

## 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. Boom boxes, beagles, our bodies, insects, the Internet, instruments, farms, frogs, fish, telephones, televisions, trees, wind, weather, and the water cycle all require energy. You cannot understand the world you live in without understanding energy.

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.



**Drivers, who must rely on energy to power traffic signals and streetlights, can be left helpless when the power fails.**

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 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.

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

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# 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 any Scout who wants to be a responsible member of his 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 \$34." He looked at other models. Their tags gave different yearly operating costs, ranging from \$21 to \$38. Nate wrote in his notebook the operating costs of several models.

Based on standard U.S. Government tests

# ENERGYGUIDE



Capacity: 25.3 Cubic Feet

Brand:  
Model#:

## Compare the Energy Use of this Refrigerator with Others Before You Buy

**This Model uses 724 kWh/year  
This Model's energy use ranks 9.8 on the scale**

Energy use (kWh/year) range, on a scale of 1 (Least Use) to 10 (Most Use) of all similar models

Uses Least Energy

618

Uses Most Energy

727

kWh/year (kilowatt hours per year) is a measure of energy (electricity) use. Your utility company uses it to compute your bill. Only models between 24.5 and 26.4 cubic feet with the above features are used in this scale.

Refrigerators using more energy cost more to operate. This Model's estimated yearly operating cost is:

**\$59**

Based on a June 7, 2002 U.S. Government national average cost of 8.28 cents per kWh for electricity. Your actual operating cost will vary depending on your local utility rates and your use of the product.

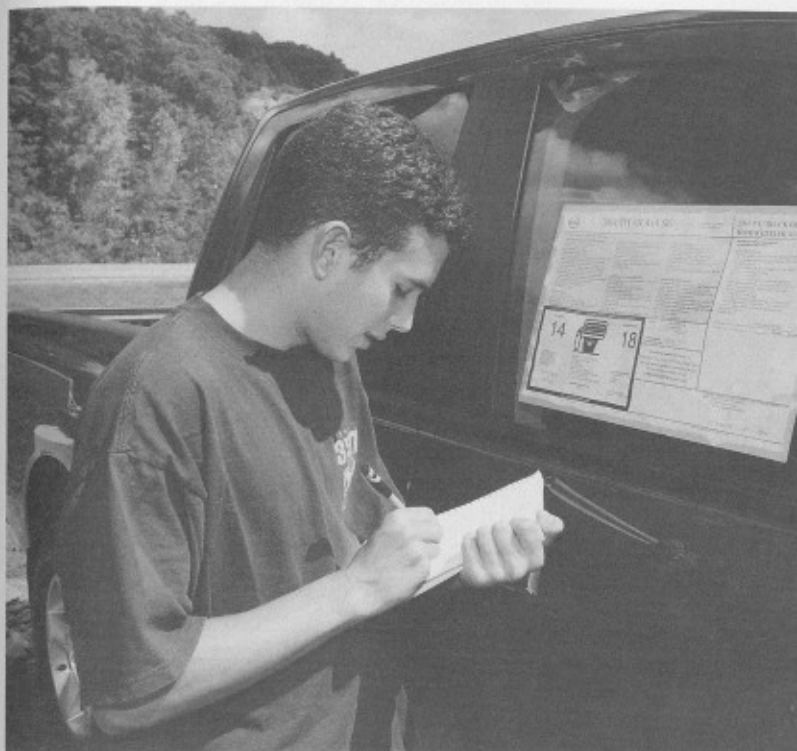
**All appliances now must come with an EnergyGuide® tag that tells how much it costs to operate the appliance for one year.**

"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, CD player, power windows, power door locks, etc. The price of some of the options was listed, but some were included in the *base price*.

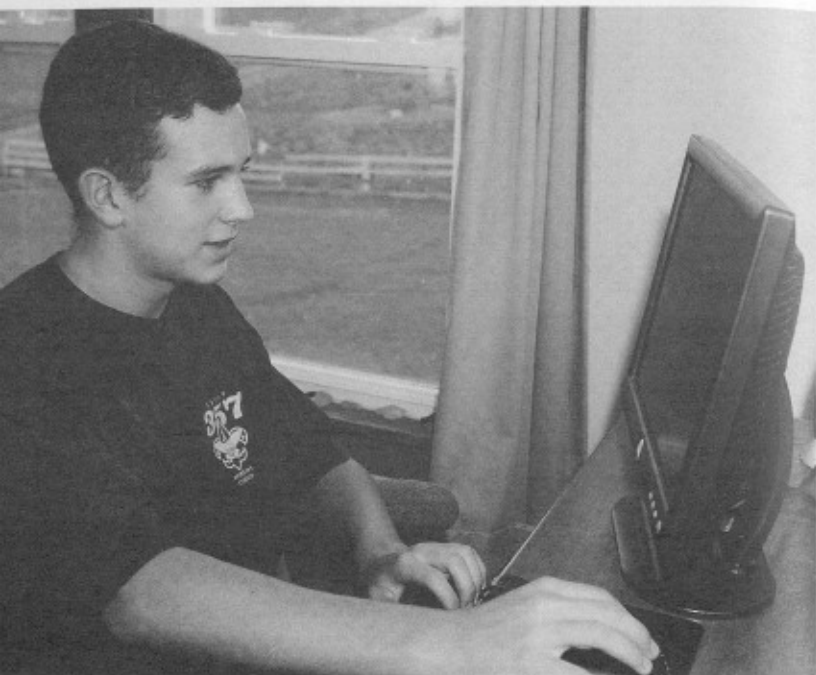
Nate wondered why operating costs would be different. He saw that the refrigerators were different sizes, shapes, colors, and brand names. They were lined up more or less in the order of their yearly operating cost. Then Nate realized they also were lined up in order of selling price. He observed that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



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 Web site 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. Only on The Knowledge Channel."

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 percent 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."

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Renewable energy  
from sources

such as sunlight,  
wind, and water

is replaced by  
natural processes.

