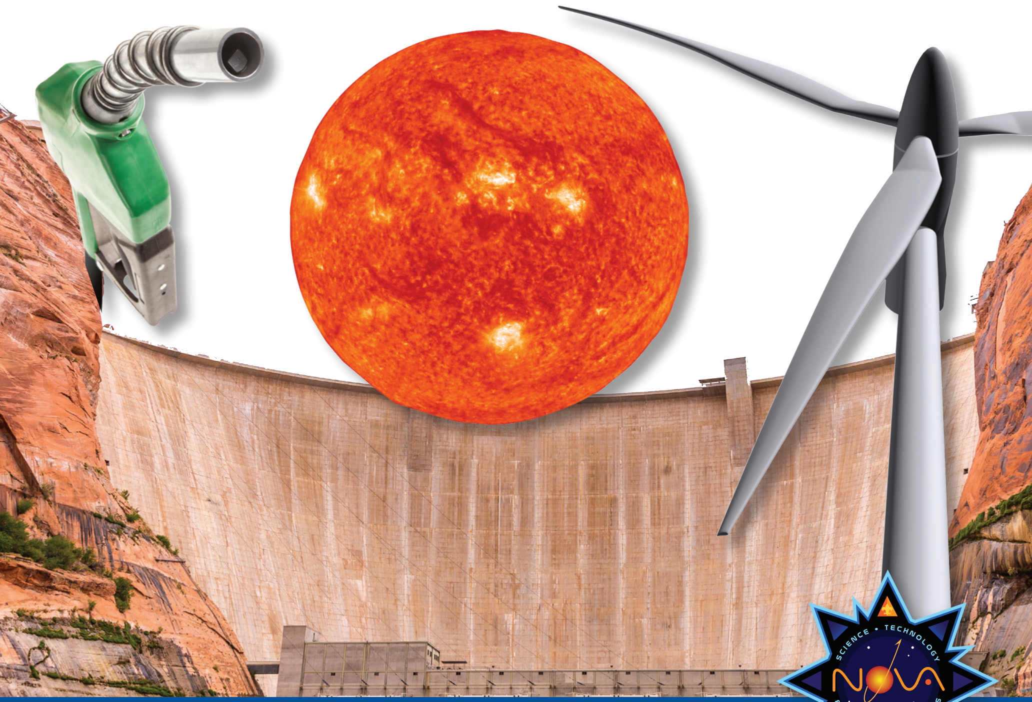
MERIT BADGE SERIES

ENERGY



Scouting America

STEM-Based

SCOUTING AMERICA
MERIT BADGE SERIES

ENERGY

"Enhancing our youths' competitive edge through merit badges"

Scouting America

Requirements

Always check scouting.org for the latest requirements.

1. Do the following:

   (a) With your parent or guardian's permission, use the internet to find a blog, podcast, website, or an article on the use or conservation of energy. Discuss with your counselor what details in the article were interesting to you, the questions it raises, and what ideas it addresses that you do not understand.

   (b) After you have completed requirements 2 through 8, revisit your source for requirement 1a. Explain to your counselor what you have learned in completing the requirements that helps you better understand the article.

2. Show you understand energy forms and conversions by doing the following:

   (a) Explain how THREE of the following devices use energy, and explain their energy conversions: toaster, greenhouse, lightbulb, bow drill, cellphone, nuclear reactor, sauna, electric vehicles.

   (b) Construct a system that makes at least two energy conversions and explain this to your counselor.

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3. Show you understand energy efficiency by explaining to your counselor a common example of a situation where energy moves through a system to produce a useful result. Do the following:
   (a) Identify the parts of the system that are affected by the energy movement.
   (b) Name the system's primary source of energy.
   (c) Identify the useful outcomes of the system.
   (d) Identify the energy losses of the system.

4. Conduct an energy audit of your home. Keep a 14-day log that records what you and your family did to reduce energy use. Include the following in your report and, after the 14-day period, discuss what you have learned with your counselor.
   (a) List the types of energy used in your home such as electricity, wood, oil, liquid petroleum, and natural gas, and tell how each is delivered and measured, and the current cost; OR record the transportation fuel used, miles driven, miles per gallon, and trips using your family car or another vehicle.
   (b) Describe ways you and your family can use energy resources more wisely. In preparing your discussion, consider the energy required for the things you do and use on a daily basis (cooking, showering, using lights, driving, watching TV, using the computer). Explain what is meant by sustainable energy sources. Explain how you can change your energy use through reuse and recycling.

5. In a notebook, identify and describe five examples of energy waste in your school or community. Suggest in each case possible ways to reduce this waste. Describe the idea of trade-offs in energy use. In your response, do the following:
   (a) Explain how the changes you suggest would lower costs, reduce pollution, or otherwise improve your community.
   (b) Explain what changes to routines, habits, or convenience are necessary to reduce energy waste. Tell why people might resist the changes you suggest.

6. Prepare pie charts showing the following information, and explain to your counselor the important ideas each chart reveals. Tell where you got your information. Explain how cost affects the use of a nonrenewable energy resource and makes alternatives practical.
   (a) The energy resources that supply the United States with most of its energy
   (b) The share of energy resources used by the United States that comes from other countries
   (c) The proportion of energy resources used by homes, businesses, industry, and transportation
   (d) The fuels used to generate America's electricity
   (e) The world's known and estimated primary energy resource reserves
7. Tell what is being done to make FIVE of the following energy systems produce more usable energy. In your explanation, describe the technology, cost, environmental impacts, and safety concerns.
   - Biomass digesters or waste-to-energy plants
   - Cogeneration plants
   - Fossil fuel power plants
   - Fuel cells
   - Geothermal power plants
   - Nuclear power plants
   - Solar power systems
   - Tidal energy, wave energy, or ocean thermal energy conversion devices
   - Wind turbines
8. Identify three career opportunities that would use skills and knowledge in energy. Pick one and research the training, education, certification requirements, experience, and expenses associated with entering the field. Research the prospects for employment, starting salary, advancement opportunities, and career goals associated with this career. Discuss what you learned with your counselor and whether you might be interested in this career.

Contents

Where Would We Be Without Energy?

Energy is necessary to heat, cool, and light our homes, schools, offices, and factories. Energy moves cars, trucks, buses, planes, trains, and ships. Our bodies, insects, the internet, instruments, farms, frogs, fish, phones, televisions, trees, wind, weather, and the water cycle all require energy. You cannot understand the world you live in without understanding energy.

A high personal energy use rate is an indicator of a high living standard.

The United States in the 21st century is the most energy-intensive society in human history. In our high-tech country, we take for granted complex communication and transportation systems, unrivaled health care, safe water, comfortable homes, and a prepackaged food supply. All of these features that American citizens expect require abundant energy to produce or operate.

The level of goods and services in one's everyday life is known as the *standard of living.* The kinds and amounts of energy a nation uses is a major factor in creating its standard of living. Access to energy leads to economic freedom—having the resources to live and work comfortably. To understand the possibilities and problems of America's future, we must understand our use of and reliance on various kinds of energy.

Electricity is a big part of how Americans use energy today. You can do no work at all without energy. Think how your life changes when the power fails during bad weather. You cannot flip on a light, watch television, use the computer, run a fan, toast bread, warm a drink in the microwave, or do anything else that requires electricity. Most of your regular activities abruptly stop.

Now think what would happen if the entire United States had to go without power. The life of the country as we know it today could not continue.

Efficient operation of traffic in our country requires consistent supplies of fuel as well as electricity to control traffic signals.

To understand energy and its importance in our way of life, you will need to understand the science of energy and the engineering of energy-using devices—engines and machines. You will need to learn about people's use of energy and how habits can be hard to break.

Saving, producing, and using energy wisely will be critical to America's future. If we are to leave future generations with a world in which they can live as well as or better than we have, you and other potential leaders of tomorrow must begin the hard work of understanding energy and the vital role it will play in the future.

A Scout Raises Questions

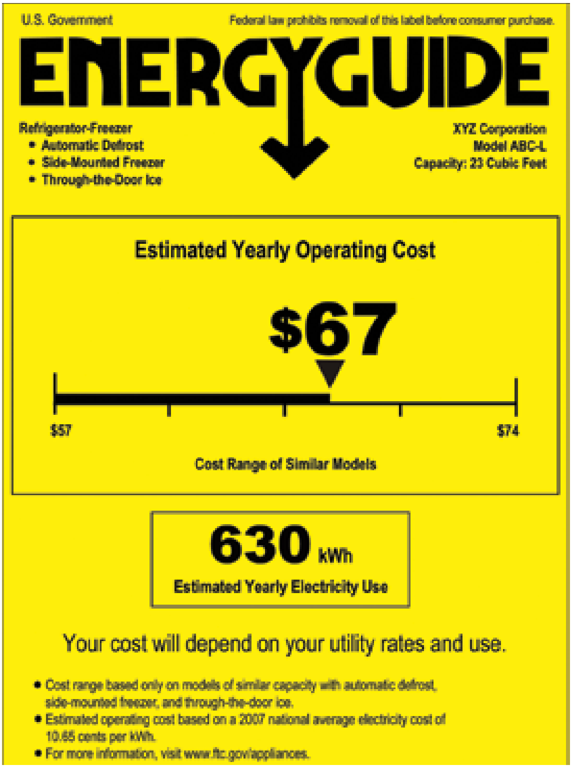
Nate walked out of the court of honor wearing a wide, proud smile. He could still hear his name being called to come to the front and receive his new rank patch: “Nathan Robert Gomez, Star Scout.”

Already he was planning his next step. What merit badge would he work on next? He had talked about it with Joe Philips, an assistant Scoutmaster with Troop 21. Joe said: “Energy is a good badge to work on. Understanding energy and its use is important to Scouts who want to be responsible members of their family, community, country, and world. Responsible energy use touches every aspect of our modern lives every day. The Energy merit badge will show you how to conserve energy and use it wisely. It will help you understand why energy is vital to the way we live.”

That was good enough for Nate. Energy it would be.

The next day, Nate and his family went shopping. Nate wanted to see what he could learn about energy while shopping, so he brought along a notebook. His family needed a new refrigerator. The store had rows of refrigerators and other appliances. While his mother talked with the salesperson, Nate walked up and down the rows. He noticed a large yellow sticker on each refrigerator.

The sticker was the EnergyGuide® tag and it contained lots of information. The statement that drew Nate’s attention was “This model’s yearly operating cost is $44.” He looked at other models. Their tags gave different yearly operating costs, ranging from $31 to $59. Nate wrote in his notebook the operating costs of several models.



Most appliances come with an EnergyGuide® tag that tells how much it costs to operate the appliance for one year.

Nate wondered why operating costs would be different. He saw that the refrigerators were different sizes, shapes, colors, and brand names. They were lined up more or less in the order of their yearly operating cost. Then Nate realized they also were lined up in order of selling price. He observed that the least expensive refrigerators were the most costly per year to operate, and the more expensive models were cheaper to operate.

"Why is that?" Nate wondered. He tried to think of things that might affect the price of a refrigerator and the cost of running it. Why would one refrigerator use more electricity than another? Nate didn't know much about how a refrigerator works, so he didn't get far with his questions. "Those will be good questions to ask my Energy merit badge counselor," thought Nate, and he made a note for himself in his notebook.

After finishing at the appliance store, the family stopped at a car dealership. Nate's dad needed a new truck and he wanted to look at different models. Every truck had a sticker the size of a sheet of notebook paper on the side window. These stickers contained lots of information besides the vehicle price. Each listed the make and model of the truck and the various options that came with it—air-conditioning, power windows, power door locks, etc. The price of some of the options was listed, but some were included in the *base price.*

Nate saw that every sticker also listed the "MPG highway" and "MPG city." He wondered why these two numbers for miles per gallon would be different. He also wondered if the more expensive trucks were cheaper to operate, like the refrigerators. However, after checking, Nate found that higher-priced trucks generally got *lower* fuel mileage, making them more expensive to drive than lower-priced models.

A salesman saw Nate scribbling in his notebook and came over. Nate explained what he was doing, and the salesman did his best to explain what affects mileage figures: engine size, air-conditioning, weight of the truck, transmission type, and more. Nate made notes, but he was not satisfied. He now had more questions for his Energy counselor.

When he got home, Nate searched the internet for information on gasoline mileage. He read how Congress in 1975 passed a law requiring companies that make cars and *light trucks* including pickups, SUVs, and vans to build these vehicles so they get certain gas mileages. The law was supposed to require more efficient cars and trucks so the country would use less gasoline and diesel fuel. The website said the law was meant to get average gas mileage up to 40 miles per gallon.

Nate wondered: If requiring 40 miles per gallon saved gas, why not make the law so that vehicles got 45 miles per gallon? Or 50? Or 100? If you can pass a law requiring car companies to build cars with better mileage, why was 40 miles per gallon the goal?

“Hey, look at this!” Nate’s dad exclaimed. “You’re working on the Energy merit badge, right?” Mr. Gomez handed Nate the evening television schedule, which had this program listed: “America’s Energy Future," 7 p.m.

At 7 p.m. Nate was in front of the television with his notebook and pencil. He recorded information that especially caught his attention. This included:

- Of the electricity produced in the United States, more than half comes from coal-fired power plants.
- A large coal-fired power plant can consume 10,000 tons of coal per day.
- The same size plant will produce more than 10,000 tons of carbon dioxide, water vapor, particulates, and fly ash.
- Of the energy in the coal that goes in, only about 35% comes out as energy in the electricity produced.

Nate watched the scenes of a coal-fired plant and its huge cooling towers. The narrator told how waste heat was released into the air as the plant operated. Nate saw giant plumes of steam rise into the sky. “Why don’t they insulate the plant so the heat doesn’t escape?” he thought. “Or reuse the heat?”

When the show was over, Nate put aside his notebook and grabbed the *Daily Chronicle* to check the sports scores. The sports section was in the same part of the paper as the business news. Nate saw a headline in the business pages: "Fuel Cells Trying to Be the Future Today."

The article talked about pollution-free cars and clean energy sources. Every line told how fuel cells were marvels of energy production. A sidebar article described other alternative sources of energy: photoelectric cells that convert sunlight directly into electricity; wind turbines using the free energy of the wind to power homes and businesses; garbage changed to useful energy by producing a gas called *methane*.

As Nate read the fuel-cell article, a date caught his attention: "Fuel cells were first developed by William Grove in the 1830s." That made Nate stop and think. "If fuel cells are clean, quiet, and a good source of energy, why don't we use more of them? If they have been around for more than 170 years, why are we still talking about how they *will* provide energy in the future? In fact, with all the good things said about solar cells, windmills, and other forms of *renewable* energy, why are we using coal and gasoline and running power plants that lose two-thirds of the energy they take in as fuel?"

Nate's questions bounced in his head. He thought: "Understanding energy seems easy. So why can't scientists, engineers, politicians, and other adults answer these easy questions?" As he headed for his first meeting with his merit badge counselor, he had a notebook full of information and a head full of questions. Nate understood there was much to discover about energy that he did not understand right now, but he was willing to learn.

Renewable energy from sources such as sunlight, wind, and water is replaced by natural processes. *Nonrenewable* energy sources (including coal and oil), once used, cannot be replaced.

Alternative energy sources, like these solar panels, can help cut down on pollution.

Energy From the Stars

The questions Nate asked as he prepared to study energy are important ones. To understand the answers, you must learn about the science of energy. Then you will understand that the answer to all of Nate's questions (and many others) relies on the same basic principle, called the *second law of thermodynamics.*

To learn the second law, you must first learn about the forms and characteristics of energy, where energy comes from, and (naturally) the first law of thermodynamics. All of this important information begins with the story of energy.

The Story of Energy

All forms of energy trace their origin to the stars.

Stars are huge balls of mostly hydrogen held together in space by crushing gravity. Stars radiate vast amounts of energy in all directions by changing hydrogen into helium and other heavier *elements.* Through this process, stars either release energy or store it in the *nuclei* of the heavier elements they create. In the tremendous heat and pressure of a star, two hydrogen *atoms* are crushed together until they join nuclei in a process called *fusion.*

> *Elements* are fundamental substances that cannot be broken into simpler substances by chemical means. Elements that occur naturally on Earth range from lightweight hydrogen and helium to metals such as iron and gold to dense, radioactive uranium. An *atom* is the smallest unit of a chemical element having the properties of that element. The core of an atom is its *nucleus* (plural *nuclei*).

