, these fuel sources are mostly made of carbon and hydrogen and potentially oxygen atoms. When the fuel reacts with oxygen, a chemical reaction occurs. Energy is transformed from the chemical energy in the fuel into light, heat, or motion. The material products are carbon dioxide and water vapor. Following is the chemical reaction that occurs when methane burns: $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$.

Notice how similar this equation is to cellular respiration that occurs as our bodies "use" or "burn" food to fuel our body functions: $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$.

Both of these processes begin with a carbon-based material—either a food or a fuel. They react with oxygen to produce carbon dioxide and water vapor. All these processes—burning wood, fossil fuels, or food in our bodies—do similar things chemically to meet specific energy needs.

EMISSION COEFFICIENTS



Fossil fuels, as well as wood, give off varying amounts of carbon dioxide in relation to the energy output. This graph shows that burning wood and coal produce more carbon dioxide compared to burning other fossil fuels for the same amount of energy output. Data for this graph can be downloaded from the U.S. Energy Information Administration emission coefficient page: http://www.eia.doe.gov/oiaf/1605/coefficients.html.

In the Classroom

Learning From a Burning Candle

Recording the mass of a candle both before and after burning makes an easy demonstration of combustion that can be completed in your classroom (Environmental Literacy Project). During burning, the mass of the candle decreases. Students may ask (or you may ask them), "Where did the missing mass go?" Students may focus their explanations on the candle melting, but probe further, so students must explain what happened to the liquid wax. Students might also focus on the smoke, but continue asking them to explain what they mean by *smoke.* (e.g., What is smoke made up of?). To check understanding, you can also light and burn a match, and ask students what happens to the wood of the match as it gets shorter.

Materials

- Digital Balance sensitive to 0.1 or 0.01 grams
- Good-quality candle, at least votive size
- Lighter
- Paper/chart to record observations
- Match (optional)

Directions

1. Prior to conducting the demonstration with students, test the demonstration on your own. Depending on the sensitivity of your digital balance and on the quality of your candle, you may get inconsistent results. Good-quality candles that will stay burning even when the building's air system is on and a balance sensitive to 0.01 grams will ensure convincing results for your students. If your balance is sensitive only to 0.1 grams, consider using a slightly larger candle and burning it over an entire class period to get valid results.
2. Gather digital scale, candle, and lighter, and make sure that students can see the demonstration.
3. Turn on and zero out the digital balance. Weigh the candle and record the start mass.
4. Light the candle, and let the candle burn for at least ten minutes. During the burning, have students write and discuss their predictions for what will happen to the candle mass. Ask students to make a prediction whether the mass will go up, down, or stay the same, and to explain the reasoning behind their predictions in writing and with their partner.
5. After at least ten minutes, record a second mass reading for the candle. Have students discuss whether the second mass reading supports or disproves their prediction. Use the following questions to generate discussion.
6. Variations and Extensions: Variations on this activity might include placing the burning candle inside a cool glass jar to collect moisture. Some teachers may even monitor carbon-dioxide levels using probeware as the candle burns. Also, consider taking additional readings across the class period to establish patterns for the decrease in mass.

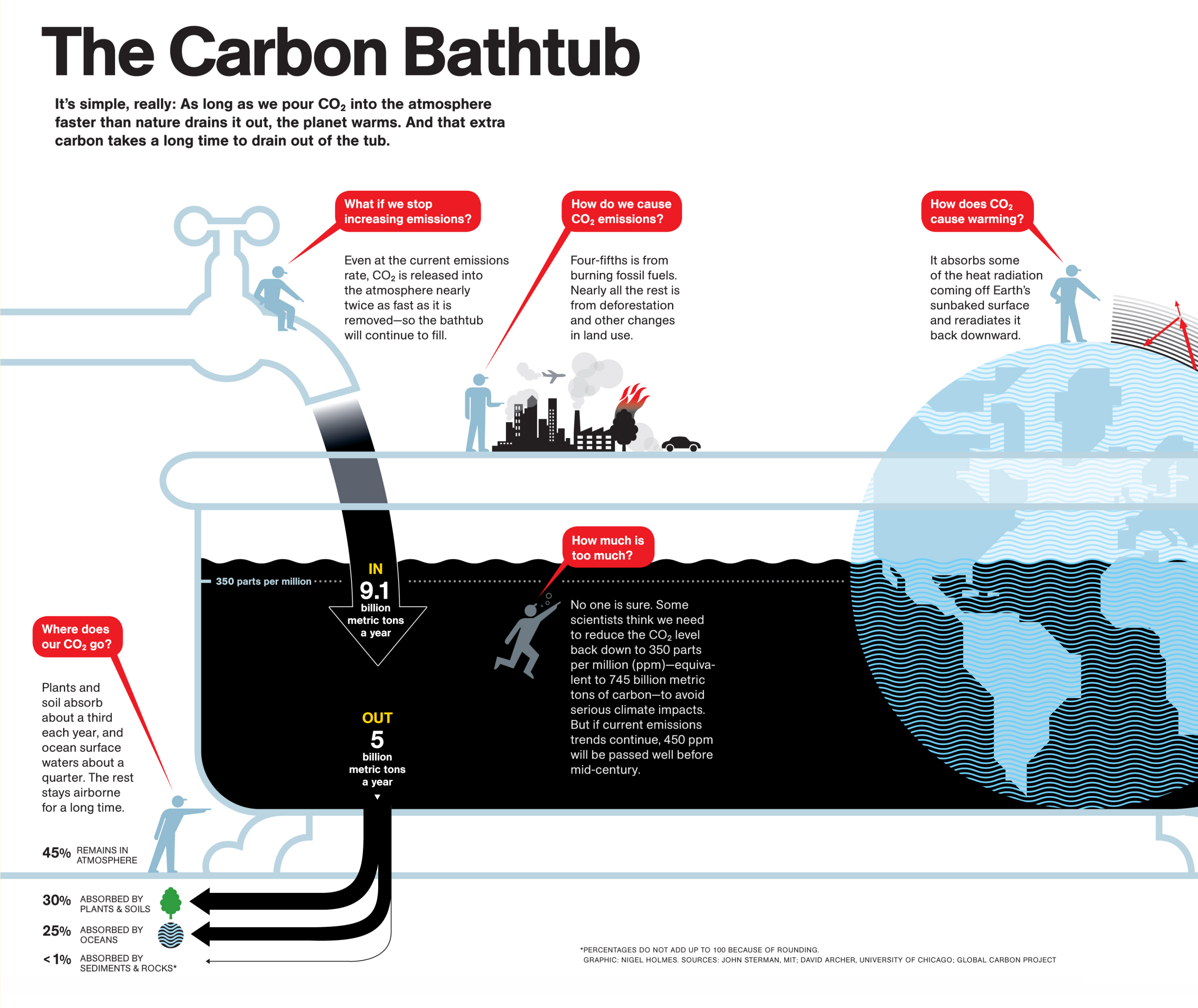
Ask Your Students

1. Where does the mass of the candle go as it decreases?
2. How do the materials change when the candle burns?
3. How does energy change when the candle burns?
4. How is the candle burning like burning gasoline in your car or propane in your barbeque grill?

Representations of Science

The Atmospheric Bathtub

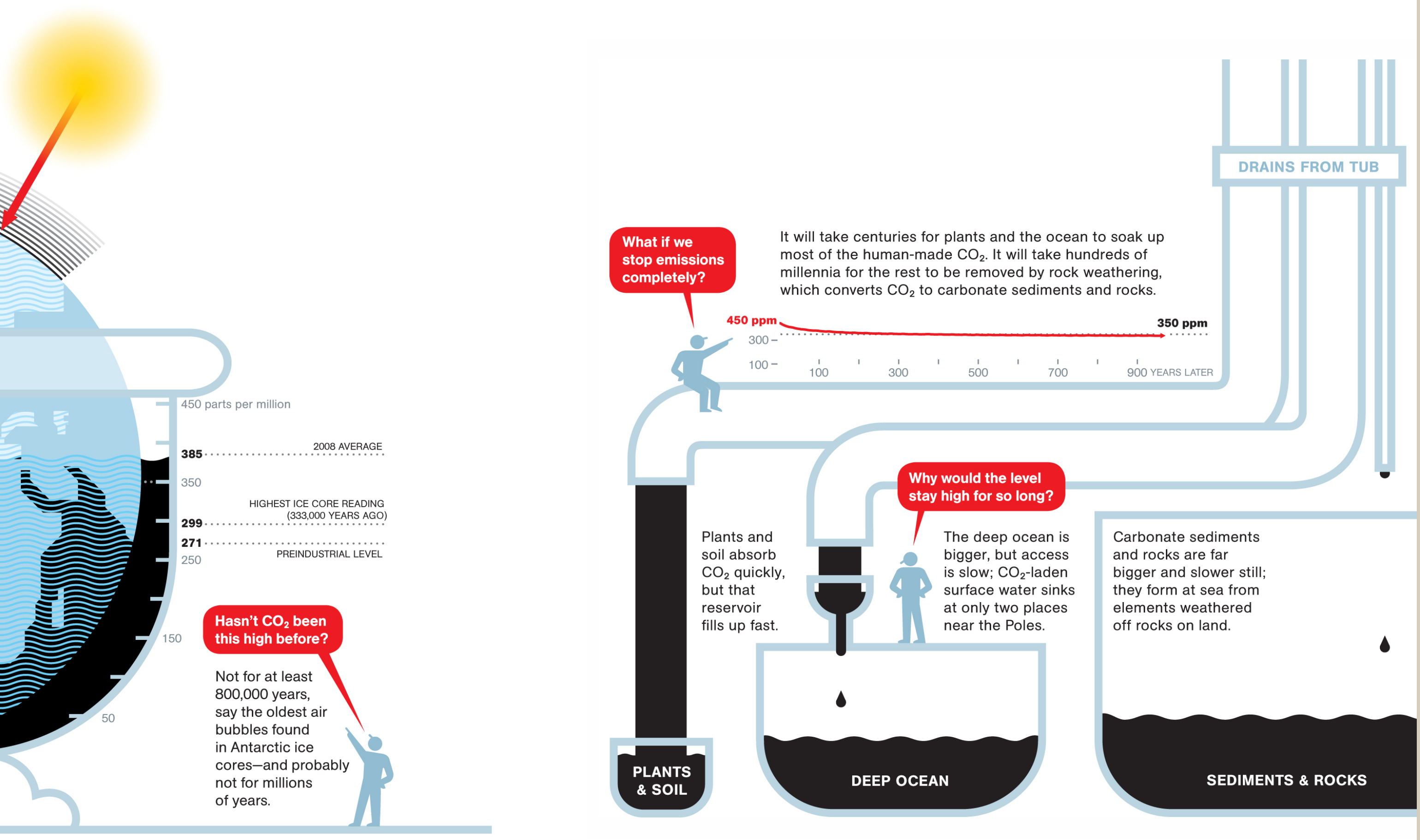
One representation of carbon emissions that has been used with adults is the atmospheric-bathtub analogy. The atmospheric-bathtub analogy likens inputs of carbon dioxide into the atmosphere to water filling up a bathtub. Processes that take carbon dioxide out of the air, such as ocean absorption and photosynthesis, are likened to water running down the bathtub drain. The idea is that the bathwater level will stay the same if the amount of water entering the tub is equivalent to the amount of water draining out of the tub. Like the bathtub, our



atmosphere is filling up with carbon dioxide, but the "drain" is not removing it as fast as it enters our atmosphere.

On the surface, this analogy seems simple enough that even young children may understand the general principles. Yet, as Sweeney and Sterman (2000) show, even adults have difficulty with this concept, especially when the atmospheric bathtub becomes more complicated than our bathtubs at home. For example, our atmospheric bathtub has multiple drains (i.e., carbon sinks) compared to the one drain on our bathtubs at home. The capacities of those drains are different and work on different time scales. The delayed effect of one drain compared to another may confuse students given that water generally runs very quickly down the drains found in our bathtubs.

Think about the benefits and limitations of the atmospheric-bathtub analogy. How could such an analogy be used to help students understand large-scale emissions? Where might students struggle with using this analogy?



Pictures of Practice

A Burning Candle

Combustion is a challenging concept for students to understand. At the visible scale, it seems like matter disappears as it burns. A match burns and gets shorter. A gasoline tank becomes empty. A candle burns until all the wax is gone. How do students make sense of these experiences, especially when they do not fully understand gases as a form of matter? All these experiences can be explained by fuels (such as wax, wood, or fossil fuels) being oxidized and giving off carbon dioxide and water as products. So how do teachers use everyday experiences, such as burning a match or a candle, to help students understand that solid or liquid fuels become gases? One suggestion is the candle activity described on page 59, **In the Classroom: Learning From a Burning Candle.** By simply taking an everyday experience, like a burning candle, and asking students to explain where the wax material goes, you can open the door for rich discussion about combustion.

Students: Grade 5

Location: South Gate, California (a coastal community)

Goal of Video: The purpose of watching this video is to see students discuss what happens to materials and energy as a candle burns.

Classroom Context

The candle activity occurred in the middle of Ms. Walker's lessons on climate change. Ms. Walker wanted to teach about combustion of gasoline in cars but used the candle activity first to help students make the connection between fuel becoming gases during the burning process.

Video Analysis

At the beginning of the candle lesson, Ms. Walker asks her students to make predictions about whether the candle would gain or lose mass as it burns. Steven hypothesizes the candle will gain mass, explaining that it will have "more atoms." However, Amaya suggests that the candle will become lighter, because "CO_2 is rising." Next, students watch the candle burn for several minutes, and eventually the candle loses one gram of mass. Ms. Walker then asks her students to explain what happened to the mass. You will see that some students quickly identify carbon dioxide, while others struggle to explain where the matter went. During the post interview, Ms. Walker expresses her satisfaction with the activity, explaining that she thought many students understood how burning puts carbon dioxide into the air and that matter never actually "goes away." This understanding is confirmed by post interviews with Alan and Samantha. Afterward, Ms. Walker uses the candle activity as a bridge to discussing burning gasoline in cars.

Reflect

How would you help students connect combustion and carbon dioxide?

During the classroom discussion, several students use terms such as *goes away* or *rises.* Do students really mean that matter disappears? How could you probe for further information? In their post interviews, Samantha and Alan are able to connect what they had learned from the burning candle to carbon dioxide entering the air, but their understanding of the actual burning process is limited. What concepts would you focus on when teaching the process of burning? Why?

References

Energy Information Administration. Annual Review. 2006.

Energy Information Administration. "History of Energy in the United States: 1635-2000." http://www.mnforsustain.org/energy_in_the_united_states_1635-2000.htm. June 6, 2010.

Sweeney, L. B., and J. D. Sterman. "Bathtub Dynamics: Initial Results of a Systems Thinking Inventory." *System Dynamic Review,* 16.4 (2000): 249–286.

Teaching Resources

Basic information about coal: http://tonto.eia.doe.gov/kids/energy.cfm?page=coal_home-basics

Basic information about natural gas: http://tonto.eia.doe.gov/kids/energy.cfm?page=natural_gas_home-basics

Basic information about oil: http://tonto.eia.doe.gov/kids/energy.cfm?page=oil_home-basics

California Education and the Environment Initiative resources: http://www.calepa.ca.gov/Education/EEI/default.htm

Carbon Bathtub Article: http://ngm.nationalgeographic.com/big-idea/05/carbon-bath

EIA Energy Flow figure: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec1_3.pdf

Population versus Energy consumption: http://www.worldpopulationbalance.org/population_energy

U.S. Department of Energy Resources: http://fossil.energy.gov/education/energylessons/

4 Environmental Impacts of Energy

by Jose Marcos-Iga and Tania T. Hinojosa

Energy is part of the natural world—it occurs everywhere, in every environment. As described previously, virtually all energy on our planet comes from the sun. This energy is transformed as it moves from one system to another and from one cycle to the next—powering everything from the water cycle to wind and tides to all life on Earth. The food chain is a manifestation of the flow of energy from one living thing to another.

Humans are part of this system, but we are different from other living things in that we have learned to harness and transform energy, mostly in the form of electricity, to power our modern lives. We use energy for every single thing we do, from driving a car to cooking a meal to making a phone call, and we have weaved energy into our lives so seamlessly that it would seem as if it has always been there for us to use. Human energy extraction has many consequences throughout the Earth system. This use of energy may create a ripple effect into all dimensions of our environment, affecting not only animals and plants and whole ecosystems, but also our own health and survival.

Oil spills, air pollution, watershed alteration, **desertification,** and ultimately, global climate change are all consequences of human extraction of resources for the generation of electricity and other energy forms. In this chapter, we will explore the environmental impacts of energy harvesting and use, from well-known fossil fuels to less-known effects of other, more sustainable, renewable sources of energy, such as wind and hydropower.

Energy Extraction: Bringing the Planet Out of Balance

Virtually all energy sources require humans to modify their environment to gain access to them. The impact that each of these extraction practices have on our planet depends on the energy source itself. Nonrenewable resources, such as fossil fuels, tend to have a bigger impact because we are required

GRADE	STANDARD	EEI UNIT
Grade 3	3.3.d 3.1.2 3.5.1-3	Living Things in Changing Environment The Geography of Where We Live California Economy—Natural Choices
Grade 4	4.1.5	Reflections of Where We Live
Grade 5		
Grade 6	6.6.a	Energy: It's Not All the Same to You!
Grade 7		
Grade 8	8.5.c 8.6.1 8.12.1	 Agricultural and Instustrial Development in the United States

to extract the resources from deep underground and transform them from a stored form of carbon into gases that enter our atmosphere. Most renewable resources, except for biomass, provide a readily available source of energy that we simply harness from natural environments, such as the solar radiation reaching Earth's surface or the natural movement of wind. Yet, even these energy resources have environmental impacts. The most important idea to consider is that virtually every energy resource has benefits and trade-offs, and these vary depending upon geographic region. In the following pages, we explore some of the environmental impacts of these different energy sources.

Nonrenewable Resources: Pros and Cons

Oil Extraction. As the top consumer of oil, the United States uses it for everything from transportation to home heating to electricity generation, as well as to make products such as plastics and fertilizers. Also known as petroleum, oil is a fossil fuel produced from the decomposition of organic materials over millions of years. To get to it, we have to access underground reservoirs, in many cases having to drill up to 30,000 feet to reach oil deposits.

The environmental effects of oil drilling and refining vary depending

CHAPTER OVERVIEW

Humans in the 21st century are incredibly dependent upon electricity, which is generated from a variety of energy resources. Each energy source has its advantages and drawbacks, from how we obtain them and convert them to electricity to the wastes that result.

There are many costs to using nonrenewable resources such as coal, oil, and natural gas for electricity production. Drilling or mining for these fossil fuels can upset land and water resources and habitats and result in the release of pollutants. Burning fossil fuels also releases greenhouse gases, contributing to climate change. Many of these activities impact safety and health of both natural and human communities.

Renewable energy resources also have their costs and benefits. Wind turbines do not emit greenhouse gases but can be dangerous to birds and bats. Hydropower is also a clean energy source, but dam construction affects land and freshwater species. Nuclear power is clean-burning, but waste products from these power plants are very dangerous and remain active for thousands of years.

This chapter explores the environmental impacts and trade-offs of different energy sources.

on the type of extraction and transportation methods used. Oil wells are a source of the powerful greenhouse gas methane, which is trapped in the oil reserves and released into the atmosphere during extraction. After the extraction, crude oil is transported to a refinery, where it is processed and refined, removing some of the impurities, such as nitrogen and sulfur. The final products are usable forms of petroleum, including gasoline, propane, kerosene, diesel, and jet fuels. Oil is transported from the refinery to its final destination. The machinery used during the drilling, refining, and transporting of oil also uses fossil fuels to run, which gives off greenhouse gas emissions. As people burn these fuels during activities such as driving cars, carbon dioxide and other greenhouse gases are released into the air.

Students may not be aware of the role of water in energy production. Production of energy not only requires significant amounts of water, but also water systems are also impacted by energy extraction methods. During the oil drilling phase, water is required to remove any obstructing materials from the well. A bigger impact to the watershed is in the form of contamination, both to groundwater with oil from the well and to the surface water from polluted runoff coming from the extraction area. Water is also used during several steps of the refining process, and the resulting wastewater is then released into streams. In most cases this wastewater is treated to meet Clean Water Act standards. The wastewater sludge and other solid waste produced during oil refining contain high levels of toxic and metal compounds that must be carefully disposed (Environmental Protection Agency 2007).

These oil refineries in Chalmette, Louisiana, represent the typical landscape in an oil-industry region, especially along the Gulf coast.

Coal Mining. At this point in history and after extensive public discussion in America and around the globe on the effects of greenhouse gases on climate change, your students might be well aware of the impact of burning coal as a source of energy. But they might not be as aware of the environmental impacts involved in other parts of the process of coal extraction and use—more specifically, mining.

One of the most direct and obvious impacts of coal extraction, especially in open-pit mining, is the large area of land disturbed in the process. When dust and other pollutants enter an ecosystem, it changes the chemistry of the air, soil, and water, making the environment potentially uninhabitable by native organisms. One type of coal-mining practice that is particularly invasive is mountaintop removal. Mountaintop removal is a form of surface mining in which entire mountain summits and ridges are removed to reach coal seams. This type of mining is mostly contested because it damages the physical landscape and makes mountains unsightly. However, the water and air quality in these areas is also affected, and the biodiversity in local deciduous forests is threatened. Lastly, another form of land disturbance that occurs

Teaching Tip

Your students likely know that burning fossil fuels produces "pollution" or "bad gases," but they may need additional help understanding carbon dioxide as a gas, how it comes from burning fuels, and what happens when too much enters our atmosphere. You may consider showing the following series of short clips from National Public Radio (NPR), *Global Warming, It's All About Carbon,* that discusses carbon and its role in global warming: http://www.npr.org/templates/story/story.php?storyId=9943298

Consider watching only one or a few at a time, depending on where you are in your discussion of carbon and greenhouse gases. Be certain to discuss each clip before moving on to the next one.

Case Study

Pros and Cons of ANWR Drilling

Each energy source has environmental impacts, but the environment is not the only dimension considered by decision makers when defining policy. Costs to the environment, costs to local cultures and communities, and financial investments and gains, influence the decision-making process. Approaching any of these energy sources through the analysis of pros and cons is an excellent way to help your students understand the complexity of the energy debate.

Opening the Arctic National Wildlife Refuge in Alaska (ANWR) for oil drilling has been a heated political debate in the United States for more than 30 years. ANWR was established in 1980 as the largest protected wilderness in the United States, comprised of 19 million acres (Mitchell 2001). Following is a list of pros and cons to drilling in ANWR. For more information on the ANWR drilling debate, visit http://ngm.nationalgeographic.com/ngm/data/2001/08/01/html/ft_20010801.3.html.

This map shows the location of the Arctic National Wildlife Refuge (ANWR) and the National Petroelum Reserve-Alaska (NPRA) on the northern slope of Alaska.

The pros and cons model can also be applied to many of the other energy sources discussed in this chapter, such as the impact of hydroelectric dams on fish populations and the impact of wind turbines on birds and bats.

PROS

- Tapping open what could be the greatest onshore petroleum reservoir in the United States
- Could produce between 4 and 12 million barrels of oil, which translates into billions of dollars in revenue
- Could help reduce the U.S. dependence on foreign oil
- Using advanced technology, such as multilateral and directional drilling, can help reduce the impact
- Would represent more jobs for Americans
- Alaska residents would be rewarded with an increased annual dividend from oil-lease revenues
- Economic benefit would also help many Inupiat

CONS

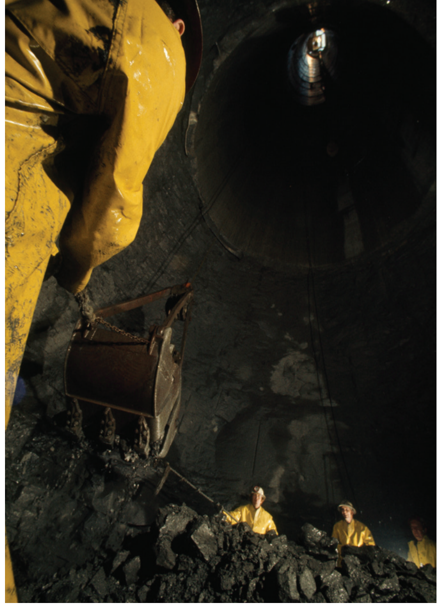
- Forever changing the balance of the biological center of one of the largest natural protected areas on the planet
- Uncertainty as to how much oil can actually be extracted
- Reduction of U.S. oil imports would be less than 10 percent
- More than 200 species of birds and mammals, including the caribou, would be adversely impacted by the construction of necessary infrastructure, including roads, airstrips, and drilling pads
- Oil exploration could also displace maternal polar bears and their newborn cubs from their winter dens
- Drilling operations would disrupt wilderness migration from two adjacent Canadian protected areas
- Gwich'in Indians, who depend upon caribou hunting as a source of protein in their diets, would be negatively affected

with underground mining is **mine subsidence,** in which the empty space left by the mine causes the ground level to drop (World Coal Institute 2010).