Nonrenewable  
energy sources

(including coal  
and oil), once

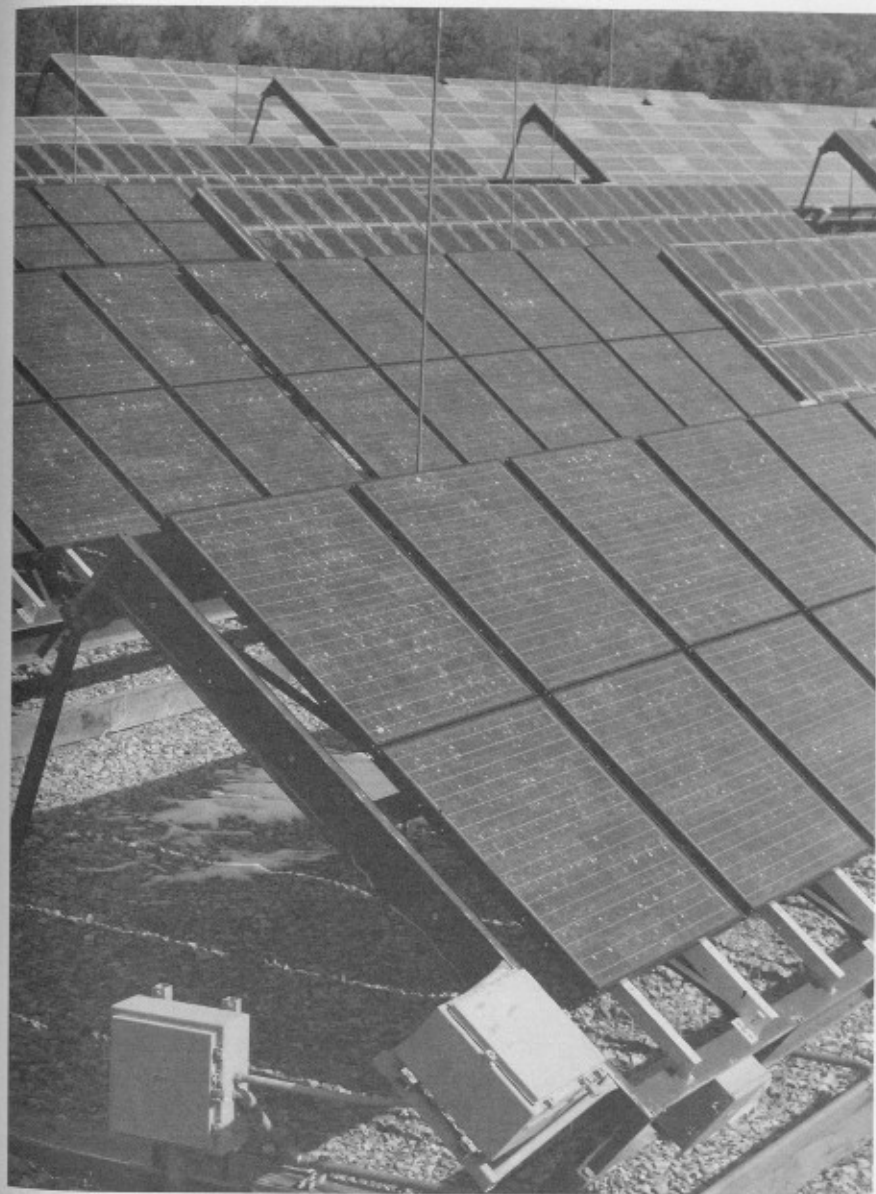
used, cannot  
be replaced.

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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.



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.

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.

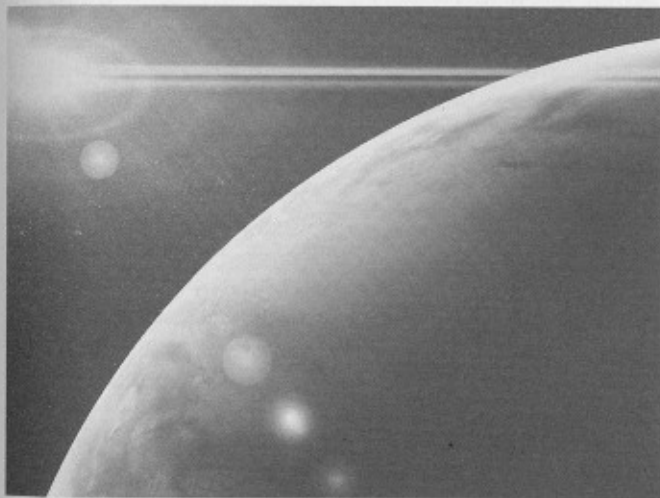
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A watt is a  
measure of power.

One horsepower  
equals 746 watts.

A *megawatt* is  
1 million watts.

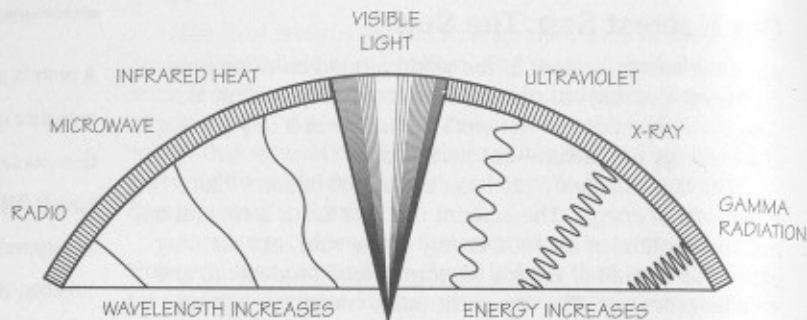
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## Products of the Sun's Energy

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, EMR 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.



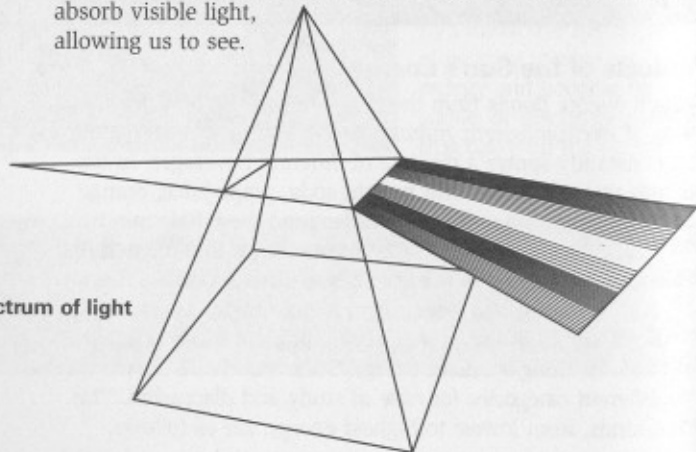
The electromagnetic spectrum

**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.** 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 expose photographic film 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 produces 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.