The new nucleus formed through the fusion of hydrogen is of a different element—helium. The mass of the helium nucleus is less than the mass of the two hydrogen nuclei that formed it. The tiny amount of lost mass is converted into energy that spreads out from the star into space. This *radiant energy* is the main character of our story as it moves energy from the stars to Earth.

As stars get older, they fuse atoms into heavier elements. However, stars cannot form atoms heavier than iron because for fusion to continue, it must produce more energy than it uses in forming the heavier atoms. To make atoms heavier than iron by fusion requires energy put into the process.

Supernova

Heavy atoms form in a spectacular way. Very large stars eventually explode in an event called a *supernova.* This explosion creates very heavy atoms and spreads them into space. Scientists believe that all atoms heavier than iron were produced by supernova explosions.

Some nuclei have energy stored in them after their formation. Over time they release this energy through *radioactive decay.* By radioactive decay, an atom may release pure energy and become more stable, or discharge particles that carry off the energy.

Some very heavy elements release energy in still another way. The nuclei of uranium or plutonium can break apart in a process of *fission.* The mass of the pieces formed is less than the mass of the original nucleus that broke apart. The lost mass is converted into pure energy.

Our Nearest Star: The Sun

All of the energy sources in the world around us come from the energy pouring out of stars. And most of the energy that powers the functions of our world comes from a tiny portion of the energy of the sun—our nearest star.

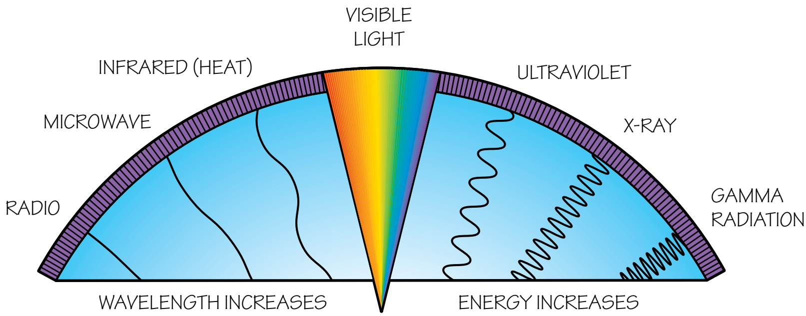
The sun constantly produces about 400 billion billion *megawatts* of energy. The amount that hits Earth is tiny (about five 10-billionths of the total energy of the sun), but that tiny portion powers all of Earth's life forms, food production, and weather processes. The rest of the sun's energy goes flying past us into space.

A watt is a measure of power. One horsepower equals 746 watts. A *megawatt* is 1 million watts.

Products of the Sun's Energy

Radiant energy floods from the sun as a mixture of different forms of *electromagnetic radiation*. Think of this as a fountain that constantly sprays a mixture of different beverages. In the mixture are coffee, tea, fruit punch, soda, grape juice, orange juice, and lemon juice. We can understand the whole mix by understanding the different types of beverages that make it up. While this concoction is made of seven different drinks, they all are alike in one way—each is made of mostly water.

Similarly, electromagnetic radiation is a mix of seven different kinds of what is basically one thing—radiant energy. Scientists divide the mixture into different categories for ease of study and discussion. The seven kinds, from lowest to highest energy, are as follows.



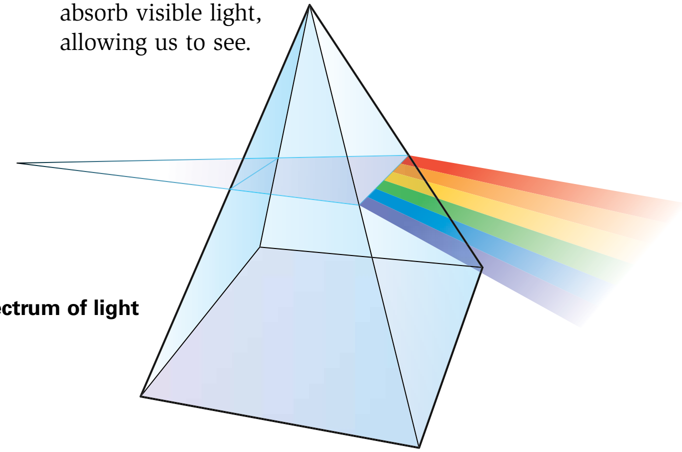
The electromagnetic spectrum

1. Radio waves. People use radio waves to send information to receivers—radios. Many stars and nebulae (dust and gas clouds in space) also give off radio waves. Another natural source is lightning. As a thunderstorm approaches, you hear crackles on the radio caused by bursts of radio waves created by lightning flashes.

2. Microwaves. Stars and galaxies create natural microwaves. In microwave ovens, microwaves penetrate food and cause water molecules in the food to vibrate, producing heat to cook the food.

3. Heat *(infrared radiation)*. Heat possesses enough energy that we can feel it if it is intense enough.

4. Visible light. Objects in the world around us scatter and absorb visible light, allowing us to see.



The visible spectrum of light

5. Ultraviolet light. Ultraviolet light has enough energy in its waves to damage the receptors in our eyes or the outer layers of our skin. UV radiation is the cause of suntans, sunburns, and some forms of skin cancer.

The powerful energy of an X-ray can be put to use in the medical field.

6. X-rays. X-rays have so much energy they can pass through our bodies and create a digital image on the other side. Hot gases in our galaxy emit natural X-rays.

7. Gamma radiation. This is energy so powerful it can penetrate deep through solid materials. Star processes or the decay of some radioactive atoms produce gamma radiation.

Earthly Energy

Energy comes to Earth from electromagnetic radiation given off by the sun, stars, nebulae, and other sources in our galaxy. Energy is stored in heavy atoms made in the death explosions of stars. So how does this celestial energy drive the natural processes in our earthly world?

Mechanical Energy: Objects in Motion

Mechanical energy is the motion energy of physical objects. Solar radiant energy can move objects, including air molecules in Earth's atmosphere. As air molecules absorb heat from the sun, they gain energy and move faster. As they move faster, they spread out. As they spread out, the air in a given space gets thinner, making it lighter, and it rises. The rising of heated air causes winds that have many powerful effects on Earth.

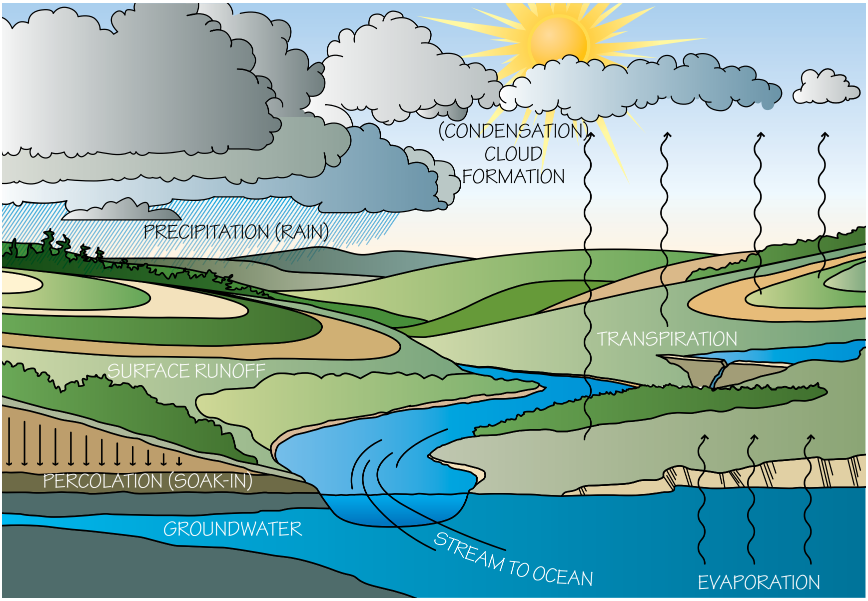
For example, if wind becomes strong enough, it picks up sand and dust and becomes a powerful eroding force. Wind blowing over water creates waves and currents. Wind pushes sailing ships, and it can help you ride your bike (or hold you back).

All of the effects of wind are due to the radiant energy of the sun heating the air.

Another form of mechanical energy is the effect of the wind on movable solid objects. As wind vibrates leaves, a dining fly, or the siding on a house, it produces sound. Any time the use of energy causes air vibrations, the result is sound waves. Sound carries the energy of molecules in motion.

Sound can be powerful. Sonic waves can blast cavities out of teeth or crush kidney stones. The roar of a jet engine or an explosive blast can cause pain. People who are deaf can feel music coming out of strong speakers.

Radiant energy has other effects on the natural environment. Heat, microwaves, and visible light all make water molecules move faster. Solar energy increases the temperature at the surface of the oceans and adds energy to snow and ice until they are warmed enough to melt into water. But probably the most important effect of the sun's radiant energy on water is to evaporate liquid water into water vapor, which rises into the atmosphere and is moved about by the winds. When it cools, it condenses back into liquid water and falls as rain.



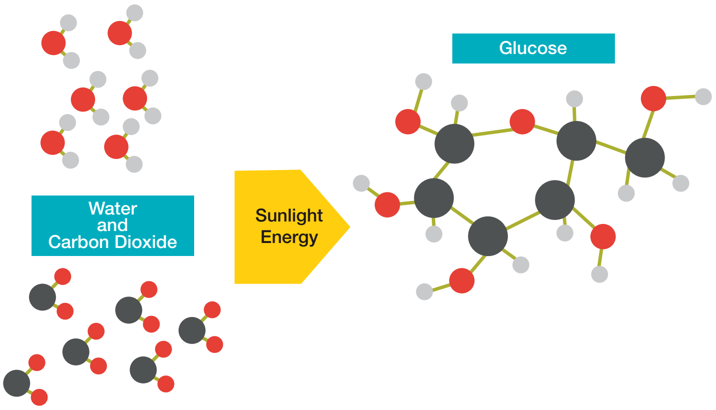
The water cycle

Chemical Energy

The sun's radiant energy drives processes by which atoms form bonds that store energy. The best-known way this is done is *photosynthesis.* A plant absorbs low-energy substances from its environment (mainly carbon dioxide and water) and, using radiant energy from the sun, builds complex molecules (glucose being the most important). The complex molecules have energy stored in their bonds.

Chemical energy includes the energy in batteries.

The plant may use the energy in these complex molecules for its own growth, repair, and reproduction. An animal may eat and digest the plant and use the energy released from the plant's molecules to make molecules for its own use. Also, burning the plant will release the chemical energy stored in the molecules. Burning gives radiant energy—light and heat.



Light energy is converted to chemical energy stored in the bonds of glucose and other molecules.

This process of storing radiant energy in high-energy molecules has been happening on Earth for a long time. Uncountable tons of plants and animals have lived, stored up the sun's energy in their molecules, then died. In many places, large amounts of these plants and animals were buried under layers of sediment that turned to rock. Under the pressure of the rocks and the heat from the interior of Earth, these materials became coal, oil, and natural gas. These forms of stored chemical energy are known as *fossil fuels.*

Volcanoes and hot springs are evidence that radioactive decay is releasing heat energy inside Earth.

Nuclear Energy

The heat from inside Earth that helped form the fossil fuels is *radioactive decay*—one of the few forms of energy that does not come directly from our sun. Radioactive atoms, formed in stars, release energy from their nuclei. Inside Earth, a constant release of this energy continues to heat the interior. If not for this process, Earth would long ago have cooled to a frozen mass, even with the energy input of the sun.

Electrical Energy

Radiant energy from the sun produces electrical energy in nature by stirring the winds and clouds. This stirring builds up electrical charges in clouds and results in lightning. Lightning produces the flash of light (electrical energy) we see.

Another form of nuclear energy, mentioned earlier, is fission. Fission occurs when very heavy atoms absorb neutrons (atomic particles) and split, converting mass to energy. Today, the fission process is used in nuclear reactors in power plants that produce electrical energy.

Another source of electricity in nature comes from certain *electrochemical reactions*. The most interesting of these may be the reactions in the bodies of electric eels that use bursts of electricity to stun prey and for defense. Electrochemical reactions also produce the electricity in most batteries.

People have discovered that the most useful way to produce electricity is to move a strong magnet near a conductor like copper. The field of the magnet causes an electric current in the conductor. Such a device is called a *generator* and is used in cars, power plants, and other places. By using sources of mechanical energy, magnets can be spun inside coils of wire, producing huge amounts of electrical energy.

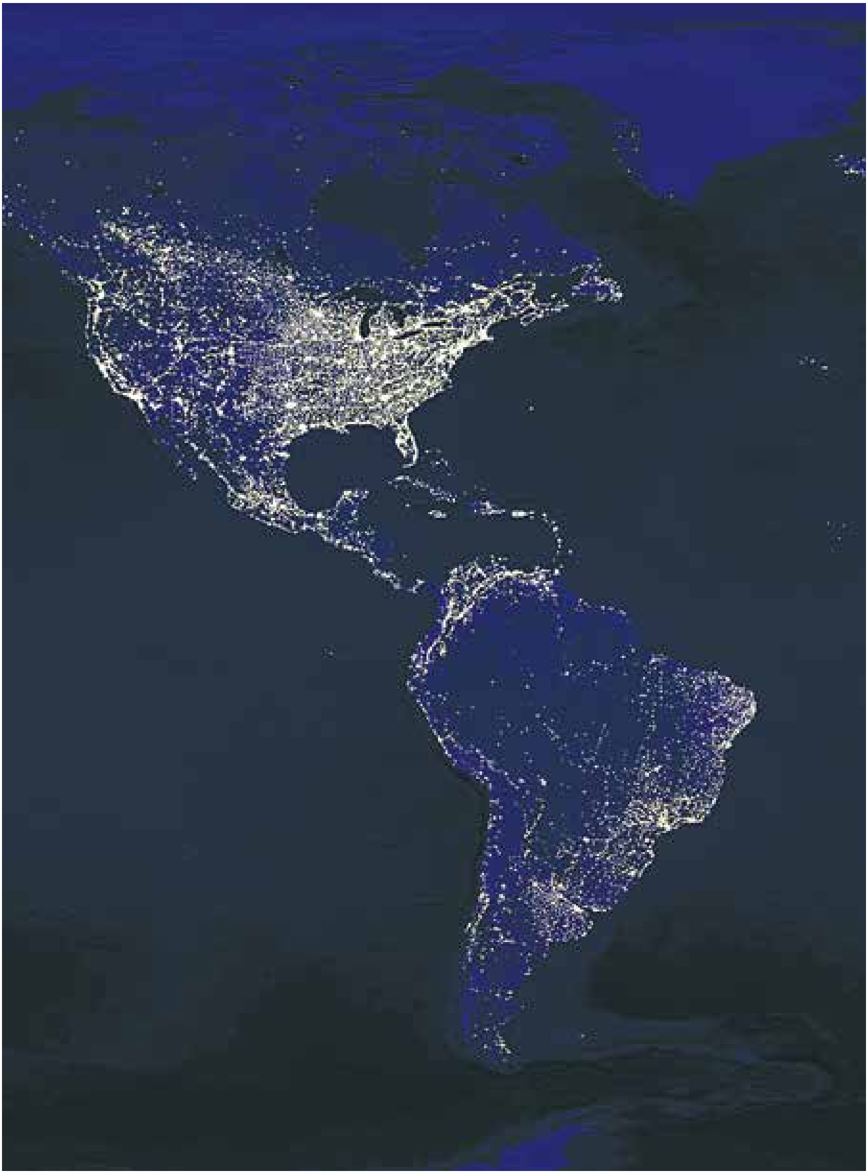
Summary of the Kinds of Energy

We are awash in a sea of energy. Everything that moves, makes sound, gives off light or heat, changes from a solid to a liquid, changes from a liquid to a gas, burns, grows, or does much of anything else interesting involves energy. Most of that energy traces its origins to our sun.

While chemical energy is useful for storing radiant energy until it is needed, electrical energy is useful for moving energy from place to place. Electrical energy is convenient, making energy available at the flip of a switch. For more about electric currents, see the *Electricity* merit badge pamphlet.