In addition to greenhouse gases given off by burning coal, coal mining generates large amounts of waste materials. One form of waste is known as **Acid Mine Drainage** (AMD), which is sulphuric acid created when coal is exposed to air and water. The resulting runoff ends up in rivers and other bodies of water and is toxic to aquatic life. These chemicals become biomagnified—they grow in concentration at each trophic level of the food chain—and may affect humans who consume the fish and drink the water.

Another pollutant generated during coal mining is methane (CH_4), a greenhouse gas that is 23 times more potent than carbon dioxide in terms of its heat-trapping ability. Methane is generated during the natural formation process of coal and then released by humans during mining operations (World Coal Institute 2010). Both coal and oil extractions release methane into the atmosphere.

The environmental impacts of coal mining affect the miners directly as



Debris is cleared from a deep coal-mining operation in Alabama.

well. Miners are exposed to toxic fumes and gases and may develop respiratory diseases, including black lung disease, emphysema, and chronic bronchitis. Other environmental health issues affecting miners include heatstroke, exhaustion, and noise-induced hearing loss. Your students may have heard about sending canaries into coal mines. Throughout history, people have used living things as early indicators of potential threats to human safety or health. Canaries were once sent into coal mines to detect the presence of methane or carbon monoxide gases. If the canaries sang, the mines were safe. If the canaries died, that indicated the mines were unsafe, giving miners an early warning to get out of the mines. These types of animals have been called animal sentinels because they are used to warn humans of dangers.

Natural Gas. Natural gas, which is mostly methane, is often considered the cleanest of all fossil fuels. And just like other fossil fuels, it is a nonrenewable resource that forms over millions of years as layers of buried plants and animals undergo extreme pressure and heat. Beyond the common household use for heating and cooking, natural gas is burned to generate electricity. When analyzing the entire power production process from natural gas—from extraction and treatment, transportation to the power plants, and combustion to boil water and move turbines to generate electricity—we find environmental impacts at each of these steps. From the moment of extraction and later with the construction of the power plants, natural ecosystems and the animals and plants in them are impacted through erosion, landslides, and loss of soil and plant cover.

Methane is a primary component of natural gas and can be released into the atmosphere through leaks occurring during transportation. Nonetheless, the biggest environmental impact occurs at the power plant, where the natural gas is burned to move a turbine that generates electricity either directly or by boiling water to produce steam. Burning natural gas, like any other fossil fuel, produces carbon dioxide and nitrogen oxide. Release of other chemicals, such as mercury and sulfur dioxide, are not significant.

According to the Environmental Protection Agency (2007), natural gas produces an average of 1,135 pounds per Megawatt hour (lbs/MWh) of carbon dioxide, 1.7 lbs/MWh of nitrogen oxide and 0.1 lbs/MWh of

Teaching Tip

After learning about the environmental impacts of different energy sources, this may be a good time to discuss the safety of different energy sources. For instance, you could have students research accidents such as the mining incident outside Copiapo, Chili, the Deepwater Horizon oil rig explosion, or the nuclear meltdown a the Fukushima nuclear plant following the 2011 earthquake and tsunami. Students may have heard about these accidents in the news, and taking a closer look at different accidents may help them make sense of what they have heard. Discuss pros and cons of each energy source, people's need for energy, and the economy of these businesses.

sulfur dioxide. As one can see, natural gas produces much more carbon dioxide than either nitrogen oxide or sulfur. When we compare the average emission rates of pollutants from burning natural gas with those from coal, we find that coal produces more than twice as much carbon dioxide, three times as much nitrogen oxide, and 100 times more sulfur dioxide.

Out of the two methods used to generate electricity through the combustion of natural gas, direct combustion turbines use almost no water. However, the more common gas-fired boiler method requires large amounts of water, which is taken from nearby **aquifers,** and impacts aquatic life and the wildlife and human communities that depend upon these resources. Similarly, after recycling the water several times, pollutants concentrate in the water. While most of these wastewaters are treated, the discharged areas that receive the wastewater can still be altered by changes in water chemistry and temperatures.

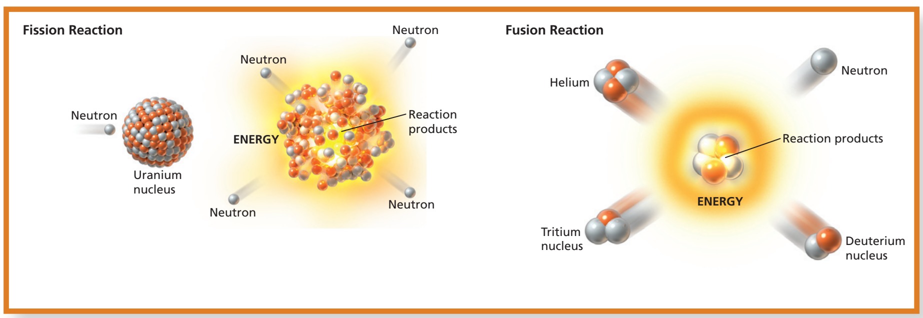
Nuclear Energy. Nuclear energy has been surrounded by controversy over the years. Proponents claim that it is a low-carbon option that compares to renewable energy sources. Opponents contend that nuclear energy is dangerous to humans and the environment and are concerned with the radioactive waste generated by it. Nuclear energy is a nonrenewable source of energy that originates through fission, or the splitting of uranium atoms. The energy released by fission is used to create steam, which in turn, is used to move a turbine to generate electricity. Nineteen percent of the electricity used in the United States is generated using nuclear energy. In California, the percentage of energy from nuclear power was 12.9 percent in 2006 (EEI Energy Resources Map).

AIR EMISSIONS

Fuel Source	Carbon Dioxide lbs/MWh	Nitrogen Oxide lbs/MWh	Sulfur Dioxide lbs/MWh
Coal	2249	6	13
Oil	1672	4	12
Natural Gas	1135	1.7	0.1

Uranium, the chemical element used in nuclear energy, has to be extracted from underground and open-pit mines. Once extracted, the uranium ore is processed into a concentrated fuel through a process known as **uranium enrichment,** which produces radioactive waste. At the nuclear power plant, the enriched uranium is used in a chain reaction to generate steam, which is used to move a turbine and generate electricity.

Every couple of years, the used uranium has to be replaced. The spent fuel is now radioactive waste and must be safely stored. The U.S. produces about 2,000 metric tons of radioactive waste per year, which is stored at the same nuclear plants that generate it. This is roughly equivalent to 4.4 million pounds of radioactive wastes produced each year! The radioactive waste is stored using two methods: In concrete containers, reinforced with steel inner canisters or in water-filled vaults that are made of concrete and lined with steel. Over time the radioactive wastes become harmless through decay, but this may take thousands to hundreds of thousands of years. Long-term disposal of this waste will require a deep geological repository.



Nuclear power plants use fission or fusion reactions to create energy. This power plant is located at Three Mile Island in Middletown, Pennsylvania. Nuclear energy is nonrenewable because it requires materials, such as uranium, that are limited in supply.

The areas where radioactive waste is stored can be contaminated, affecting the water and land with toxic by-products, as well as the natural habitat for plants and animals. Another way that habitat can be impacted is during the mining of uranium, which not only disturbs the land, but also releases fossil-fuel emissions into the atmosphere (Environmental Protection Agency 2008).

Renewable Energy: Pros and Cons

Wind Power. Wind energy is considered to have the lowest external costs when compared to nonrenewable sources, such as coal and oil, and even when compared to other renewable sources, such as biomass, hydropower, and photovoltaic, according to a European Commission report (2003). The report determines external costs by considering global warming, loss of biodiversity, crops and building damage, and human-health impacts.

Electricity generated through the harvesting of wind power emits no greenhouse gases. The only carbon footprint generated is during the production of parts and assembly and during the transportation and installation of the wind turbines. Various studies have calculated that the energy invested in this process is paid back within a few months and usually not longer than a year (Lenzen and Munksgaard 2002).

There are, nonetheless, environmental impacts from harvesting wind power. Simply building large wind farms in prairie and desert ecosystems disrupts the natural system, placing some species (e.g., desert tortoise, prairie chicken) at risk. The one impact that has caught the attention of conservation biologists around the world is bird and bat mortality caused by wind turbines. Nonetheless, a recent study (Sovacool 2009) shows that fossil fuels are to blame for 10 times more bird fatalities than wind energy. These deaths occur mostly because of habitat alteration, pollution, and open-pit mining. And while each wind turbine kills an average of four birds per year (Marris and Fairless 2007), this only represents a tiny percentage of the number of bird casualties by human activity, especially when compared to birds killed by airplanes, cars, and domesticated cats.

In contrast, the number of bat fatalities is considerably greater than that of birds. A study conducted by Bat Conservation International in Pennsylvania and West Virginia in 2004 reported more than 2,200 fatalities by 63 turbines in a six-week period (Arnett and Wallace P. Erickson 2005). Risk varies by species of bat and migration period. Fatalities are caused either by direct impact with the turbine blades

Teaching Tip

Your students may have heard that nuclear power is dangerous, relating these power plants to nuclear bombs or nuclear waste. In actuality, there have been few historical instances of accidents at nuclear power plants (e.g., Chernobyl). There are many checks and balances built into the use of nuclear power plants. This may be a good time for your students to research—both online and at a library—these checks and balances and the overall safety of nuclear power. They can use this research to develop an opinion (either written or for a debate) that incorporates their ideas on nuclear power prior to their research, their research findings, and their opinions on nuclear power post research. Websites that may help with this research include http://www.epa.gov/cleanenergy/energy-and-you/affect/nuclear.html and http://www.nrc.gov/ (U.S. Nuclear Regulatory Commission).

Wind farms are typically built in prairie and desert habitats, or around mountain passes, which form natural wind tunnels.

or towers or by what is known as **barotraumas,** which happen when bats suddenly pass through a low air pressure region around the blade tips of the turbine.

Bat fatalities caused by wind turbines can be significantly reduced by two-thirds with simple-but-consistent practices. Two of the most effective practices include stopping or slowing wind-farm operations during times of high bat activity, such as low wind conditions (E. B. Arnett 2009) and placing microwave transmitters on the wind turbines, which deter bats (Aron 2009).

Hydropower. A relatively clean and renewable source of energy, hydropower relies on the kinetic energy from flowing water to generate electricity, which in theory, makes for a very low-impact source of energy. The water used to move the hydraulic turbine that generates electricity is returned to the stream on the other end of the dam; however, the negative consequences of building hydroelectric dams cannot be ignored.

Because hydropower depends mostly on precipitation and elevation changes, the most adequate sites in the United States are those with dramatic changes in elevation and heavy rainy seasons, such as in the Pacific Northwest. The construction and operation of hydroelectric dams affect the rich biodiversity of this region by modifying the natural river systems. This has important consequences in fish and other wildlife populations.

The upside is that there are virtually no greenhouse gas emissions while operating a hydropower plant because no fuels are burned. One rare exception occurs when the riverbanks of a site selected for a hydroelectric dam are covered by abundant vegetation. Once the area upstream from the dam is flooded, the plant matter can decay underwater, releasing methane.

Teaching Tip

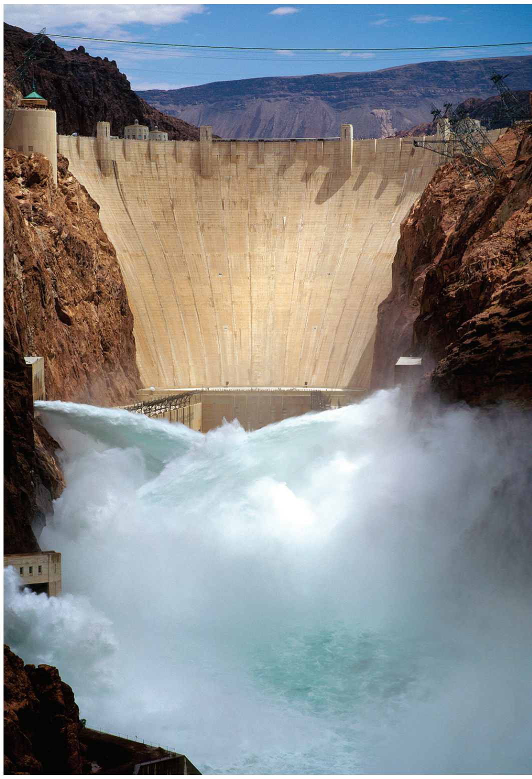
Now, more than ever, in the era of climate change and sustainable development, we need to prepare our students to analyze each environmental problem from a holistic perspective and understand the trade-offs of every potential solution. Engage your students in a discussion by asking the following questions:

- Is it worth the sacrifice of thousands of birds and bats every year to secure a cleaner source of energy? Why or why not?
- What other solutions could be used to reduce bird and bat loss and still develop clean wind power?
- Are there places where wind power should not be used?
- Why is it important to consider all of the effects and trade-offs of any solution to an environmental problem?

As an extension to this discussion, you may consider framing this lesson into a debate format, with half of the class acting as proponents of wind power and the other half as opponents of wind power. Be certain to give each side ample time to back-up their opinion with evidence.

Another important change in the flooded area upstream is the habitat condition for fish, because the bottom of the lake is much colder and oxygen levels are much lower than in the flowing parts of the river. Species of fish adapted to survive in a flowing river cannot adapt fast enough to flooded areas. As a result, entire populations tend to disappear over time. At the same time, some of these dams hold the water for long periods, releasing it all at once. This causes sudden floods downstream, erosion, and other impacts to the ecosystem and the water supply that is meant for human use.

One of the best-known examples of how hydropower affects wildlife is that of the salmon populations in the Northwest. These populations depend upon healthy river systems to reproduce successfully. Populations of salmon have been drastically reduced in the Northwest by the extensive series of dams in the Columbia River Basin (Environmental Protection Agency



Hoover Dam is a concrete arch-gravity dam located on the Colorado River on the border between Nevada and Arizona. Lake Mead is the reservoir created by the dam construction.

2007). Dams work as physical barriers, affecting salmon flow both upstream and downstream. The blades of hydropower turbines sometimes can kill salmon returning to the ocean. Salmon also struggle to pass through the dams when swimming upstream to reproduce. Many hydroelectric dams now have specially-designed structures called fish ladders to help salmon continue their journey upstream.

Biomass Power. In recent years, energy from biomass has received a great deal of attention. Biofuels are solid, liquid, or gas fuels derived from living or once-living organic materials. Most often we associate biofuels with ethanol and biodiesel, both of which are derived from plant-based materials. Interestingly, ethanol is actually an alcohol produced through fermentation of plant matter. At present, ethanol is made from starches and sugars in plant material, but new technology is being developed to produce ethanol from fibers and cellulose parts of plants (NREL 2010; learn more at http://www.nrel.gov/learning/re_biofuels.html).

While corn is the iconic biofuel plant, and students likely have heard of using corn to make these fuels, we can actually make biofuels from a number of different plants. Sugar cane and switchgrass are two top contenders. Alcohols, such as ethanol, can be made from fermenting corn, sugar cane, wheat, as well as many natural prairie grasses. Interestingly, switchgrass is a relatively low-maintenance, high-yield crop being considered in biofuel research to produce **cellulosic ethanol.** Switchgrass requires less water, can withstand drought and flooding conditions, requires very little fertilizers and herbicides, can persevere even in poor soil, and can grow virtually in every temperate climate. Furthermore, it yields more potential fuel for less space, meaning that less land would need to be converted to grow the fuel crops.

Fish ladders are structures built to assist fish species (salmon, trout) in migrating past dams to upstream spawning grounds.

Using biofuels can have many drawbacks, one of which is the amount of land that must be used in order to grow the crops. Forests are converted to farms, and then a great deal of water, fertilizers, and energy must be used to sustain those bioenergy crops. Many South American forests, including the Amazon rain forest, are being reduced to make room for biofuel crops. These crops store less carbon and minimize habitats for living organisms. In addition, making biofuels is energy- and water-intensive, sometimes requiring more energy inputs than are offset by using biofuels over traditional fuels. There is added complexity when considering choices to make food for humans and livestock versus using land and crops to make fuels. Nonetheless, new technologies will continue to make biofuel production more efficient and a more viable energy option for our future.

Teaching Tip

It is common for students to only associate fossil fuels with negative impacts on nature, and to think of renewable sources of energy as carbon neutral. It is important to present to them each alternative with their pros and cons and make the case that even when these cleaner sources have a lesser impact in nature, their extraction and use still carry some level of consequence. They will hear this debated as our country starts switching to more renewable forms of energy. Consider using T-charts or other graphic organizers to help students track both the benefits and trade-offs of each energy source. For older students, have students consider benefits and trade-offs from different stakeholder perspectives so that students better understand the arguments made by each stakeholder group.
Following is a link to a site with a variety of graphic organizers: http://www.ascd.org/ASCD/images/publications/books/fisher2007_fig5.5.gif.

Pictures of Practice

Energy From Biofuels

Biofuels come from plants, so they must be good, right? Actually biofuels are a promising energy option for our future, but currently biofuels are very energy- and water-intensive to produce. Students likely are not aware of drawbacks to using biofuels. One starting point for discussing this energy source is to consider how changing land use might impact the environment. While biofuels have additional complications at present, focusing on land use can add a new level to their understanding of biofuels.

Students: Grades 4 and 5

Location: San Diego, California (working class community)

Goal of Video: The purpose of watching this video is to hear students discuss drawbacks to biofuel power.

Classroom Context

Ms. Howard addresses energy concepts with her elementary students across several grade levels. The lesson on biofuels occurred after students discussed fossil fuels, electricity generation, and energy efficiency of lightbulbs. Ms. Howard pulls out cards and images of several resources we get from Earth, using a globe she has modified for the activity. As she pulls out each resource, students discuss what the resource is and whether there are drawbacks to our use of the resource.

Video Analysis

In the video, students discuss drawbacks of biomass power. Biomass power comes from organic materials, such as plant matter. When burned, biofuels give off carbon dioxide and water vapor. Biofuels give off less toxic chemicals than fossil fuels but still add carbon dioxide to the air, and the production of biofuels alters our landscape and requires a great deal of energy, water, and maintenance. Ms. Howard wants her students to understand that biofuels are not simply good options because they come from plants. She wants her students to focus on drawbacks as well, so she pointedly asks them to brainstorm drawbacks. She also asks them to think about negative consequences of planting too much corn in America. Students bring up pesticides, which leads to a discussion of pesticide runoff into the ocean. In the post interviews, students appear to retain much of the pesticide discussion and recognize that cutting down forests is bad, but students still seem to have gaps in their understanding of drawbacks of biofuels.

Reflect

What would be your next step in teaching biofuels?

Students seem to understand that planting crops will require pesticides and take up space where other things could grow. What concepts do they not seem to understand yet? What additional concepts would you teach these students, and how would you plan this instruction?

Student Thinking

Trade-Offs of Energy

Students may evaluate energy sources using black-and-white, or single, perspectives as opposed to evaluating the many trade-offs that inevitably come with each energy system. Fossil fuels easily get a bad reputation because they appear dirty, they smell bad, and power plants have iconic smoke stacks emitting "pollution" into the air. Renewable energy sources often have a good reputation, but students do not recognize that there are environmental impacts to using those as well. An added layer of confusion comes when examining different energy sources from various stakeholder perspectives. Students may question why we don't simply change to renewable energy without having an understanding of some of the unresolved issues associated with these energy options.

	Common Student Ideas	Scientific Concepts
Dirty fossil fuels	Fossil fuels are dirty and give off pollution, making them bad for the environment.	Fossil fuels are a relatively inexpensive and accessible energy source. The pollution of greatest concern is not "dirty." Instead, it is invisible gases that alter temperatures in our atmosphere and can lead to acid rain.
Plants are good	Biofuels are good because they come from plants, and plants are good for the environment.	On the surface, biofuels appear carbon neutral and, therefore, are better than fossil fuels. But cutting down forests and using energy to make biofuels quickly diminishes their efficiency.
Nuclear power is dangerous	Nuclear power plants can explode like nuclear bombs and are dangerous.	Nuclear power provides a great deal of energy, and there have been few accidents because of nuclear power. However, accidents are potentially fatal to many, and we do not have sufficient nuclear waste disposal plans.
Dams are good energy	Dams provide us with water and clean energy because they don't give off pollution.	Dams provide a renewable source of energy and do not emit greenhouse gases, but dams change the natural flow of rivers and threaten freshwater life, as well as the habitats of flood plains. In droughts, dams may be unreliable sources of power.

Ask Your Students

1. What is the pollution given off by fossil fuels? How does this impact the environment?
2. How does changing a forest to a farm to grow biofuels change the environment?
3. How does a dam change a river? Are dams worth changes to the river environment?
4. What is the first thought that comes to mind when you think of nuclear power?

Case Study

Future of the Desert Tortoise

Green energy, green jobs, green economy—sounds ideal. What's the problem? Building a massive array of solar-energy panels seems well-suited to an area that receives sunshine for most of the year, especially an area that many people consider a desolate and barren open space. But for the people who live in the desert communities in southern California and those who study the area, there is more to this issue.

Although the temperature and geography in the Mojave Desert can be harsh, the ecosystem is actually quite fragile. The plants and animals that live in the desert are highly adapted to the fluctuations in temperature and moisture. However, many of the species that live there are on the state's threatened or endangered lists. Perhaps the most well-known is the desert tortoise, formally recognized as threatened for more than 20 years.

The slow pace of the desert tortoise is a key to understanding the challenges it faces. They can live 80—100 years. They don't begin reproducing until they are between 12 and 20 years old and then usually produce fewer than eight eggs. This long period of infertility, coupled with the small clutch of eggs and natural predation, present a survival challenge to the desert tortoise. In recent years, its habitat has seen an increase in population and development from people. Decrease in habitat and increased use of off-road vehicles have killed much of the tortoise population. Because their survival has been so threatened in the wild, several groups have been trying to maintain the species by raising them in their homes, which requires special permits.

Even though the benefits of clean electricity are apparent, the environmental impact on this area could be hugely negative. The Ivanpah solar-power plant will have more than 300,000 billboard-sized solar panels and three 459-foot water towers spread over 3,400 acres by 2014. Because of its potentially negative impact on rare animals, plants, and the overall ecosystem, several organizations became involved in advocating for changes in the initial plant proposal. The California Energy Commission has oversight for licensing

large-scale solar-power plants. The California Energy Commission explained that the best way to avoid conflicts between energy developers and desert tortoises is for developers to choose areas not favored by the animal. Despite the CEC recommendation, BrightSource Energy (the development company) hired scientists to survey the land and scout sites for relocation of the desert tortoise. Past relocation efforts have been met with catastrophic results. In 2008, desert tortoises were relocated to Fort Irwin with more than a 40 percent mortality rate.

It is not easy to balance interests regarding energy projects; therefore, there is much discussion about how to develop this technology in the best way. As it turns out, there are many different interpretations of "best." Given that this endeavor is new, claims about preservation, interference, and mitigation are not backed up with the data that making an informed decision requires. The stakes are high, and the consequences could cause the demise of more species, so it is critical to carefully scrutinize the impacts on the ecosystem.

While it may seem evident to all that we need to continue to develop alternative sources of energy, it is imperative that in our haste we do not abandon the importance of sustaining biodiversity. Humans have a tremendous capacity for creative problem solving when we take time to carefully observe the issues, analyze the situation, and generate new solutions.

Energy By-products: Greenhouse Gases and Climate Change

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."

Thomas Edison, 1931 (qtd. in Gore 2009)

By now it is clear that the current climate crisis has been accelerated by human activity over the last several centuries. While a great deal of the crisis has resulted from the way we have altered natural landscapes, a big portion of the greenhouse gases released into the atmosphere is a by-product of our use of fossil fuels as a source of energy. The problem, in simple terms, is that we are putting gases into the atmosphere that trap the energy from the sun in the form of heat. This is raising the temperature of the planet, and the only way to slow down this process is if we reduce the amount of greenhouse gases we release into the atmosphere and if we figure out ways to remove the gases we have already emitted.

There are six main types of gases that contribute to climate change, though not all of them are considered greenhouse gases (Gore 2009):

- Carbon Dioxide: Carbon dioxide is the biggest contributor to climate change and is the greenhouse gas that is responsible for 43.1 percent of the problem. The main source of carbon dioxide is the burning of fossil fuels to generate electricity.
- Methane: Methane is a greenhouse gas that contributes 26.7 percent to climate change and is much more effective at trapping heat than carbon dioxide. Energy consumption is not the main source of methane, but leaks of natural gas, which consists mostly of methane, contribute to the problem. Another significant source is livestock (cows, for example), as they produce methane when they digest plants.
- Black Carbon: Black carbon is not a greenhouse gas but is a significant contributor to climate change (11.9 percent). Black carbon is released into the atmosphere when people burn biomass (wood, cow dung, and charcoal) or some debris to heat their homes or cook their food. Another source in developing countries comes from the burning of forests to clear the land for farming and cattle-raising.
- Halocarbons: **Halocarbons** are greenhouse gases that represent 7.8 percent of the climate change problem. Even with the Montreal Protocol in place, which calls for a phase-out of ozone-depleting halocarbons such as **chlorofluorocarbons (CFCs),** certain forms are still in use. We use these in refrigeration equipment and production. However, with tighter standards, people have managed to greatly reduce the emission of these gases through the use of aerosol spray cans.
- Carbon Monoxide and Other Organic Compounds: These compounds represent 6.7 percent of the causes of climate change. Carbon monoxide comes from both car exhausts and the burning of biomass.
- Nitrous Oxide: At 3.8 percent, this gas is released into the atmosphere mainly by the generation of human-made fertilizers, which are also energy-intensive to produce.