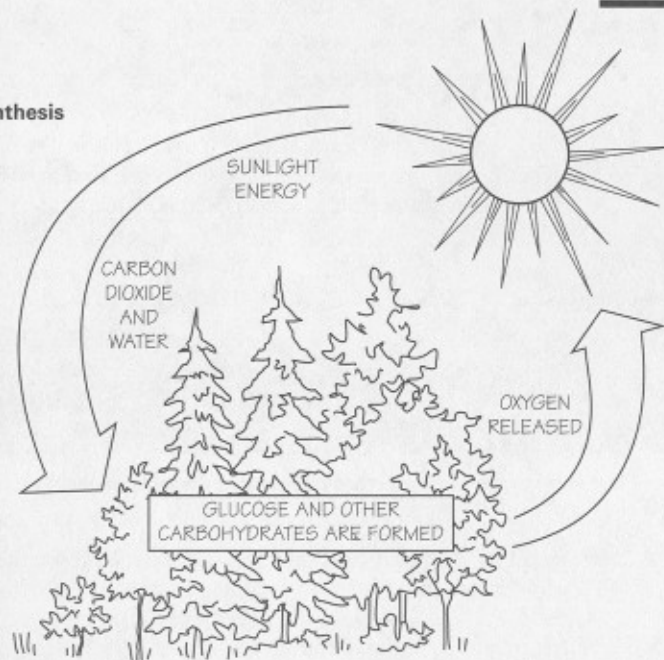
Radiant energy has other effects on the natural environment. Heat, microwaves, and visible light all make water molecules move faster. Solar energy increases the temperature at the surface of the oceans and adds energy to snow and ice until they are warmed enough to melt into water. But probably the 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.

## 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.

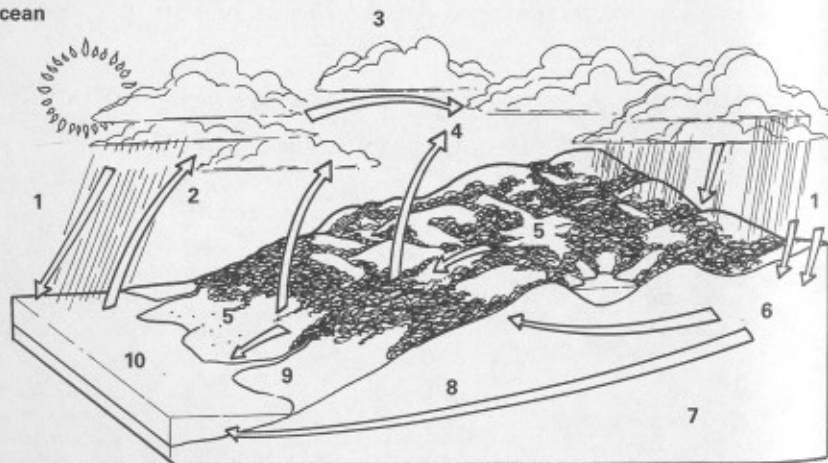
## Photosynthesis



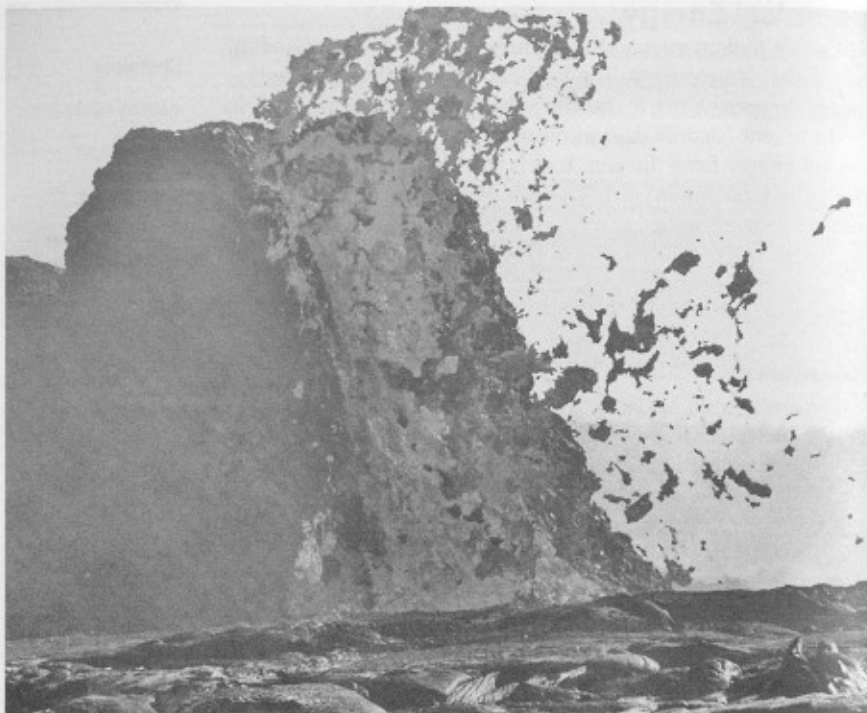
The plant may use the energy in these complex molecules for its own growth, repair, and reproduction. An animal may eat and digest the plant and use the energy released from the plant's molecules to make molecules for its own use. Also, burning the plant will release the chemical energy stored in the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

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

- 1 Precipitation
- 2 Evaporation
- 3 Condensation
- 4 Transpiration
- 5 Runoff
- 6 Infiltration and percolation
- 7 Aquifer
- 8 Groundwater movement
- 9 River
- 10 Ocean



The water cycle



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

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*.

## 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.

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.