This introduction to the forms of energy allows us to discuss the scientific rules and helps us understand energy use. We will cover more about most of these ideas later.

Electrical energy is important as an easily transferred, readily available, on-demand form of energy.



This satellite image shows how developed countries like the United States are brightly lit compared with less developed areas of the world (like the interior of South America), which are dimly lit.

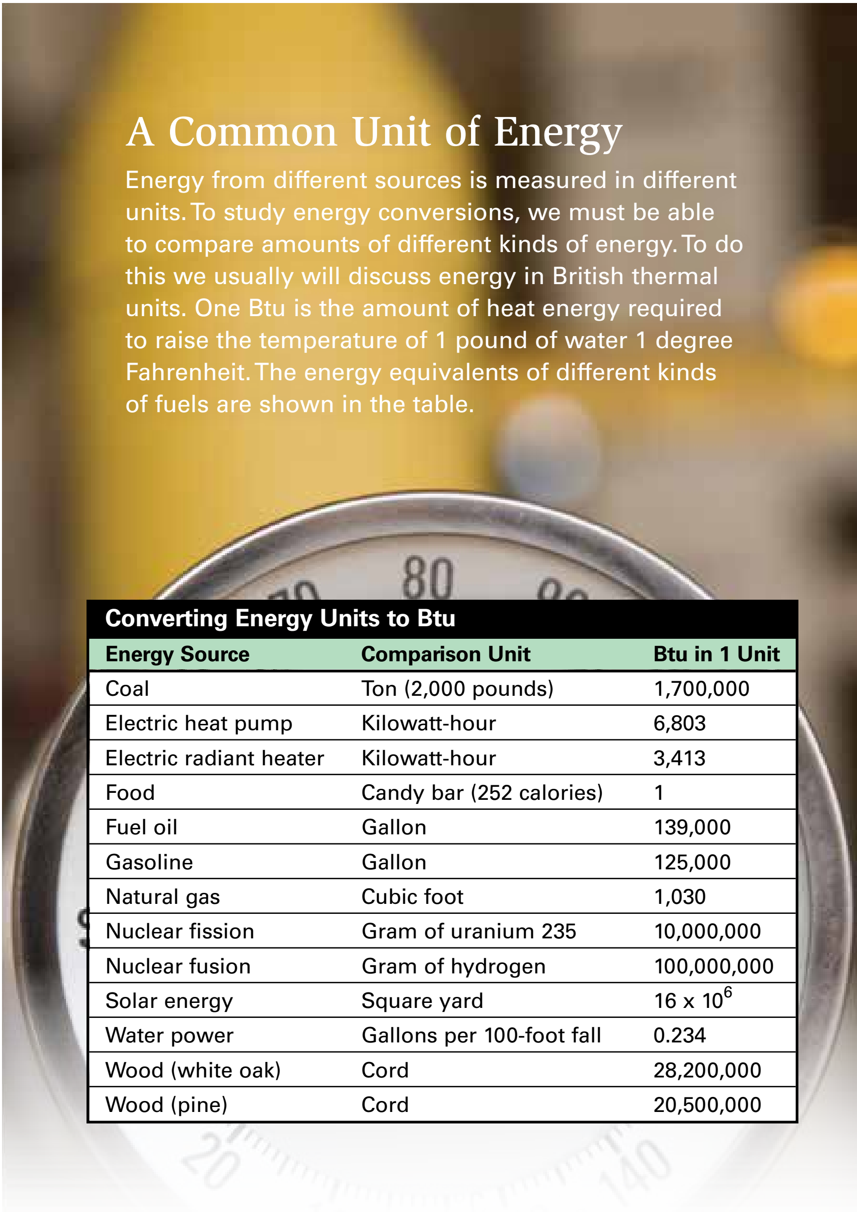
The First Law: Good News

To appreciate why we should not waste energy, we must understand the rules that describe the behavior of energy. These rules were learned mostly over the past 200 years.

By the end of the 1840s, three scientists—Julius Mayer, James Joule, and Hermann Helmholtz—all came to the same conclusion from different evidence. They learned that energy is never destroyed, nor can it be created. Energy does change from one *form* to another, but the universe always has the same total amount of energy. This principle that energy cannot be created or destroyed is known as the *law of conservation of energy.*

This was a key discovery because it focused the study of energy on understanding energy *conversions.* Scientists at this time were mostly interested in one form of energy—heat—and its movements. Because of this, the name given to the study of heat energy comes from two Greek words meaning "heat" and "movement"—*thermodynamics.* The law of conservation of energy also is known as the *first law of thermodynamics.*

We usually think of conservation as saving resources and using them wisely. But to a scientist studying energy, *conservation* of energy means that, in any system that runs on energy, the energy going in must equal the energy coming out.



A Common Unit of Energy

Energy from different sources is measured in different units. To study energy conversions, we must be able to compare amounts of different kinds of energy. To do this we usually will discuss energy in British thermal units. One Btu is the amount of heat energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit. The energy equivalents of different kinds of fuels are shown in the table.

Converting Energy Units to Btu

Energy Source	Comparison Unit	Btu in 1 Unit
Coal	Ton (2,000 pounds)	1,700,000
Electric heat pump	Kilowatt-hour	6,803
Electric radiant heater	Kilowatt-hour	3,413
Food	Candy bar (252 calories)	1
Fuel oil	Gallon	139,000
Gasoline	Gallon	125,000
Natural gas	Cubic foot	1,030
Nuclear fission	Gram of uranium 235	10,000,000
Nuclear fusion	Gram of hydrogen	100,000,000
Solar energy	Square yard	16 x 10^6
Water power	Gallons per 100-foot fall	0.234
Wood (white oak)	Cord	28,200,000
Wood (pine)	Cord	20,500,000

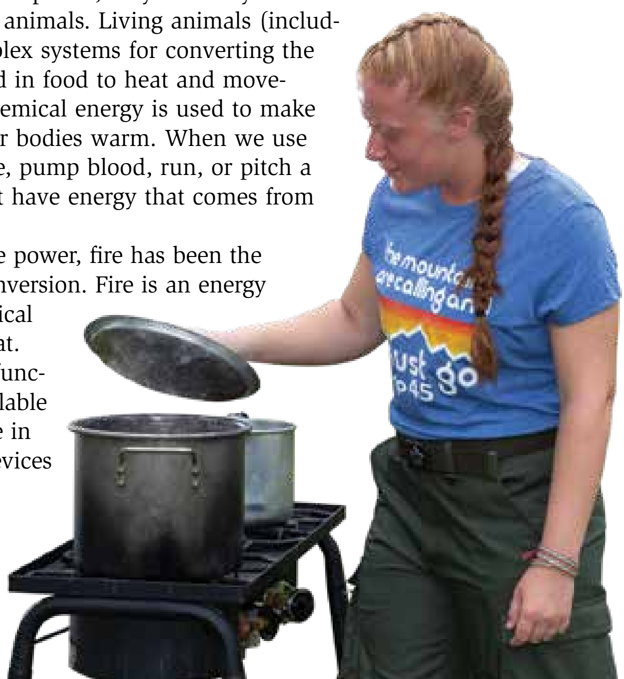
The first law of thermodynamics (energy cannot be created or destroyed, but only changed in form) helps us understand how we might use energy to drive some useful process. We must concentrate a form of energy and then create a system that changes it into the form we want (usually light, heat, or motion). To make electricity, we must get machine parts moving. Electricity can be used to make light, heat, and motion. Chemical energy of fuels is used to make cars move.

In every case where we want useful work done, we must find a source of energy, because energy cannot be created.

Energy Conversion Devices

Every useful process happens through the conversion of energy from one form to another. Before people invented cars, tractors, and power plants, they had only the muscle power of humans and animals. Living animals (including humans) are complex systems for converting the chemical energy stored in food to heat and movement. Some of that chemical energy is used to make the heat that keeps our bodies warm. When we use our muscles to breathe, pump blood, run, or pitch a tent, the muscles must have energy that comes from the food we ate.

Other than muscle power, fire has been the most useful energy conversion. Fire is an energy conversion from chemical energy to light and heat. Furnaces and heaters function to make heat available to keep us comfortable in cold weather. Many devices have been invented to make use of heat to help us accomplish other tasks.

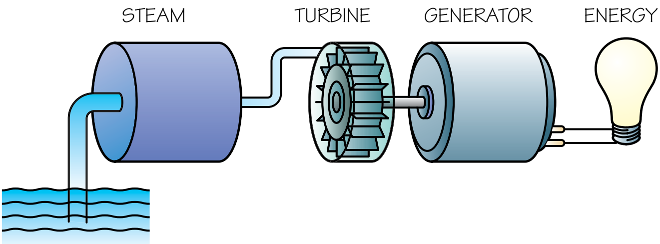


An *engine* is any device designed to convert thermal (heat) energy into useful motion (mechanical energy). People have invented many different systems to accomplish this vital energy conversion. Early steam engines used fire to power trains, ships, and farm machinery. Today cars, trucks, buses, trains, airplanes, and tractors get their power from *internal combustion* engines, which use fire inside a chamber in the engine. A *rocket engine* uses the rapid burning of its fuel to provide the powerful pushing force to send vehicles into space.

Electric motors are machines that convert electrical energy into mechanical energy. Many devices rely on electric motors creating movement when we need it. Fans move air and push air out of furnaces and air conditioners to heat and cool us. Freezers and refrigerators use electric motors to move heat. The windshield wipers of cars work on electric motors. Water pumps, garage door openers, elevators, drawbridges, car hoists, and construction cranes all rely on electric motors.

Substances with stored chemical energy that can be converted to useful motion in an engine are *fuels.* The most common fuels are materials that are burned to produce heat or power. Food is fuel—the source of the energy we use to move, think, and heat our bodies. Materials used in a nuclear fission or fusion reactor also are called fuels.

Energy conversions are used to make electricity. Many power plants rely on a combustion *boiler* to use a chemical fuel to boil water into steam. Nuclear plants use a *nuclear reactor* as their source of heat and steam. Steam-powered power plants need to convert the motion of the steam from a straight line into a circular, spinning motion. The device that does this is a *turbine.* The spinning motion of the turbine shaft can then be connected to a *generator,* which converts this mechanical energy to electricity.



Steam-powered power plant

We often convert electrical energy into light. The most common electric light is an *incandescent* light, which superheats a wire inside a bulb until it glows. *Fluorescent* lights are different and actually make two energy conversions. First, electrons passing through a mercury gas strike mercury atoms and give off ultraviolet light. The UV light strikes a coating on the inside of the tube and changes UV light into white light. This effect is known as *fluorescence.* We also are able to convert electricity into a useful form of light with *lasers.*

Batteries provide portable, stored electricity. They commonly power flashlights, radios, and other portable devices. Inside these batteries, reactions change chemical energy into electric current. When all of the chemicals have reacted, the battery cannot be made to produce more electricity.

Electrons are particles of an atom that carry a negative charge of electricity.

Storage batteries make use of two energy conversions. They use electricity to store chemical energy, then switch chemical energy back to electricity when needed. A car battery is a storage battery that uses an acid solution and lead plates to store the electricity used to charge it. Rechargeable *lithium* batteries produce electricity by transferring lithium atoms from the anode (negative pole) to the cathode (positive pole). By applying electricity to the battery, the lithium atoms can be forced back to the anode. Then the battery is ready to use again.

Most modern cellphones get their energy from rechargeable lithium batteries. Cellphone manufacturers strive for the lightest batteries possible that can store the most energy. This energy is converted to radio waves, or electromagnetic energy, when the phone is in use. This electrical energy conversion gives off thermal energy as waste and is why your phone can sometimes feel hot when you are using it.

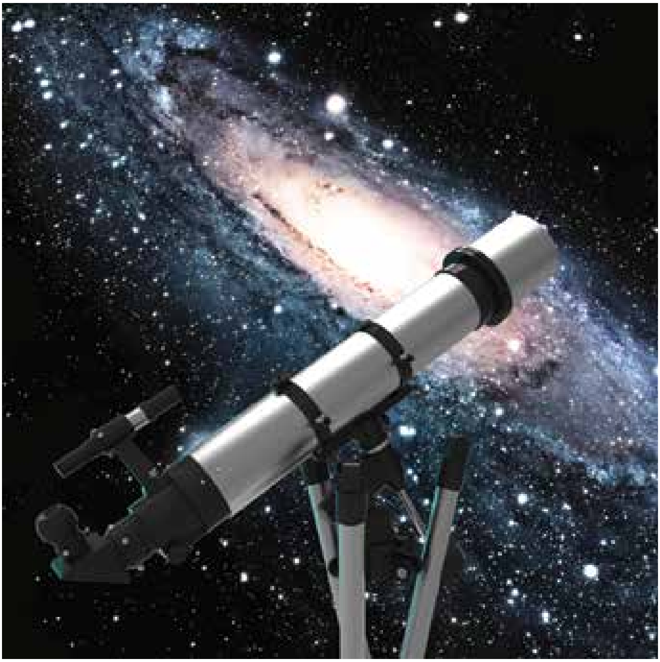
So many other devices convert energy, it is impossible to name them all here. This list, however, may give you additional ideas for completing requirement 2.

- *Radio transmitters* convert electricity into radio waves, and *radio receivers* convert the radio waves back into electricity that speakers can change to sound (mechanical) energy.

Lithium ion batteries have high power and energy.

- *Solar cells* convert radiant energy, or sunlight, directly into electricity.
- *Explosives* convert chemical energy into motion—in a hurry!
- A car *transmission* takes in mechanical energy and gives out mechanical energy, but it allows us to control this energy more precisely.
- A *computer* takes in electricity and makes many changes to it to store and use the information it represents.
- *Sailboats* use the mechanical energy of the wind to create mechanical motion of the boat.
- *Telescopes* and *microscopes* work by gathering light energy and organizing it so we can see hidden objects better.

The first law of thermodynamics is good news for energy users because it tells how energy can be changed from one form to another to make it usable. Many different devices use energy conversions to provide the systems that make modern living possible.



The Forms of Energy table lists devices that convert energy from one form to another. The columns represent the energy that is used; the rows show the energy that results. Shaded boxes mean there is no practical device that makes the conversion described. For example, no way is known to use chemical energy to make atomic (nuclear) energy.

Some of the devices in the table will be familiar to you, and some are probably unfamiliar. Discuss the table with your counselor as you complete requirement 2.

Forms of Energy

To \ From	Heat	Light	Mechanical	Electrical	Chemical	Nuclear
Heat	Sauna, Trombe wall	Greenhouse	Bow drill, friction, air resistance	Toaster, resistance heater, wire resistance	Fire	Fission, fusion, radioactivity
Light	Incandescent lightbulb	Lasers	Steel striking flint	Fluorescent light tubes	Fire, glow sticks, fireflies	Fission or fusion
Mechanical	Boiling water to steam	Radioscope	Turbine, car transmission, propeller, collisions	Electric motor, voltmeter	Internal combustion engines	Motion of fission fragments or fusion nuclei
Electrical	Thermocouple	Photovoltaic (solar) cell	Generator, piezoelectric effect	Transformers, rechargeable batteries, cellphones	Wet batteries, fuel cells	
Chemical	Chemosynthetic bacteria	Photosynthesis		Electrosynthesis	Chemical reactions	
Nuclear			Fusion in stars			

The Second Law: Bad News

Now we come to the second law of thermodynamics, the scientific principle that will let us answer all the questions Nate asked as he began working on the Energy merit badge. The second law is one of the most important principles in science yet one of the most difficult to understand. It will be the basis for almost all of the remaining work you will do to understand energy. Are you ready? Here it is:

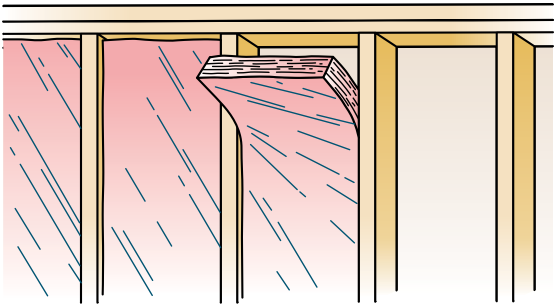
Heat flows from hot to cold.