It is common for students to see the world through the lens of the "good-or-bad" dichotomy. Students may ask, what are good sources of energy? Or, students may define a specific energy source as bad, such as nuclear or fossil fuels, because of their negative image or consequences. Nonetheless, to help students develop the necessary skills to understand and address real-life environmental issues with more than one solution, it is important to break this dichotomy.

For example, it is well known that compact fluorescent lightbulbs (CFLs) use only one-third of the electricity needed by an incandescent lightbulb to produce the same amount of light. It is also well known that CFLs contain mercury, which has stopped many people from using them. What most people don't know is the fact that a household thermometer can have up to 100 times the amount of mercury than that of a CFL. Furthermore, about three times the amount of mercury in a CFL is released into the atmosphere when burning the coal needed to generate the electricity used by an incandescent lightbulb during its lifespan.

COMPARING LIGHTBULBS

Source: Energy Star, 2010

Light Bulb Type	Watts	Hours of Use	kWh Use	National Average Mercury Emissions (mg/kWh)	Mercury From Electricity (mg)	Mercury From Landfills (mg)	Total Mercury (mg)
CFL	14	8,000	104	0.012	1.2	0.6	1.8
Incandescent	60	8,000	480	0.012	5.8	0	5.8

Student Thinking

Greenhouse Gases

Students struggle understanding gases as a form of matter. While they may be able to recite that matter comes in three forms—solid, liquid, and gas—they treat gases as quite different from solids and liquids. It can be a challenge for students to understand that although gases are invisible, they have mass and take up space. Many students have difficulty understanding the effect of greenhouse gases because they don't have a strong grasp of gases as real, tangible materials. When looking at greenhouse gases in particular, they may believe that these gases are bad because they are linked to global warming.

Scenario

You have just finished a lesson on greenhouse gases and want to see if your students learned the main concepts. You ask the class to discuss the following question as a summary to the day's lesson.

Question

Are greenhouse gases—carbon dioxide in particular—good or bad?

Scientific Answer

Greenhouse gases are essential to life on Earth. Greenhouse gases are needed in the atmosphere to regulate temperatures to sustain life. While water vapor is the most important greenhouse gas, carbon dioxide is also important because of its necessary role in photosynthesis. An amplification of greenhouse gases, as is seen today, can alter atmospheric temperatures and raise the global average temperatures.

Student Answers

Sarah: I think carbon dioxide is a bad gas even though it's helping us. So in different ways, it's a bad gas because it does so many bad things to us. But it's helpful if you have the right proportion of it, if you go overboard.

Thomas: I know there are greenhouse gases that aren't necessarily good for us. And a big one I think is carbon dioxide cause it's not that great for us.

Jacob: Because greenhouse gases pollute the world like carbon dioxide.

Joyce: It's good and bad, because trees get carbon dioxide and they need it, and they give us oxygen, but carbon dioxide is also bad because when we inhale it, it's bad for our bodies.

What Would You Do?

1. Many students seem to focus only on the negative aspects of greenhouse gases (or amplified greenhouse gases). Joyce understands the necessity of carbon dioxide for life. How would you reteach the lesson to ensure more students understand the difference between naturally occurring greenhouse gases and amplified greenhouse gases?

Additionally, it is easy for students to feel discouraged when they learn about bird and bat casualties to wind turbines, but when put into perspective, the damage caused by climate change to these animals can be even more dramatic. Yes, all sources of energy have environmental impacts linked to their harvesting and use, and yes, in general, renewable sources of energy tend to be cleaner and have a lower carbon footprint. However, labeling them as the "good" sources of energy is too simple of a statement and diminishes the power of our students to analyze each source objectively, to include all possible environmental trade-offs, and to decide for themselves if an energy source is more efficient and environmentally friendly than others.

Environmental Disasters: When Things Go Terribly Wrong

If there is one thing we can be certain of when it comes to human enterprises, it is that eventually something will go wrong. Even when we take all the precautions and safety measures necessary, accidents happen. Two of the most common energy-related accidents affecting the environment are nuclear disasters and oil spills.

Nuclear Disasters. According to a recent study by Sovacool (2008), nuclear-energy–related accidents account for only 23 percent of the energy-related accidents of the last century. They also account for about 4,000 human fatalities. In comparison, the largest single energy-related accident was at a hydroelectric facility—Shimantan Dam—which resulted in 171,000 deaths when the dam failed in 1975 (Sovacool 2008). Why is nuclear energy perceived as such a dangerous energy source? Perhaps it is because of the potential it has to generate great and long-lasting damage. It is possible that, for this reason, safety measures related to this industry tend to have higher standards than those of other energy sources.

The biggest nuclear accident in the United States was the Three Mile Island Plant incident of 1979, near Middletown, Pennsylvania. No human casualties were reported as a direct consequence of the accident, and environmental and health effects associated with radiation were believed to be minimal.

That was not the case seven years later in another nuclear disaster. The infamous Chernobyl, Ukraine, disaster of 1986 was responsible for the death of at least 4,000 people and the evacuation of 300,000 more. It has been estimated that the amount of radiation released during the accident was 200 times more than that produced by the two atomic bomb explosions in Japan during World War II. The negative effects of radiation were felt all over Europe, where it has been estimated that more than 10 million people may have experienced health problems related to the explosion (Newton 2006). Radioactive contamination also affected agricultural land, polluting the soil, water, harvests, and livestock (Sovacool 2008).

In the Chernobyl nuclear accident, local communities were destroyed and abandoned. This image shows the Chernobyl nuclear power plant facilities in the background and the abandoned community of Pripyat, Ukraine, now being taking over by natural succession.

"We are concerned that the oil is already disrupting with the underwater marine ecosystem. It is virtually certain that fish, shrimp, and many other vital cogs in the web of life are dying underwater, unseen. The loss of these critical sources of food has potentially devastating consequences for both birds and the coastal economy."

Frank Gill, President of Audubon

Oil Spills. The negative effects of oil spills are many, and the risks increase exponentially as reserves are diminished and humans have to go deeper and farther underground to reach oil deposits. Oil spills such as the *Exxon Valdez* oil spill of 1989, and the Deepwater Horizon oil spill of 2010 are two of the most iconic energy disasters in U.S. history. The Deepwater Horizon oil spill was labeled by many experts as the biggest environmental disaster the United States has ever faced.

The most obvious victims of an oil spill are birds. We are all familiar with the images of oil-drenched pelicans. When a bird dives into open water for food, its feathers get covered by oil. The oil separates the feathers, ruining their waterproof feature. The birds' natural reaction is to preen, whereby some oil is ingested that causes poisoning (IBRRC 2010). This affects important species of migratory birds and shorebirds, including the brown pelican, least tern, and northern gannet, which already struggle to survive in an increasingly reduced habitat (Gill 2010). Sea turtles are also affected by direct contact with oil through increased egg mortality, developmental defects, and direct mortality. Oil affects their digestive and immune systems, as well as their blood, skin, and salt glands.

In the case of the Deepwater Horizon oil spill, thousands of miles of shoreline were potentially threatened, including areas of mangrove estuarine habitats. Mangroves have a key role as the interface between land and sea and are extremely important as nursery grounds for marine life. These amazing plants are also very sensitive to oil. Exposure to petroleum can be lethal in a matter of weeks or months. Oil spills also seriously impact another important host of marine biodiversity—coral reefs. Petroleum can severely damage or even kill corals, depending, among other things, on the length of exposure and the amount of oil. Oil toxicity affects the reproduction, growth, and development of corals.

Oil spills also impact commercial fisheries. According to the National Oceanic and Atmospheric Administration, during the Deepwater Horizon oil-spill crisis, 35 percent of the Gulf of Mexico's federal waters were closed to commercial and recreational fishing, due to concerns of oil exposure in fish. Effects on fish exposure to oil include reproductive impairment, reduced potential of spawning success, reduced growth, and other health complications.

It may be many years before we know the true outcome of the Deepwater Horizon spill on the Gulf-coast ecosystems, as well as the Gulf-coast communities.

Teaching Tip

You may consider doing an Internet-based research activity on the Deepwater Horizon oil spill or other oil spills at this point in your lessons. Give students the following five questions to answer regarding the spill:

1. What's happening to the oil that was spilled?
2. What's happening to life on the sea floor?
3. What's happening to the marine life at the ocean surface?
4. What's happening to coastal ecosystems?
5. What's happening to fisheries?

After approximately one to two hours of research, set up five large posters in your classroom, each of which has one of the questions. If students research more than one oil spill, partition off space on the posters. Divide students into five groups, with group one starting at question #1, group two starting at question #2, and so forth. Give students approximately five minutes at each poster station, where they will write phrases or make visuals relating to the questions and to specific spills. Have students rotate to each poster, where they will add information, whether it is in the form of adding information to other students' written words or creating their own statements or visuals. Following are websites that may be helpful for students to obtain answers to the questions:

- National Geographic: http://news.nationalgeographic.com/news/2010/09/100916-sea-snot-gulf-bp-oil-spill-marine-snow-science-environment/
- National Oceanic and Atmospheric Administration (NOAA): www.noaa.gov
- Center for Disease Control and Prevention (CDC): http://www.bt.cdc.gov/gulfoilspill2010/

Aquatic and marine wildlife are often the most affected after an oil spill incident.

In the Classroom

Cleaning up an Oil Spill

Students are probably aware that oil and water form separate layers when mixed together, but they may not have thought of this fact in terms of density or how it influences what happens in real-life oil spills. In this activity, students conduct a simple experiment demonstrating the variable densities of corn syrup, water, glycerin, and vegetable oil. Students will then transfer this concept to an examination of cleanup methods used in oil spills.

Materials

- 1/3 cup (80 milliliters) light corn syrup
- 1/3 cup (80 milliliters) glycerin (available in drugstores)
- 1/3 cup (80 milliliters) water
- 1/3 cup (80 milliliters) vegetable oil (plus more oil for the second part of the experiment)
- 4 small glasses
- 1 tall, clear glass or jar
- At least 3 food-coloring options
- Funnel
- Aluminum pans, spoons, dish-washing soap, extra glasses

Directions

1. Discuss the density difference between oil and water. Which liquid is more dense? Have students make predictions.
2. Conduct a layering experiment using the materials listed. Color at least three of the liquids to make the layers distinct. Add each liquid to a small glass, and then carefully combine the liquids into the tall glass or jar, using the funnel. For older students, consider expanding this layering to include variations in salinity and temperature to show that sometimes salty, warm water layers on top of oil.
3. Ask students to think about the relationship between the demonstration and an oil spill. What do they think happens to the oil that has spilled out of a ship or a well and into the ocean?
4. Ask students to hypothesize how an oil spill might be cleaned up. Do they think that because oil doesn't dissolve into water the cleanup would be easier or harder than if it completely dissolved into the water?
5. Pass out aluminum pans to pairs of students. Pans should be filled with ¾—1 inch of water. Then add several large drops of vegetable oil to the water. Have students experiment with different cleanup methods (spoon acts as a skimmer, dish-washing soap acts as a dispersant). Have students think about the following questions:
   - What does this cleanup method involve? What is done?
   - What are the benefits of this cleanup method?
6. After students explore cleanup methods, have students share their results and trade-offs of different methods.

Discuss

1. Which cleanup method do they think is most effective? Which is the easiest?
2. Which takes best advantage of basic physical properties they learned about in the activity?
3. What are potential drawbacks to using dispersants in our ocean?

The Santa Barbara Oil Spill

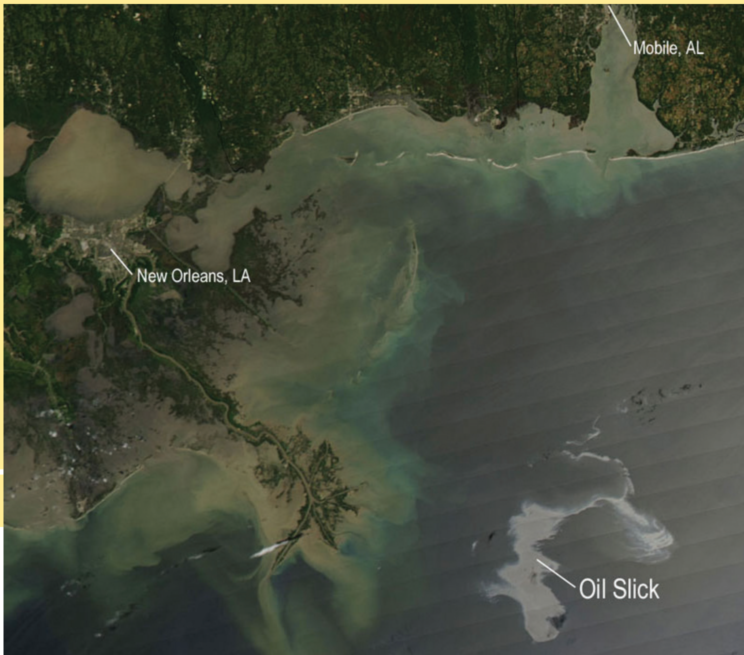
Case Study

One of the worst incidents involving an offshore oil-drilling platform in the United States took place approximately five miles off the coast of Santa Barbara, California, on January 28, 1969. The Santa Barbara oil spill ranks as the third-largest oil spill in U.S. history behind the *Exxon Valdez* spill (second) and the Deepwater Horizon spill (first). A "blowout" occurred as drill bits were being changed on the platform. This resulted in a massive spill (up to 210,000 gallons of oil spilled in the first two weeks); a mix of gas, oil, and mud blew to the ocean surface for several days. The winds, currents, and tides eventually moved this material onshore, so it had a great effect on aquatic organisms and their habitats. Sea walls and buildings onshore became coated with this oil mixture. Birds, intertidal invertebrates, and kelp forests were also destroyed. Additionally, this spill had significant economic effects on the fishing industry. It caused a loss of recreational facilities, and personal property damage (boats, buildings, seawalls) was far reaching as well.

The cleanup after the oil spill involved more than 54 boats, more than 1,000 people, and approximately 125 pieces of equipment. In total, it cost about $4.5 million to completely clean up the Santa Barbara area after this spill. Many people were involved in manually removing the oil that was on beaches and floating offshore by using straw to absorb the oil. Additionally, rocky beaches were cleaned using high-pressure washers, and a mixture of naphtha and talc was used to dissolve the tar-like oil on rocks and sea walls. More than 3,700 birds died as a result of this oil spill as well; in particular, gulls and grebes were most heavily affected. Many people were involved in trying to remove oil from feathers of the birds that were still alive during clean-up.

Other Notable Oil Spills

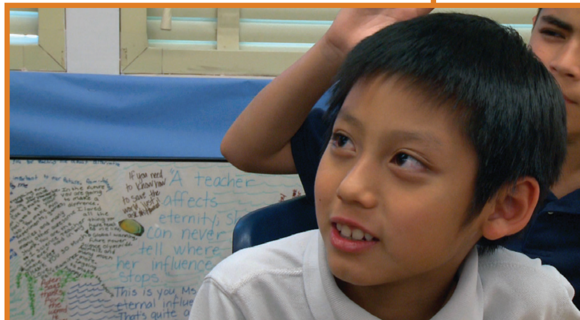
The *Exxon Valdez* Spill that occurred in 1989 spilled more than 10 million U.S. gallons of oil into the Prince William Sound of Alaska. It took many years to cleanup, and its impacts, some scientists argue, are still being felt today. The *Cosco Busan* oil spill, which occurred in 2007 in San Francisco Bay, resulted when a container ship struck the San Francisco-Oakland Bay Bridge. While the spill was considered medium-sized, it resulted in many beach closings both north and south of San Francisco Bay, and affected organisms, including seabirds and seals. On April 20, 2010, an oil spill occurred in the Gulf of Mexico that was much larger than the Santa Barbara, *Cosco Busan,* and *Exxon Valdez* spills. The Deepwater Horizon Spill quantity is estimated at more than 200 million gallons, and its impact—both economic and ecological—will take years to determine. Its restoration will likely take even longer.



Pictures of Practice

Impacts of Using Energy

At the most basic level, students recognize that burning fossil fuels makes “pollution,” but students may not move beyond this basic understanding to develop more sophisticated ideas about energy use, especially as it is connected to large-scale problems such as global climate change and toxins in our food systems. Furthermore, understanding by-products from burning fossil fuels can be confusing because students may not differentiate between “smoke,” “pollution,” “carbon dioxide,” and “bad gases.” Working on improving student understanding of by-products will help students develop more sophisticated ideas about energy impacts.



Students: Grades 4 and 5

Location: San Diego, California (working class community)

Goal of Video: The purpose of watching this video is to hear student ideas about energy impacts on climate change and biomagnification of toxins.

Classroom Context

During one of Ms. Howard’s last lessons on energy, students discuss impacts of energy use, focusing mostly on by-products given off from burning fossil fuels. Ms. Howard gives students a set of cards that are to be ordered in the sequence of electricity generation from coal. At each step along the sequence, Ms. Howard has students discuss impacts to the environment. Students do this activity in small groups first, followed by a whole-class sharing of their ideas.

Video Analysis

In the video, Martinez asks a question about how mercury gets into fish. Mercury can enter the food chain from many sources, but it is often a particulate by-product given off from burning coal. It may enter the air, and precipitation causes the mercury to enter our freshwater and marine systems. The mercury is then taken up by primary producers and moves up the food chain. Living things cannot easily rid their bodies of the mercury. Higher-order consumers typically have higher concentrations of toxins such as mercury. Ms. Howard works on this explanation with Martinez through a one-on-one discussion. Then, during the whole-group discussion, other students bring up the by-product carbon dioxide and its relationship to climate change. In these discussions, students are learning about two negative by-products from energy use—mercury and carbon dioxide. However, in student post interviews we see confusion about these by-products. Esme describes burning coal as giving off “black, poisonous air” that enters our bodies when we breathe. Ezequiel says that burning fossil fuels creates gases that break down the ozone layer. Martinez has developed ideas about mercury as a by-product but seems confused about “smoke” and how mercury is actually given off and enters the food chain.

Reflect

How would you respond to student ideas about the impacts of using energy?

Students seem to understand that there are by-products from burning fossil fuels but seem confused about the different by-products and how they impact our environment. If students shared their interview responses during a whole-class discussion, how would you respond? What would be your next step for teaching this topic?

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5 Energy in Our Human Communities

by Tania T. Hinojosa and Jose Marcos-Iga

Energy enables life on our planet and allows humans to make progress and improve our way of life. But just as energy has moved society forward, the economic and political implications of differential access to energy have brought about negative social unrest around the world. Students may be aware that energy is an environmental issue. They have seen images or heard news about environmental catastrophes like oil spills. Energy, like freshwater, is an excellent context for discussing politics and social unrest caused by human activities.

Energy is an important and complex global and social issue. It may not seem so at the surface. When you flip a switch in your home, the lights come on. The gasoline stations are still filled with gasoline for our cars. Air conditioners run in the summer, and heaters still work in the winter. Life is still happening much as it has been for the last several decades. Yet, a great deal of attention has been given in recent years to the need for a future that relies less on fossil fuels and more on locally available, renewable-energy resources. In fact, students may wonder why people are not simply making the move to new energy resources given all the attention this topic has in the media today.

The present-day energy crisis is about the unequal distribution of oil, electricity, and overall energy resources, as well as the impending depletion of the fossil fuels worldwide. It is also about rising worldwide population, and as a result, increasing use of energy to power consumer-driven lifestyles. As Thomas Friedman describes, we have entered the Energy-Climate Era with the following key issues to tackle: energy supply and demand, petro-dictatorships, climate change, energy poverty, and biodiversity loss (Friedman 2008). This chapter takes a closer look at several of these issues, focusing mostly on social politics around energy use and what your students may or may not understand with respect to this topic.

GRADE	STANDARD	EEI UNIT
Grade 3	3.4.1-2 3.5.1-3	California Economy—Natural Choices
Grade 4	4.5.3	
Grade 5		
Grade 6	6.6.a	Energy: It's Not All the Same to You!
Grade 7		
Grade 8	8.12.1	Agricultural and Instustrial Development in the United States

Energy in Changing Communities

Our current dependence on fossil fuels can be traced back to the **Industrial Revolution,** which started in Western Europe and the United States in the late 1700s and continued through the late 1800s. Societies in these areas shifted from an agriculture-base to an industrialized one. In traditional agricultural societies, people were responsible for harnessing their own energy. Traditionally, they used renewable resources such as wind and water or by burning plant-based materials such as wood or charcoal. When coal mining advanced and oil was discovered, people were able to use energy more effectively for heat, mechanical power, transportation, and electricity. These fossil fuels supported a newly industrialized society. The industrialized areas became dependent upon fossil fuels, which had widespread and enduring impacts on lifestyles in those nations.

Industrialized cities were associated with wealth or opportunity, so people migrated to cities to make money, often by working in factories. Work opportunities were readily available. Rural life became less attractive to many, and others were forced to move to cities for job opportunities. Until recently, the fossil fuels powering the industries seemed to be an endless and relatively harmless source of energy.

Meanwhile, much of the world lagged decades to centuries behind Western Europe and the United States in terms of industrialization. Some areas, such

CHAPTER OVERVIEW

Since the Industrial Revolution, humans have become dependent upon high-quality energy to power our everyday lives. Obtaining and processing energy sources comes at a cost, as energy resources are not equally distributed around the globe.

People in rural areas of the developing world have little access to energy, even if energy resources are readily available in their countries—a condition known as energy poverty. This is true in developed countries such as the United States as well, as mining towns have some of the highest poverty rates in the nation. Richer countries and communities often pay top dollar for energy resources, taking them away from local people who need them. Energy poverty limits economic opportunities, leads to environmental destruction, and continues the cycle of poverty. This is also an important issue that relates to environmental justice.

The United States is incredibly dependent upon foreign oil, making our nation susceptible to issues of petropolitics, such as oil embargoes, and prompting involvement in the political issues of oil-rich nations. As 21st-century citizens, we must consider the global political issues related to our energy consumption.

as in the Middle East and Africa, were found to be rich in energy and mineral resources such as oil, copper, and zinc. Industrialized nations, which had already been claiming colonies in developing areas, began to extract their natural resources. For the most part, however, even resource-rich developing countries did not begin to industrialize until much later. Resource extraction in both developed and developing nations results in environmental concerns and also in social issues. For example, many countries in Africa deal with violence surrounding the charcoal trade. Now, as the value of fuel rises, social unrest in some of these developing countries has increased. Industrialized nations are starting to question the future of energy—will the cost continue to rise? How accessible will these fuels be in the future?

Interestingly, students may not recognize that rural or agriculture areas, especially in developing nations, do not have access to energy as most Americans do today. They may believe those communities do not want or need energy. Yet, many of those communities struggle to survive because they do not have the necessary energy resources they require. Imagine life without energy to pump water into our homes. Imagine not having electricity or gas to cook food or boil water. While communities in developing nations appear to need little energy when compared to U.S. lifestyles, even some of the most basic energy needs are still not met.

Teaching Tip

Ask your students to share what they know about the energy needs of industrialized versus developing nations. Create one class list of all the things than a U.S. family needs energy to do. Then, ask students to brainstorm a list of things a family in rural Africa might need energy to do. This family might farm and/or raise livestock. Compare both lists.

Then, share the following data with students:

According to the World Bank, America uses more than 7,000 kg of oil per person, per year. Compare this to countries such as the Sudan (about 350 per capita), Nigeria (about 750 per capita), or Tanzania (about 450 per capita). Ask your students the following questions:

- What do you think about the difference of oil use in America and African nations?
- How would your life be different if we used much less energy?
- What if everyone on earth consumed as much energy as Americans?

Running Out of Control—And Just Running Out

The inexpensive and widespread access to fossil fuels for industrialized nations has resulted in extremely heavy use of Earth's finite resources. According to the World Bank, the United States uses more than ten times the energy per capita than many African nations. Over time the American way of life has shifted to a new standard of living the relies heavily on energy even for the most conscientious of consumers. Some consumers feel entitled to this level of energy use even when they urged by power companies to conserve energy. People around the world are looking to this lifestyle as one of prosperity and success as opposed to overuse or unsustainable use of resources. Consider discussing with students: What would we do if all people around the world had the same lifestyle as Americans or other industrialized countries? How would our power companies manage the demand for fossil fuel energy? How long before we would run out?