## 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 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.

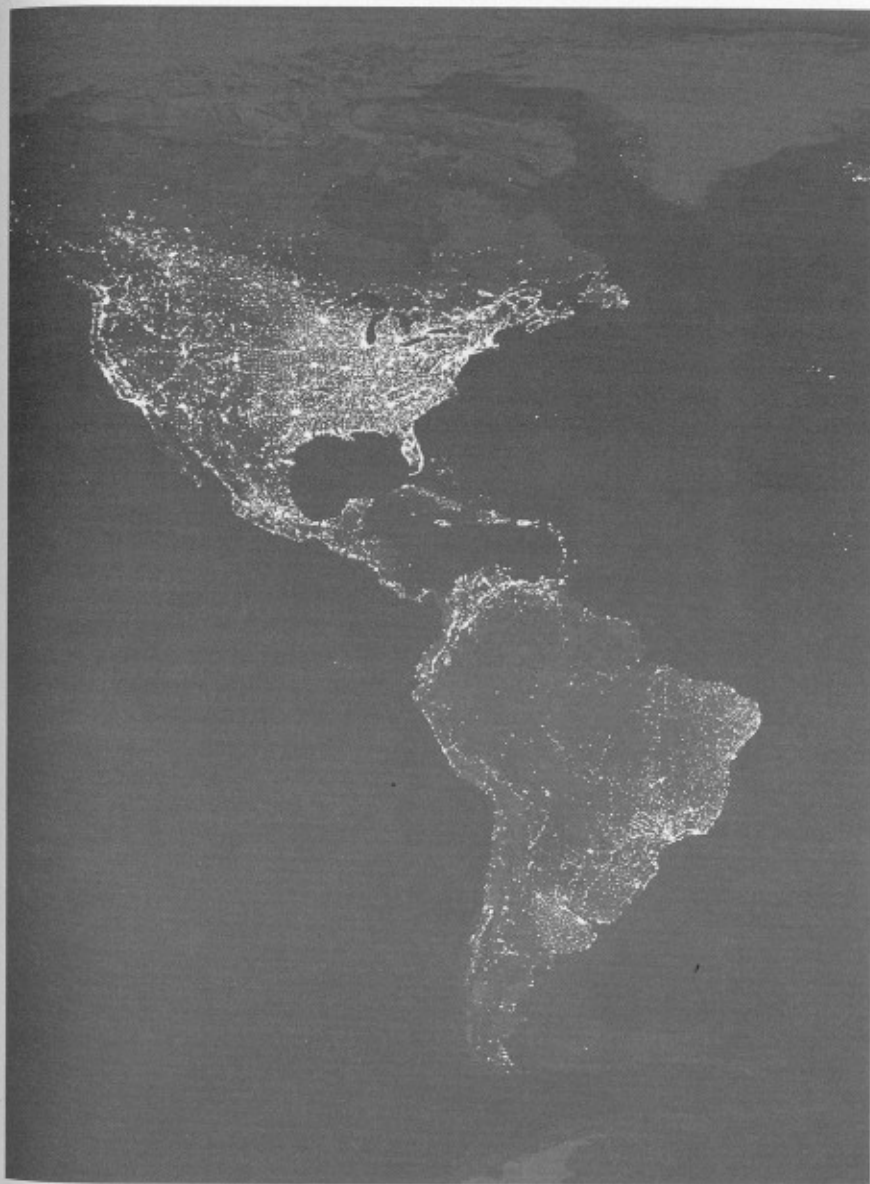
While chemical energy is useful for storing radiant energy until it is needed, electrical energy is useful for moving energy from place to place. Electrical energy is convenient, making energy available at the flip of a switch. For more about electric currents, see the *Electricity* merit badge pamphlet.

## 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.

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

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.



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 of the science of 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*.

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.

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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.

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

## 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

one 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 radiant heater	Kilowatt-hour	3,413
Electric heat pump	Kilowatt-hour	6,803
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	$16 \times 10^6$
Water power	Gallons per 100-foot fall	.234
Wood (white oak)	Cord	28,200,000
Wood (pine)	Cord	20,500,000

## Energy Conversion Devices

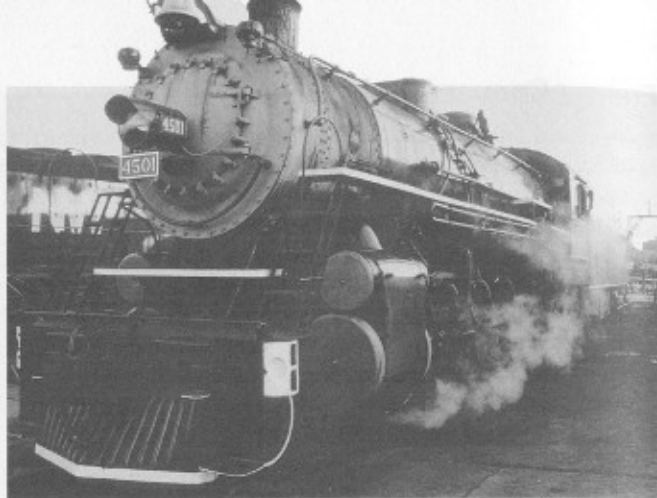
Every useful process happens through the conversion of energy from one form to another. Before people invented cars, tractors, and power plants, they had only the muscle power of humans and animals. Living animals (including humans) are complex systems for converting the chemical energy stored in food 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.

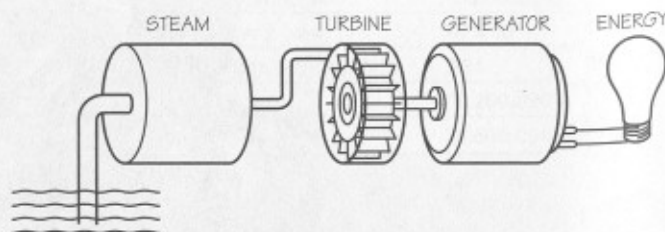


Substances with stored chemical energy that can be converted to useful motion in an engine are *fuels*. The most common fuels are materials that are burned to produce heat or power. Food is fuel—the source of the energy we use to move, think, and heat our bodies. Materials used in a nuclear fission or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



*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.

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*.