There! Don't you feel smarter already? Come to think of it, it doesn't look all that hard. However, the important thing is that you *understand* what it means—how it is applied to the world we live in. That is what makes it difficult.

First, take the statement apart and make sure you understand the key words and the ideas behind the words: heat, hot, and cold. *Heat* is a form of radiant energy that can increase the temperature of materials or cause melting, evaporation, or other physical effects in matter. *Hot* and *cold* are comparative terms that refer to the relative temperature of different parts of a system. Any part of a system with more heat than another part is *hot.* The part of the system with less heat is *cold.* An ice cube with a temperature of 30 degrees Fahrenheit sitting outdoors on a 20-degree day is *hot* for the purposes of the second law. Heat will flow from the ice cube, making the cube colder than it was.

But the second law still does not explain much. Why can't legislators pass a law requiring 100-mile-per-gallon cars? Why do electric power plants waste so much heat? The second law does not answer those questions—yet.

To make the second law more useful, we must ask, "What *causes* heat to move from hot to cold?" The answer is that nothing makes it move; it just does. That is a critical point of the second law. You do not have to do anything to make heat move from hot to cold. In fact, you cannot do anything to stop it. The process is *spontaneous.*



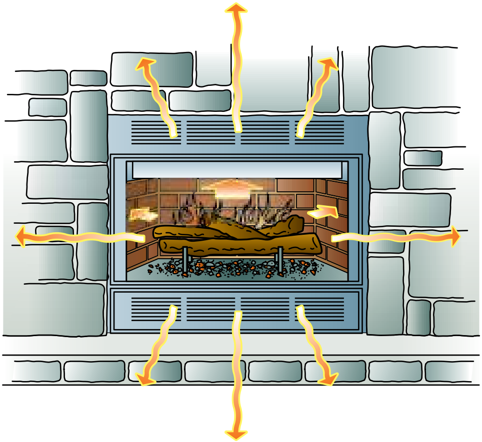
Insulation only slows the movement of heat from hot to cold.

We often want to stop heat from flowing from hot to cold. Materials designed to do exactly that are called *insulation.* When we have heat energy in a place where it is useful, we try to keep it there. We build homes so they retain heat during the winter. We have insulated containers to keep soup or hot chocolate warm. Ovens are lined with materials to keep the heat inside to cook the food and not warm up the kitchen.

We can slow the movement of heat from hot to cold, but we cannot stop it. That is an important part of the second law of thermodynamics. To remind us that heat flows from hot to cold with no action needed to start it, and that we cannot stop it from flowing, we state the law as:

Heat flows spontaneously from hot to cold.

Another element of the second law is that when heat is concentrated in one place in a system, it will move toward *all* parts of the system that are cooler. It moves in all directions. If you build a fire in a fireplace, the heat not only moves into the room, it also heats the bricks in the back and floor of the fireplace. Some of the heat goes up the chimney with the smoke.



Just as we insulate to slow heat flow, we use reflecting materials to direct heat to where we want it. However, we can never get all of the heat in a system to go where it will do what we want it to do. That is part of the second law as well.

The flow of heat in all directions is important to the second law. To help us remember the importance of this idea, we will add another phrase:

Heat flows spontaneously from hot to cold in all directions.

Energy Is Lost But Not Destroyed

Energy losses are possibly the most important thing you must understand about the second law. The most common form of lost energy is simply the tendency for heat to move spontaneously in all directions. Earlier you learned that engines depend on producing heat and using it. Every engine must produce extra heat because some of the heat will go away from where it is useful. Heat that goes where it does not do the work of the system is wasted heat.

The first law of thermodynamics says energy cannot be created or destroyed. If energy cannot be destroyed, then you might think we will never run out of energy. However, even with lots of energy around, it may not be in forms we can apply for practical purposes. Energy is not destroyed, but it can be *lost* to us as a source of useful energy.

Friction is a force that resists motion when surfaces come in contact with each other.

Energy-using systems produce waste heat.

Physical systems generate waste heat in other ways. Some heat that we do not intend to produce occurs anyway. All systems with moving parts that contact other parts produce heat through *friction*. Lubrication or bearings can reduce but not eliminate friction. In every real system, friction converts mechanical energy into heat.

All electrical systems also produce heat. As electricity passes through any conducting material, some heat is generated. The more *resistance* a conductor has, the harder it is for electricity to pass through and the more waste heat it makes.

Resistance causing a conductor to become hot does useful work in a toaster. The wires in this small appliance heat up to toast bread.

Systems with parts that move through a *fluid* lose energy. (Gases and liquids are fluids.) In air, the energy loss is through *air resistance* or *drag*. Parts moving through air stir the molecules and cause them to increase their motion. The energy used to increase the air-molecule motion must come from somewhere (the first law). This energy gain in the fluid (air) becomes an energy loss in the system.

Another energy loss comes from sound or noise. Noise (sound) is a shock wave that moves air molecules as it travels through them. This increased motion of the air molecules is increased heat in the air. Any system that is making a sound is losing energy and releasing heat.

The second law says that no system can use all the energy in its source. Every time we try to take advantage of the first law by converting energy from one form to another, some of the source energy gets lost—it cannot be used to do the work of the system.

Scientists and engineers divide energy in mechanical systems into two categories. The energy that does what the system was built to do is called *useful energy.* The energy that is lost because all systems obey the second law is called *waste energy.*

To compare different systems, we look at the ratio of useful work the system does to the total energy it uses. This ratio is the *efficiency* of the system and usually is expressed as a percentage. It is determined by dividing the useful energy by the total energy that went into the system and then multiplying by 100. The useful energy plus the waste energy must always exactly equal the total energy that was put into the system (the first law). Efficiency of a real system must always be less than 100% because the total energy must always be more than the useful energy of a system (the second law).

Efficiency = (Light Output/Power Input) x 100

Planes lose energy through air resistance during flight.

We can improve efficiency by building better-quality devices made with more refined materials, more precise parts, and more careful construction. However, even using the best materials and the most careful processes, lightbulbs, car engines, and other machines always achieve less than 100 percent efficiency. This is the second law at work.

No physical system can be 100% efficient.

Another way to increase energy efficiency is to develop better technologies. While incandescent lightbulbs are only about 5% efficient, a fluorescent lamp works at almost 12% efficiency. A coal-burning steam locomotive may have been only about 4% efficient, but modern train engines have efficiencies of about 35%. Cars became more energy-efficient when they switched from carburetors to fuel injectors.

Here are some common situations you might consider for requirement 3: A traditional incandescent lightbulb changes electricity into light with about 5% efficiency. LED lighting consumes up to 90% less energy than incandescent bulbs. Gasoline cars are less than 10% efficient. Motorcycles are about 20%. Plants convert between 3% and 10% of the sunlight they receive into stored chemical energy. The rest of the sunlight just warms their leaves.

The second law says that heat flows from hot to cold, and we can use this heat to do useful work, but some energy *always* will be wasted. And there is more bad news. We know that as a fire burns, it produces *low-energy materials* such as carbon dioxide, water, ashes, and smoke. These materials have some energy in their molecules, but we cannot make use of it—ashes do not burn. Every system that uses fuel to do useful work eventually ends up with low-energy waste materials.

If we want more work out of the system, we must put more high-energy material (fuel) into the system. The more fuel we use, the more wastes we produce. Those wastes must go somewhere. If we release those wastes into the environment, they affect plants, animals, and ecosystems. The second law now says that we cannot use energy for useful purposes without producing *pollution.*

Now you know that the simple, six-word second law of thermodynamics has proven to be highly complex. It explains why we use insulation and reflectors to control heat energy. It tells us why machines cannot be 100% efficient. It shows us why all energy systems produce some kind of pollution.

Next, we will apply the second law and answer some of the questions Nate raised.

Fuels will be reduced to low-energy materials that can be a source of pollution.

A Good Energy Family

A fish never thinks about the water it swims in. In the modern world, people are like fish living in a sea of energy. Energy is all around us, and yet we tend to overlook it the way a fish ignores the water.

Some uses of energy are more obvious than others. We may heat our homes with oil or gas. We put gasoline in our cars to make them go. Electricity cooks our food, lights our way, and operates the television. These are easy-to-find uses of energy.

But much of the energy we use is unseen. Millions of Btu are hidden in the materials of our houses, furniture, appliances, food, and clothing. Thousands of Btu may go into your garbage can every day, in the energy used to make the paper, plastic, and other materials you discard. To become aware of the sea of energy, you must learn to look at a newly mown lawn or the snow removed from a driveway and see it in terms of the energy it took to accomplish that task.

Consider one example: a can of corn. What forms of energy go into producing it?

A farmer starts a tractor. The tractor is made with about a ton of steel. One ton of steel requires 52 million Btu of energy to produce. To form the steel into a tractor requires more energy. The tires, wiring, windshield, and other parts are made of other materials that also require energy to make.

The United States supplies food to a good part of the world with its energy-efficient food production and distribution system.

The farmer fills the tank with diesel fuel, hooks up a plow, and plows the field. (A modern 12-bottom plow is made from another ton of steel.) The plowed field is rough, so the farmer hooks up a disk (another ton of steel), refills the diesel tank, and smooths the soil. Then to plant the corn, the farmer refuels (more diesel), hooks up the corn planter (more steel), and pulls the planter over the field.

The corn sprouts. Solar energy drives the complex chemical interactions that cause the plants to grow. The plants use sunlight to convert carbon dioxide, water, and soil nutrients into roots, stems, leaves, and corn.

The new plants need water. If rainfall is scanty, water must be pumped to the crop. The water pumps (made of steel) usually are fueled by propane, butane, or natural gas.

Insects, fungi, and other pests try to feed on the growing plants. Weeds invade, blocking the sunlight and robbing the corn of water. The farmer fights back with the sprayer (made of steel) that is filled with chemicals to kill the pests. These chemicals are made from oil or natural gas that can be manufactured into weed killers, insecticides, and fungicides.

When the corn is ripe, the farmer fuels the corn picker (more diesel and steel) and harvests the corn. The corn is loaded into a truck (more diesel and steel) and driven to the packing plant.

The packing plant is a building made of steel, concrete, and glass. The corn is processed, cooked (usually with natural gas), and canned. The cans are packed into cardboard boxes, which are loaded into a different truck (more diesel and steel) and taken to a grocery store (more steel, concrete, and glass). The store has electric lights, refrigeration, air-conditioning, and heating. The store's electrical supply likely comes from coal or nuclear electrical plants.

How Much Energy Does It Take to Make?

Aluminum	48 million Btu per ton
Cardboard	19 million Btu per ton
Concrete	75 million Btu per ton
Glass	90 million Btu per ton
Steel	52 million Btu per ton

You ride to the grocery store in a car (made of steel, runs on gasoline). You buy the corn, take it on your next campout, empty the can into a steel pot, and heat the corn over a fire.

The corn you have eaten is a product of modern agriculture that would not be possible without abundant energy. It took coal, oil, natural gas, propane, butane, gasoline, diesel fuel, nuclear power, hydropower, muscle power, a fire, and lots of energy stored in tons of steel and other materials. And where did it all begin? The energy the corn needed to grow came from the sun.

Now you have some idea how much energy surrounds us and affects our daily lives.

The Second Law at Home

A modern home is a complex collection of systems that provide heat; light; shelter; water; entertainment; ways to store, cook, and eat food; sewage disposal; and garbage removal. (And that is only a partial list.) In all systems designed to do these tasks, the first law of thermodynamics will be at work. To use energy to do useful work, the energy must be changed from one form to another.

Survey Where You Live

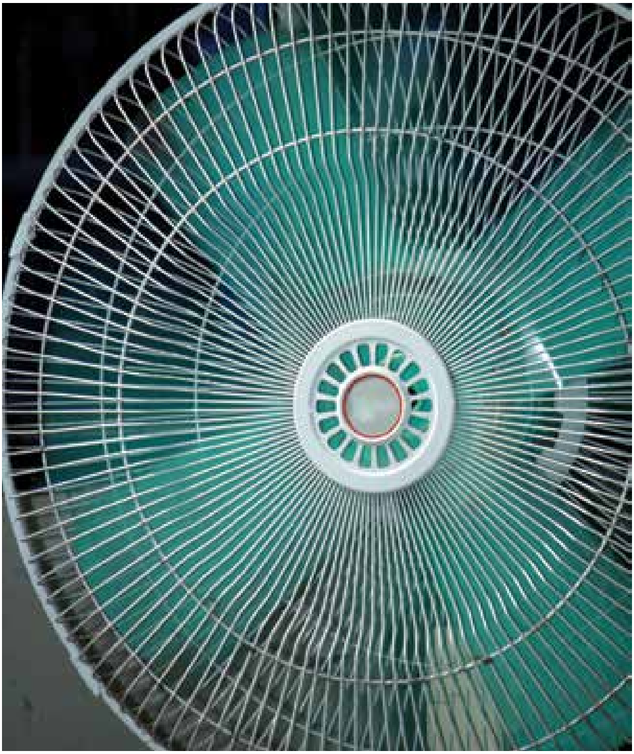
For requirement 4, watch for energy use (and energy waste) in your home. You might:

- List devices that do work for you. Record the task done, the device used, the energy source, and how the task would get done without the device.
- Keep track of energy hidden in materials. Watch the garbage can as a meal is prepared or while yard work or some other task is done. If possible, weigh some of the discarded materials and convert the amounts into Btu lost.
- Compare the energy used in one room, such as the kitchen, with another room, like the bathroom.

Whenever the first law is functioning to get useful work done, the second law also will be acting to limit the efficiency of the energy conversions. In modern homes, people pay for the electricity and fuels they use to operate the various systems. Therefore, in our homes we have a special case of the second law:

Energy wasted = Money wasted

An example of the second law at work at home is the effect of overheating. If the inside of a house is warmer than the outside, heat will move from the inside to the outside. If the difference between inside and outside is small, the energy loss will be small. If the inside is much hotter than the outside, the energy loss will be much greater.



Many home appliances (such as a washer, dryer, mixer, fan, garage door opener, or water pump) have motors that use electrical energy to move mechanical parts.

Trade-Offs

The second law of thermodynamics in your home is also a law of *trade-offs.* In a trade-off, when you act to seek a good thing, other things happen too. You can never eliminate all problems.

At one time, people heated their homes by building fires indoors. Fires make smoke, and smoke filling the space where you live and breathe is bad for your health. So people built stoves that contain the fire, release the smoke, and radiate heat into the living space.

One trade-off in building a stove is that you must *have* energy to *use* energy this way. You cannot build a proper stove from wood or stone. You need a material like steel to contain the fire and transfer the heat. You must live in a society that has the energy to make steel to build stoves to help make your living space more comfortable.

A second trade-off is that a stove is less efficient than a fire in your living room. As the stovepipe carries the smoke away, some of the heat of the fire goes out the chimney with it. Now you must use more fuel to get the same amount of heat into your home. You have improved the safety and comfort of your heating system, but the new system is less energy-efficient than the original.

Whenever people use energy, they want it to be convenient. Warming a house during a cold winter takes much wood. Coal has more concentrated heat. Where coal is available, people can switch to it for more convenient heating.

But coal does not grow aboveground like wood. Coal must be mined. Coal miners need special tools for mining. Energy goes into making those tools. It is easier to mine coal with powerful machines, but building mining machines takes more steel and also energy to run the machines.

Although coal is a good heating fuel, someone must regularly feed it into the furnace. Oil can be fed in by automatic pumps. Heating with oil requires electricity to start the furnace, pump the oil, and run a fan to blow air over the firebox. Also, oil has many uses other than for heating. If we use oil for home heating, we have less for other purposes.

Using electric heaters is the most convenient way to heat a home. If you want more heat, just turn up the heater. The trade-off is that electricity comes from a system that is about 30% efficient. Therefore, we must use 100 Btu of fuel to deliver 30 Btu of heat energy to a home.

Trade-offs are an unavoidable consequence of the second law of thermodynamics. Solving problems of safety, pollution, supply, and convenience requires making more complex systems. Complex systems have more energy conversions. With each energy conversion, some energy is lost. These energy losses require more fuel to run the system and, as a result, produce more *pollutants* (any material that can harm the health, survival, or well-being of an organism).