As different businesses flourished around the world, they began to need services or products from other countries around the world. Aided by international treaties that allowed for free trade of goods and services between nations, a trend started that changed the world forever—a trend we now know as **globalization.** Globalization describes the way regional or local economies and cultures become more integrated into a global community. Globalization made it clear that access to goods, wealth, and comfort was achieved only with access to energy. Today, many of the poorest parts of the world do not have access to oil, coal, or other means to produce electricity, which in turn limits their access to food and clean water sources. Friedman describes this situation as **energy poverty** (2008). Unlike energy-poor nations, countries with access to oil have great power to change the economic and political agenda of nations around the globe. Friedman uses the terms **petropolitics** and **petrodictatorships** to capture the idea that fossil fuels are inextricably linked to the way politics work today. Let us take a closer look at both energy poverty and petropolitics.

Energy Poverty: Is Energy a Right?

One glimpse of satellite imagery of our planet at night shows the world's uneven distribution of energy, or more

The Earth at Night shows clear distinction between the energy haves and the energy have-nots. View more images at NASA: http://visibleearth.nasa.gov/view_detail.php?id=1438.

specifically, electricity. Show your students an image of Earth at night and see what conclusions they can make about haves and have-nots when it comes to energy. They should notice that vast areas are completely dark, where others are shining brightly. If we carefully observe, Africa is one of the darkest areas on the globe, and other dark areas are found in Asia and South America. It could be argued that the darker areas could be undeveloped and pristine natural areas, but sadly, that is not necessarily the case. In fact, many poor, rural communities depend upon unsustainable sources of biomass for their energy. Do your students know where some of these rural communities are located in the world?

The concept of energy poverty might be difficult to understand for American students who have grown accustomed to access to electricity on demand. Even given our energy-rich status in America, we still find energy poverty in areas with low household income (Power 2010). For the most part, though, industrialized countries such as the United States have had the benefit of energy access and have developed infrastructure to deliver that energy to their citizens. In developing countries the situation is different. Households in the slums and rural areas of developing nations are, in most cases, not connected to the grid. If they are connected, it is highly probable they would experience rolling blackouts or outages caused by insufficient generation of energy or inadequate infrastructure. In these countries, power plants can be insufficient to fulfill energy demands. This is also true in some regions in developed countries.

The most important thing to understand about energy poverty is that it limits economic growth and "perpetuates social inequality" (Friedman 2008). People living in poverty can become even poorer without access to clean water, health care, and connections to the rest of the world that allow them to learn at the same pace as those in industrialized societies. Education, health, industry, and agriculture problems will not be solved as long as a region or a country is energy poor. These are some of the energy issues that define the present situation in energy poor areas:

- Countries in Africa, especially in rural areas, depend on charcoal, which causes deforestation and spurs violence due to the illegal charcoal trade. Trees are cut down and the wood is buried and burned underground. Burning the wood without access to oxygen forms charcoal, which is a valuable commodity.
- Natural resources obtained for the generation of energy are exported rather than used for domestic purposes.
- Schools, hospitals, and small businesses do not have the advantage of regular power supply and tend to face power outages that obstruct basic services for the population.
- Poor communities not only have limited access to energy, but also may be on the receiving end of pollution. This is a matter of environmental justice. The public health in these areas may suffer from both water or air pollution, even in developed areas of the United States.

Energy poverty is common among many nations and many communities within Africa. Corruption, lack of management, and endless wars can cause or exacerbate unequal access to energy sources. In addition to all this, Africa is fossil-fuel poor relative to other regions around the world. There are not enough fossil fuels to generate energy for the entire continent, and the oil and coal they have are controlled by elite, wealthy businesses. African countries cannot compete financially for fossil fuel resources when they are bidding against wealthier countries.

It is a complex scenario with no simple solutions. Many of these communities are learning to meet their energy needs by bypassing fossil fuels altogether and using renewable energies, such as solar, wind, and hydropower. While these countries are energy poor by U.S. standards, they are some of the best examples of countries going green!

Energy also flows across borders in complex ways. For example, the United States receives much of its natural gas through pipelines from Canada and Mexico. Interestingly, the United States also exports natural gas to Mexico. Moving energy across borders brings into question whether citizens are aware of imports and exports of energy and whether energy-poverty countries have the same voice compared to citizens in the energy-hungry countries. Encourage your students to consider the idea of energy poverty, and how it plays out both in the United States and across the globe.

Pictures of Practice

Energy Across Borders

Students: Grades 4 and 5

Location: San Diego, California (a coastal community)

Goal of Video: The purpose of watching this video is to hear students discuss buying natural gas from Mexico.

Students may not realize where their energy is obtained—from the cars they ride in on their way to school to the electricity that powers their televisions and computers. Yet, much of the energy resources we use everyday may come from places far away. Like many resource issues, energy resources can create problems between two countries. When energy is extracted in one country to sell to another country, the benefit may not be equally distributed to the people of both countries. Relatively poor countries may sell their energy resources to wealthier countries to bring in revenue. The citizens of the poor countries may not have a say in how this exchange happens, while the citizens in the wealthier countries are likely unaware of the inequity that may occur. This phenomenon is also true within the United States. For example, West Virginia is one of the most energy-rich areas of the nation, yet the state's residents are among the poorest in the nation.

Classroom Context

Ms. Howard addresses energy concepts with her elementary students across several grade levels. Ms. Howard pulls out cards and images of several resources we get from Earth and uses a globe she has modified for the activity. As she pulls out each resource, students discuss what the resource is, and whether there are drawbacks to our use of the resource. When Ms. Howard pulls out the natural-gas resource card, she introduces the controversy over natural gas from Mexico and probes one student's—Ezequiel—ideas about the issue.

Video Analysis

Ms. Howard pulls out the natural-gas resource card and introduces the controversy of getting natural gas from Mexico. Ms. Howard says that San Diego is piping in natural gas from Mexico and asks her students what they think about the issue. Interestingly, this is not a one-sided issue. While Americans import natural gas from Mexico, Mexico also imports natural gas from the United States. Canada is also a major importer and exporter of natural gas in North America. Thousands of natural gas pipelines run across the borders between countries, especially between Canada and the United States (see more information at http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/impex.html). However, Ms. Howard brings up an interesting question about whether Mexican citizens and U.S. citizens voted on sharing natural gas resources across borders. One student—Ezequiel—says that they made a border between Mexico and the United States for a reason. Ms. Howard, Ezequiel, and the class also discuss why Mexico might sell natural gas to the United States in order to get money.

Reflect

What issues would you teach about social inequalities of energy?

Buying energy resources from other countries, whether it's Mexico, Canada, or overseas, can be a confusing topic for students. However, as the world becomes more globalized, our citizens will need to be more aware of energy flowing across borders, global or local, and the effects on people on both sides. How would you introduce this topic to your students? What concepts would you focus on, and why?

Case Study

The Charcoal Trade and Social Unrest

Charcoal has played a major role in energy history and has been a mainstay in African culture. Charcoal is essential to cooking or heating in many countries in Africa. For thousands of years, biomass, such as wood and charcoal, has been the most essential source of energy for rural communities. These sources of energy allowed for heating, lighting, and cooking, as well as other nonessential activities important to the development of the local cultures (e.g., firing of ceramics and metalworking). Today, charcoal is produced by cutting down trees and bushes, and placing the pieces into a pit in the ground. The wood is then lit and buried with sediment, depriving the fire of oxygen. The resulting material is charcoal.

Several countries in Africa that have been heavily militarized are dealing with armies that control the protected national-park areas and also control the illegal charcoal trade. Such is the case in the Democratic Republic of the Congo, where dense forests in protected parks are rapidly disappearing to fulfill the growing demand for charcoal. Since civil war officially ended in 2003, profits from charcoal and firewood have increased. Farmers would rather cut down trees for the production of charcoal than wait for two years to harvest food. This is turning many forested regions of the country into deserts (Lovgren 2007).

The majority of the population have to rely upon charcoal for cooking and heating, so the illegal trade of charcoal is a lucrative business, especially for military personnel who are sent to patrol the forested areas and do not receive pay for their work. This illegal trading, in turn, creates unsafe communities. Park rangers cannot perform their jobs because anyone acting against the illegal charcoal trade is physically threatened or thrown into jail.

Wildlife has been impacted as well because conflict over charcoal occurs in forested, mountain areas where gorillas and other endangered species reside. Park rangers, charged with enforcing park regulations and protecting wildlife, often risk their own lives trying to safeguard gorillas. For example, at least 150 rangers from the Congolese national wildlife service have been murdered in the last decade (Raffaele 2007). Seemingly endless human conflict in the eastern Congo region makes it hard to pay attention to preservation of forests and wildlife. While Americans and others around the world want to protect gorillas and other imperiled species, **refugees** fleeing conflict are more concerned with meeting their daily needs for food, water, and shelter. The people need energy for cooking and boiling water—energy that charcoal can supply. Unfortunately, the very same groups that forced entire communities out of their homes in the first place also control charcoal trading. Profits from the trade go back into fueling the war (McConnell 2009).

Two other detrimental outcomes from this system are air pollution and depletion of natural resources. The production and use of charcoal generates air pollution, and more people are becoming ill and dying as a result of poor indoor-air quality. Women and children are the most affected by poor air quality in the homes, which is now one of the leading causes of death in Africa, after malnutrition, AIDS, and water pollution.

Most people participating in the charcoal trade are likely unaware of the environmental consequences of such a system. Such communities are likely open to alternative sources of energy—sources of energy that are reliable and reduce dependence on the corrupt charcoal-trade system. The solutions for these communities must look toward renewable, portable, and inexpensive energy for all people.

In the Classroom

Energy Use in the Americas

In this activity, students will discuss energy consumption in North, Central, and South America. They will also use technology to research leading countries of energy consumption and then graph, map, and analyze the information.

Country Name	Total Population	Energy Consumption (kg of oil equivalent per capita)
Canada		
United States		
Mexico		
Brazil		
Chile		
Columbia		

Materials

- Pen/pencil
- Computer lab/Internet access
- Energy Consumption chart/worksheet
- Map of the Americas (North, Central, and South America)

Directions

1. Distribute and discuss components of the Energy Consumption chart/worksheet.
2. Have students circle the two countries they anticipate will have the highest energy consumption.
3. Allow students to access the Internet, and guide students to the following website to find information for completing the Energy Consumption chart/worksheet.
   a. Source: http://www.google.com/publicdata/directory
   b. World Development Indicators → World View → Total Population
   c. World Development Indicators → Environment → Energy Use (kg of oil equivalent per capita)
4. Have students fill in their charts and compare their answers to a neighbor in order to verify that they have recorded the correct information.
5. Prompt students to graph all columns as they find information for each country. NOTE: This will be done automatically on the screen for each data set. Students may print the screen or sketch each onto the back of the worksheet page.
6. Once everyone has finished, ask students to rank the countries in order of overall consumption (#1—highest, #5—lowest) and label each on a map of the Americas.

Discuss

1. What are the two highest energy-consuming countries in the Americas? Were your initial predictions correct?
2. What do you notice when you compare each country's population size to its consumption? What about its population size compared to its area size (using a map)?
3. Are there any patterns you recognize in the chart, graph, or map data?
4. If countries in Africa and Asia were included, how would their numbers compare to your findings?

Case Study

Peak Oil

The amount of crude oil extracted from our planet has been rising for the past 150 years. This rise in extraction can't continue forever, simply because oil is a nonrenewable resource, meaning Earth holds a fixed quantity of oil.

If people continue burning oil, eventually the store will be depleted. It will not run out suddenly, in the same manner as a car that is driven until its gas tank runs dry and then sputters to a stop. Instead, most experts expect the world's oil extraction would gradually rise over many decades, reach a peak, and then gradually decline over many more decades. The pinnacle, the point of "peak oil," would mark a crucial turning point—the dividing line from an era when the world had more and more oil over time, to an era when it has to get by with less and less all the time.

U.S. Peak in Crude Oil

Crude oil extraction in the United States has followed this pattern of a rise, peak, and decline. The first U.S. oil well was drilled in Pennsylvania in 1859, and this country soon became the world's biggest oil producer, a title it held for more than a century. A graph of the whole history appears like a mountain, with the maximum rate of oil extraction—nearly 10 million barrels a day—in 1970.

Since the 1970 peak, more than 600,000 new oil wells have been drilled in the United States, but crude-oil extraction has declined decade after decade. This is partly because most new wells are reaching smaller or more remote oil fields. In 2010, the United States extracted about 5.5 million barrels a day, a little more than half as much as at the 1970 peak (EIA statistics).

World Peak in Crude Oil

The world appears to have reached the peak of crude-oil production in 2006 (International Energy Agency 2010). Since that date, crude-oil production has been flat, neither rising nor falling. Meanwhile, the price of oil quintupled from 2000 to 2008, reaching an all-time high of nearly $150 a barrel. Since then, prices have remained high, averaging about $100 a barrel in 2011.

New Sources of Liquid Fuels

Since passing the U.S. production peak in 1970, some giant oil fields have been discovered and tapped—such as in Prudhoe Bay, Alaska. Also, development of technologies, such as ultra-deepwater drilling, has allowed oil companies to gain access to "extreme oil"—deposits that had appeared before to be too difficult or too expensive to tap (Strahan 2009). Examples of ultra-deepwater drilling in the Gulf of Mexico include the floating production platform Perdido, which operates in 8,000 feet of water, and the Deepwater Horizon drilling rig that had reached a drilling depth of 13,000 feet into the seabed when the Macondo well blew out, causing an explosion and the eventual sinking of the 58,000-ton mobile rig.

In the meantime, the oil producers are boosting the amount of gasoline and diesel from sources besides normal crude oil. For example, the United States may be able to increase its extraction of oil a bit in the coming decade, primarily by using a technique known as hydrofracturing, or fracking, according to the U.S. Energy Information Administration. This process uses water to move petroleum deposits into more extractable areas. Fracking is controversial due to concerns over contamination of local water supplies. Fuel companies could also produce more liquid fuels by turning coal into liquids or by mining a black rock known as kerogen (more commonly known as tar sands) that can be cooked to make it release oil (EIA 2011). However, these unconventional technologies may have more environmental impacts than extraction of regular crude oil and have been more expensive to use to this point.

The production of all kinds of liquid fuels may also reach a peak in the next half-century, with the most pessimistic predictors saying it could come by 2020 (Hirsch 2007). One of the most optimistic forecasts is from oil historian Daniel Yergin, who foresees a peak around 2050 (Yergin 2011). Petroleum in all its forms is a nonrenewable resource and, therefore, won't be around forever.

Petropolitics: Oil and Politics Don't Mix!

Have you ever heard the phrase, "independence from foreign oil?" This phrase has been used ubiquitously among politicians in the United States. What does it mean to depend upon foreign oil, and why do we need to become independent? Unfortunately, Earth's oil deposits are not equally distributed around the globe, and therefore, relatively few nations hold the major sources of oil for all the others. Given the high demand for this resource, rich oil deposits and weak political stability in some countries have caused petrodictatorships to develop—dictatorships that control much of the world's oil so that many countries are affected.

Petro is another word for *oil,* so when added as a prefix to words such as *dictatorship* or *politics,* these words take on new meanings. *Petropolitics* describes the political arena around global oil distribution. *Petrodictatorships* describes countries with leaders who control not only the rights of their own citizens, but also exert great influence upon countries around the world through the oil industry.

Experts agree that petroleum is reaching its peak, or the maximum production rate of its supply. Once the peak has passed, the rate of production enters decline. This is hard for economies such as the United States that depend upon oil for their growth, but also for developing countries that rely upon oil for meeting their basic needs. Gas prices increasing and policies allowing for offshore drilling are signs of the times we are living. We always need more oil and are in constant search of it in places previously off limits, such as the Arctic National Wildlife Refuge (ANWR). Citizens are discovering that the true price of our oil addiction is not necessarily paid at the pump.

Thomas Friedman (2006) describes an interesting relationship between the price of oil and the pace of freedom. He calls this the first law of petropolitics—that in countries rich with oil resources, the freedom of local people diminishes as prices for crude oil rises. Leaders in these countries become more confident and more controlling when the world depends upon them to supply crude oil. The law also works in the opposite direction. If oil prices drop, then leaders in oil-rich nations lose their stability (or control) and become more vulnerable to opposition and outside voices.

One interesting dimension of petropolitics happens when a powerful nation, such as the United States, which is dependent upon foreign oil, interferes in the affairs of oil-rich nations. Nations with high energy usage mostly interfere to secure a continuous flow of oil. The oil-rich countries are then under constant scrutiny and pressure from the energy-hungry countries. Experts call this the **resource curse,** also known as the paradox of plenty (Auty 1993). This paradox describes scenarios in which nations and regions with abundant natural resources tend to develop at a slower pace with less economic growth than nations and regions with fewer natural resources.

Teaching Tip

The concept of petropolitics is complex and can be a difficult subject for younger students. Petropolitics considers different aspects of society and life. Teaching such a topic may require a multidisciplinary approach that combines what students already have learned in geography, history, science, and civics. One of the most important aspects of petropolitics that students should understand is that energy is a commodity traded on the world market. Consider using small objects, such as tokens or candy, to show how energy could be unequally divided among "buyers" depending on the one doing the selling. Energy may also be unequally divided depending upon how much each buyer is willing pay. Such an activity may help students understand why countries don't simply "share" their resources with each other equally.

Iranians show their love of soccer as they play among the oil fields. The Middle East is one of the world's regions rich with oil deposits.

Case Study The 1973 Oil Embargo

Several times in the last 50 years, some petroleum-rich countries have implemented oil embargoes against western nations to express discontent about specific western actions and policies. On June 6, 1967, one day after the beginning of the Six-Day War, several Middle Eastern countries limited their oil shipments to deter any countries from supporting Israel militarily. The 1967 Oil E**mbargo** lasted three months, but the United States did not see much change in oil availability because the embargoing countries were not consistent.

However, a few years later, a real energy crisis occurred during the more successful Oil Embargo of 1973. In this case, the members of the Organization of Arab Petroleum Exporting Countries (OAPEC) proclaimed an embargo when the United States decided to assist the Israeli military during the Yom Kippur War. This time embargoing countries held strong on their threat. The 1973 embargo had great impacts in the United States until it ended six months later in March 1974.

Even though countries that supported Israel were the targets, repercussions were felt globally. Prices of oil soared, and many nations struggled financially to keep up with the increases. The price of oil actually quadrupled at one point during the crisis. The world was watching and waiting for a global recession that seemed imminent (U.S. Office of the Historian 2010).

Luckily, many industrialized nations had stockpiled oil for such a situation, but prices of oil increased dramatically in the United States during the embargo. The retail price of a gallon of gasoline almost doubled. The U.S. government imposed several strategies for controlling gasoline sales: Congress passed a national speed limit of 55 miles per hour because fuel consumption in automobiles increases rapidly at higher speeds. Many stations did not sell gasoline on Saturday nights or Sundays, which created long lines the rest of the week. Many stations went out of business or did not sell gasoline at all. Lines at the pump were common. In order to control the lines at the pump, the government had drivers with license plates that ended in even numbers buy fuel on even days of the month. Drivers with license plates that ended with odd numbers bought fuel on odd days. Many American consumers lashed out in anger by rioting or going on strike because of the fuel costs and fuel rations.

World leaders engage in talks over oil controversies in the 1970s.

Although U.S. policy makers' focus on the issue abated as oil prices dropped, the fallout of the oil embargo was more attention to fuel conservation and domestic energy production. For example, the oil embargo prompted immediate attention to alternative energy sources such as wind or solar. Campaigns around the country focused on educating citizens on energy conservation. We are still struggling with the issue of energy consumption today.

Read more at The U.S. Office of the Historian: http://history.state.gov/milestones/1969-1976/OPEC.

Invisible Communities: The Coal People

"Whenever we scoop a teaspoon of baking powder, drive down a street, shine a flashlight, or brush our teeth, we are using one of several thousand by-products generated by the coal economy. We are all inextricably bound to these coal-mining communities and yet we all know so little about them".

Melanie Light (2006), Author of Coal Hollow: Photographs and Oral Histories

A young coal mining boy with a coal-streaked face smiles outside a Pennsylvania mine.

While energy can be transported thousands of miles to its point of use, that transport begins at a place where residents are intimately tied to energy extraction, refinement, and transport. Whether oil in South Louisiana, natural gas in Alaska, or coal in West Virginia, energy extraction has a profound impact upon communities. This section focuses on coal, which is but one example of how communities can be intimately tied to energy—for better or for worse.

Coal use has dated back to ancient China, Greece, Rome, Britain, and the Aztecs. These civilizations used coal for different activities, ranging from metal work and heat to ornamentation. As mentioned before, the Industrial Revolution triggered a need to obtain larger amounts of coal, and the development of more effective ways to do so. This led to the development of communities around the coal mines, where job opportunities were abundant and workers were in great demand. Years ago these communities were filled with people willing to labor for enough money, or food, to survive. Even today, these communities struggle with poverty and health issues. Because technology has replaced the need for manual labor, fewer jobs are available. Nonetheless, these communities still survive because of the increased energy demand around the globe. A peek into these communities is a great way to learn about the people behind the energy we use every day.

As the Industrial Revolution movement advanced in England, so did the extraction techniques used for coal mining. Coal-mining towns sprouted around the industry. Over the years, coal-mining communities suffered from instability because the industry was under pressure by competing resources, such as oil and natural gas, and because some coal mines were depleted. Miners and their families moved to new mines to work, accepted low salaries, or were forced into unemployment. Like in all industries, business ebbs and flows, although high poverty rates are not uncommon in mining towns.

Coal Mining Communities in the United States. In the United States, coal became the preferred fuel in cities, replacing wood by the early 1850s. There was also great demand for coal to be used in railway locomotives and steam engines, along with demand from the steel industry. In the late 19th century, thousands of European immigrants and African Americans migrated to southern West Virginia to work in coal mines owned by big companies, which also owned the tools and the equipment. Miners were required to lease the equipment and tools from the company. A miner's pay also took into account deductions for housing and purchases from company stores. Some coal companies forced miners to purchase from company-owned stores exclusively.

Economic depression following the American Civil War caused mine owners to continue to seek less expensive labor. These positions were filled mostly by immigrants from English, Scottish, Irish, and German ancestry. By the 1870s, immigration from Poland and Lithuania grew steadily, but by the early 20th century, many coal miners were immigrants of Slovak, Ukrainian, Russian, and Serbian decent. Needless to say, American coal mines created diverse communities of new immigrants from all over the world.

Energy Extraction Is Risky Business. Extraction of natural resources, including oil, minerals, and coal, can be dangerous. There have been several instances of accidents in coal mines. In West Virginia alone, several accidents have hit these communities hard. In December 1907, the worst mine disaster in U.S. history occurred in Monongah, West Virginia, where an explosion killed 362 miners. In fact, between the years of 1907 and 1913, the three worst mining accidents in U.S. history occurred, killing almost 900 miners combined across the three sites (USMRA 2010a).

Three decades later, 91 miners were killed by an explosion in Bartley, West Virginia, in 1940. Farmington, West Virginia, saw its own share of tragedy when in 1968 a night crew was buried underground after an explosion. Twenty-one miners were able to escape, but 78 miners died, including 19 whose bodies were never recovered (USMRA 2010b).

The incessant battle about mine safety between the coal industry, the United Mine Workers, and the government has lasted for more than a century. Like in most industries, legislation is spurred by accidents. The Upper Big Branch Mine disaster of April 2010 is considered the worst in the United States since 1970. The explosion left 29 out of 31 miners buried 1,000 feet underground at Massey Energy's Upper Big Branch coal mine in Montcoal, West Virginia.

Teaching Tip

Before teaching this section, you may consider assessing your students' prior knowledge of people who work with coal. Do students have preconceived notions of such people? Are their attitudes positive or negative? Do their ideas come from recent media coverage of coal-mining accidents in the world? You may then consider asking your students to write questions they have about coal workers, because in many cases (especially with younger students), they may not have much prior knowledge on this subject. These questions may help you direct your teaching of the concepts that follow in this chapter.

Most often miners do not survive these accidents; however, some amazing survival stories exist. Your students may have heard some of these inspiring stories of survival. In 2006 one miner survived the Sago Mine explosion in West Virginia after being trapped for a couple of days. Thirty-three Chilean miners were trapped more than 2,000 feet underground for 69 days in 2010. All of the miners were rescued.

Satiating Our Need for Coal. Coal continues to be the number one source of energy to produce electricity in the United States. Coal mining reached an all-time high in 2008, existing in 26 states across the country. In 2006, more than 80,000 people were employed in coal mining in the United States. The average age of coal miners is 48 years. There are now 54 coal mines in this country, and the average per capita income in these communities is lower than the nationwide average. For example, in 2000, communities averaged a per capita income of $16,246—25 percent lower than the U.S. average of $21,587 (Sourcewatch 2010).

Coal mining communities represent a struggling sector of our society and are charged with a risky job—often under poor conditions—that allows the rest of us to enjoy electricity every day of our lives. As nations move to cleaner renewable sources of energy, such as solar and wind, these communities will have to adapt, migrate, and find a place in the new era of green-collar jobs. Our students will be needed as the world's next scientists, technologists, and engineers to address large global-energy issues.