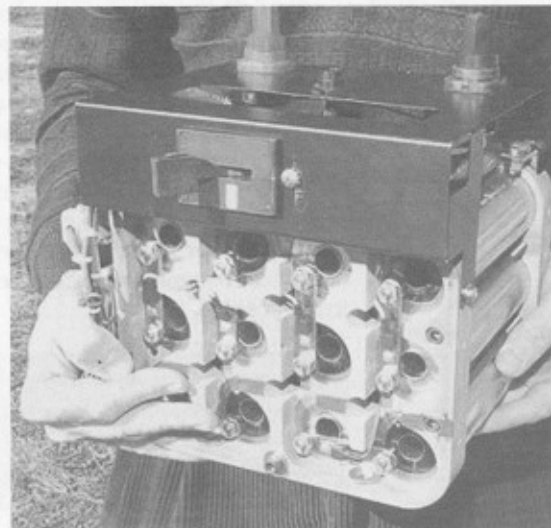
*Batteries* provide portable, stored electricity. They commonly power flashlights, radios, and other portable devices. Inside these batteries, reactions change chemical energy into electric current. When all of the chemicals have reacted, the battery cannot be made to produce more electricity.

*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.

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.

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



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 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.

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.

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

From

To

	Heat	Light	Mechanical	Electrical	Chemical	Atomic
Heat	Sweat lodge, Trombe wall	Greenhouse	Bow drill, friction, air resistance	Toaster, resist- ance 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 fis- sion fragments or fusion nuclei
Electrical	Thermocouple	Photovoltaic (solar) cell	Generator, piezoelectric effect	Transformers, rechargeable batteries	Wet batteries, fuel cells	
Chemical	Chemosyn- thetic bacteria	Photosynthesis		Electrosyn- thesis	Chemical reactions	
Atomic			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.

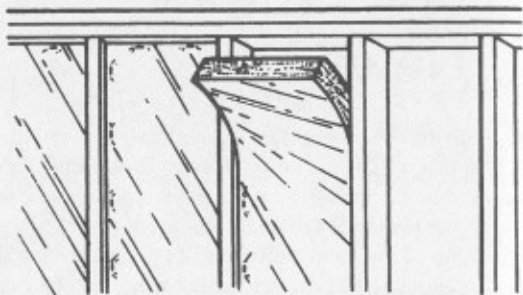
## **Heat flows from hot to cold.**

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*.



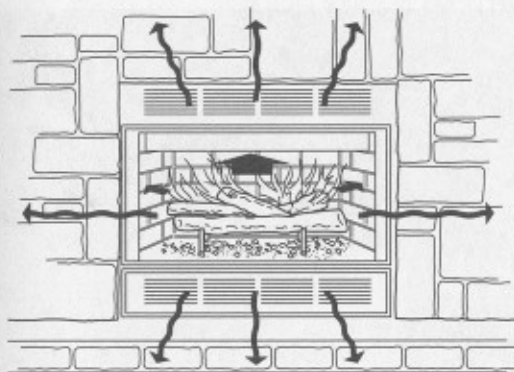
**Insulation only slows the movement of heat from hot to cold.**

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.

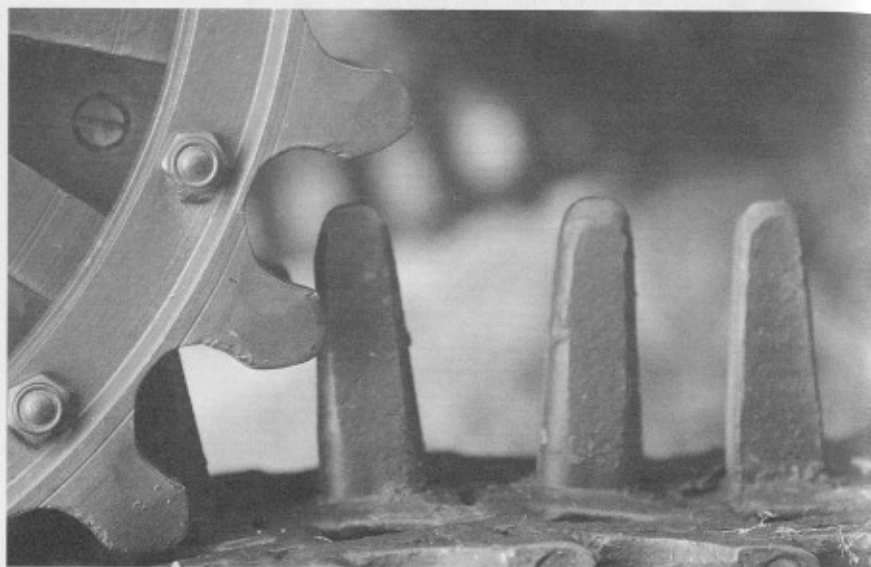
The flow of heat in all directions is important to the second law. To help us remember the importance of this idea, we will add another phrase:

**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 percent because the total energy must always be more than the useful energy of a system (the second law).



**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.

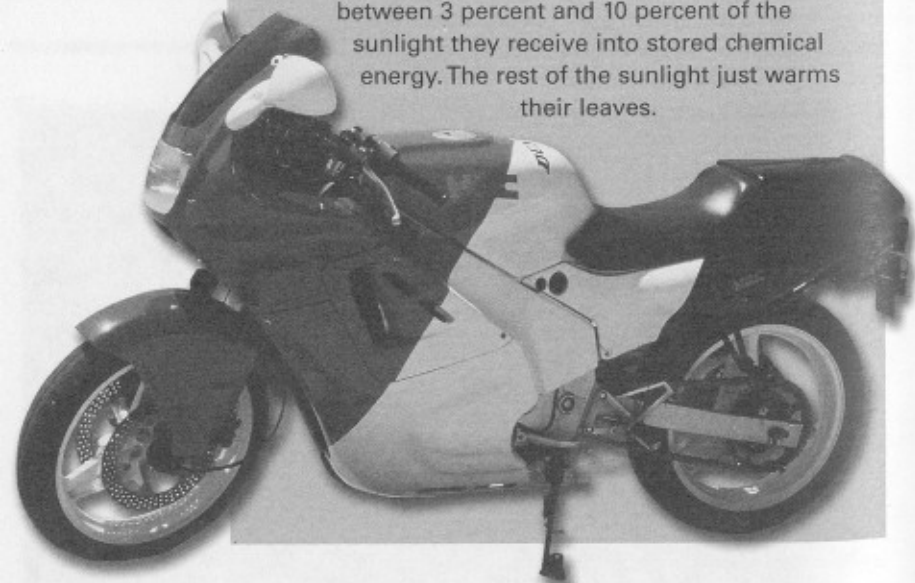
Another way to increase energy efficiency is to develop better technologies. While incandescent lightbulbs are only about 5 percent efficient, a fluorescent lamp works at almost 12 percent efficiency. A coal-burning steam locomotive may have been only about 4 percent efficient, but modern train engines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

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

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No physical  
system can be 100  
percent efficient.