Recovery Costs

Earlier we tagged along as Nate Gomez looked at refrigerators. Nate found that more energy-efficient refrigerators cost more money. This is the second law at work, resulting in another trade-off.

The principle of building a refrigerator is simple: Construct a box and place a cooling unit against the outside surface. The cooling unit uses energy to do work in removing heat from the sides of the box. Then the heat in the air inside moves to the cooler side of the refrigerator. Heat in food put inside then goes into the air.

As soon as you start up a refrigerator, the second law kicks in. The motor changes electricity into motion and makes noise and waste heat in the process—energy is lost. The coils draw heat from the food box, but they also draw heat from the air around the refrigerator. Not all of the cooling does the work we want. As soon as the food box is cool, heat from the outside starts moving in—heat moves from hot to cold.

The refrigerator we are considering uses a lot of energy (and wastes much additional energy). We want to make it work better. We can reduce the noise and waste heat of the compressor by building it more carefully with better materials. The trade-off for a better compressor is higher cost of labor and materials. We can use more efficient coils, with the trade-off of more labor, materials, and cost. We can slow the movement of heat into the refrigerator by insulation, but more or better insulation adds to the cost. It is harder to assemble this better refrigerator, and that costs more in labor.

We end up with a refrigerator that may cost much more than our original one. Who would buy it? Smart Scouts, that's who! The cost of using a refrigerator is not only the price to buy it, but also the cost to run it.

Consider two refrigerator models, A and B, as compared in the chart. If you buy one and use it for 15 years, which refrigerator is more expensive?

	Refrigerator A	Refrigerator B
Purchase price	$ 379	$ 499
Energy for 15 years	$1,299	$ 975
Total cost	$1,678	$1,474

Refrigerator B saves money over time. The more expensive electricity is in your area, the more model B will save you. (Better appliances also usually last longer.) But the trade-off is you must spend more money *now* to purchase the better appliance.

A government-backed program called Energy Star® identifies appliances that are especially energy-efficient. Energy Star® appliances exceed federal efficiency standards. (To qualify for the Energy Star® rating, refrigerators must exceed federal standards by 20%.)

More Trade-Offs

Still other trade-offs affect energy use at home. Comfort is an issue with home heating in the winter. A house heated to 66 degrees Fahrenheit uses about 8% less heat than one at 72 degrees Fahrenheit. However, people like to be warm. They may not be willing to lower the heat and wear more clothes indoors to save energy.

Sometimes, appearance is a trade-off for energy efficiency. A solar home may get much of its energy free from the sun, but some people dislike the look of solar panels on the roof, a *Trombe wall* on the southern face, or other adaptations that solar houses have.

A Trombe wall is a masonry or other thick wall that absorbs solar heat by day and releases it into the building at night.

Habits may be the most powerful barrier to energy savings. People get used to how they use energy, and these habits are hard to break. Wearing more clothes in a cooler house feels different. Many people would rather spend more money (and use more energy) than change their habits.

Reduce: The First R

One strategy for cutting energy use and costs at home is to *reduce* activities that use energy. This can be as simple as using electronic devices less often for entertainment or making it a habit to turn off lights you are not using.

Here are some other ways to reduce your energy use.

- Lower the thermostat. Every 1 degree the thermostat is lowered saves about 1% of the heating energy. (Be sure to discuss this with your family first!)
- Have your parent or guardian lower the temperature of the water heater. Water heaters do not need to be set above 120 degrees Fahrenheit. The hotter the water, the more heat will flow out of the heater and the more money it will cost to operate.
- Every three months, drain a quart of water from the valve on the bottom of the water heater. This prevents sediment buildup and keeps the unit efficient.

- Hand-shovel snow, use a push mower, use hand-operated trimmers, rake leaves, and sweep walks and driveways with a broom.
- Replace ordinary (incandescent) lightbulbs with compact fluorescent lightbulbs, which are more energy-efficient.
- If possible, your parent or guardian can pay household bills by computer. Many companies will send an electronic bill, and customers can pay the same way.

Reuse: The Second R

Another great way to save energy and money is to *reuse* things that require energy to produce or process. By using products twice, you can cut energy use, and therefore costs, by half or more.

As a Scout, you may already practice this idea on long camping trips. (When you must carry what you use, you learn to be efficient.) Maybe you carry one towel and use it at least twice before it is washed.

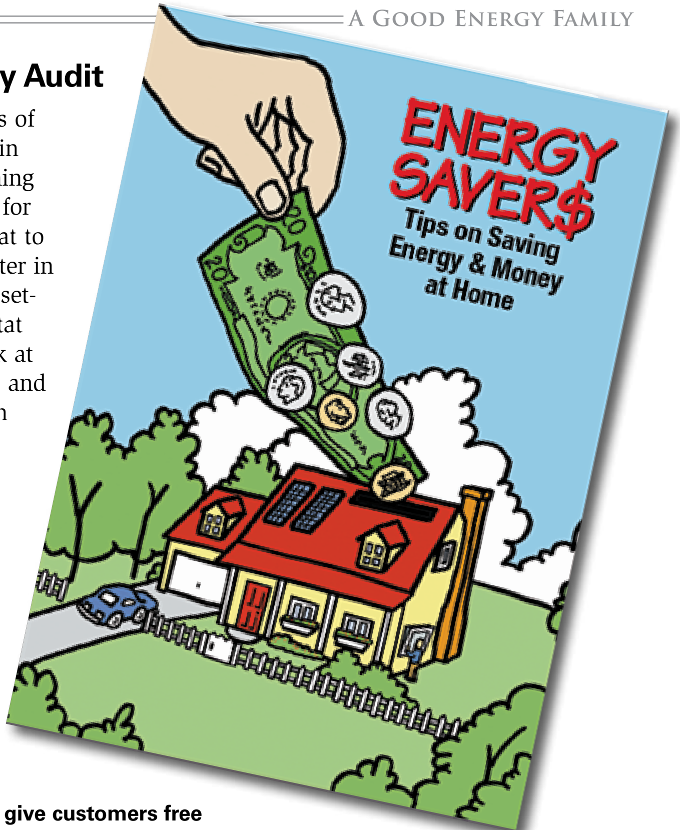
You can do the same at home. Hang up a towel and use it again, and you will cut the energy needed to wash towels by 50%. By using towels twice, each year a family of four can save 73 loads of laundry, 1,000 gallons of heated water, detergent, fabric softener, and the cost of running a dryer.

What other items can you reuse to save energy? A short list might include the following.

- Use the back of scrap paper for printing drafts on your computer or doing homework.
- Take bags with you to the store to carry purchases home.
- Check junk mail for envelopes you can reuse.
- Get things you want (like video or computer games, music CDs, videos, and DVDs) from yard sales or swap with friends to save money and energy.
- Build a compost pile to turn food scraps, leaves, and dead plants into free, effective fertilizer for a garden or landscaping.

A Formal Energy Audit

Do a thorough analysis of energy use and waste in your home by performing an energy audit. Look for air leaks that allow heat to escape in winter or enter in summer. Examine the settings on your thermostat and water heater. Look at the kinds of lightbulbs and other energy devices in your home.



Most local utilities will give customers free pamphlets or kits for doing an energy audit. You can also locate helpful internet sites (with your parent or guardian's permission) by searching for "energy audit."

By now you should see every piece of glass, plastic, steel, aluminum, wood, concrete, and paper as both raw materials *and* the energy it took to turn the materials into finished products. Efficient energy use not only conserves vital natural resources, but also saves money. An energy-efficient family today must break wasteful habits and find ways to use energy more wisely. When the second law of thermodynamics has free run of a home, energy and money go out into the cold.


Recycle America

A Good Energy Neighbor

Think about what makes up your local community—the houses, businesses, schools, churches, government buildings, banks, restaurants, gasoline stations, recreation facilities, and maybe power plants. Just as we obey laws in our community, we also must obey the second law of thermodynamics. At home, the second law means wasted energy and wasted money. Fighting energy waste is even more important when we gather together in communities of people. In communities, energy waste means wasted taxes and fees, community lands polluted or spoiled, and energy abuse (deliberately using more energy than is necessary) that harms our neighbors.

Bad News/Good News

Running modern communities takes large amounts of energy. In the past 150 years, Americans have obtained the necessary energy by building power plants, hydroelectric (water power) dams, oil refineries, coal mines, and other energy-producing systems. In every case we are trying to concentrate energy into fuels and electricity. This gives us the forms of energy we need but produces waste energy and pollution.

Consider a coal-fired electric power plant. To produce 800 megawatts of electricity, a modern coal-fired plant uses 10,000 tons of coal per day. The carbon compounds in the coal are burned with air to release heat that was stored in the compounds. This burning produces tons of carbon dioxide and water that go up the chimney stack.

A lump of coal is only partly carbon compounds. It also contains minerals that will not burn. Some of the unburnable material becomes a fine powder that will go out the stack with the water and carbon dioxide, if allowed.

But this fine dust is not good for plants, animals, or humans. It must be contained. Containing it uses some of the energy the plant produces and so reduces the total efficiency of the system.

Coal ash may contain uranium, arsenic, antimony, cadmium, beryllium, lead, and other substances that harm humans and the environment if released in large amounts, and so they must be disposed of in some safe way.

A coal-fired power plant cannot run at 100% efficiency. Comparing the energy in the fuel (the coal) to the energy in the delivered electricity shows that a well-running plant is about 35% efficient. The energy in the fuel must be converted to heat in steam, converted to motion in a turbine, and converted to electricity in a generator. In each of those conversions, energy is lost.

Oil refineries, nuclear plants, solar electricity, coal mines, hydroelectric dams, and natural gas systems all have environmental impacts. They cannot escape the second law.

If society did not accept some energy trade-offs, much of our medical technology would not be available to help save lives.

However, the second law is a law of trade-offs, which means good news comes with the bad. A power plant produces energy that we use to live our lives. Without large-scale energy, we could not light, heat, or cool our buildings. We could not communicate through phones, television, radio, or the internet. We would not have access to a safe supply of food as it is grown, harvested, processed, delivered, refrigerated, and cooked. We could not operate modern hospitals, water-treatment facilities, waste-treatment plants, and other health and safety systems.

A 100-watt lightbulb left burning for a year creates 600 pounds of air pollution at a cost of about $60.

While every large-scale energy use affects people and the environment, modern society greatly benefits from energy availability. Our challenge is to balance benefits and costs—a trade-off. We live with the second law every day.

The American Car

Modern American communities depend on people's ability to easily move around in personal vehicles (passenger cars, light trucks, SUVs, etc.). According to the U.S. Department of Transportation, there are more than 200 million household vehicles in the United States. These vehicles travel more than 4 billion passenger miles each year.

The gasoline-powered piston engine is the most widely used car engine today. Cars are mechanical systems that obey the laws of thermodynamics. You already have learned that there is a limit to the efficiency achievable in burning fuels to do work. Because of the limitations, car engines run at about 30% efficiency; that is, 30% of the potential energy in the fuel is converted to useful work.

Nate stopped reading and put down his merit badge pamphlet. "I see," he thought. "This answers a question I had when I started to work on Energy. Legislators might want to pass laws to require better gas mileage. But even if they want to, they can't pass a law that makes a car more efficient than the laws of thermodynamics allow. Nature gets the last word!"

An engine efficiency of 30% would be good if all of the energy went directly to the wheels to make the car go. However, the force made by the engine must go through a clutch and transmission so we can shift gears. The transmission must turn a driveshaft that is connected to a differential that allows the wheels to turn at different rates around a corner. Finally, an axle turns the tires, which rub on the road by friction to make the car move. This adds up to at least five energy conversions.

The second law of thermodynamics says there is an energy loss in each conversion. In the end, only about 14% of the energy in the car's fuel produces motion of the vehicle. When the trip is completed, the car's movement is stopped by road friction, air resistance, and braking. Considering that the only useful work performed was moving you from one place to another, the process is less than 5% efficient.

More efficient diesel engines are one alternative to gasoline-powered cars. Diesel fuel has a higher energy content than gasoline, and diesel engines can operate at up to 45% efficiency.

Then why aren't more personal vehicles diesel-powered? Partly because diesel engines are harder to start in cold weather, are noisier, and tend to vibrate. Diesel engines also are more expensive to build. America's fuel supply system is set up mainly to deliver gasoline. Personal preferences and habits also have a part. Car buyers complain that diesels smoke more than gasoline cars and the exhaust has a bad odor.

A future option may be the electric car. Electric cars are beginning to have the power, speed, and range that consumers want.

The first functional electric car was built in 1915.

Many people see electric cars as a pollution-free method of transportation. However, the electricity used to charge an electric car does not come without energy losses and pollution. A local utility may use coal, oil, or liquid petroleum or natural gas to produce electricity for electric cars. As utilities increase electric production, they produce more carbon dioxide and water vapor, which go into the atmosphere with other pollutants. Burning more fuel to produce more electricity means the whole system can actually produce *more* pollution.

Efficient electric cars may come in the future. But in the meantime, inventors have developed a cross between a gasoline car and an electric car. Called *hybrid cars,* these are on the market today. A hybrid car uses a conventional engine for accelerating and an electric motor for cruising. Hybrid cars use *dynamic braking,* which slows the car by taking energy from the car's motion to charge the battery.

The first law is at work in dynamic braking. The energy to charge the battery must come from somewhere. It comes from the motion of the car, and so, makes the car slow down.

Recycling: The Third R, A Community Effort

To save energy at home, you can *reduce* energy use and *reuse* materials that require energy to produce. The third R—*recycling*—is a little different. Recycling requires more than an individual or family commitment. It takes a community effort.

Recycling is collecting used materials to serve as raw materials for manufacturing. Recyclable materials required energy to produce. The heat that was necessary originally to separate iron or aluminum from its natural ores is not needed in melting steel or aluminum cans. Far less energy is needed to make new goods from recycled materials. Also, many plastics are made from oil. Recycling therefore saves energy resources two ways.

Recycling not only saves energy, but also keeps materials out of landfills and garbage dumps.

As shown in the table, it takes much less energy to recycle used materials than to use new raw materials.

Energy Savings From Recycling*

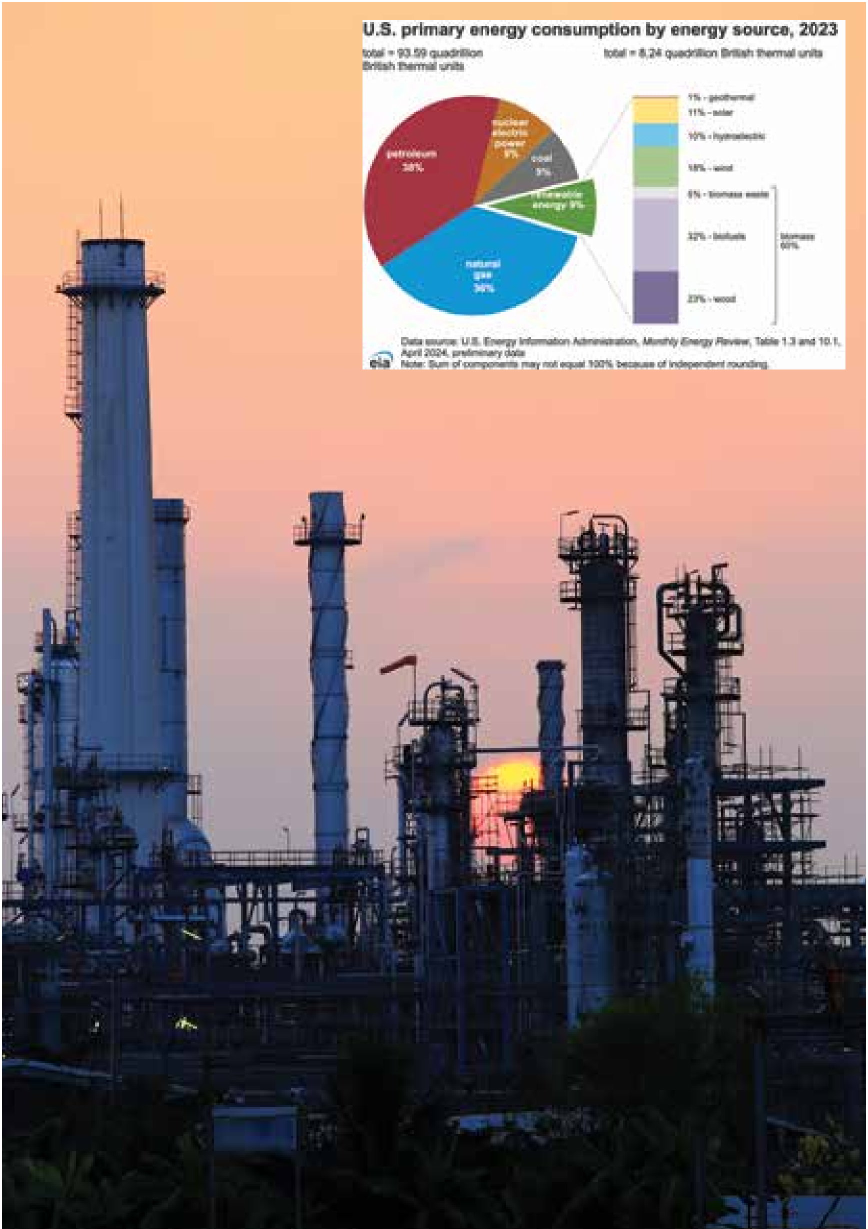
Material	Btu per Pound	Energy Saved by Recycling
Cardboard	9,600	25%
Glass	45,000	30%
Paper	8,500	60%
Steel	26,000	76%
Plastic	40,000	90%
Aluminum	24,000	95%

*The data in this table come from various sources. Different sources may give other figures.