A closer look at social issues that arise around energy allows us to better understand how our actions every day, and our choices as consumers, impact the larger picture worldwide.

Coal miners work in confined locations and take risks on the job. Coal-mining history is filled with disasters and accidents.

Pictures of Practice

U.S. Energy Use Today

Students: Grades 4 and 5

Location: San Diego, California (a coastal community)

Goal of Video: The purpose of this video is to watch students discuss U.S. energy use, especially the hidden energy costs of transporting goods to our communities.

Americans know that we use a lot of energy, but the numbers that show our use of energy compared to other countries worldwide are staggering. Our need for electricity to support our homes and businesses is substantial. Our energy resources and infrastructure can typically meet these demands, but some countries either do not have the energy resources or do not have the energy infrastructure, therefore, limiting energy use. Discussing energy or carbon footprints with students is important, as well as having students conduct energy audits of their own use. But much of our energy use is hidden from sight, which is the focus of this video.

Classroom Context

At the end of Ms. Howard's energy unit, students begin to discuss energy footprints (how much we use) and energy conservation actions (how we can reduce our energy use). Students have conducted an energy audit of their homes, specifically focusing on lightbulb use but also identifying types and use of appliances and electronics. This discussion occurred as Ms. Howard attempted to have her students consider hidden energy use.

Video Analysis

In the classroom discussion, students consider U.S. energy use today. Americans use a great deal of energy in their everyday activities—watching television, driving cars, using cell phones and computers, heating and cooling homes and offices, and turning on lights for as long and as much as is needed. While Americans pay for energy, the energy often seems limitless and at our disposal whenever we want it. Although Americans make up just 5 percent of the world population, we emit up to 25 percent of the greenhouse gases. Ms. Howard uses this fact to spark a discussion among students about why this happens. Students share several ideas about Americans using more resources, driving cars, and generally "using too much." One student brings up the food industry, and Ms. Howard uses this moment to introduce the idea that a great deal of energy is used to transport food. Students then brainstorm solutions to reduce this energy use, such as taking "shorter routes" and growing "food closer to home." In the post interviews, students consider what the United States would be like if we ran out of fossil fuels. Students know that we use fossil fuels for almost everything we do in our lives. These interview responses represent their beliefs about what the world would be like without those fuel sources. For example, Martinez believes we would have to walk everywhere, and Ezequiel describes a scenario in which we would go back in time, doing without electronics and using candles. Knowing more about energy use and energy footprints can help students better understand how our world is intimately tied to the future of fossil fuels and energy resources.

Reflect

How would you teach energy footprints to students?

Students hear a lot about energy use and the idea that fossil fuels are running out. What do you think students should understand most about their energy use (or energy footprint)? How could you connect this to students' actions today? Students' projections about a future without fossil fuels can seem alarming. How would you respond to their ideas?

Student Thinking

Who Gets Energy?

Living in the United States, students have easy access to energy and may not realize the energy issues that occur in developing nations. They may take an idealistic view that countries and people should simply share energy, but at the same time, they may believe that if they are paying for energy, it is rightfully theirs to use. What happens to those who cannot afford the market prices for energy resources? Be on the lookout for the following misconceptions, and encourage your students to think about ways to conserve energy.

	Common Student Ideas	Scientific Concepts
Sharing energy	Countries should divide energy resources equally; all countries should share energy.	Energy is not distributed equally around the globe. In poor communities, securing energy often results in conflict.
Paying for energy	Everyone should have to pay for energy; when you pay for energy, that means it's yours to use.	Energy is a commodity, but fossil fuels are limited. Not all countries have the means to provide energy access for their citizens.
Energy poor countries don't need energy	People in rural, developing areas don't have a lot of technology so they don't need as much energy.	Energy use in industrialized nations is much higher than in the developing world. All people need access to energy to meet their daily survival needs.

Ask Your Students

1. How should countries ensure that everyone has access to energy? Is it even the responsibility of the United States to see that this happens?
2. A wealthy country takes energy resources from a poor country. The wealthy country pays for the energy resource, though, so is this fair? Why or why not?
3. Does everyone need energy resources? Why? If a community does not have TVs, computers, and appliances, does it still need energy?

Case Study

Energy and Community Health

We want energy to make our lives easier, but an oil refinery in our neighborhood? Is that something you would want? Oil refineries require a lot of employees, which provides jobs for the community. Those employed have money to spend for shopping, eating at restaurants, going to movies, and paying more taxes. All of these activities are good for the economy. However, the bad news is what is happening to the health of people who live in communities surrounding these refineries.

A recent study published in the *American Journal of Public Health* compared air inside homes in Richmond, California (a community bordering an oil refinery), and homes in Bolinas, California (a nonindustrial comparison community). The study concluded that, "the air indoors, where Americans spend 90 percent of their time, was more polluted than the air outdoors in both communities, with 104 toxics detected inside Richmond homes and 69 in Bolinas" (Brody et al. 2009). The chemicals present in the Richmond homes were also at higher levels of concentration for fine particulates (linked to respiratory and cardiovascular problems and early death), and the levels of vanadium and nickel (resulting from heavy oil combustion) were among the highest in the state.

The emissions from oil refineries can be spilled or leaked into our water and aggregated into our soil, besides wafting in our air. In 1998, the Chevron oil refinery in Richmond was found guilty of violating environmental laws when it periodically bypassed a wastewater-treatment system, discharging wastewater into San Pablo Bay (part of San Francisco Bay) from 1991 to 1995 and failed to make notifications about it. As a result of the lawsuit, Chevron agreed to enlarge its filtration-treatment system (Schmidt 1998).

Over the last few years, California has enacted several laws in addition to federal regulations to insure its citizens a basic standard for air and water, as well as safeguarding their right to be notified when there has been a significant toxic spill or leak. Many of California's oil refineries were built long before these laws were in place (e.g., the Richmond oil refinery was built in 1902).

Recently, the Richmond oil refinery applied to the city of Richmond for a Conditional Use Permit to allow for expansion of its facility. The expansion would allow the refinery to process heavier and dirtier crude oil, but in doing so, there would be increased releases of mercury (a neurotoxin), sulfur compounds (which form acid rain), and greenhouse gasses. The city council not only approved a Conditional Use Permit so Chevron could proceed with their expansion, but also agreed to keep the environmental review outlining these increased hazards confidential. In 2008, a suit was filed by lawyers of Earthjustice against the City of Richmond on behalf of the Asian Pacific Environmental Network, Communities for a Better Environment, and West County Toxics Coalition. They claimed that their rights were being transgressed, and the courts sided with them.

We need energy, and it is not unusual for us to explore ways to increase its production. It is crucial, however, that citizens consider both sides of issues in their communities. What decisions are our local representatives and industry making? Do they act according to the community wishes? Many communities can be impacted by our quest for energy, and it's important to know what's happening in our own backyards.

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Teaching Resources

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

U.S. Energy Information Administration Energy Kids: http://www.eia.gov/kids/energy.cfm?page=4

6 Solutions for Our Energy Future

by Jose Marcos-Iga and Tania T. Hinojosa

"We are like tenant farmers chopping down the fence around our house for fuel when we should be using Natures inexhaustible sources of energy—sun, wind and tide."

Thomas Edison, 1931 (qtd. in Gaworecki 2010)

By now it is clear that energy is essential for not only progress, but also the basic functioning of our society. Many would agree that we are in the middle of an energy crisis. The International Union of the Conservation of Nature and other respected groups link this time of crisis with the pollution of our air, water and soil as well as with our changing climate. This energy crisis is not only impacting our environment and the survival of precious plants and animals, but it is also creating or exacerbating conflict and inequalities in our own communities. Yet, humans are resourceful and innovative, and we have the power to change our energy future. Changing our energy future will involve the following areas:

- Energy Policy: Who regulates energy resources within the United States and around the world? What are some of the current laws in place? What are some examples of current energy reform?
- Energy Innovations: Why do we need to rework our energy portfolios? Which alternatives to fossil fuels exist? What are the benefits and trade-offs of these cleaner sources of energy?
- Energy Action: What can each of us do to make a difference? Why should individuals conserve energy? How can we make choices that are more energy efficient?

All of these areas relate to two concepts that are key for understanding energy solutions. Both concepts are ones that your students have likely heard over and over, and both work in tandem to address our energy problems: e**nergy conservation** and **energy efficiency.**

GRADE	STANDARD	EEI UNIT
Grade 3	3.1.2 3.3.3 3.4.1-2 3.5.1-3	The Geography of Where We Live California Economy—Natural Choices
Grade 4	4.1.5 4.4.6 4.5.3-4	Reflections of Where We Live
Grade 5	5.7.3	
Grade 6	6.4.a 6.6.a-c	Energy: It's Not All the Same to You! Energy and Material Resources: Renewable or Not? Made From Earth
Grade 7		
Grade 8	8.3.2 8.3.6 8.12.1	Agricultural and Instustrial Development in the United States

Energy conservation means "reducing energy consumption and waste." Examples include turning off lights when we leave a room and wearing a sweater indoors during the winter to keep the thermostat a few degrees lower. *Energy efficiency* involves the use of technology and strategies that allow for reduced energy use without reduced benefit (Alliance to Save Energy 2007). This can include weatherizing your home to conserve heat (insulation, for example) and using a programmable thermostat. Both conservation and efficiency are important as part of a successful approach to solving the energy crisis.

Energy Policy

International agencies, countries, states, cities, and towns, as well as private-sector businesses, develop energy policies to describe their energy resource extraction, trade, and consumption practices. They

CHAPTER OVERVIEW

As fossil-fuel abundance wanes, the need to integrate renewable energy into the U.S. and world's energy portfolios increases. The need for consumers to conserve energy is also an important piece of the energy puzzle.

Government policy will play a critical part in reaching both conservation and efficiency goals. International organizations, such as the United Nations, are setting the tone for energy policy, and the U.S. government is also making strides to decrease our dependence upon fossil fuels. Learning about new technologies in renewable energy resources can also be a step toward student understanding of how efficiency is improving every day. In addition, learning small, practical changes they can make in their everyday lives can make a difference in how your students actively participate in reducing their energy use.

In this chapter we investigate energy policy at multiple levels, strides in renewable-resource technology and practical steps students can take to reduce their energy consumption.

do this through the use of legislation, treaties, and protocols aimed at defining emissions standards, incentives, and security measures that relate to energy. When students are asked who regulates or controls energy, they often point to their utility companies, but know little about how our government—at different levels—actively participates in energy policies and planning. Knowing the people involved not only improves student understanding of the issues, but also can empower them as citizens to become more engaged as voters and community members.

In the United States, at the federal level, the Department of Energy (DOE) oversees energy policy. DOE's mission is to "advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex" (U.S. Department of Energy 2010). Interestingly, the DOE was not created until 1977 and only after the United States experienced several energy crises. Some may be surprised to learn that the DOE has only been around for a little more than 30 years. Who was in charge of American energy plans before that time?

Before the DOE existed, other federal entities served several of the energy-related needs of the country, which began in earnest around World War II. The Manhattan Project was created under the U.S. Army Corps of Engineers to lead the development of the atomic bomb. After the war, the Atomic Energy Act of 1946 was enacted to create the Atomic Energy Commission, which took over the Manhattan Project, putting the field of atomic research under civilian-government control. Later, in 1954, the Atomic Energy Act opened the development of nuclear power to the private sector and gave the Atomic Energy Commission the authority to regulate the new industry.

Two decades later, in response to changing needs, the Energy Reorganization Act of 1974 abolished the Atomic Energy Commission and created two new agencies: the Energy Research and Development Administration and the Nuclear Regulatory Commission. The former intended to manage the energy development, naval reactor, and nuclear weapons programs; and the latter to regulate the nuclear-power industry. Shortly thereafter, in response to oil embargoes described in Chapter 5,

Teaching Tip

Energy conservation and energy efficiency are concepts that may be used interchangeably by the media or by adults. Students might have difficulty understanding the difference, but using examples and comparing the two would be a great way to help students differentiate between both concepts. For example, give students a list of actions such as those following and have them sort the actions into one of two groups: *Efficiency* or *Conservation*. Then discuss where students disagree and generate working definitions for each word that make sense to your students:

- Using Compact Fluorescent Lightbulbs (CFLs) (efficiency)
- Turning off lights when leaving a room (conservation)
- Unplugging electronics when not in use (conservation)
- Applying weather stripping to windows and doors (efficiency)
- Buying Energy Star appliances (efficiency)
- Riding your bike to school (conservation)

Since the middle of the 20th century energy has been a top agenda item for U.S. Presidents. In this photo President Obama tours the DeSoto Next Generation Solar Energy Center in Florida. Renewable energies will play an important role in solving our energy problems.

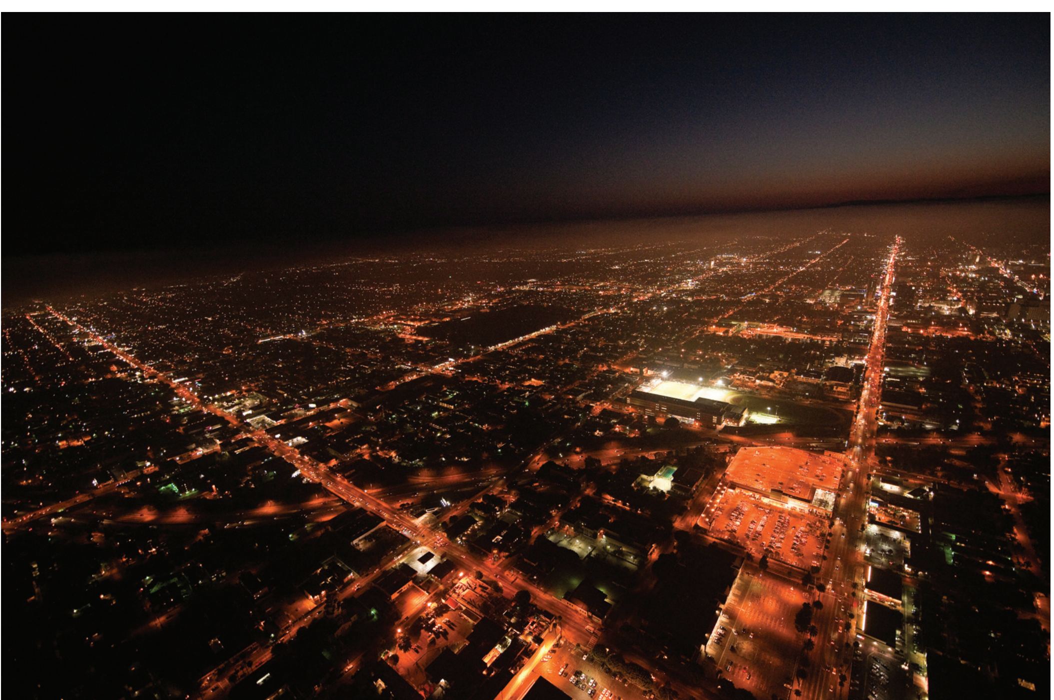
President Jimmy Carter signed the Department of Energy Organization Act of 1977. The legislation called for the creation of the Department of Energy to help end the U.S. dependence on foreign oil and unify energy organization and planning—goals the United States has been working toward since that time. The key point to make for students is that when energy legislation is passed, it is often the DOE that actually carries out the mandates in the legislation.

States also have their own departments of energy that create policy and state-level energy plans. For example, California has the California Energy Commission that was created in 1974, three years before the DOE was created. State commissions such as the California Energy Commission oversee energy-efficiency standards in building/development, provide incentives for using renewable energies, funding for innovative research and programs, and general energy planning for the state, just to name a few responsibilities. When energy legislation is passed at the state and federal levels, it is often the state's energy department or commission that sees the legislation carried out.

Energy policy varies widely from state to state, typically in response to that state's resources and needs. Some states, for example, must include regulations regarding hydropower, while others are more concerned with coal power or offshore drilling. To make state-level policies more accessible to students, consider discussing resources—major rivers, deserts, coastal areas, or biofuel crops—that could be used for energy generation, and then compare that with the future direction of your own state's energy plan.

Cities and towns have departments that oversee the energy policies within the municipality. These departments carry out legislation passed at the state or federal levels, but based on their city's energy needs and current energy system. For example, Los Angeles has the Department of Water and Power, the largest municipal utility in the United States. The agency's role is to provide residents of Los Angeles with power. The revenues paid by customers cover the cost of operations, often with surplus to put back into the city's budget.

Los Angeles, California, is the second most populous city in the United States (after New York City). The L.A. Department of Water and Power faces the challenge of supplying this urban area with clean and reliable water and energy, day and night.



While city-level departments implement state and federal energy mandates, they typically have their own set of commissioners that can enact citywide energy policies, as long as these policies do not contradict legislation. For example, in 2001 the city of San Diego created the Energy Conservation & Management Division (under the Environmental Services Department) with the main goal of overseeing San Diego's movement toward renewable energy resources, energy conservation, and energy efficiency—these goals were in line with California's overall energy plans. Think about how your local energy commissioners come into office. Are they appointed? What does this mean for our role as voters? Exploring the local energy commission or department makes this complex—and often distant—process much more real for students and gives them a specific way they can become involved in their community's energy plans.

At all levels—national, state, and municipal—government-run offices develop and enact energy policy. Most of these departments answer to voters in some way or another—through the election of city officials or state and national congress members—so that voters have a voice about the energy policies they believe will meet the needs of their communities.

Important Energy Legislation

Energy-related legislation is often being passed at national and state levels. Sometimes the laws do not appear to relate directly to energy. For example, the speed limits on highways were not only implemented for safety reasons, but also imposed to control fuel consumption. Many nations worldwide have used Daylight Savings Time as a strategy to conserve fuel resources, especially in times of increased energy use (e.g., war), increased energy demand (e.g., rising prices), or reduced access to energy (e.g., embargoes). If your students live in an area that follows Daylight Savings Time, ask them a few questions regarding this time: What time of year does it take place? Is there more or less daylight during this time of year? As a result, do you use more or less light/energy at home? Why?

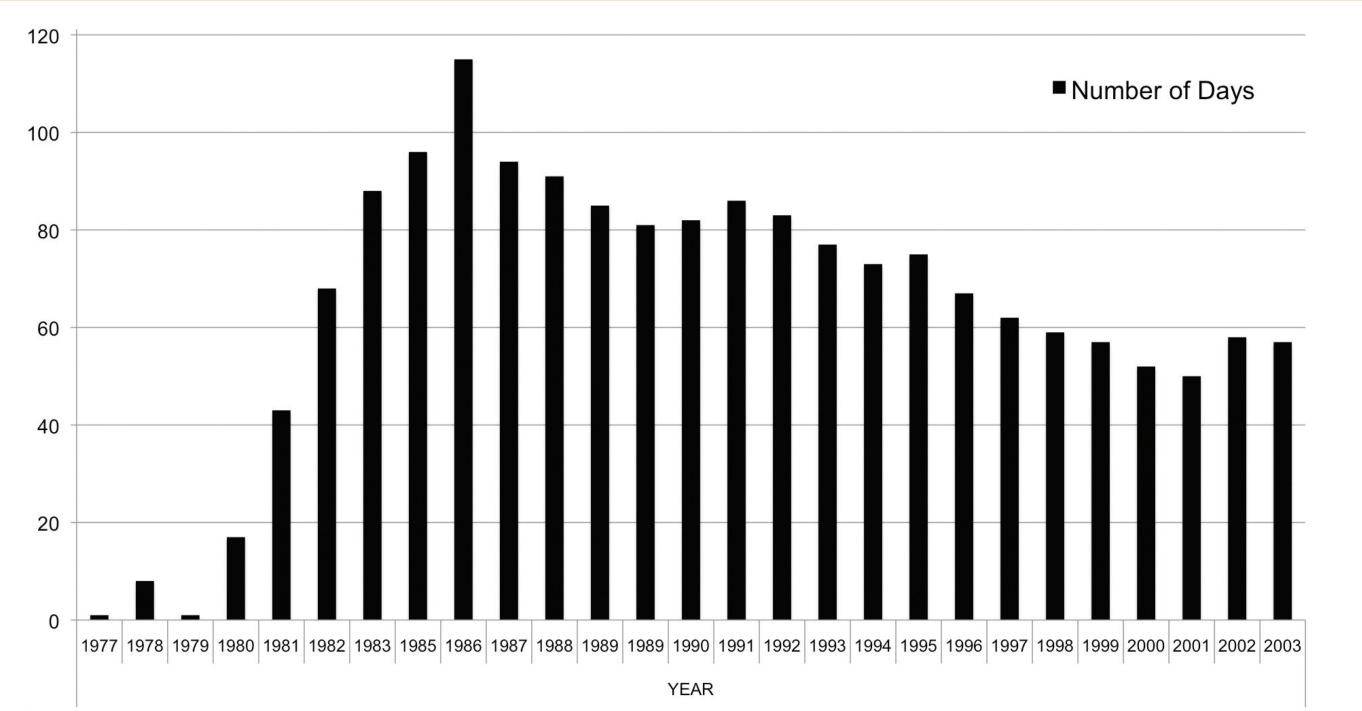
Other legislation is specifically designed to change our energy policies and programs. This legislation could seem distant to your students. They may even ask why it is important or how it will affect them. But much of this legislation has immediate impacts on citizens—from changes to appliance and lightbulb standards, to incentives to homeowners using renewable energies, to rising costs of gas at the pump. The following pieces of legislation are notable ones that altered America's energy policy, and ones that students should learn.

Strategic Petroleum Reserve. Two years before the Department of Energy was established, President Gerald Ford signed the Energy Policy and Conservation Act in 1975. The legislation called for the establishment of a reserve of up to 1 billion barrels of oil, later called the Strategic Petroleum Reserve. This need had been recognized for more than half a century, but it was the dramatic economic impact of the oil

Teaching Tip

This may be a good time to have your students create a small poster that shows the time line of the important legislative actions pertaining to energy described above. As an extension for older students, you may have them research local energy legislation that has taken place over the past 50 years and add local legislation and events to the time line as well. Have students differentiate between federal legislation (in one color) and local legislation (in a second color), and then compare how the two match. Also have students note the special features of the local legislation that may tell them something about their local community.

STRATEGIC OIL RESERVE



How many days' worth of oil imports are stored in the Strategic Petroleum Reserve? The maximum number of days of import protection ever held in the reserve was 115 days in 1985. Almost 20 years later, as oil consumption and imports have increased, that length of time has dropped to 57 days' worth of petroleum that could be met in an emergency. Learn more at http://www1.eere.energy.gov/vehiclesandfuels/facts/2004/fcvt_fotw321.html

A security guard stands near an oil-reserve pipeline at the Strategic Petroleum Reserve in Bryan Mound, Texas.

embargo of the 1970s that emphasized the urgency of an oil reserve (as described in Chapter 5). The act also required “the President to prescribe one or more energy conservation contingency plans,” which needed to include rationing and prioritizing use of the energy resources available (U.S. Library of Congress 1975).

Energy Policy Acts. Since the 1990s, the U.S. government has passed three pieces of energy-policy legislation—referred to as the Energy Policy Acts of 1992 and 2005 and the Energy Independence and Security Act of 2007—each with their own focus and purpose.

The Energy Policy Act of 1992 addressed several key issues related to energy efficiency and conservation (e.g., establishing standards for efficient building and appliances and more efficient motors). The act included regulations on trading of natural gas across borders as well as establishing programs to support alternative-fuel vehicles and electric vehicles. In addition, it included a section on radioactive waste and called for the Environmental Protection Agency to outline standards for protecting against radiation at the Yucca Mountain nuclear-waste repository, which was the chosen site for disposing of nuclear waste from America’s nuclear power plants.

President George W. Bush signed the Energy Policy Act of 2005 to address growing energy problems. Importantly, this policy provided new tax incentives and loan guarantees for various forms of energy production. For example, certain companies received tax incentives if they agreed to drill offshore in the Gulf of Mexico as opposed to importing oil from another country. Other companies received loan guarantees or **subsidies** if they were investing in clean coal or renewable energies. Another feature of this legislation was the promotion of biofuels, and protecting the Great Lakes from oil drilling. While the act included incentives for both fossil-fuel industry and renewable industry, many critics argued that the subsidies mostly benefited the traditional energy industry, particularly oil, coal, and nuclear (Grunwald and Eilperin 2005).

After negotiations between the House and Senate, the Energy Independence and Security Act was signed into law (Freeman, 2007). This act focused on increasing the fuel standards for automobiles so that by 2020 there is a fleet-wide average gas mileage of 35 miles per gallon. The bill also included efficiency standards for lightbulbs and appliances, increases in biofuel use, new standards for energy efficiency of federal office buildings, and money to create a more efficient “smart” energy grid.

The Vincent substation is expanded and modernized to bring solar and wind power to the Los Angeles Basin.