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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 percent 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.

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

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# 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 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.

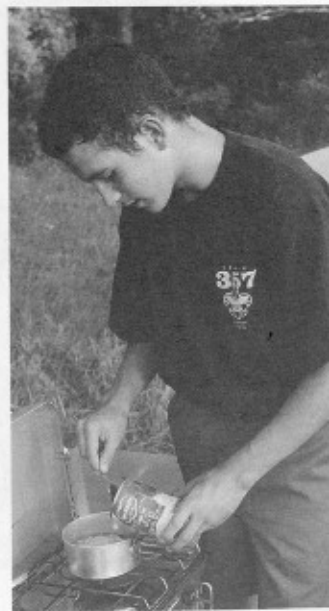
#### How Much Energy Does It Take to Make?

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



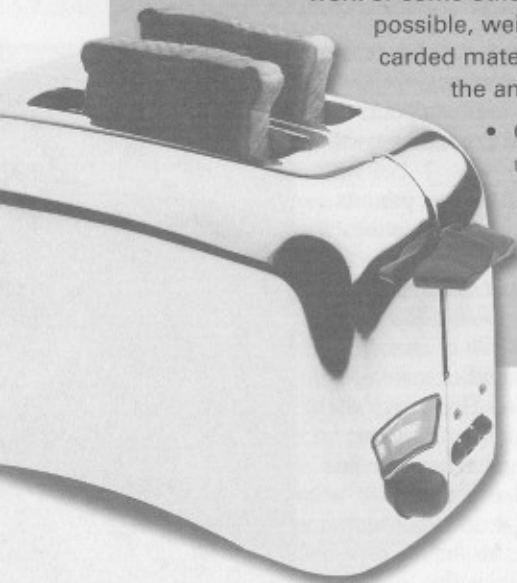
## The Second Law at Home

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. To warm 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 percent 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.

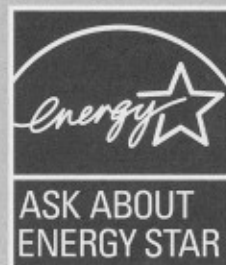
The refrigerator we are considering uses a lot of energy (and wastes much additional energy). We want to make it work better. We can reduce the noise and waste heat of the compressor by building it more carefully with better materials. The trade-off for a better compressor is higher cost of labor and 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.

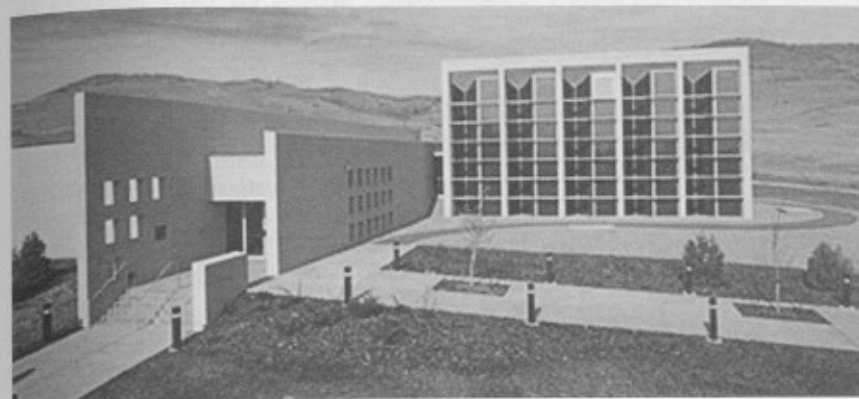


A government-backed program called Energy Star® identifies appliances that are especially energy-efficient. Energy Star® appliances exceed federal efficiency standards. (To qualify for the Energy Star® rating, refrigerators must exceed federal standards by 20 percent.)

## 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 percent 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 percent of the heating energy. (Be sure to discuss this with your family first!)
- Have one of your parents 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 parents can pay household bills by computer. Many companies will now 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 percent. 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'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.

# 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.

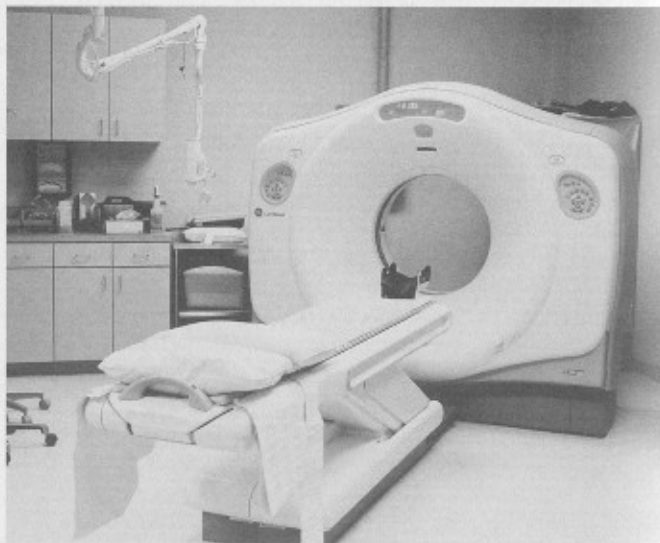
A lump of coal is only partly carbon compounds. It also contains minerals that will not burn. Some of the unburnable material becomes a fine powder that will go out the stack with the water and carbon dioxide, if allowed. But this fine dust is

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 percent 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 percent 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 telephones, 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.

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 percent efficiency; that is, 30 percent 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!"

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

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An engine efficiency of 30 percent 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 percent 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 percent 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 percent 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.

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: 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.

The first functional electric car was built in 1915.

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 percent
Glass	45,000	30 percent
Paper	8,500	60 percent
Steel	26,000	76 percent
Plastic	40,000	90 percent
Aluminum	24,000	95 percent

\*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.