Most communities today have recycling programs. People who bring materials to recycle or put them on the curb for collection need only be careful to clean and separate. For example, newspaper is efficient to recycle, but papers with too much dirt, mold, or other contamination are not suitable. Metals can be recycled many times, but problems arise if consumers include paint cans or containers with toxic materials.

As a good energy neighbor, you have a responsibility to use energy wisely to reduce pollution that might harm others or the environment. As you complete requirement 5 for the Energy merit badge, remember that the laws of thermodynamics say we cannot use energy on a large scale without waste heat, noise, and pollution. But by encouraging community leaders to use energy wisely and to have a community recycling program, we can lessen the chance our energy use might harm our neighbors or our environment.

For recycling to do the most good, people must make it part of everyday living. Many sources have information on recycling and how to start a program in your community if one does not already exist.


U.S. primary energy consumption by energy source, 2023
total = 93.59 quadrillion British thermal units
total = 8.24 quadrillion British thermal units
petroleum 38%
nuclear electric power 9%
coal 9%
renewable energy 9%
natural gas 36%
1% - geothermal
11% - solar
10% - hydroelectric
18% - wind
5% - biomass waste
32% - biofuels
23% - wood
biomass 60%
Data source: U.S. Energy Information Administration, Monthly Energy Review, Table 1.3 and 10.1, April 2024, preliminary data
Note: Sum of components may not equal 100% because of independent rounding.

A Good Energy Citizen

Today, with 5% of the world's population, the United States consumes 25% of the world's energy and produces more than 25% of the world's goods and services. To understand energy use nationwide, we must look at how energy is consumed and supplied.

Understanding energy use on a national scale requires a unit of measure called the *quad,* which stands for 1 quadrillion British thermal units, or Btu. A Btu is a relatively small amount of energy. (A candy bar has about 1 Btu of food energy.) A quadrillion of anything, however, is a huge amount. An ounce is small, but 1 quadrillion ounces is more than 31 billion tons. And 1 quadrillion seconds is more than 317 million years.

At the start of the 21st century, the United States was using almost 99 quads a year from all energy sources—more than three times the national use in 1949.

U.S. Energy Consumption 1950-2023

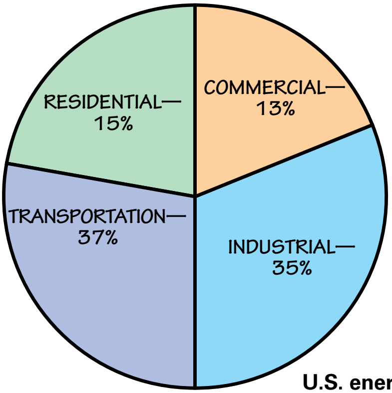
Year	Quads of use	Year	Quads of use
1950	33.5	1990	82.2
1955	39.2	1995	88.5
1960	43.9	2000	96.5
1965	52.6	2005	98.0
1970	66.1	2010	95.0
1975	69.8	2015	94.3
1980	76.0	2020	88.7
1985	74.1	2023	93.6

The good news is that U.S. energy consumption decreased in 2020 to levels not seen in more than two decades—even though U.S. homes power more devices than ever before. According to the Energy Information Administration, several factors contributed to this drop:

- Consumers moved from energy-sapping desktop computers to energy-sipping tablets, laptops, and cellphones. The Electric Power Research Institute reports that it costs just $1.36 to charge an iPad each year compared with $28.21 to use a desktop computer.
- Some of today's flat-screen TVs use 80% less power than old models.
- Federal regulations led to increased energy efficiency in household appliances such as refrigerators and air conditioners.
- Energy-efficient home-building practices, better insulation, and energy-efficient windows reduced consumers' use of energy to heat and cool their homes.

Supply and Demand

In discussing energy use, we look at four main *sectors.* The *residential* sector is made up of all U.S. homes. Schools, places of worship, and businesses together comprise the *commercial* sector. Farms, factories, and plants that produce items such as food, steel, glass, and plastic or finished goods are part of the *industrial* sector. The fourth sector, *transportation,* includes cars, trains, planes, buses, and every other form of moving people and goods.



U.S. energy use in 2023

The information in this section on energy use and supply by sector is taken from year 2023 data available from the Energy Information Administration, an agency of the U.S. Department of Energy. In completing requirement 6, use the most current information available to you.

Earlier, in considering energy in our homes and communities, we mainly examined the residential and commercial sectors. We looked at energy used to light, heat, and cool our homes; supply water and electricity; store and prepare food; and provide entertainment. Energy use by the residential and commercial sectors in 2023 amounted to about 28% of the U.S. total. Industrial energy use in 2023 took about 35% of the national total. The food, paper, chemical, petroleum, and primary metals industries use the most energy in this sector.

The transportation sector relies heavily on liquid fuels. Individual cars, not public mass-transit systems, use much of the energy for transportation in the United States. Because of our reliance on individual vehicles, 10% of the world's oil use every day goes to fuel personal cars and light trucks in the United States. Transportation accounts for about 28% of U.S. energy use and more than two-thirds of our oil use.

Fossil fuels, besides being used as fuels, are converted into many products. Coal is used in making plastics, tar, synthetic fibers, fertilizers, and medicines. Oil is a resource to make paints, lubricants, wax, synthetic rubber, plastics, drugs, and detergents. Liquid petroleum gas is used to replace fluorocarbons as an aerosol propellant, and to fuel vehicles and heat appliances. Natural gas is important in the production of fertilizer, plastics, antifreeze, dyes, medicines, and explosives.

Production by Source

Fossil Fuels

Fossil fuels, including petroleum, natural gas, and coal, have long produced most of the world's electricity and powered the transportation sector. Fossil fuels continue to account for the largest share of energy production and consumption. In 2020, fossil fuels accounted for almost 80 percent of U.S. energy consumption and 61 percent of our electricity generation. In addition, currently, 99 percent of U.S. hydrogen production is sourced from fossil fuels, with 95% from natural gas. Hydrogen is emerging as a low-carbon fuel option for transportation, electricity generation, and manufacturing applications, because it could decarbonize these three large sectors of the economy.

A growing concern with the use of fossil fuels is that their combustion produces carbon dioxide and other greenhouse gas emissions. Research is ongoing to find innovative ways to capture and store these gasses, for example carbon dioxide, as well as to develop technologies and systems that operate more efficiently and emit fewer greenhouse gases.

Oil

Oil is the largest source of energy in America, supplying almost 35% of the energy we use. *Crude oil* taken from the earth must be processed or *refined* into specific products such as gasoline, heating oil, diesel fuel, or kerosene before it can be used. To meet our demand, we depend on oil from other countries. We import about 45% of the oil we use. Our nation's transportation fuels (gas, diesel, jet fuel) account for almost 70% of crude oil consumed.

Natural Gas

Natural gas provides about one-third of our energy supply. Natural gas requires little processing before use. It has fewer pollutants than other fossil fuels so it keeps the air cleaner. It also does not produce a solid waste for disposal like coal. About 41% of homes in the United States are heated with natural gas. Gas also is useful to operate stoves, clothes dryers, and water heaters. Nearly 42% of our natural gas is used to produce electricity. Like oil, gas must be produced through wells and also raises concerns about environmental impacts.

Oil is available within the United States; however, today's technology and costs limit the amount of oil that can be produced. Concerns about environmental damage limit exploration for new oil fields and pipeline construction.

Coal

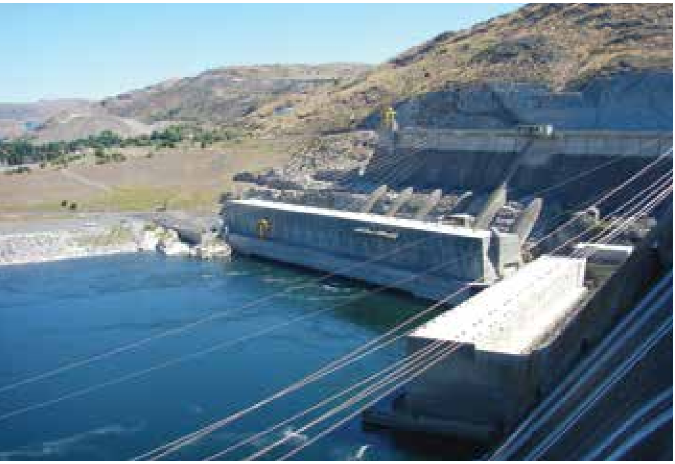
Coal is the fossil fuel most abundant in the U.S., and we lead the world with over 260 billion short tons of recoverable coal reserves—28% of total global reserves. Coal meets 9% of our energy demand. Almost 92% of the coal burned in the United States is for producing electricity. In 2023, coal-fired power plants supplied about 19% the electricity we use. Because coal produces ashes and smoke as it burns—as well as sulfur and nitrous oxides, carbon dioxide, and water vapor—we must consider and address environmental concerns associated with coal utilization. Coal mining also raises environmental issues.

Nuclear Power

Nuclear energy is one of the largest sources of emissions-free power in the world. There are more than 440 commercial nuclear reactors around the world, including more than 90 units in the United States. The main job of each reactor is to house and control nuclear fission—a physical process where atoms split and release energy. It generates nearly 800 billion kilowatt hours of emissions-free electricity each year and meets 25% of the nation's total electric power needs. More than 90 U.S. reactors operate around the clock and operate at full power more than 92% of the time making nuclear energy one of the most-reliable energy sources on the grid today. The nuclear industry supports nearly half a million jobs in the United States with average salaries that are 50% higher than other energy sources. This process yields millions of times more energy than other sources (has a higher energy density). Nuclear power has the potential to produce substantial amounts of electricity without adding carbon dioxide or other gases to the atmosphere. The disposal of radioactive wastes is the trade-off, however, which must be managed when using nuclear power.

Hydroelectric (Water) Power

Hydroelectric power is a type of renewable energy that uses moving water as a source of power. Hydropower is one of the oldest types of renewable energy. In 2023, hydropower provided about 37% of America's renewable energy (10% total) generation. Water constantly moves through a vast global cycle, evaporating from lakes and oceans, forming clouds, precipitating as rain or snow, then flowing back down to the ocean. Because the water cycle is an endless, constantly recharging system that is not reduced in the hydropower process, hydropower is considered a renewable energy. Three states—California, Oregon, and Washington—produce more than half of the *hydroelectricity* in the United States. While the fuel (flowing or falling water) is free and hydropower creates little pollution, it does affect migratory fish and local environments as river valleys are flooded to build the necessary dams.



Grand Coulee Dam in central Washington

Other Power Sources

Biomass, geothermal, solar, and wind power contribute most of the remaining 8% of our energy supply. Biomass (chemical energy stored as plants process sunlight) currently accounts for most of this amount. Wood burning is the most common use of biomass for energy. Plant and animal materials also can be converted to liquid or gaseous fuels such as ethanol or methane.

The Second Law, Again

In all of this, the second law of thermodynamics is vital for understanding the problems in controlling our energy use. Of the approximately 93.6 quads of energy consumed in the United States annually, 32.1 quads (almost 35%) are converted into only 12.4 quads of electricity (with a 59% loss). Of the 13.2 quads of electricity, 0.8 quad (more than 6%) is lost from resistance in electrical lines.

Internal combustion engines are only 15% to 20% efficient at converting the chemical energy in petroleum fuels to mechanical energy that moves our vehicles. In other words, 80% of all fuels used in transportation become wasted energy cast out into the environment.

The effect of dumping wasted energy into the environment is only one impact of the second law. In addition, energy waste assures that we will continue to rely on imported oil to meet our energy needs—especially transportation fuels. As other countries develop their economies, they will rely more on the world's limited energy supplies. Competition and tensions will grow as more people seek a share of energy resources. It is important that we use our available resources wisely even as we move to develop *sustainable* energy technologies.

Energy *reserves* are supplies that are known to exist. Coal is the largest of the world's fossil-fuel reserves. Known sources of coal could last 140 years at today's rate of use. The global oil reserve, however, could be exhausted within 50 to 60 years. Natural gas reserves also could be used up in about 60 years. Uranium reserves for nuclear fission are projected to be sufficient through 2050 according to the International Atomic Energy Agency.

To be a good energy citizen, you must understand the tight-knit relationships between energy and our economy, energy and our standard of living, energy and our security in the world, and energy and our future.

The Future of Energy

When Nate began work on the Energy merit badge, he raised several questions that made him think about the past *and* future of energy. If electric cars, fuel cells, solar electricity, and other technologies have been used for many years, why are we not using more of them? Because Nate had learned so much about the science, technology, and economics of energy, he could now see the answer.

At any time, people use the forms of energy that meet their needs at the lowest expense. Hydrogen may burn more cleanly than wood, but if wood is plentiful and cheap and hydrogen is expensive, people will use wood. To keep down the cost of using wood, wood users find ever-better ways of managing it. This means improving wood-using technologies.

In most uses of energy, the technology is improved to its greatest practical efficiency until replaced by a better, more efficient technology. For example, car engines had carburetors for many years. As gasoline increased in cost, carmakers needed to make ever-more-efficient carburetors. Eventually carburetors could not be any more efficient, but fuel injectors, a superior technology, replaced them. Then the technology turned to making more efficient fuel-injected engines.

In the same way, as oil and other nonrenewable energy sources become scarcer, they will become more expensive. Then other forms of energy will be less expensive than nonrenewables. Costly fossil fuels will be used less and less, until renewable sources completely replace them. This eventual switch of technologies will happen before the world runs out of oil, coal, or any other nonrenewable fuel.

Renewable, or sustainable, energy comes from sources that theoretically cannot be exhausted, such as solar, water, and wind. Fossil fuels are nonrenewable sources of energy.

To meet the world's future energy needs, existing technologies must be improved and new ones developed. In this section you will read about several technologies, each of which needs development to change our future. Use this information to help meet requirement 7 and as a starting point to locate other resources for a fuller picture of energy technologies.

The Future of Fossil Fuels

Fossil fuels have long produced most of the world's electricity. Coal will continue to be a vital fuel for electrical generation. One option for improving coal use is *coal gasification.* By separating the burnable components of coal from the impurities, the solid fuel can be changed into a gas. In the short term, coal gasification can boost the efficiency of electricity production to 50%, up from about 33% now.

Carbon dioxide is the major *greenhouse gas* that is produced in large quantities in any process that burns carbon. Coal gasification technologies concentrate carbon dioxide, which can be captured and used for other purposes. In addition, *coal gas* can be used like natural gas in other applications including high-grade transportation fuels.