American Recovery and Reinvestment Act. In response to an economic crisis, Congress passed the American Recovery and Reinvestment Act of 2009 to help create jobs and stimulate investment in American industries. President Barack Obama signed the bill, also known as the stimulus package, into law in February 2009 (U.S. Government 2010). Even though this was not an energy bill, it included several provisions related to improving and expanding energy infrastructure and supporting renewable clean sources of energy. The stimulus package included $21.5 billion for energy infrastructure, including renewable energy, electric transmission, and **smart-grid technologies** It also included $27.2 billion for energy-efficiency and renewable-energy research and investment, including research, development, and demonstration projects in biofuels, geothermal, wind, hydroelectric, and solar technologies, as well as electric-vehicle technology development.

State Legislation. Each state in the United States has opinions on energy resources and energy solutions. For example, while California is considered one of the largest users of energy because of the population and industry, it actually has one of the lowest per capita energy uses when compared to other states! That is partly because of California's mild climate, but also partly due to innovative energy-efficient appliance and building standards. New York State, the third most populous state in the country, actually has the very lowest energy use per capita, even given its geographic location. Interestingly, Wyoming, the least populous state (with a population less than that of the District of Columbia), uses more energy per capita than any other state. Ask your students to brainstorm reasons why New York and Wyoming use energy in the manner in which they do. Explore more comparisons at the Energy Information Administration (http://www.eia.doe.gov/states/sep_sum/plain_html/rank_use_per_cap.html).

Teaching Tip

For students, and even adults, following the entire process of enactment of a law by Congress—from its preliminary versions to amendments by the House of Representatives and the Senate to the final signage by the President—can be an overwhelming task. Guiding your students through the entire process by dividing the class into groups representing the different positions of power can be a great way to get them familiar with this process. This can help them answer important questions that arise when analyzing the energy bills described in this chapter as well as any other law they may study in the future. Some important questions include:

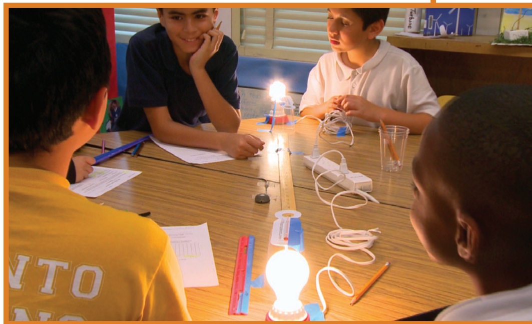
- What are the different roles played in Congress?
- Who drafts the initial bill?
- What is an amendment, and why are there so many of them?
- Why does the bill that is passed and signed look so different from the one that was initially drafted?
- What are the implications of this when studying the energy laws described here?

Our government is continuously looking for ways to improve our energy system. This photo shows President Obama meeting with a bipartisan group of senators in the Cabinet Room of the White House, to discuss passing comprehensive energy and climate legislation, June 29, 2010. (Official White House Photo by Pete Souza)

Pictures of Practice

Energy Efficiency of Lightbulbs

Lightbulbs offer one of the most basic examples of energy efficiency. CFL lightbulbs may use up to 75 percent less energy and last 10 times longer than an incandescent lightbulb. Many students already know that CFL lightbulbs are more environmentally friendly compared to incandescent bulbs, but they may not realize why there is a difference. Conducting a hands-on investigation with both types of bulbs can provide students with a memorable experience that allows them to see firsthand the efficiency difference—through the measurement of temperature change—between the two bulbs.



Students: Grades 4 and 5

Location: San Diego, California (working-class community)

Goal of Video: The purpose of watching this video is to see students investigate lightbulbs and describe what they learn about efficiency.

Classroom Context

Ms. Howard introduces energy efficiency to students through a lab investigation in which students compare the efficiency of an incandescent bulb to a CFL bulb. This lesson occurred early in the energy lessons, just after students completed an activity in which they tried to identify the most efficient way to move a stack of books from one location to the next. The lesson also occurred after students had already talked about different forms of energy and how energy changes between these forms. Prior to beginning the investigation, students took a closer look at different bulbs, comparing the writing (i.e., watts) marked on different bulbs and discussing the words *watt, lumens,* and *heat* (i.e., *waste heat*).

Video Analysis

Ms. Howard starts the investigation with reviewing the word *efficiency*—doing the same amount of work with less energy. Students compare the watts of different lightbulbs, connecting the word *watt* to energy used by the bulb. Students learn that some incandescent bulbs use 60 watts, while others use 100 watts. Students also learn that a 60-watt incandescent bulb gives off the same lumens as a 14-watt CFL bulb. After reviewing the lightbulbs, Ms. Howard tasks students with finding the different amounts of heat given off by the bulbs. Students take temperature measurements using a thermometer located near the bulbs. They measure the temperature change after the bulb stays lit for 10 minutes, recording a temperature reading every minute. Students tangibly feel that the incandescent bulb gives off more heat than the CFL bulb. Andrea shares that the CFL is more energy efficient and mentions that it gives off less waste, or heat. Henry piggybacks onto Andrea's idea, saying that heat is a waste product because it is not being used. In post interviews, Esmerelda questions why incandescent bulbs give off so much heat, while Ezequiel seems confused about what *energy efficiency* means. When Ezequiel hears the word *efficiency* he thinks of "more power" and "better," rather than doing the same work with less energy.

Reflect

How would you teach energy efficiency?

What ways would you approach the concept of energy efficiency? How does the lightbulb activity support student learning of the concept? How would you respond to Ezequiel's post interview explanation of efficiency? What would you do next with Ezequiel?

Case Study

What's So Cool About California?

California is at the helm of climate-change mitigation initiatives. The government of the state of California decided the debate on climate change was over by passing the Global Warming Solutions Act of 2006, an environmental law, signed by former Governor Arnold Schwarzenegger on September 27 of that year. The bill established a timetable and the measures necessary to bring California closer to the goals of the Kyoto Protocol. This bill was the first approved legislation by any U.S. state to cap emissions across all economic sectors. California, where one out of eight Americans live, now requires major industrial producers to reduce emissions 25 percent by 2020. In other words, California has to cut its annual release of carbon dioxide by 174 million metric tons. The reductions are so significant that it would take a forest twice the size of New Jersey to process all those emissions (California Energy Commission 2008).

In order to achieve these goals, California has set a series of key strategies in six areas. The strategies are taken from the California's Climate Plan Fact Sheet (California Energy Commission, 2008). Visit http://www.climatechange.ca.gov/ to see complete versions of each strategy and learn more about California's climate plan.

Santa Rosa CityBus uses diesel-electric hybrid buses.

Solar panels transform light energy into forms of energy we can use.

Cap-and-Trade Program. By setting a limit on the quantity of greenhouse gases emitted, a well-designed **cap-and-trade** program will complement other measures in California. The program provides a firm cap on 85 percent of the state's greenhouse-gas emissions.

Transportation. California will reduce 30 percent of its vehicle greenhouse-gas emissions by 2016. By 2020, California will decrease by 10 percent carbon-intensive vehicle fuels through its low-carbon fuel standard. Other transportation measures include using more efficient delivery trucks, heavy-duty trucks, and goods movement.

Electricity and Energy. California continues to improve appliance and building standards. By 2020, a total of 33 percent of the energy used in the state will come from renewable sources. Other efforts include the following programs: Million Solar Roofs; Solar Hot Water Heating; Green Buildings; and water efficiency.

High Global Warming Potential Gases. In order to minimize gases that potentially influence global warming, the state is making an effort to capture high global-warming-potential gases already in use. California is also reducing future impact by encouraging the use of leak-resistant equipment, putting restrictions upon use of products that release these gases, and imposing additional fees.

A former industrial site is replanted with trees.

Forestry. California is making an effort to preserve forest sequestration by minimizing the cutting down of forested areas so the protected trees will continue to take up, or sequester, carbon dioxide from the atmosphere. Additionally, California is reducing atmospheric carbon dioxide by encouraging forestry projects in which new trees are planted.

Agriculture. The agriculture industry in California contributes to production of carbon-dioxide emissions, as well as the release of other GHGs. In order to reduce the impact of agriculture on climate change, California is promoting the use of more efficient agricultural equipment and by minimizing fuel and water use through transportation and energy measures.

Changing Energy Portfolio. In early 2011, the state of California voted to increase its Renewable Portfolio Standard (RPS) to 33 percent by 2020. This legislation means that renewable energies must comprise 33 percent of utility companies' retail sales by that time.

Explore More

Cool California is a great resource created as part of the efforts under the Global Warming Solutions Act. This website, created through a partnership between government, universities, and nongovernmental organizations, offers a toolkit for schools, as well as success stories that can inspire your students to act in their school and community (California Air Resources Board 2010). Examples include:

- The city of San Diego reduced its GHG emissions by 3,814,000 tons between 1999 and 2003. Between 2003 and 2010, the city had a target to reduce an additional 5,488,000 tons to accomplish its goal (California Air Resources Board). Explore more at http://www.coolcalifornia.org/case-study/city-of-san-diego.
- Solar capacity in the city of Santa Monica has doubled since the launch of its solar program (Solar Santa Monica). To date, there are 139 grid-connected solar projects in the city, representing 926 kilowatts of solar capacity. Explore more at www.coolcalifornia.org/case-study/sustainable-santa-monica.
- In 2001, Marin County became the first local government to calculate its ecological footprint. Marin County has set a target to reduce GHG emissions 15—20 percent below 1990 levels by the year 2020 for internal government and 15 percent countywide. Explore more at www.coolcalifornia.org/case-study/reducing-residents-ecological-footprint.
- Reforest California is a million-tree challenge to help raise funds to replant trees in Southern California State Parks that have been impacted by wildfires (The Coca Cola Company 2009). Explore more at www.reforestcalifornia.com.

Case Study: Is Cap-and-Trade in Our Future?

To slow global warming, people will need to emit fewer greenhouse gases. Many scientists agree that to avoid "dangerous" climate change by about 2050, the world would have to cut greenhouse-gas emissions to a small fraction of what they are today (Stern 2009).

Use of renewable energy from wind turbines and solar panels is growing, as are energy-efficiency measures in homes and in more efficient cars. Nonetheless, greenhouse-gas emissions have continued to rise decade after decade, reaching an all-time high in 2010 (IEA 2011).

To try to ensure that people will quickly cut back greenhouse-gas emissions, one of the most popular approaches has been to build programs known as "cap-and-trade." These programs include a legal limit on the amount of greenhouse gases people are allowed to emit in a year—that is the "cap." Over decades, this cap could be continually lowered, so that eventually people would be emitting only very small amounts of greenhouse gases. Such a cap on emissions is similar to limits on fishing that governments have in place, that allows people to catch a certain amount of fish each year.

Under a cap-and-trade system, governments issue permits that allow businesses or individuals to release a certain amount of greenhouse gases into the air each year. To help make it easier for people to adjust to the emissions cap, then they are allowed to trade these permits between each other—that is the "trade" part of "cap-and-trade."

Some industries will probably find it easier to cut their emissions than others. For example, there are many ways of producing clean energy, using wind and solar energies instead of fossil fuels are two ways. Other industries—such as transportation and agriculture—may find it harder to cut their emissions. As a result some industries may have to cut their emissions to near-zero, so that other industries may emit more greenhouse gases (Stern 2009).

Under a trading system, then businesses or individuals that have leftover permitted emissions can sell what is left of their permits to others who have run out.

The permits could be traded within countries and between countries. This trade in permits is meant to make it cheaper for people to cut greenhouse-gas emissions. It also gives people an incentive to cut their emissions more than required, because they can sell any leftover permits. Finally, it also allows people to choose how to cut emissions—for example, they could either cut how much energy they use, or they could use cleaner energy (Stern 2009).

Cap-and-trade has worked for cutting some kinds of pollution. The first such market was for sulfur-dioxide emissions, which come primarily from coal-burning power plants and which can cause acid rain and smog. Starting in the United States in 1990, the cap-and-trade system has been successful at cutting sulfur-dioxide emissions at a relatively low cost (Coniff 2009).

Today there is no one cap on greenhouse-gas emissions worldwide, but some countries have created cap-and-trade systems to fight global warming. The first such system—and still the world's largest—is in the European Union (European Commission 2010). Another cap-and-trade system was created by the Kyoto Protocol, an international agreement forged through the United Nations, which put caps on emissions from the richer countries that signed the agreement and allows countries around the world to trade emissions permits. California's Global Warming Solutions Act of 2006 also established a cap-and-trade system that went into effect in 2012 (California Air Resources Board).

There are other approaches to cut greenhouse-gas emissions, such as a simple tax on emissions or an encouragement of cleaner or more efficient technologies. If countries take further action to fight global warming, they are likely to use various combinations of these three approaches (Stern 2009).

Energy Innovations

"So we stimulate 100,000 innovators in 100,000 garages, trying 100,000 things; 1,000 of which will be promising, 100 of which will be way cool… and two of which will be the next green Google and green Microsoft."

Thomas L. Friedman

Our current rate of development requires immense amounts of energy. For more than a century—since the Industrial Revolution—we have turned primarily to fossil fuels to obtain the energy we need. We have studied in previous chapters the social and environmental impacts of our dependence upon fossil fuels for our energy needs. Foreign-oil dependency has brought political and social instability around the world and along with coal—the primary source of electricity in the United States—has considerably increased the amount of greenhouse gases we put into the atmosphere. We know there are alternatives to fossil fuels—cleaner, more sustainable alternatives. Cheaper? Maybe not, at least not in the short term. But when we look at the long term and take into account the environmental and sociopolitical costs of harvesting and burning oil and coal, it can start to make more economic sense. But, how do we make the big turn to these energy innovations? Do your students think this is going to be an easy or difficult process? Do they have any ideas on how we are going to make this switch? One way is to reconsider energy portfolios, making adjustments each year toward more renewable energies.

According to the U.S. Department of Energy's Energy Efficiency and Renewable Energy Program, a **Renewable Portfolio Standard** (RPS) is "a state policy that requires electricity providers to obtain a minimum percentage of their power from renewable energy resources by a certain date" (U.S. Department of Energy 2009). By 2009, 24 states plus the District of Columbia had in place RPS policies, accounting for more than half of the electricity use in the United States. Nonetheless, the state average for renewable energies is less than 20 percent, with only Maine and California pledging for a goal of more than a third of their energy to be from renewable resources. The earliest deadlines to achieve the targeted goals are for Vermont and New York State in 2013. The latest is California in 2030 (U.S. Department of Energy 2009).

The Department of Energy website developed an interactive map of the United States, showcasing the different RPS programs by state. You can consult the map by visiting the following link: http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm. Show this map to your students and start a discussion on the various RPS's by state. What do the percentages on the map refer to? Is one state more dedicated to increasing renewable energy resources than others? How can you tell? Find the state where you live on the map and discuss that particular RPS.

One piece of the energy-solution puzzle involves more investment in developing the innovative ideas and technologies that can move us toward renewable energies. We need solar power, but also a cheaper, more efficient way to harvest solar energy, with minimal environmental impact. We need hydropower that incorporates lower impact techniques that take into consideration the watershed and its inhabitants. We need nuclear power, but also a safe way to dispose of nuclear waste. In the following pages, we will review some of the most promising energy innovations and their potential as the next best thing for our energy future. Students often classify these energy resources as either "good" or "bad," but the issues are much more complicated than that. For each, we consider the benefits and trade-offs, because no one solution is the right solution for everyone and every place.

Workers install solar panels in California. These panels use photovoltaics.

Wind. Perhaps one of the most environmentally friendly sources of electricity, wind is a virtually never-ending source of kinetic energy. Wind energy occurs when different surfaces of Earth absorb heat from the sun at different rates, generating a variation in temperature in different portions of the atmosphere. When this happens, hot air rises, atmospheric pressure at Earth's surface is reduced, and cool air is pulled down to replace it. The result is air movement, or wind. The kinetic energy generated by the movement of air mass is harvested and transformed into electricity through the use of a turbine. Turbines rotate when wind flows over their blades, which moves the electric generator inside the turbine to generate the electricity.

The Altamont Pass wind farm was commissioned in 1981 in response to energy crises in the 1970s. Since that time, wind technologies have advanced greatly. The turbines at Altamont Pass are being upgraded to reduce impacts on local wildlife.

Some estimates predict that we could supply close to 20 percent of our electricity using wind energy (American Wind Energy Association 2010). Wind energy is considered to have the lowest external costs when compared other renewable sources (European Commission 2003). Electricity generated through the harvesting of wind power emits no greenhouse gases. The only carbon footprint generated is during the production of parts and assembly and during the transportation and installation of the windmills. Various studies have calculated that the energy invested in this process is paid back within a few months to a year (Lenzen and Munksgaard 2002).

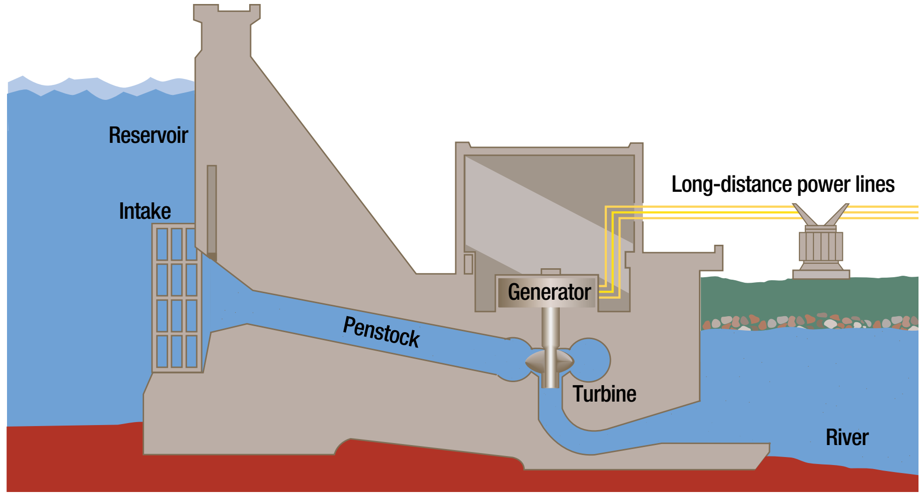
Perhaps the most important environmental impact of wind power is bird and bat mortality caused by wind turbines. A study conducted in Pennsylvania and West Virginia in 2004 by Bat Conservation International reported more than 2,200 fatalities by 63 turbines in a six-week period (Arnett et al. 2005). Risk varies by species of bat and migration period. Bat fatalities caused by wind turbines can be reduced by two-thirds with simple-but-consistent practices. Two of the most effective practices include stopping or slowing wind-farm operations during times of high bat activity, such as low wind conditions (Arnett et al. 2009), and placing microwave transmitters on the wind turbines, to deter bats (Aron 2009).

Interestingly, wind turbines kill relatively few birds when compared to other human practices. Would you believe that feral and domestic cats actually kill hundreds of millions of birds each year compared to only 10,000–40,000 killed by turbines? The power lines running from power plants are actually more of a concern, killing millions of birds annually. Yet, bird carcasses are often found in wind farms such as the Altamont Pass wind farm in California. But the Altamont Pass wind farm is not the usual story for most wind farms. This farm was built in the middle of a migratory bird route and used an older design that attracted birds. Most new turbines move slower because they have larger blades, and most new farms are built taking into account migratory routes. Newer turbine designs at this facility are significantly reducing the bird mortality observed in the past. Needless to say, wind energy is part of our future—it's an energy resource that is just too clean and reliable to pass up!

Hydroelectric. It is largest source of renewable-based electricity (World Energy Outlook 2010). Hydroelectric power uses the kinetic energy from flowing water to rotate a turbine, which in turn moves a generator that produces electricity. The rate of electricity generated by a hydroelectric plant depends on the quantity of water flowing at any given time (also called the flow rate) and the height from which the water falls (also known as the head), which directly relate to the pressure behind that water. The most common type of hydroelectric plant is a "high head" and generally uses a dam to store water at a higher elevation. In contrast, low-head plants use a fall only a few meters high. The benefit of low-head hydropower technology is that it can expand the opportunity to produce electricity from smaller waterways, such as washes, creeks, and irrigation canals (The Environmental Education Exchange 2004).

Hydroelectric power produces virtually no waste or pollution, but it does have other environmental impacts. The development of large-scale hydropower plants in the United States has declined in recent years because of environmental problems such as altered river flow and water quality, restriction of fish passage, and damage to upstream environments caused by inundation. Nonetheless, countries such as China continue to develop dams as a solution to their increasing need for electricity. Natural river systems are modified by the construction and operation of hydroelectric dams, and this affects fish and wildlife populations. The flooded area upstream affects the habitat condition for fish, because the bottom of the lake is much colder and oxygen levels are much lower than that in the flowing parts of the river. Species of fish adapted to survive in a flowing river cannot adapt to the changes fast enough, and entire populations tend to disappear over time. At the same time, some of these dams hold the water for long periods and release it all at once. This causes sudden floods downstream, erosion, and other impacts to the ecosystem and the water supply for human use.

Two of the most-affected fish populations are the salmon and steelhead trout of the Northwest, which depend on healthy river systems to reproduce successfully. Dams work as physical barriers, preventing fish from moving upstream to spawn and downstream to reach the ocean. Populations of salmon and steelhead trout have drastically decreased in the Northwest because of the extensive series of damns on major rivers such as the Columbia River (Environmental Protection Agency 2007). Many hydroelectric dams have now constructed fish ladders to assist salmon in returning upstream. Fish ladders create an alternative path around a dam that mimics the natural rapids a fish may normally navigate.



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.htm#diagrams).

All this said about hydropower, many students actually do not realize the role of dams in energy generation. Students often believe that dams help to store water so that it's ready for use or that dams actually clean water to make it safe for drinking. For students, dams are related to water and not necessarily to energy, so showing students how dams work can change this perception. After you show the students how dams work, consider a discussion on the pros and cons of hydroelectric power. For older students, this may turn into a well-planned debate on both sides of the issue (consider having students do more research first).

Nuclear Energy. Nuclear, or atomic, energy is **potential energy** stored in the nucleus of an atom, and it is what holds the particles of the nucleus together. Inside the sun, nuclear energy is released when the nuclei of light atoms, such as hydrogen, join together to form heavier nuclei. Human-generated nuclear energy is released through fission, or the splitting of uranium atoms. This happens at a nuclear power plant, where initiating a fission chain-reaction in enriched uranium fuel rods inside reactors produces electricity. The heat released by the fission process is used to create steam, which rotates a turbine to activate a generator that produces the electricity.

Nuclear power is considered to be one potential power source for our energy future. It can supply millions of people with reliable power with virtually no greenhouse gas emissions. It can also be a reliable source of energy if other sources—wind, solar, or hydro—are not producing consistently. While it is presently very costly to construct and maintain a nuclear power plant, as the cost of fossil fuels rises, nuclear power may very well become an economically-competitive alternative.

Nuclear power plants have much lower emissions than fossil fuels and is comparable to many renewable choices. Some believe that nuclear power may be the most attainable choice for decreasing our dependence on foreign oil. When taken as a whole, nuclear power plants have few accidents as compared to the fossil-fuel industry. On the other hand, critics insist that nuclear power is dangerous and are worried about the radioactive waste generated by it. Another legitimate concern is accidents at nuclear power plants, which can result in radioactive materials leaking into the surrounding environment. For example, following a major earthquake and tsunami in 2011, radioactive materials contaminated areas near a Japanese power plant. They also argue that the main source of nuclear energy, uranium, is nonrenewable and will eventually be depleted. Nonetheless, 20 percent of the electricity produced in the United States comes from nuclear energy, and it is a reliable and clean source of energy that we depend upon.

Uranium, the chemical element used in nuclear energy, has to be extracted from underground and open-pit mines. Once extracted, the uranium ore is processed into a concentrated fuel through a process known as uranium enrichment. This process produces radioactive waste, which must be safely stored. The United States produces about 2,000 metric tons of radioactive waste per year, which is stored at the same nuclear plants that generate it, or sometimes at a designated disposal site. Although radioactivity decreases over time, all radioactive waste remains active for thousands of years. The areas where radioactive waste is stored can be contaminated, affecting the water and land with toxic by-products (Environmental Protection Agency 2008).

Unfortunately, most students view nuclear energy as negative, often because of its association with explosions, bombs, and toxic wastes. It is important to show students that nuclear energy is actually a viable energy option but that we still need to work on solutions for nuclear safety and waste disposal.

Biofuels. Biofuels are a form of bioenergy, which is energy made available from biomass. Biomass is any material from biological sources, including solid waste, animal waste, and plant matter such as trees, grasses, and agricultural crops. **Biogas,** such as methane, is the gas from the decomposition of organic matter, and is also considered a biofuel.

In some cases, biofuels offer a great way to reuse or take advantage of energy sources that were going to be wasted otherwise. Through bioenergy technology, waste and manure can be converted into fuel for transportation and power generation. One example of this is the methane gas that is generated as a by-product of **anaerobic decomposition** in a landfill. The methane generated is a powerful greenhouse gas. By trapping it and burning it to generate electricity, we are taking advantage of this resource. This way, we reduce the need for fossil fuels and lower the emission of methane into the atmosphere. Another example of reusing biomass to generate power is the use of waste vegetable oil (cooking oil from restaurants and households) to power converted diesel engines. This is different from biodiesel, which is also produced from the same source, but requires additional chemical processing. In general, burning biofuels emits fewer particulates than other energy sources.