# A Good Energy Citizen

Today, with 5 percent of the world's population, the United States consumes 25 percent of the world's energy and produces more than 25 percent 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 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.

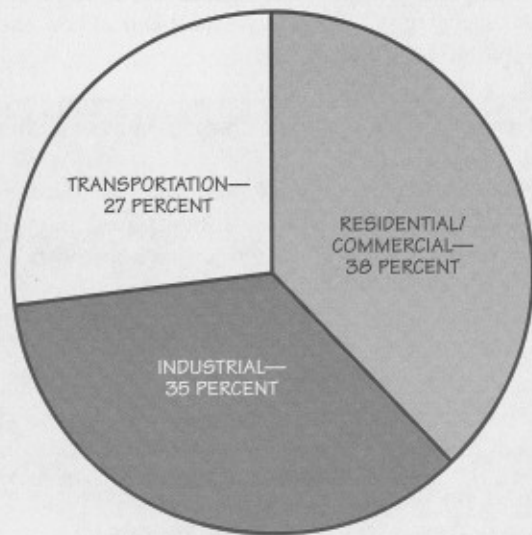
**U.S. Energy Consumption 1949–2002**

Year	Quads of use	Year	Quads of use
1949	31.9	1975	72.0
1950	34.6	1980	76.3
1955	40.2	1985	76.4
1960	45.1	1990	84.6
1965	54.0	1995	91.2
1970	67.8	2000	98.9

## Supply and Demand

In discussing energy use, we look at three main *sectors*. Our homes, schools, churches, and businesses together comprise the *residential/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 third sector, *transportation*, includes cars, trains, planes, buses, and every other form of moving people and goods.

U.S. energy use in 2000



The information in this section on energy use and supply by sector is taken from year 2000 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/commercial sector. 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/commercial sector in 2000 amounted to about 38 percent of the U.S. total.

At the beginning of the 21st century, industrial energy use took about 35 percent 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 percent of the world's oil use every day goes to fuel personal cars and light trucks in the United States. Transportation accounts for about 27 percent 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

### Oil

Oil is the largest source of energy in America, supplying almost 40 percent of our 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 heavily on oil from other countries. We import about 55 percent of the oil we use. Our nation's transportation fuels (gas, diesel, jet fuel) account for almost 70 percent of crude oil consumed, and 3 percent goes to electrical generation.



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.

### Natural Gas

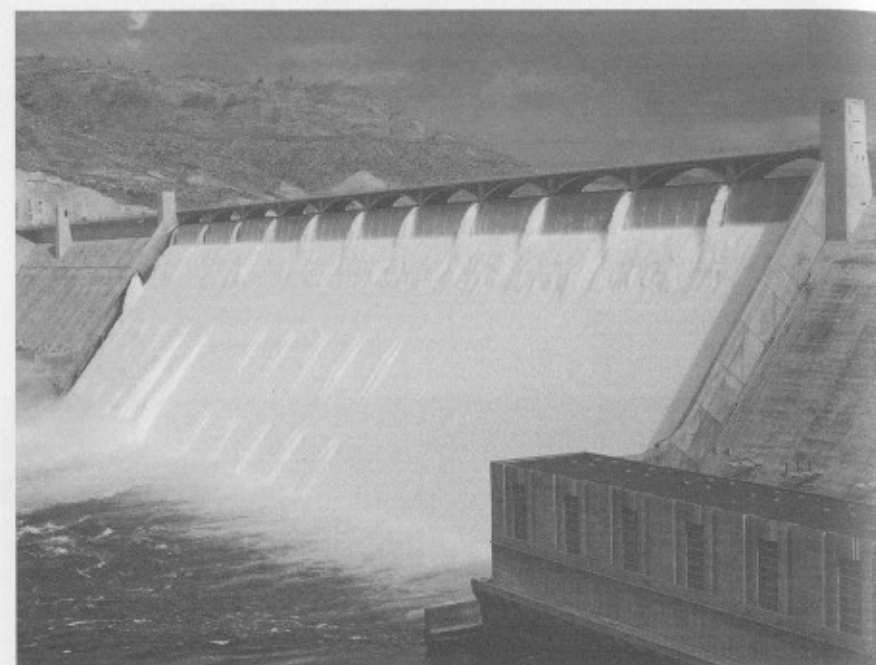
Natural gas provides about one-fourth (24 percent) of our energy supply. Natural gas requires little processing before use. It has fewer pollutants than other fossil fuels so it keeps the air cleaner. It also does not produce a solid waste for disposal like coal. About one-half of homes in the United States are heated with natural gas. Gas also is useful to operate stoves, clothes dryers, and water heaters. About one-fourth of our natural gas is used to produce electricity. Like oil, gas must be produced through wells and also raises concerns about environmental impacts.

### Coal

Coal is the fossil fuel most abundant in the United States. Coal currently meets about one-fourth (23 percent) of our energy demand. About 90 percent of the coal burned in the United States is for producing electricity. Coal-fired power plants supply about one-half of 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 environmental concerns when determining coal's usefulness in the future. Coal mining also raises environmental issues.

### Nuclear Power

Nuclear power produces about 8 percent of our energy, all in the form of electricity. Nuclear-generated electricity is about 20 percent of U.S. electrical production. 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 in using nuclear power.



The Grand Coulee Dam in central Washington

### Water Power

Water power provides about 3 percent of the U.S. energy supply through production of electricity. 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.

### Other Power Sources

Biomass, geothermal, solar, and wind power contribute most of the remaining 3 percent 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 98.9 quads of energy consumed in the United States annually, 38.2 quads (almost 40 percent) are converted into only 12.4 quads of electricity (with a 66 percent loss). Of the 12.4 quads of electricity, 0.8 quads (more than 6 percent) is lost from resistance in electrical lines.

Internal combustion engines are only 15 percent to 20 percent efficient at converting the chemical energy in petroleum fuels to mechanical energy that moves our vehicles. In other words, 80 percent 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 200 to 300 years at today's rate of use. The global oil reserve, however, could be exhausted within 40 to 60 years. Natural gas reserves also could be used up in about 60 years. Uranium reserves for nuclear fission are estimated at about 50 years.

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.

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 energy future. You can use this information to help meet requirement 7 and as a starting point to locate other resources for a fuller picture of energy technologies.