New burners and *catalytic* (gas busting) systems will reduce pollution emissions from burning coal. New technologies are being developed to recycle ash into construction materials such as masonry blocks, concrete, and asphalt. Computer systems, sensors, and controls linked through state-of-the-art software also will help to control pollution.

As power-plant fuels, oil and natural gas are more expensive than coal. However, oil and gas plants can be built more cheaply and quickly. And they can be started up as needed more easily than coal or nuclear facilities. New high-tech turbines are being developed, including some that can switch between gas and oil to use the fuel that is cheapest at the time.

Biomass

Bioenergy is a form of renewable energy that comes from organic materials (previously living organisms made up of carbon-based compounds). Some of the most common biomass materials include crop wastes, forest residues (the parts of trees

and plants that aren't used when we harvest wood), grasses and woody plants grown for use as biomass, algae, wood waste from urban areas, and food waste. Biomass can be used to produce transportation fuels, heat, electricity, and products.

Biomass is versatile because the material can be put to many uses. Bioenergy technologies allow us to reuse the carbon compounds that exist in biomass materials: when we use biomass to make products and energy, we use carbon that could otherwise be wasted by sitting in a landfill or decaying. We turn biomass material into reduced-emissions fuels, bioproducts (like new kinds of plastic that can replace plastics in items you buy at the grocery store), and renewable power.

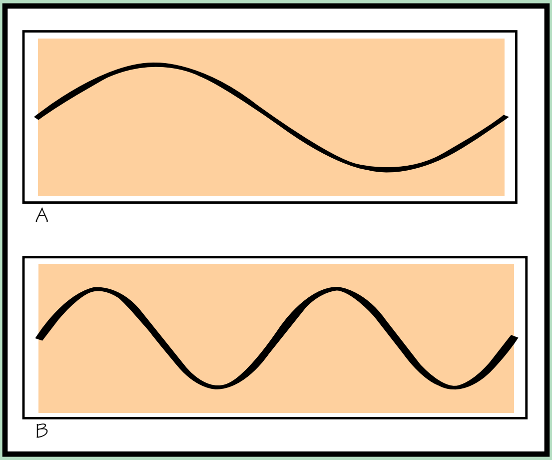
When biomass is specifically used as an energy source, it is transformed into heat and electricity using similar processes as fossil fuel energy. There are three ways to convert the energy stored in biomass into biopower: burning, bacterial decay, and conversion to a gas or liquid fuel. Burning involves setting dry biomass material on fire in a controlled environment, and using the heat and chemicals produced by the fire to heat stored air or water, which can then be used to warm or cool buildings or move turbines to produce kinetic energy (energy that comes from moving) to create electricity.

The Greenhouse Effect

Carbon dioxide, water vapor, and methane are known as *greenhouse gases* because, in Earth's atmosphere, they act to trap energy from the sun much like the glass roof and walls of a greenhouse. Here is what happens.

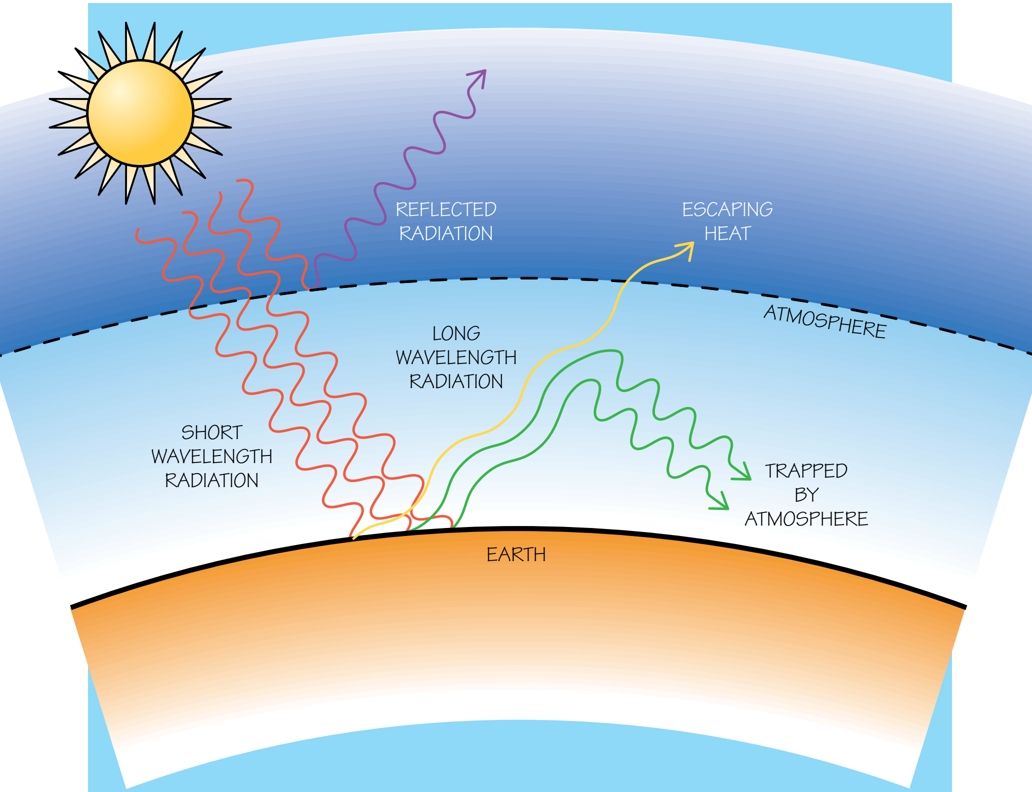
Sunlight comes to Earth as waves of radiant energy with different wavelengths. The short-wavelength energy easily passes through air (or greenhouse glass). When that energy reaches land or water, it is absorbed. The second law of thermodynamics holds that the process of absorption and release cannot be 100% efficient. The waves lose some energy to the molecules they strike, heating the molecules and increasing the wavelength of the energy waves.

Figures A and B can help you understand the relationship between wavelength and energy. Trace wave A with your finger as you say "the second law" (not too fast). Do this a few times. Because all radiant energy waves travel at the same speed, wave B crosses the page in the same time. Trace wave B as you say "the second law" at the same speed as before. Repeat this and feel the difference.



It takes more energy to trace wave B because the wavelength is shorter. You felt the difference that shows wave A carries less energy than wave B.

The *greenhouse effect* occurs because short-wavelength radiant energy can pass easily through air, but longer wavelengths do not. Light that comes freely into a greenhouse loses energy, and the glass holds the heat waves inside. The atmosphere works the same way as sunlight warms the land and sea, and air traps the heat near Earth's surface.



Human activities, including the burning of fossil fuels, add carbon dioxide and water to the atmosphere. These gases can increase the greenhouse effect by more effectively trapping heat in the atmosphere. An increased greenhouse effect could lead to global warming with a worldwide temperature increase that affects weather, sea levels, agriculture, forests, and other natural and human systems.

Many concerned scientists and leaders are working on ways to manage human activity that will not increase the greenhouse effect. It is hoped that nature will compensate for past and future human activity in a way that will minimize or avoid global warming. Much research still is needed to understand the greenhouse effect, and even more research will be needed to solve the problems it may cause.

A car heater uses waste heat from the engine to warm the car's passenger compartment. This is an example of cogeneration—waste energy used for a practical purpose.

Bacterial decay means we leave materials to break down, which releases chemicals like methane in the process. We can capture the released chemicals (in the form of gas) and burn those to produce energy in the same way as directly burning the material. Finally, when we want to convert biomass to a gas or a liquid, we use chemical processes to change the physical properties of the biomass. Different types of materials are put in different controlled environments (like in machines that have extremely high temperatures or pressures), which can break some of the material's chemical bonds and cause it to change its state from a solid to a liquid or a liquid to gas.

Biopower can reduce the need for burning fossil fuels in power plants, since these fossil fuels create greenhouse gasses which create major changes in our world's climate. Some forms of renewable energy can only be used under certain environmental conditions (solar power can only be created when the sun is out, and wind power can only be created when there are fast enough winds), but since biomass can be stored and turned into energy whenever we need it, it can help keep the electric grid "flexible", meaning we can make sure to provide electricity to people at any time of day and under any type of weather conditions.

Cogeneration

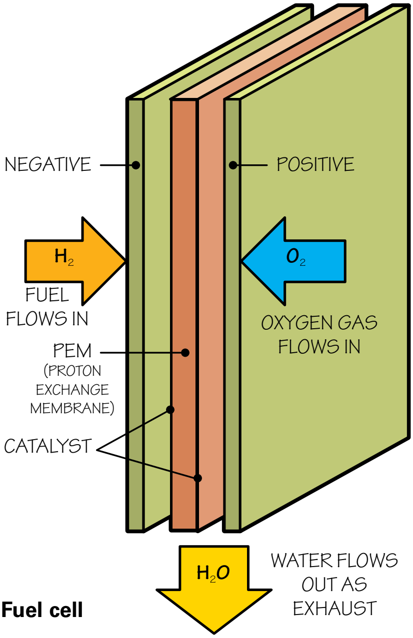
Cogeneration systems produce useful heat and usable power from a single process. The most common design is to capture the heat in the exhaust gases of industrial boilers or machinery. This produces hot water or steam that can be used for space heating or other processes. Heat from running generators, air compressors, and other machinery also can be put to good use. Cogeneration is being used today in the automotive, metal, and mining industries and in water and wastewater treatment.

Two factors make cogeneration an important part of our energy future. First, industries face growing pressures to reduce their impact on the natural environment. Second, the rising cost of traditional fuels means energy must be used and reused as efficiently as possible, which cuts costs at the same time it reduces pollution.

Hydrogen and Fuel Cells

Hydrogen is the simplest and most abundant element on earth, making up 75% of the total universe's mass. Hydrogen is an energy carrier, not an energy source. It is found within water, fossil fuels, and all living matter, but it rarely exists as a gas on Earth – it must be separated from other elements. We can make hydrogen from water using our nation's abundant energy resources such as wind, solar, and nuclear, or from natural gas with carbon capture to avoid emissions. When we produce hydrogen from water using electricity generated from renewables or zero-carbon sources – a process called electrolysis — hydrogen becomes a zero-emission resource to deliver, store, and use energy.

We already produce nearly 10 million metric tons of hydrogen annually in the United States which is roughly one seventh of the global supply. Today, hydrogen is primarily used to refine oil, and as part of many industrial and chemical processes required to make food and other essential products like plastic, fuels and even cosmetics. Current hydrogen infrastructure includes over 1,600 miles of pipelines, a growing network of stations, and thousands of tons of storage in underground caverns. More than 45,000 hydrogen-powered forklifts help move goods in warehouses and supermarkets, and thousands of fuel cell backup power units, which may use hydrogen, can provide electricity during blackouts.



Fuel cell

Hydrogen can help reduce emissions in hard to decarbonize sectors when used as an input in metals and steel manufacturing, and as a fuel in heavy duty transportation, including trucks. When blended with natural gas, hydrogen can help make natural gas burn cleaner. Hydrogen can also complement our electrical grid by storing energy from solar, wind, or nuclear energy sources, and with the help of a fuel cell, hydrogen can be converted back into clean electricity to be used when it is needed.

Much like a battery, a hydrogen fuel cell produces electricity through an electrochemical reaction, which generates electricity without any combustion. It uses hydrogen and oxygen as inputs and releases electricity and water as outputs. Unlike batteries, a hydrogen fuel cell doesn't run down or need to recharge.

The field of study for fusion processes and related research is called *plasma science.* Today, nuclear fusion can be done only in research labs.

As long as there's a constant source of hydrogen and oxygen, hydrogen fuel cells will continue producing electricity to power systems as large as a utility power station and as small as a laptop computer. Hydrogen fuel cells do not emit carbon dioxide or other air pollutants which makes them an important tool to address climate and air quality challenges.

Geothermal

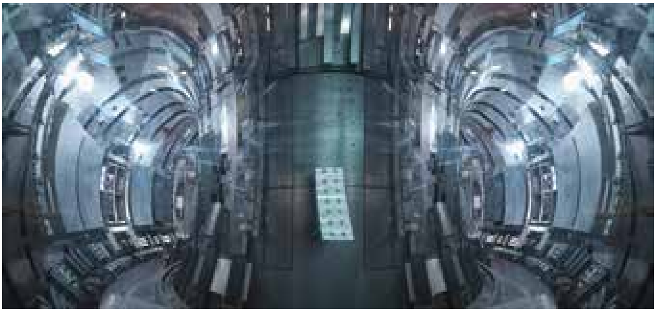
Under Earth's crust, deep down, the Earth is really hot (many hundreds of degrees Fahrenheit). The heat at the center of Earth is a byproduct of chemical and nuclear reactions happening deep in the Earth's core - reactions that have been occurring for billions of years. A common byproduct of these reactions is heat, which then slowly migrates up through the Earth until we can reach it by drilling into the ground. This heat can be used to generate energy, called geothermal energy, and produce electricity and heat and cool homes. Geothermal energy is available all the time, across the entire country, and does not produce greenhouse gas emissions. Because these reactions deep inside the earth will continue to happen, any heat we use will be replaced, or renewed.

Geothermal generation accounted for about 30% of electricity from renewable sources in 2022.

How Fission Works

In nuclear reactors, fission is induced by neutron absorption: large atoms absorb a neutron, causing them to excite and split into two smaller atoms, also known as fission products. In addition to tremendous amounts of energy, individual neutrons are often released during a fission event. These neutrons then interact with heavy isotopes (large atoms), inducing more fission events. Eventually, this becomes a chain reaction. Due to their high probability to undergo fission, uranium and plutonium are the most commonly used elements in nuclear reactor fuel. Fission in nuclear reactors is easily regulated by introducing control rods, which contain a neutron absorbing material.

Nuclear power plants do not produce carbon dioxide or other emissions that contribute to greenhouse gases in the atmosphere. Problems arise, however, with disposing of highly radioactive spent nuclear fuel.



Inside a reactor

How Reactors Work

Nuclear reactors use low enriched uranium for nuclear fuel. The uranium is fabricated into small ceramic pellets and stacked together into sealed metal tubes called fuel rods. Typically, more than 200 of these rods are bundled together to form a fuel assembly. Each reactor core is made up of a couple hundred assemblies, depending on the power level and reactor design. Inside the reactor vessel, the fuel rods are immersed in water which acts as both a coolant and moderator. The moderator helps slow down the neutrons produced by fission to sustain the chain reaction. This is necessary because even though neutrons from fission are born fast, fission in current reactor designs has a higher probability of happening when induced by slow neutrons. The energy released during fission reactions heats up the water. The water temperature increases until it starts to boil. The steam from the boiling water is used to turn turbines, generating electricity. Control rods absorb neutrons and can be inserted into the reactor core to reduce the reaction rate or can be withdrawn to increase it. All commercial nuclear reactors in the United States are light-water reactors. This means they use normal water as both a coolant and neutron moderator. New advanced reactor designs are currently being developed that can use molten salt, gas, or liquid metal as a moderator to operate at higher temperatures, resulting in higher efficiencies.

Safeguards are technical measures used to detect and deter the diversion of nuclear material and the misuse of nuclear facilities. The International Atomic Energy Agency (IAEA) works to independently verify the correctness and

A small portion of the heat stored in the ocean could power the world. Each day, the oceans absorb enough heat from the sun to equal the thermal energy contained in 250 billion barrels of oil.

completeness of nuclear programs in states that have signed the corresponding safeguards agreements. New technologies and reactors under development in the United States will be smaller in size and more flexible and affordable to operate. These systems, along with the current fleet of reactors, can use their thermal heat and power to generate clean hydrogen, drive industrial processes and even purify water without emissions. New designs such as small modular reactors and microreactors could be online within the decade.

Nuclear Fusion

As described earlier, fusion is the energy process that powers the sun and other stars. To use fusion on Earth, systems must be created to carry on the fusion process and convert that energy into electricity.

Even after we learn to control the process, it will take years to develop power plants to deliver substantial amounts of energy to people. Engineers will need to design systems to transfer the heat to fluids that could power turbines and generators. Separate plants will be needed to produce *deuterium* (the hydrogen fuel for fusion reactions) and *lithium* (a light metal) in large amounts to fuel the process.