On the other end, some biofuels use primary resources, such as crops, to generate a usable energy form. Ethanol from corn is the most well known and also the most controversial, because Its production is energy intensive. Opponents argue that it takes just as much energy to create the fuel as the ethanol produces. Current research by the National Renewable Energy Laboratory (2010) is concentrated in developing a technology to produce ethanol from cellulose, a form of carbohydrate that is not fit for human consumption but that is high in energy content. This would resolve part of the conflict generated by growing food crops for energy use. Furthermore, many scientists are investigating high-yield, but low-water-intensive crops—those that do not require large amounts of water to grow, such as switchgrass, as alternatives to growing corn or sugarcane for biofuel.

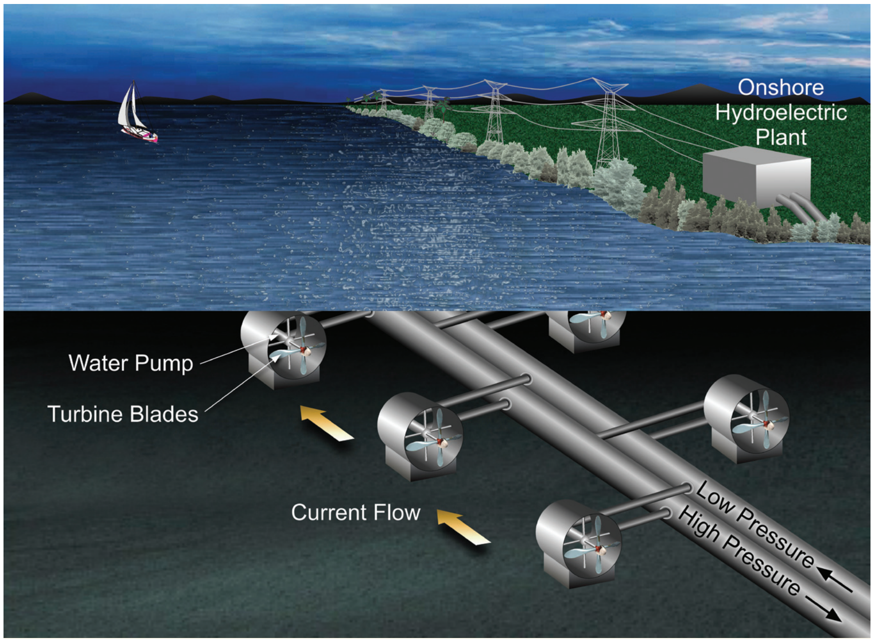
Some consider biofuels to be carbon-neutral sources of energy because the carbon released from using biofuels was originally taken in by the plants. However, the process of cultivating the plants and processing the fuels actually requires energy, which often comes from fossil-fuel-based power. In addition, creating bioenergy tends to be water-intensive, and there are concerns about food crops being diverted to fuel production, causing rising food prices that may leave people in some areas hungry. (The Environmental Education Exchange 2004).

Note that students may initially think that biofuels are good because they are plants. Plants are often viewed as 'good,' but when asked the question, "Is cutting down forests to grow biofuels okay?" students then reconsider the situation. Students still see burning plants as cleaner than burning fossil fuels, but they are ready to weigh other environmental impacts and trade-offs of biofuels to develop a more complete understanding of this energy option.

Ocean Energy. Wave and tidal power are two ways to harness the energy from the constant movement of the ocean. Neither of these technologies has been widely developed nor tested, but studies show potential because of their possibly low environmental impact. Wave power is the kinetic energy transported by ocean surface waves. There have been several attempts at developing commercial wave farms in the last few years; none of them have been widely successful. For example, in 2008, a British company created the Aguçadoura Wave Park off the shores of Portugal. The project intended to generate electricity for more than 1,500 homes but was cancelled after technical failure of the equipment just a few months later (Jha 2008). Ocean wave technology, because it is so young, is still under study. Companies are currently testing different designs to see which are most effective, and there is great promise that our ocean may be a viable energy source in our future.

Tidal power comes from the kinetic energy produced by the rise and fall of sea levels, and it is compared to wind energy in its reliability to generate electricity for prolonged periods. Just like with wind power, tidal power can be harvested through the use of turbines connected to an electrical generator. Another harvesting method for tidal power uses barrages, or dams, across the width of an estuary. Like clockwork, these systems would generate very predictable energy. Scientists are also looking at turbine systems that could take advantage of known ocean currents.

The downside of ocean energy sources—tidal, wave, or current—is the limited availability of sites that would be productive, as well as the high cost of generating electricity from them. Like all new technologies, ocean energy technologies are very expensive. Additionally, there is some concern that ocean energy systems may impact marine life, especially when built in known migratory routes. For example, currents are frequented by marine organisms for the same reason that we would build turbines in those locations—reliable, moving water.



The movement of water causes the underwater turbine blades to rotate, which send high-pressured fluid to turn turbines in an onshore hydroelectric power plant.

The ocean can also be a location for offshore wind and solar energy. With all these ocean energies, students may be concerned that water and energy don't mix. They learned from an early age that water is dangerous around electricity, so may question how we get electricity from objects sitting in water. It is important to reassure students that this type of energy is safe.

Teaching Tip

Many of the energy innovations presented in this chapter might seem foreign to students. To make their learning significant, invite students to explore which of these are feasible in your region, state, city, community, and school. Start by having them research online and in the school's library more about the requirements for each of these innovations and then compare them to the features in your community. Pose a list of questions to guide their inquiry process:

- What type of renewable sources of energy do we have in abundance?
- Which of these innovations makes more sense in our community?
- What would be the cost of incorporating them?
- What would be the benefits?

For younger students, have them journal about the top three energy sources they think are best for their community. For older students, consider having students draft their own energy plan, using the research they found online as well as information they learned during class discussion.

Case Study

Solar Energy

Adapted from *Powering Our Future: Renewable Energy Education* (The Environmental Education Exchange 2004)

The sun is the ultimate source of energy on Earth. The sun drives water cycling and wind and weather patterns and is the source of energy for all life on Earth. This means that solar energy is the ultimate source of many other energy sources on Earth, including fossil fuels, biomass, and wind. Of course, the term *solar energy* is commonly used to refer to the forms of energy that we obtain more directly from the sun. Sunlight, also called solar radiation, is the most inexhaustible, renewable source of energy known to humankind. The amount of energy that the sun radiates onto Earth every hour is greater than the amount of energy used worldwide in a full year.

In general, the ways we use the sun's energy can be described as passive or active. **Passive solar energy** involves using the sun's energy with no or minimal mechanical or electrical devices. Passive solar energy can involve using the sun's energy as a light or a heat source. Lighting buildings with natural light is called daylighting. Passive applications of solar thermal energy, or the heat energy of the sun, include heating water and buildings. Using passive solar techniques for heating is very efficient. Heat energy is considered low-quality energy. Electricity, for instance, is a high-quality energy because it is very concentrated. When electricity is converted to another form, heat, a low-quality energy, is given off. Using electric heat, for instance, is inefficient. You are using a high-quality energy source for a low-quality need. A lot of energy is "wasted." Passive thermal systems prevent this type of waste. This is because the energy is used in the same form (heat) rather than converted from one form to another.

Active solar energy is any type of solar application that uses electrical and/or mechanical equipment. Solar thermal power plants are an example of active solar thermal application. At such plants, sometimes called "power towers," the sun's rays are concentrated as a heat source to boil water or another fluid, producing steam. The steam is used to rotate a turbine, activating a generator that produces electricity. This is very different from photovoltaic energy.

British Motor Car Distributors in San Francisco, California, installed solar panels on their carports to supply the dealership with enough power to meet its daily energy needs.

Photovoltaic, or PV, energy is a form of active solar power that is created when light energy from the sun is converted on an atomic level directly into electrical energy. Photovoltaic technology actually produces electricity with no moving parts and without burning fuel. PV technology is based on an interesting fact of physics and chemistry that light energy can stimulate an electrical current in certain materials or semiconductors.

The basic building block of all photovoltaic systems is the photovoltaic cell. The PV cell is where the energy conversion process takes place. Although other materials can be used, today almost all photovoltaic cells are made of a very thin wafer of crystalline silicon. Silicon is the second most-abundant element in Earth's crust (the first being oxygen). The photovoltaic effect occurs when sunlight strikes silicon (or certain other semiconductors) and the light energy is absorbed, energizing electrons so that they become free from their atoms and move through the material. A PV cell is designed to enhance this natural process. By connecting the cell to a circuit along which the electrons can flow, we can harness the electricity and put it to use.

More than 3,300 solar panels have been erected on a vacant five acres at NASA's Kennedy Space Center in Florida to create the Solar Energy Center.

Sunlight is comprised of a range of wavelengths. It is light energy, per se, that causes the photovoltaic effect. The heat energy in sunlight is central to solar thermal applications, like passive solar buildings and water heaters, but plays no role whatsoever in photovoltaics.

The performance of a PV cell is measured in terms of its efficiency at converting light energy into electricity. Some types of PV cells available today reach efficiencies of about 15 percent. *Efficiency* refers to the amount of energy that is actually obtained from a process, as much energy is lost as heat when it is converted into electricity or other forms. As per the laws of physics, no conversion of energy can be 100 percent efficient. For comparison, use of fossil fuels to create electricity is about 30 percent efficient; that is, 70 percent of the energy is lost during conversion and transport.

Photovoltaic power has proven extremely reliable. A photovoltaic array has no mechanical (or moving) parts, and PV equipment can operate reliably for long periods with virtually no maintenance. No fuel or input is required other than sunlight. Because sunlight is free, there are no fuel costs (and no unpredictable variations in fuel costs over time). The cost of a PV system is almost entirely paid up front for equipment and installation, and operating costs are quite minimal. Developing PV plants, however, can be very expensive.

Producing PV cells does result in some pollution. However, in contrast to electricity generated by conventional energy sources, photovoltaic electricity does not involve the release of greenhouse gases and other air pollutants, production of toxic or radioactive waste, large PV projects can cover thousands of acres, which disrupts the natural ecosystem. The downside of using photovoltaic power is the high cost of the technology and the habitat loss when solar plants are built in pristine habitats. Of course, solar units cannot generate power at night and are less efficient during cloudy weather. Also the storage of energy from PV plants can be a challenge. Although solar panels are expensive, the price of PVs is decreasing and will continue to do so as the technology improves and more homes and businesses purchase it.

Student Thinking

Renewable Resources

Often, students are introduced to renewable energy resources as a "no harm" energy alternative to traditional fossil fuels such as oil, coal, and natural gas. While students are interested in learning about renewable energy, they often have misconceptions that may hinder their understanding of these resources. They may also be confused about how to determine whether an energy source is renewable or not.

	Common Student Ideas	Scientific Concepts
Impact on environment	Renewable energy resources have no negative impacts on the environment.	In general, renewable energy resources emit fewer particulates and less carbon dioxide than fossil-fuel burning. Renewable resources still have negative effects on the environment. For instance, building any power plant disrupts ecosystems and can endanger wildlife.
Biofuels	It is only the heat produced by burning biomass that can be used for energy (such as burning firewood).	There are several different types of biofuels. Burning biomass is often used for heating and cooking. Biogas is produced when organic matter decomposes, such as in a landfill, and can be used to produce electricity. Some biofuels are produced from crops, which can be energy- and water-intensive and may cause food prices to rise.
Efficiency	Renewable energy resources are 100 percent efficient.	There are no energy resources that are 100 percent efficient. In fact, some renewable energy resources, such as solar power from PV cells (see **Case Study: Solar Energy,** page 116), are less efficient than fossil fuels.
Nuclear energy	Nuclear energy is renewable because it is considered a "clean" form of energy.	Nuclear energy emits virtually no greenhouse gases, so it is often lumped together with renewable resources. However, there is a finite amount of uranium on the planet, and therefore, it is not renewable. Additionally, nuclear waste disposal and potentially lethal accidents are concerns.

Ask Your Students

1. What kind of impact do renewable energy resources have on the environment?
2. How is biomass such as wood, agricultural crops, and so on, used to create energy? Are there any drawbacks to using biofuels?
3. How efficient are renewable energy resources?
4. Is nuclear energy renewable?

Taking Action

The most effective way to make learning about energy significant is to discuss actions that are reasonable solutions for individual people, families, schools, and the local community. Students will often ask themselves, “What can I do about this?” The answer is that every individual, even our youth, can do a lot to help with energy solutions. There are many ways students can help with energy conservation at school or at home. Using energy wisely makes a lot of sense—even to young citizens. Two important strategies for taking action include energy conservation and energy efficiency, both of which can reduce energy use while simultaneously reducing a home’s or school’s cost for energy.

What Can You and Your Family Do?

Reduce Obvious Energy Use. The first step is a simple one: turn off lights, even if they are energy-efficient bulbs. With just the flip of a switch, energy conservation is at everyone’s fingertips. Use compact-florescent lightbulbs because they use roughly 75 percent less energy than incandescent bulbs and last up to 10 times longer. LED lightbulbs are more costly but even more efficient than CFL bulbs. In winter and summer months, adjust the thermostat just a few degrees. A large portion of home energy use goes to heating and cooling. In the winter, lowering the thermostat by as little as 1°F can reduce a heating bill by three percent. On milder days, such as in spring and fall, open windows instead of using air conditioning.

Reduce Hidden Energy Use. Turn off and/or unplug electrical appliances when they are not being used. Electronics use energy even when turned off. This is called “phantom power” because it’s a hidden energy drainer. Using a power or surge strip with an on/off switch can make turning power off fairly easy. In some locations, weatherizing one’s home is an important energy-efficiency strategy. Extra weather stripping around doors and windows reduces air leaking through the cracks. Also, conserving water conserves energy. It takes energy to move water into our homes and industries. Turning off faucets and using less water means conserving energy indirectly.

Upgrade. Investigate your appliances and more energy-efficient alternatives. When upgrading appliances, look at Energy Star appliances (http://www.energystar.gov/), which have better energy-efficiency ratings. This is particularly important for furnaces, hot water heaters, and refrigerators. In fact, the refrigerator is the biggest energy consumer in a home—improving its efficiency can mean both big savings and much better home energy efficiency.

Reduce Transportation Costs. Monitor your daily driving habits and consider replacing one day of driving with public transportation, carpooling, bike riding, or walking. Also, consider reducing the transportation (and fuel) costs for the food you purchase. When appropriate, choose food products that are locally grown and appropriate to your climate. For example, citrus fruits such oranges and grapefruits are grown in the mild climate of southern California. Choose these local products when in season rather than those from Florida or South America.

Changing lightbulbs to energy-efficient bulbs can reduce energy use and save on electricity bills. A CFL bulb uses only 14 watts of energy compared to 60-watt or higher incandescent bulbs.

Simply turning off unused lights in your home is one of the easiest energy-conservation practices everyone can do.

Dryers use a lot of energy that could be conserved if people used the sun’s energy to dry their clothes instead.

What Can Your Classroom and School Do?

Create an Energy Challenge. Develop a program at school to reduce energy use. Have each classroom develop an energy plan, and then monitor the school's energy use across the year. The energy plans might include reminding students to turn off lights when not in use, replacing school lightbulbs with energy-efficient alternatives, and adjusting classroom temperatures a few degrees to reduce energy use.

Develop a List of Local Sustainable Vendors. Have your students develop a list of vendors—shops, restaurants, grocery stores, and markets—that carry locally-grown or locally-made products or companies that have programs to conserve energy. Once your class has created a list, consider asking these vendors to visit your classroom to talk about what they are doing to reduce their use of energy or to make energy more efficient.

Let Your Voice Be Heard. Investigate ways to get involved in the community or the community issues being discussed. As a class, weigh-in on the issues. Write a class letter to your local newspaper, create a blog, or make a video about what's important to your classroom. As adults, we can sign petitions, vote for political leaders that promise to act, and contact our local and state representatives, but students can also let their voices be heard by contacting their representatives and informing them of the importance of energy conservation.

What Can Your Community Do?

Learn About Local Incentives. Communities (and states) may offer incentives or subsidies for installation of alternative energy sources, such as solar or wind.

Teaching Tip

Have your students make a pledge for one action they will take to conserve energy or become more efficient. Have students share their action with the class, justifying their choice with scientific evidence or explanation. As students share their pledges, maintain a class list. Make sure to follow up with students after several weeks' time to see how effectively they followed through on their pledge and to discuss any difficulties they encountered.

Support Public Transportation. Advocate for public transportation in your community, as well as well-developed and safe bike trails. If these systems are in place, make sure to support them by riding the public transportation system when possible and biking to work or for fun with family and friends. Also, support your community in replacing government and public automobiles with fuel-efficient or hybrid alternatives.

Get Connected. Know your community's energy plan. What are the important goals, and how can you support these in happening? Get connected to local parks, businesses, and community groups so that you can be part of the programs happening in your local community. Become aware of these options and learn about what partnerships might be appropriate for your students or for other community groups.

Public transportation, such as subways and buses, are one way to reduce energy used on transportation.

In the Classroom

Measuring Your Energy Use

Auditing energy use is an important step for identifying actions for conservation. In this activity, students will audit their home energy use—lightbulbs, appliances, thermostat temperatures, and so on, to determine where they believe their highest energy use is and what they can do about it.

Materials

- Use an online energy meter or audit such as http://environment.nationalgeographic.com/environment/energy/great-energy-challenge/personal-energy-meter/ or print an energy audit questionnaire for students to complete at home. Even if using an online energy audit, students will need a worksheet that includes information about home energy use. See Your Energy Audit worksheet at http://www.pbs.org/wgbh/nova/teachers/activities/3519_energy.html for an example.

Directions

1. For more information prior to starting the lesson, please review http://www.eia.doe.gov/kids/energy.cfm?page=us_energy_homes-basics.
2. Explain or review the concepts of energy efficiency and energy conservation.
3. Engage in a discussion about their energy sources. Ask students, "Do you know where the energy you use every day comes from?"
4. Show the class several electricity-bill samples, and ask students to brainstorm what things they do at home that contribute to the bill.
5. Depending upon whether students are doing an online energy audit, give the class a worksheet to gather information about home energy use. Have students complete these worksheets overnight. Make sure students record number and types of lightbulbs, thermostat settings, and so on. If possible, students can also ask parents if they have a record of monthly energy use. If using an online audit, give students time to enter their information into the online program.
6. Start a class discussion about students' findings. Have students share their findings about what uses the most energy in their households. Are they already doing something that is right?
7. After all students have shared, discuss with them how the energy audit has helped them think about their own energy use. Have students design a plan to increase energy conservation and efficiency. As students develop these plans, generate a class lists of some of the most common actions that students can take.

Discuss

1. What was something that surprised you during your energy audit? Why was this surprising?
2. What patterns exist across all of our energy audits?
3. What is the number one solution that will reduce your energy use? Why do you feel this is the best solution for your home?

Case Study

The Energy-Water Nexus

Two of the biggest challenges of the 21st century include meeting the energy and water needs of an ever-growing population. These two critical resources are inextricably linked. All energy produced with fossil fuels and nuclear energy uses water. Our water distribution and treatment system also requires a great deal of energy. The connection between these two resources is known as the energy-water nexus. Our lives would not be the same without abundant supplies of both.

Energy Needs Water. Generating electricity requires water. In fact, electricity generation is one of the largest industries to withdraw freshwater resources (irrigated agriculture also withdraws a significant amount of water). Electricity that comes from fossil fuel or nuclear power plants requires up to 190,000 million gallons of water per day. That's equivalent to filling almost 300,000 Olympic-sized swimming pools per day! Electricity generation accounts for up to 39 percent of the freshwater taken from the environment. Consider this: Coal, the most common fossil fuel used for electricity generation, requires 25 gallons of water to generate a kWh (kilowatt-hour) of power. With every flip of a switch, U.S. citizens indirectly use water when they use energy.

Water Needs Energy. Our water system also requires a great amount of energy for treating and transporting water. The energy used accounts for close to 75 percent of the financial cost of water. Actually, up to 4 percent of the electricity generated for our power grid goes to our water supply-and-distribution system. In some states such as California, this amount is even higher (up to 5 percent) because California pumps water across long distances and over mountains, using a vast aqueduct system. Other factors that affect the amount of energy needed include 1) depth at which groundwater is pumped; 2) distance from surface waters that are used; and 3) the quality of the water before treatment. For example, groundwater pumped from low depths (e.g., 120 feet) that is fairly clean requires minimal energy,

while groundwater that is brackish and pumped from deeper underground (e.g., 500 feet or more) can be energy-intensive to access and treat.

As the population continues to grow, demands for both of these resources will increase. As water resources become harder to access, we will have to pump from greater depths and transport water across longer distances, as well as use more energy to treat water. All of this will affect the cost of water for consumers, and the amount of energy required. Everyone will have to cut back on water use, including our energy industry. The capacity of some power plants may be affected if they cannot get the water they need. This means that consumers may be affected by how much their local power plants can supply.

As a consumer, one might ask what can be done. Obviously, conserving both water and energy is a key to solving shortages of these critical resources. A study in California found that activities at home, such as heating water, washing clothes, and using clothes dryers, use 14 percent of the electricity consumed by people. All three of these activities have alternatives that allow people to conserve both water and energy. Consider hanging clothes on a clothesline, adjusting settings on hot water heaters to 120 degrees F, and only washing clothes when necessary, using full loads and cool water.

For more information, read about the Energy-Water Nexus at http://www.sandia.gov/energy-water/.

Pictures of Practice

Conserving Water, Conserving Energy

When you ask students about conserving energy, they may mention actions such as turning off lights, turning off electronics, and driving less. Students are less aware of complex energy relationships, such as the relationship between energy and water use. In order to pump clean water into homes and businesses, we require energy for pumping and processing. The water-energy nexus, as it is called, is a term used to describe how our use of water is intimately connected to our use of energy. Conserving one—water—is also conserving the other—energy.

Students: Grades 4 and 5

Location: San Diego, California (working class community)

Goal of Video: The purpose of watching this video is to hear students make connections between water and energy use.

Classroom Context

Ms. Howard addresses energy concepts with her elementary students across several grade levels. The lesson on energy conservation occurred at the end of her energy unit and at the very last discussion of the day. Ms. Howard asks her students to describe ways they could conserve energy.

Video Analysis

Ms. Howard asks students what they can do about energy today. Henry mentions that people can conserve energy, and Ms. Howard asks him what he means by conserve. Henry says “turning off the lights” or changing incandescent lightbulbs to CFL bulbs. But conserving energy is about more than turning off lightbulbs. Many of our actions use energy but in ways that may not seem apparent on the surface. Andrea immediately mentions that people can conserve water, and Ms. Howard asks her to elaborate. Andrea says you need electricity to pump the water. Rubysella adds to the idea of conserving water, and Ms. Howard draws comparisons between energy and water. Angel then mentions that water prices go higher and explains that prices go up to make people conserve water. In fact, energy costs may account for up to 80 percent of the costs on our water bills (Taylor, Philpot, & Ruppert 2009), so all three students share ideas that indicate they are starting to connect the two resources. Read more in **Case Study: Water-Energy Nexus,** page 122.

Reflect

How would you connect energy conservation with water conservation?

These students show they are making the connection between energy and water. Where would you go next with these students? What concepts should they know more about? If you were teaching energy conservation to your own students, how would you introduce students to water conservation and other “hidden” energy costs?

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Teaching Resources

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

U.S. Energy Information Administration resources: http://www.eia.doe.gov/kids/energy.cfm?page=3

National Geographic energy meter:
http://environment.nationalgeographic.com/environment/energy/great-energy-challenge/personal-energy-meter/

National Geographic energy diet:
http://environment.nationalgeographic.com/environment/energy/great-energy-challenge/energy-diet/

National Geographic energy conservation video:
http://video.nationalgeographic.com/video/player/environment/energy-environment/energy-conservation.html

National Geographic's Action Atlas: http://www.actionatlas.org/map

National Geographic's wind energy interactive:
http://environment.nationalgeographic.com/environment/global-warming/wind-power-interactive/

Glossary

acid mine drainage (AMD)
(A-sihd MIN DRAY-nihj)
Flow of acid or acidic liquid from metal mines or coal mines.

active solar energy
(AK-tihv SOH-lur EH-nur-jee)
Power from the sun that is increased by the use of electricity or other mechanical equipment.

anaerobic decomposition
(a-nuh-ROH-bihk dee-kahm-puh-ZIH-shun)
Process by which microbes such as bacteria decompose organic material in the absence of oxygen.

anthracite
(AN-thruh-sit)
Most valuable type of coal, containing high carbon content. Also called hard coal, black coal, and stone coal.

aquifer
(AH-kwuh-fer)
An underground layer of rock or earth that holds groundwater.

barotrauma
(bair-oh-TRAH-muh)
Injury, often to the inner ear, caused by a change in atmospheric pressure.

biofuel
(BI-oh-fyool)
Energy source derived directly from organic matter such as plants.

biogas
(BI-oh-gas)
Fuel produced by bacteria helping to decompose organic material, such as plants and sewage.

biomass
(BI-oh-mas)
Energy in living organisms.

bituminous
(bih-TOO-mih-nus)
Type of coal containing bitumen, an organic, tar-like substance.