Fusion energy has advantages over fossil-fuel and nuclear-fission plants in producing electricity. The fuel for fusion (hydrogen) is abundant. Its main by-product, helium, can be released without increasing greenhouse gases or air pollution. However, the process does create some radioactive waste. During fusion, high-energy neutrons strike the materials of the fusion reaction vessel. This will cause some of the atoms in these vessel materials to become radioactive. After many years of operation, these materials will have to be permanently disposed of as radioactive wastes.

In 2023, the first-ever demonstration of fusion ignition was achieved in the U.S. by Lawrence Livermore National Laboratory's National Ignition Facility; a breakthrough for fusion energy and a key initial step in a decades-long quest for limitless clean energy.

A major problem slowing widespread use of direct solar energy is personal taste. Solar homes need to be oriented to the sun, not parallel to the nearest road. They may be low or built partially into the ground. Many people do not like the distracting look of solar panels on their roof or property.

Solar Energy

Solar energy is the energy that comes from the sun as sunlight. Every location on Earth receives sunlight at least part of the year. The amount of sunlight that reaches any one spot on the Earth's surface varies according to geographic location, time of day, season, local landscape, and local weather.

Solar energy can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. Because the earth is round, the sun strikes the surface at different angles, ranging from 0° (just above the horizon) to 90° (directly overhead). When the sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse.

Solar photovoltaic (PV) technologies convert sunlight into electrical energy. A single PV device is known as a cell. When the sun shines onto a solar panel, energy from the sunlight is absorbed by the PV cells in the panel. This energy creates electrical charges that move in response to an internal electrical field in the cell, causing electricity to flow. In order to withstand the outdoors for many years, cells are sandwiched between protective materials in a combination of glass and/or plastics.

In order for solar energy to be useful in a home or business, a number of other things must be in place. The best way to install solar is through a qualified professional who holds a certification to work with and install solar panels. You can install solar panels on the rooftop of your home depending on that rooftop's size, shading, tilt, location, and construction. PV technologies must be mounted on a stable, durable structure that can support it and withstand environmental elements like wind, rain, hail, and corrosion over time. Another way to install is by rack mounting. Rack mounting is currently the most common method for large fields of solar panels because it is versatile and easy to construct and install.

Solar energy works well with other technologies, like batteries, which help save solar energy for longer periods of time. The reason: Solar energy is not always produced at the time energy is needed most—like at nighttime or on cloudy days. Solar energy can help to reduce the cost of electricity, because once you install a solar system, you don't ever need to refuel it—just point it to the sky! It can also help to produce backup power when the power goes out, like after a major storm. Solar energy and other renewable energy is quickly replacing older forms of electricity generation like coal or gas power plants. This transition—or "modernization"—will help to reduce our impact on climate change and will create millions of new jobs around the country.

The cost of solar electricity is about 10 to 13 cents per kilowatt-hour. This cost must be reduced to about 2 to 5 cents per kilowatt-hour for solar cells to be competitive. An alternative for producing electricity from the sun is to build generating plants powered by solar energy. However, it is difficult to produce the temperatures that are required to heat water or other fluids to make steam because sunlight comes to us very diffusely (spread out).

Ocean Energy

Earth's oceans can produce two types of energy: thermal energy from the sun's heat and mechanical energy from the tides and waves. Though ocean energy has great potential, much work is needed before this source can become a practical energy supply that is competitive in cost and friendly to ocean life and shorelines.

Oceans cover more than 70% of Earth's surface, making them the world's largest solar collectors. The sun's heat warms the surface water much more than the deep ocean water, and this temperature difference produces thermal energy. Ocean thermal energy conversion systems use this energy to drive turbines and generators to make electricity.

The mechanical energy in ocean waves can power various systems to generate electricity. One system uses floats or pitching devices to produce electricity from the bobbing or pitching movements. Another makes electricity from the wave-driven rise and fall of a column of water powering a turbine. A third system funnels or channels waves into a reservoir, then releases the water through turbines to generate electricity.

To convert tidal energy into electricity, a dam typically is used to hold water at high tide, then release the stored water through a turbine at low tide. A major disadvantage of tidal power plants is that they can generate electricity only during falling tides. Also, the plants can be built in few places because tidal power requires large differences between high and low tide. In the United States, large tidal differences occur only in Maine and Alaska.

Wind Energy

One critical issue with wind farms is that they often are located far from where the energy is needed.

Wind is caused by the sun unevenly heating the atmosphere and the earth's surface, combined with the rotation of the earth. Modern high-tech wind turbines capture the energy of wind to produce electricity. They can vary in size from smaller turbines for local use at homes or farms, to groups of very large turbines for electric utilities, called a wind farm. The most efficient place for a wind turbine to operate is high above the ground, where winds are stronger and steadier than at ground level. The towers for utility-scale wind turbines are often 300 feet tall. At the top of the tower, 3 blades form a rotor which is turned by the wind and connected to a generator to create electricity.

Wind energy is abundant, renewable, and available nearly everywhere – on land and offshore. Wind flow patterns and speeds vary greatly across the United States and are modified by bodies of water, vegetation, and differences in terrain. Some of the strongest wind sites may be found in In the American West, the Great Plains, New England, and off the Atlantic and Pacific coasts. In the past 20 years, the price of wind-generated electricity has dropped significantly, so that in some places it is the cheapest source of energy. Wind energy has become an important source of electricity nationwide and is continuing to grow.

Technology and commercial advancements are driving down the costs of wind energy. More wind energy was installed in 2020 than any other energy source, accounting for 42% of new U.S. capacity.

Wind power is now the fastest growing energy source worldwide, and many predict it will soon be a major energy contributor in the United States.

Careers in Energy

Nate enjoyed learning about energy, and he started thinking about a career in the field. In his merit badge work, he had learned that the energy industry includes many different kinds of companies that find, develop, generate, and transport various forms of energy. Universities and government agencies do additional research to improve technologies and ensure public safety.

Nate asked his merit badge counselor, Mr. Stevens, what classes he should take now to pursue a future in energy. Mr. Stevens said high school and college graduates had many opportunities in the field. His main advice was to stay in school and do well in all subjects. Reading, writing, and mathematics form a good foundation for any career. And high school classes in science, including physics and chemistry, along with any available math courses help anyone interested in preparing for a technical field.

An area of study that students in technical fields often overlook in college is writing. To sell an idea for future study or to explain to someone the results of your research, you need a good command of written and spoken English.

The Companies

Nate did follow-up research to learn more about the energy industry and the careers it creates. He found three basic groups of related industries making up the energy field: fossil fuels, nuclear power, and renewable technologies including hydroelectricity. Each has specific needs and opportunities for careers.

A small number of companies make up the coal segment of the fossil-fuel industry. They collaborate and jointly sponsor research to improve their generating efficiency and reliability and reduce environmental impact.

The oil and natural gas industry also is composed of large companies, or majors, but also small companies called independents. Majors mostly work internationally and in high-cost areas (Alaska and offshore). The independents find and produce most supplies within the United States. These major and independent companies compete to find new resources and closely guard their research results.

Renewable energy has produced many *entrepreneurs*—people who build a business around a new idea or technology.

The nuclear industry consists of electric utility companies and the businesses that support them. The utilities operate the actual plants that make electricity. They maintain the machinery, put fuel in and remove waste products, and monitor the environmental impact. Corporations supply equipment and produce uranium fuel, among other activities. The U.S. government is involved in regulating the industry and directing the systems that dispose of radioactive wastes.

The renewable energy industry has many smaller firms producing goods and services and doing ongoing research. The exception to this is hydropower, where a few large public and private companies make up the industry.

The Careers

Each segment of the energy industry needs engineers, operators, technicians, and managers. These businesses also need accountants, marketers, and lawyers. Skilled tradespeople such as electricians, plumbers, carpenters, truck drivers, and machinists find careers in the energy field. Researchers for corporations, universities, and government agencies develop better technologies and make other innovations.

Energy industry people can be found in large and small cities; in offices, laboratories, or plants; or in the field maintaining the miles of electric lines and oil and gas pipelines that bring energy to the public. Some are based in wild, remote areas, including Alaska and offshore in the Gulf of Mexico, looking for sources of fuel.

The technical side of the energy industry demands special skills and generally requires an engineering or science degree from a college or university. People with these skills not only build, operate, and maintain the generating plants, but also discover improvements that reduce costs and lower risks. These technical positions require education emphasizing math and science often including physics, chemistry, and calculus.

The two largest engineering disciplines, civil and mechanical, are found in all of the energy industries. These engineers are responsible for the design, construction, and operation of physical plants.

The fossil-fuel industry employs petroleum, chemical, and mining engineers. Petroleum engineers drill and produce oil and natural gas and ensure its safe transport and storage. Chemical engineers refine petroleum products into useful fuels and products like plastics. Mining engineers bring coal resources from the ground to the power plant. The nuclear industry employs nuclear engineers with special training to solve the many technical issues in handling nuclear materials.

Scientists also have career options in energy. Computer scientists are needed in all industry segments to help in design, operation, and maintenance. Geologists and geophysicists usually handle fossil fuels, often in outdoor laboratories discovering where the fossil fuels are hidden so that petroleum or mining engineers can extract them safely and economically. Chemists and physicists also find careers in energy research.

All types of engineers are in demand for various renewable energy and conservation approaches.

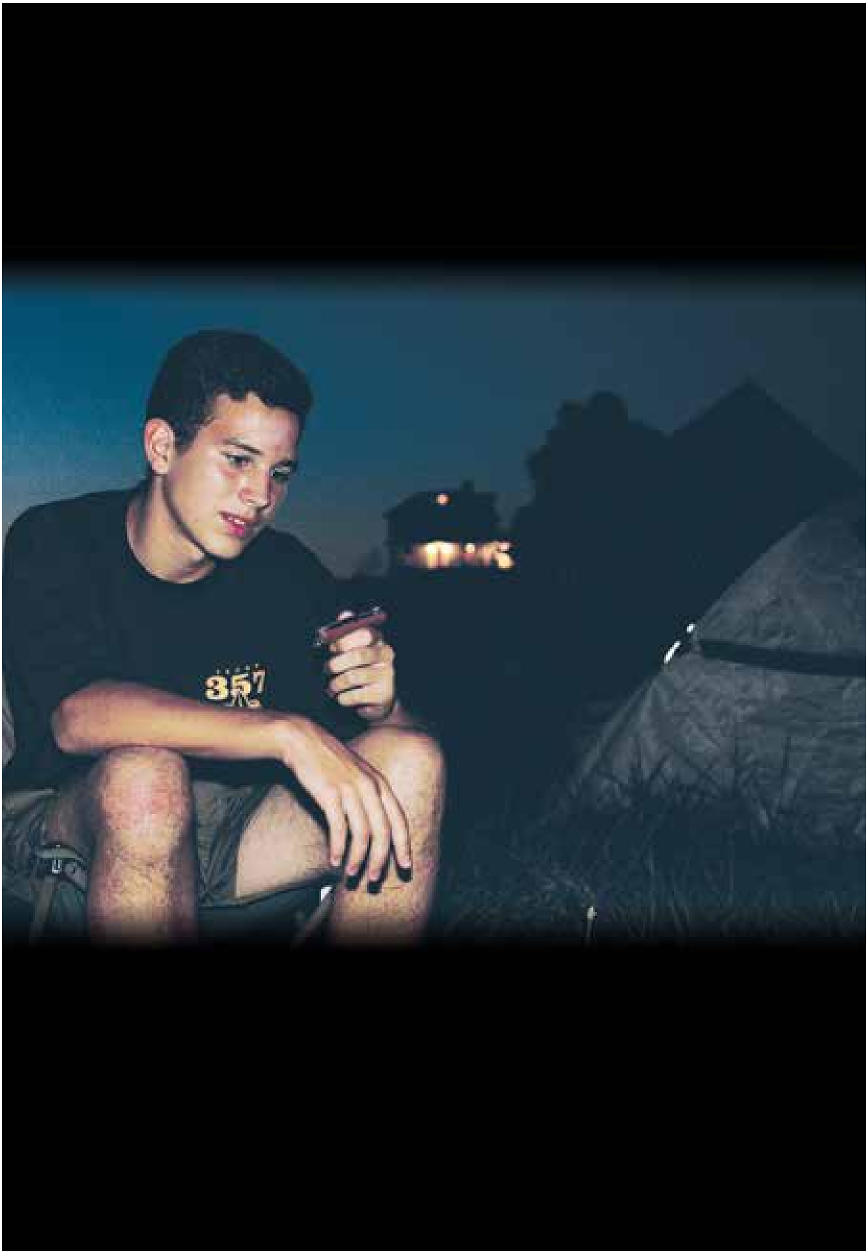
What Lies Ahead

The current, exciting transition from traditional energy sources to long-term future sources is also bringing a transition for energy careers. Before long, we will need people to improve existing technologies and delivery systems as well as manage human systems that operate manufacturing, sales, and services. Many new careers will come about as we move to increasing efficiency and controlling pollution—especially reducing carbon emissions.

Building and maintaining hybrid and electric cars is an area where jobs will require keeping your skills up to date as systems develop. A biofuels industry will create systems that capture carbon dioxide and convert it into liquid fuel. In addition, existing careers like photovoltaic systems installers and wind turbine technicians will be changing drastically.

Converting traditional electrical grids to "smart grids" is one of our biggest challenges. This will require inventions and technology systems as well as information technology experts, project managers, and systems engineers. Current systems of pump-storage hydroelectric facilities and gigantic battery systems will be augmented by technologies we have not dreamed of yet.

With energy careers, this old saying remains true: "The sky is the limit."



Epilogue: Nate's Story

Nathan Robert Gomez looked up into the starry night sky and smiled at his latest achievement. Earning the Energy merit badge had been fun and fascinating. Nate felt he had learned much about energy and was ready to be a responsible family member, community member, and citizen.

Now he looked at everything around him in terms of the energy it took to produce and operate. He knew about the connections among cost, supply, waste, pollution, and many other issues. He understood the second law of thermodynamics and saw it in play in his world each day. He was excited about the possibility of a career in the energy field.

Nate gazed down at the new pocketknife his parents had given him when he completed the Energy merit badge. He turned it over and examined the monogram on the reverse side.

"Well, no wonder!" he thought. "I had to be the most prepared Scout ever to earn the Energy merit badge. Just look at my initials—N.R.G. En-aR-Gee. Energy!"

Energy Information Resources

Scouting Literature

Chemistry, Citizenship in the Community, Citizenship in the World, Electricity, Electronics, Engineering, Environmental Science, Geology, Home Repairs, Nuclear Science, Oceanography, Plumbing, Pulp and Paper, Radio, Railroading, Space Exploration, Sustainability, Truck Transportation, and *Weather* merit badge pamphlets

With your parent or guardian's permission, visit Scouting America's official retail site, **scoutshop.org**, for a complete list of merit badge pamphlets and other helpful Scouting materials and supplies.

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Organizations and Websites

GENERAL ENERGY INFORMATION

Energy Efficiency and Renewable Energy
U.S. Department of Energy
1000 Independence Ave. SW
Washington, DC 20585
energy.gov/eere

Energy Kids
U.S. Energy Information Administration
eia.gov/kids

ENERGY EFFICIENCY AND CONSERVATION

Energy Star
U.S. Environmental Protection Agency
energystar.gov

Home Energy Saver
Energy Technologies Area,
Lawrence Berkeley National Laboratory
eta.lbl.gov

ENERGY SOURCES AND DATA

American Clean Power Association
202-383-2500
cleanpower.org

International Atomic Energy Agency
iaea.org

National Hydropower Association
202-682-1700
hydro.org

National Renewable Energy Laboratory
nrel.gov

Nuclear Energy Institute
202-739-8000
nei.org

U.S. Energy Information Administration
eia.gov

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Contributing authors to this edition are Susan Hamm, Begonia Aranguren, and Don Harris. Contributing additional expertise to the previous edition of the *Energy* merit badge pamphlet was Robert J. “Bob” Silva, PE, PG, program analyst with the U.S. Department of Energy’s Office of Fossil Energy. Thanks also to Danrick Alexander for his involvement.

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