British thermal unit (Btu)
(BRIHT-ihsh THER-muhl YOO-nuht)
Amount of heat or energy required to raise the temperature of one pound of water by one degree Fahrenheit, or 251.997 calories.

cap-and-trade
(KAP AND TRAYD)
System for reducing air pollution by placing limits on how much companies can pollute without having to pay a fee.

cellulosic ethanol
(sehl-yoo-LOH-sihk EH-thuh-nahl)
Fuel (biogas) produced from trees, grasses, and other plants.

Chlorofluorocarbon (CFC)
(klohr-oh-flohr-oh-KAR-buhn)
Chemical compound mostly used in refrigerants and flame-retardants. Some CFCs have destructive effects on the ozone layer.

combustion
(kum-BUS-chun)
Burning, or the process of a substance reacting with oxygen, to produce heat and light.

conduction
(kun-DUK-shun)
Transfer or movement of electricity or fluid through a conductor.

conductor
(kun-DUK-tur)
Material that transfers heat, light, electricity, or sound.

convection
(kun-VEK-shun)
Process of an air mass moving vertically.

desertification
(dih-zur-tih-fih-KAY-shun)
The spread of desert conditions in arid regions, usually caused by human activity.

electricity
(eh-lehk-TRIH-seh-tee)
Power associated with the changes between atomic particles (electrons).

electromagnet
(ee-lehk-troh-MAG-neht)
Material or object whose magnetic field is produced by electricity.

electromagnetic wave
(ee-LEHK-troh-mag-neh-tik WAYV)
Movement produced by an electric burst or charge.

embargo
(ehm-BAR-goh)
To outlaw trade of a certain good or service or to outlaw trade from or to a certain place.

energy
(EH-nur-jee)
Capacity to do work, available power.

energy conservation
(EH-nur-jee kahn-sur-VAY-shun)
Process of using less energy or using it more efficiently and sustainably.

energy efficiency
(EH-nur-jee ee-FIH-shun-see)
Ability to produce as much power with as little energy consumed as possible.

energy portfolio
(EH-nur-jee port-FOH-lee-oh)
Amount of electricity, water, and other energy used by a collection (portfolio) of buildings, rooms, or other specific areas.

energy poverty
(EH-nur-jee PAH-vur-tee)
Lack of access to safe, affordable electricity or other forms of power.

external combustion engines
(ehk-STUR-nul kum-BUS-chun EHN-jihn)
Machine in which the burning of fuel outside the engine heats a fluid inside the engine, which produces motion and energy.

fish ladder
(FIHSH LA-dur)
Series of steps overflowing with water, where fish can migrate upstream around a barrier such as a dam.

fossil fuel
(FAH-sul FYOOL)
Coal, oil, or natural gas. Fossil fuels form from remains of ancient plants and animals.

generator
(JEHN-er-ay-ter)
Machine that converts one type of energy to another, such as mechanical energy to electricity.

geothermal energy
(jee-oh-THUR-mul EH-nur-jee)
Heat energy generated within the Earth.

globalization
(GLOH-bul-ih-zay-shun)
Connection of different parts of the world resulting in the expansion of international cultural, economic, and political activities.

Greenhouse Effect
(GREEN-hows ih-FEHKT)
Phenomenon in which gases allow sunlight to enter Earth's atmosphere but make it difficult for heat to escape.

greenhouse gas
(GREEN-hows GAS)
Gas in the atmosphere, such as carbon dioxide and ozone, that absorbs solar heat reflected by the surface of the Earth, warming the atmosphere.

gravitational potential energy
(gra-vih-TAY-shuh-nul poh-TEHN-shul EH-nur-jee)
Force or power stored in an object's gravitational field.

halocarbon
(HA-luh-kar-bun)
Chemical substance made of carbon and one or more of the elements known as halogens.

heat
(HEET)
Energy that causes a rise in temperature.

hydrocarbon
(HI-droh-kar-bun)
Chemical compound made entirely of the elements hydrogen and carbon.

impermeable
(ihm-PUR-mee-uh-bul)
Not allowing liquids or gasses to pass through.

induction
(ihn-DUK-shun)
Process by which an object that has magnetic or electric properties is able to create a magnetic or electrical reaction in another object without contact with that object.

Industrial Revolution
(ihn-DUHS-tree-ul reh-voh-LOO-shun)
Change in economic and social activities— beginning in the 18th century—brought by the replacement of hand tools with machinery and mass production.

insulator
(IHN-suh-lay-tur)
Material that does not conduct heat, electricity, light, or sound.

internal combustion engine
(ihn-TUR-nul kum-BUS-chun EHN-jihn)
Machine in which the burning of fuel inside the engine heats a fluid inside the engine, which produces motion and energy.

kinetic energy
(kuh-NEH-tihk EH-nur-jee)
Power or force an object has because of its motion.

laws of thermodynamics
(LAHS uv thur-moh-di-NA-mihks)
Predictable, standard behavior of heat and energy.

metabolize
(muh-TA-boh-liz)
To convert a substance to its chemical parts and release its energy.

mine subsidence
(MIN sub-SI-dehns)
Process of a large area of land dropping or lowering due to the collapse of an underground mine or mine tunnels.

nonrenewable resource
(nahn-ree-NOO-uh-bul REE-sors)
Natural resource that exists in a limited supply.

nuclear fission
(NOO-klee-ur FIH-shun)
Process in which the nucleus of an atom splits, releasing energy.

nuclear fusion
(NOO-klee-ur FYOO-zhun)
Process in which the nuclei of one element, usually hydrogen, fuse with each other to form the nuclei of another element, usually helium.

passive solar energy
(PA-sihv SOH-lur EH-nur-jee)
Power from the sun that requires no other enregy or mechanical system.

permeable
(PUR-mee-uh-bul)
Allowing liquids and gases to pass through.

petrodictatorship
(peh-troh-dihk-TAY-tur-shihp)
System of government in which the export of oil and natural gas funds the total control of all policies by one person or group of people.

petropolitics
(peh-troh-PAH-luh-tihks)
Public policies and programs surrounding oil resources and distribution.

photon
(FOH-tahn)
Smallest unit of light.

photosynthesis
(foh-toh-SIHN-theh-sihs)
Process by which plants turn water, sunlight, and carbon dioxide into water, oxygen, and simple sugars.

photovoltaic
(foh-toh-vawl-TAY-ihk)
Able to produce energy when exposed to light.

piston
(PIHS-tun)
Object that moves inside a cylinder in order to move or push a fluid and create a force.

pollution
(puh-LOO-shun)
Introduction of harmful materials into the environment.

potential energy
(poh-TEHN-shul EH-nur-jee)
Force or power of an object as a result of its position in an electric, magnetic, or gravitational field.

radiation
(ray-dee-AY-shun)
Energy, emitted as waves or particles, radiating outward from a source.

radioactive
(ray-dee-oh-AK-tihv)
Having unstable atomic nuclei and emitting subatomic particles and radiation.

refugee
(rehf-yoo-JEE)
Person who flees his or her home, usually due to natural disaster or political upheaval.

Renewable Portfolio Standard
(ree-NOO-uh-bul port-FOH-lee-oh STAN-durd)
System of laws that requires increased production of energy from renewable sources, such as wind and solar.

renewable resource
(ree-NOO-uh-bul REE-sors)
Resource that can replenish itself at a similar rate to its use by people.

repulsive force
(ree-PUL-sihv FORS)
Energy or power with which objects repel each other.

resource curse
(REE-sors KURS)
Condition of regions with a high number of natural resources experiencing low development and economic growth. Also called the paradox of plenty.

rotor
(ROH-tur)
Part of a machine that rotates around a fixed point (stator).

semiconductor
(seh-mee-kun-DUK-tur)
Material that conducts electricity but more slowly than a true conductor.

smart-grid technology
(SMART GRIHD tehk-NAH-luh-jee)
System of monitoring energy use with a two-way communication system between the energy supplier and appliances in a user's home, which are controlled to save energy.

static electricity
(STA-tihk ee-lehk-TRIH-sih-tee)
Motionless electronic charge that builds up on a material.

stator
(STAY-tur)
Part of a machine that remains fixed and unmoving while other parts rotate around it.

steam turbine
(STEEM TUR-bin)
Machine driven by the movement of steam passing over blades or rotors.

subsidy
(SUB-suh-dee)
Money given to an individual or community to encourage a certain behavior.

thermodynamic equilibrium
(thur-moh-di-NA-mihk ee-kwuh-LIH-bree-um)
System in which properties such as temperature or mass will not change unless acted upon by an outside force.

thermodynamics
(thur-moh-di-NAM-ihks)
The study of the relationship between heat and mechanical energy, or work.

transformer
(trans-FOR-mur)
Device used to transfer electrical energy from one circuit to another, often increasing or decreasing the voltage.

turbine
(TUR-bin)
Machine that captures the energy of a moving fluid, such as air or water.

uranium enrichment
(yur-AY-nee-um ehn-RIHCH-mehnt)
Process of increasing (enriching) the amount of the U-235 isotope of uranium. U-235 is used to provide nuclear energy.

Facilitator Questions

Chapter 1

Student Thinking: Explaining Energy

1. How would you explain the relationship between actions and energy to your class?
2. What would be a good analogy you could use to explain how energy is different from electricity?
3. How would you help students understand that energy is not "used up," but instead changes forms?

Pictures of Practice: What Is Energy?

1. How would you explain the difference between the actual dissipation of energy and the perceived disappearance of energy to your students?
2. How would you react if a student in your classroom said, "Energy is power."?
3. How would you react if a student in your classroom said, "I'm tired. I don't have any energy."?

Student Thinking: Confusing Energy Concepts

1. How would you explain that water and air do not supply energy even though they are still essential to sustaining life?
2. What would be the best way to ensure that your students understand the difference between heat and temperature?
3. How would you respond to students who say that resting or sleeping is a way to recover energy?

Pictures of Practice: Making Sense of Nuclear Energy

1. In the preinterviews, both students show that they have misconceptions that nuclear energy is bad, and Martinez attributes this to "nuclear waste." How would you prepare for your lesson on nuclear energy given the ideas students will bring with them?
2. During the class discussion, fission is discussed. In the post interview, Ezequiel tries to explain how a uranium atom is split during fission. He explains that a power plant "puts the atom on a cutting board, and they use special tools to get to the inside of the atom." How would you respond to this idea in your classroom?

Chapter 2

Student Thinking: Burning Gasoline

1. Order these responses from least to most sophisticated. How did you determine the order?
2. All of these students are from the same seventh-grade classroom. How would your instruction change depending on your goals for Maria as compared to Karin?
3. How are Darian's ideas similar to Karin's? How are they different?
4. How would you help a student such as Jessie reach an understanding like Karin's?

Pictures of Practice: Energy From Cars

1. Students may equate gasoline with energy, or say "gasoline turns into energy." How would you respond if a student shared this in your classroom?
2. How would you teach about the other product that comes from burning gasoline—heat? How is heat a waste product from using gasoline?
3. What other misconceptions would you expect to see from students on this topic?

Student Thinking: Electrical Energy

1. How would you explain that not all of the electricity created in power plants reaches homes and businesses?
2. What is an analogy you could use for teaching about different voltages and why homes cannot receive the same voltage that is sent across transmission lines?

Pictures of Practice: Where Does Electricity Come From?

1. Students are engaged when they learn about something that relates to them. What is the path that energy takes to reach your school? How could you use this information to get students interested in electricity and where it comes from?
2. How would you explain the difference between telephone lines and power lines?
3. If your students said that power lines got power from the sun, how would you respond?

Student Thinking: Renewable and Nonrenewable

1. How would you grade the two post assessment responses? Why would you give the students these grades?
2. If Martinez shared his preassessment definition during a class activity, what would you do next to help him?
3. Andrea has clearly gained a stronger idea of energy sources that are renewable and nonrenewable, but her definition of renewable energy seems to have remained the same. Martinez, on the other hand, is using a definition close to the scientific one. How would your next steps with Andrea be different from what you would do with Martinez?

Chapter 3

Student Thinking: What Are Fossil Fuels?

1. What patterns do you notice in student responses before the instruction? What do you think causes students to develop these conceptions of fossil fuels?
2. In what ways do students make progress in their explanations of fossil fuels?
3. What remaining gaps or misunderstandings do students retain after the instruction?

Pictures of Practice: Fossil Fuels and Carbon

1. Eli describes fossil fuels as coming from dinosaurs and taking three hours to form. What would be your next step as Eli's teacher?
2. How can you help your students better understand the time span that it takes for fossil fuels to form?
3. Alan says that fossil fuels are made of carbon that "mixes and grows stronger." What do you think Alan means? How would you respond to Alan's explanation?
4. If Samantha was in your classroom, how would you re-teach fossil fuels to help her develop a better understanding?

Pictures of Practice: A Burning Candle

1. While the candle burns, Ms. Walker and her students discuss the flame of the burning candle. Amaya explains that the candle releases CO_2 caused by the flame. What do you think she means?
2. Samantha explains that "only a little bit will become a gas." What would be your next step if Samantha shared this in your classroom?
3. Look closely at what Alan describes as combustion. What ideas does he understand, and where does he need additional help?

Chapter 4

Pictures of Practice: Energy From Biofuels

1. Students tend to think of plants as something positive for the environment. How would you discuss the trade-offs of biofuels given this common idea about plants?
2. While the class spoke a lot about water runoff and loss of trees due to biofuel use, there was no discussion of the energy needed to grow and process biofuels. It takes energy to make this type of energy. How would you include this drawback in the class discussion?
3. During the discussion, one student describes "smoke" from burning biofuels. Students may also use words such as *exhaust* or *pollution* to describe the gases that come from using fuels. What do students need to know about these gases?

Student Thinking: Trade-offs of Energy

1. *Dirty* is an adjective students often use to describe fossil fuels and other pollution. What do students mean by *dirty?* What would be the learning goal you would set for your students with respect to fossil fuels and pollution?
2. It is likely students will have ideas about "good" and "bad" types of energy before you start teaching the topic of energy. Yet, each energy resource has trade-offs. How will you help students develop a more nuanced view of energy resources?
3. Discussing trade-offs of energy resources may leave students feeling like there is no solution. What activities could you do so students come to understand trade-offs of energy without developing overly negative perceptions about these resources?

Student Thinking: Greenhouse Gases

1. What would you predict your students would say in response to this question?
2. Which of the four responses do you believe to be the most sophisticated? Why?
3. How would your instruction change in response to Sarah as compared to your response to Joyce?
4. What information or experiences do these students need in order to respond to this question most appropriately?

Pictures of Practice: Impacts of Using Energy

1. If Martinez asked you about how mercury gets into fish, how would you respond?
2. In Esme's post interview response, she describes black, poisonous air from burning coal. If Esme shared this during a class discussion, what would you say or do next?
3. In the post interview, Martinez is still confused about the relationship between "smoke" and how mercury enters the food chain. If you were to continue teaching this topic, what would you do next with Martinez?

Chapter 5

Pictures of Practice: Energy Across Borders

1. Ms. Howard used pictures of resources and a modified globe to provoke discussion with her students about "resources from Earth." What resources would you teach to your students? What other ways might you engage students in the topic?
2. The idea that countries buy natural gas from others when they have natural gas in their own country can be confusing to students. How would you respond if a student asked you why this happens?

3. Ezequiel likens the sharing of natural gas across the U.S.-Mexico border to "terrorism." How do you think he developed this idea? Ezequiel questions the purpose of the border and thinks borders are supposed to divide countries, but cooperation between countries is also important. How would you respond to Ezequiel's ideas?
4. Air and water are shared across borders. How could you use this idea to show that cooperation between countries is important for protecting resources and controlling pollution?

Pictures of Practice: Unequal Energy Use

1. How do you think your students would react to the statistic that Americans make up 5 percent of the world population, but emit 25 percent of the greenhouse gases?
2. Students may think it is unfair that Americans use so much energy. Yet, they also likely believe they have a right to energy resources because they pay for them and because they need them to do the "normal" things in their lives. How can you help students see that they can have a "normal" life while also reducing their energy use?
3. Students' post interview responses were diverse—from Andrea mentioning renewable energies to Martinez describing a situation in which people walk everywhere to Ezequiel saying we would go back to candlelight. If these students shared their ideas during a class discussion, what would you do with those ideas? How would you move forward with the class as a whole?

Student Thinking: Who Gets Energy?

1. The cover photo of this chapter shows a village in Africa using firelight with the glowing lights of a natural-gas facility in the background. Students may not understand why some people do not have access to energy, even when those resources are located in their own backyards. How would you address this issue with your students?
2. Students will share idealistic solutions to energy problems. For example, they may believe people should "share" energy. Yet, they may also believe they deserve more energy because they pay for it. How would you respond to this contradiction during your instruction?
3. Students may believe that people living without energy have no need for energy because they do not own electronics and appliances like we do in the United States. Many of these villages could greatly benefit from energy if it was supplied. What is wrong with student thinking about this issue? How might you address this misconception in your classroom?

Chapter 6

Pictures of Practice: Energy Efficiency of Lightbulbs

1. One concept that comes up during the discussion and interviews is what the word *efficient* means. Some students say *efficient* means "more power." How would you address this misconception?
2. Esme asks, "What is it that makes it [lightbulb] create a lot of heat?" How would you answer Esme's question using a follow-up activity?

Student Thinking: Renewable Resources

1. Students see renewable resources as sources of "good" energy. How do you think this idea develops? What challenges might you face when teaching the trade-offs of renewable energies?
2. Are there specific renewable resources that your students are familiar with from their community that you can incorporate into your lesson?

Pictures of Practice: Conserving Water, Conserving Energy

1. Interestingly, these students (especially Andrea) make the energy-and-water connection on their own. Would your students make this connection? If not, how would you approach this topic with them?

2. Turning off lights and changing lightbulbs go a long way toward conservation, but they are not the only things students can do to conserve energy. What activities could your students do as a class to develop a more complete plan for energy conservation?

3. Energy use can often be invisible to students. For example, they may not realize that moving water into our homes is part of our energy footprint. What other consumer practices can impact the amount of energy people use (e.g., importing and transporting goods, and so on)? How can you make these practices more visible to your students?

California State Standard			Connections to EEI Model Curriculum	Teacher Guide Chapters
Grade 3				
Social Studies	3.1.1	Identify geographical features in their local region.	The Geography of Where We Live	Chapter 1
	3.1.2	Trace the ways in which people have used the resources of the local region and modified the physical environment.	The Geography of Where We Live (e.g., California Connections: California Natural Regions (pp 42—47 Ocean & Coast)	Chapter 3, 4, 6
	3.3.3	Trace why their community was established, how individuals and families contributed to its founding and development, and how the community has changed over time, drawing on maps, photographs, oral histories, letters, newspapers, and other primary sources.		Chapter 6
	3.4.1	Determine the reasons for rules, laws, and the U.S. Constitution; the role of citizenship in the promotion of rules and laws; and the consequences for people who violate rules and laws.		Chapter 5, 6
	3.4.2	Discuss the importance of public virtue and the role of citizens, including how to participate in a classroom, in the community, and in civic life.		Chapter 5, 6
	3.5.1	Describe the ways in which local producers have used and are using natural resources, human resources, and capital resources to produce goods and services in the past and the present.	California's Economy—Natural Choices	Chapter 3, 4, 5, 6
	3.5.2	Understand that some goods are made locally, some elsewhere in the United States, and some abroad.	California's Economy—Natural Choices	Chapter 3, 4, 5, 6
	3.5.3	Understand that individual economic choices involve trade-offs and the evaluation of benefits and costs.	California's Economy—Natural Choices	Chapter 3, 4, 5, 6
Science	3.1.a	Students know energy comes from the Sun to Earth in the form of light.		Chapter 1, 2
	3.1.b	Students know sources of stored energy take many forms, such as food, fuel, and batteries.		Chapter 1, 2
	3.1.c	Students know machines and living things convert stored energy to motion and heat.		Chapter 1, 2
	3.1.d	Students know energy can be carried from one place to another by waves, such as water waves and sound waves, by electric current, and by moving objects.		Chapter 1, 2, 4
	3.3.d	Students know when the environment changes, some plants and animals survive and reproduce; others die or move to new locations.	Living Things in Changing Environments (e.g., California Connections: Sweetwater Marsh National Wildlife Refuge)	Chapter 4

California State Standard			Connections to EEI Model Curriculum	Teacher Guide Chapters
Grade 4				
Social Studies	4.1.5	Use maps, charts, and pictures to describe how communities in California vary in land use, vegetation, wildlife, climate, population density, architecture, services, and transportation.	Reflections of Where We Live	Chapter 2, 3, 4, 6
	4.4.6	Describe the development and locations of new industries since the turn of the century, such as the aerospace industry, electronics industry, large-scale commercial agriculture and irrigation projects, the oil and automobile industries, communications and defense industries, and important trade links with the Pacific Basin.		Chapter 6
	4.5.3	Describe the similarities (e.g., written documents, rule of law, consent of the governed, three separate branches) and differences (e.g., scope of jurisdiction, limits on government powers, use of the military) among federal, state, and local governments.		Chapter 5, 6
	4.5.4	Explain the structures and functions of state governments, including the roles and responsibilities of their elected officials.		Chapter 6
Science	4.1.c	Students know electric currents produce magnetic fields and know how to build a simple electromagnet.		Chapter 2
	4.1.d	Students know the role of electromagnets in the construction of electric motors, electric generators, and simple devices, such as doorbells and earphones		Chapter 2
	4.1.e	Students know electrically charged objects attract or repel each other.		Chapter 2
	4.1.g	Students know electrical energy can be converted to heat, light, and motion.		Chapter 1, 2
Grade 5				
Social Studies	5.7.3	Understand the fundamental principles of American constitutional democracy, including how the government derives its power from the people and the primacy of individual liberty.		Chapter 6
Science	5.2.f	Students know plants use carbon dioxide (CO2) and energy from sunlight to build molecules of sugar and release oxygen.		Chapter 1
	5.2.g	Students know plant and animal cells break down sugar to obtain energy, a process resulting in carbon dioxide (CO2) and water (respiration).		Chapter 1

California State Standard			Connections to EEI Model Curriculum	Teacher Guide Chapters
Grade 6				
Science	6.3.a	Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.		Chapter 1, 2
	6.3.b	Students know that when fuel is consumed, most of the energy released becomes heat energy.		Chapter 1, 2, 3
	6.3.c	Students know heat flows in solids by conduction (which involves no flow of matter) and in fluids by conduction and by convection (which involves flow of matter).		Chapter 1, 2
	6.3.d	Students know heat energy is also transferred between objects by radiation (radiation can travel through space).		Chapter 1, 2
	6.4.a	Students know the sun is the major source of energy for phenomena on Earth's surface; it powers winds, ocean currents, and the water cycle.		Chapter 1, 6
	6.4.b	Students know solar energy reaches Earth through radiation.		Chapter 1
	6.5.a	Students know energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis and then from organism to organism through food webs.		Chapter 1
	6.6.a	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.	Energy: It's Not All the Same to You!	Chapter 1, 2, 3, 4, 5, 6
	6.6.b	Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, freshwater, wildlife, and forests, and know how to classify them as renewable or nonrenewable.	Energy and Material Resrouces: Renewable or Not?	Chapter 1, 2, 3, 6
	6.6.c	Students know the natural origin of the materials used to make common objects.		Chapter 3, 6
Grade 7				
Science	7.1.d	Students know that mitochondria liberate energy for the work that cells do and that chloroplasts capture sunlight energy for photosynthesis.		Chapter 1

California State Standard			Connections to EEI Model Curriculum	Teacher Guide Chapters
Grade 8				
Social Studies	8.3.2	Explain how the ordinances of 1785 and 1787 privatized national resources and transferred federally owned lands into private holdings, townships, and states.		Chapter 6
	8.3.6	Describe the basic law-making process and how the Constitution provides numerous opportunities for citizens to participate in the political process and to monitor and influence government (e.g., function of elections, political parties, interest groups).		Chapter 6
	8.6.1	Discuss the influence of industrialization and technological developments on the region, including human modification of the landscape and how physical geography shaped human actions (e.g., growth of cities, deforestation, farming, mineral extraction).		Chapter 3, 4
	8.12.1	Trace patterns of agricultural and industrial development as they relate to climate, use of natural resources, markets, and trade and locate such development on a map	Agricultural and Industrial Development in the United States (1877—1914)	Chapter 3, 4, 5, 6
	8.12.5	Examine the location and effects of urbanization, renewed immigration, and industrialization (e.g., the effects on social fabric of cities, wealth and economic opportunity, the conservation movement).	Industrialization, Urbanization, and the Conservation Movement	Chapter 3
Science	8.3.a	Students know the structure of the atom and know it is composed of protons, neutrons, and electrons.		Chapter 1, 2
	8.5.c	Students know chemical reactions usually liberate heat or absorb heat.		Chapter 1, 2, 4

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