## 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 45 or 50 percent, up from about 33 percent now. As the technologies are improved, that efficiency could reach 60 percent.

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

The simplest and most common use of biomass is burning wood. Broadly, biomass energy is energy from photosynthesis. Solar energy stored in plant and animal materials can be burned as a heat source or converted to liquid or gaseous fuels.

*Biogas* is usually methane produced from decaying animal wastes and garbage. Special *digesters* can use natural processes to break down carbon compounds and produce methane. The gas burns cleanly into carbon dioxide and water.

Liquid *biofuels* are produced by fermenting biomass sources. The two most common biofuels are ethanol and biodiesel. Adding ethanol to gasoline gives a cleaner-burning transportation fuel. Biodiesel can be used alone to power a vehicle or as an additive to reduce emissions.

Electricity generated using biomass fuels is *biopower*. Waste-to-energy plants burn trash and garbage to make electricity. Biomass sources alone do not release enough heat to power electrical generation, but they can be chemically converted and burned to do the job. Mixing biomass with coal, called co-firing, can generate electricity and reduce the pollution emitted from a power plant.

# 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.

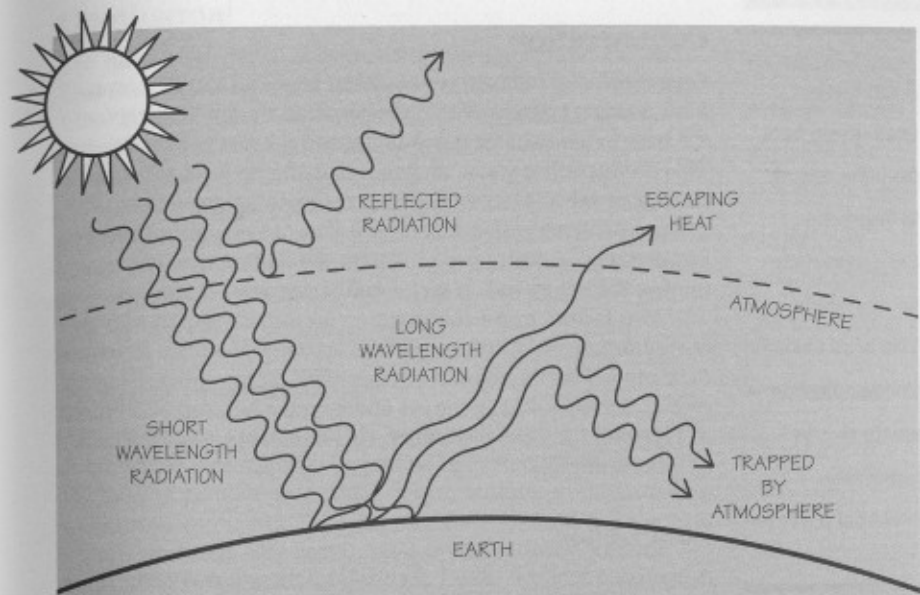
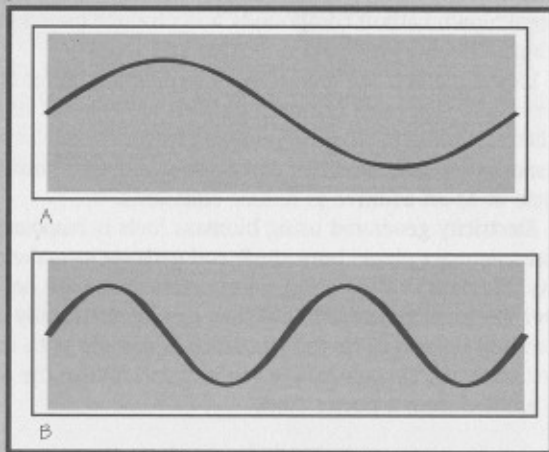
Sunlight comes to Earth as waves of radiant energy with different wavelengths. The short-wavelength energy easily passes through air (or greenhouse glass). When that energy reaches land or water, it is absorbed. The second law of thermodynamics holds that the process of absorption and release cannot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

## 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.

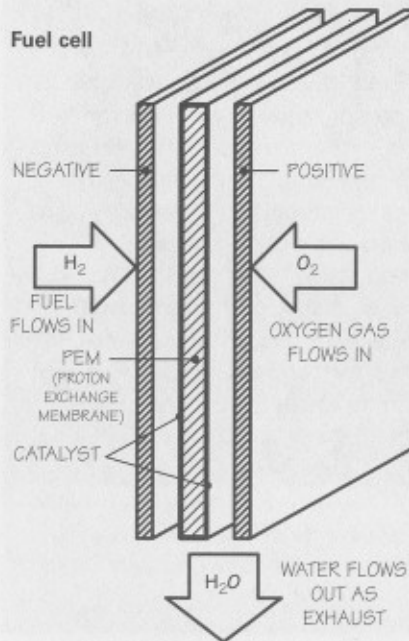
Two factors make cogeneration an important part of our energy future. First, industries face growing pressures to reduce their impact on the natural environment. Second, the rising cost of traditional fuels means energy must be used and reused as efficiently as possible, which cuts costs at the same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

## Fuel Cells

A hydrogen fuel cell uses a chemical reaction to make electricity, with water as the main by-product. Fuel cells operate at high efficiencies, converting as much as 80 percent of the energy in the fuel into useful electricity while producing little pollution.

First developed for use in spacecraft and research, future improvements will make fuel cells realistic for automobiles and even power plants. The weight and size of fuel-cell systems must be reduced to make them practical in passenger cars. Systems for producing and distributing hydrogen fuel cheaply and safely also must be developed. The cost of large-scale electrical production must be lowered to make fuel-cell power plants competitive with present sources of electricity.

Fuel cell



## Geothermal

The radioactive decay of elements inside Earth produces heat. This heat comes from the inside to heat Earth's crust and the water trapped there. This *geothermal* energy can be used directly to heat homes and businesses. In some places, this heat is enough to produce steam to generate electricity.

Geothermal energy can be tapped indirectly with a *geothermal heat pump*, a system that moves heat from the ground into a home or business in winter. In the summer, the system's operation is reversed to draw the heat inside a building out into the ground.

## Nuclear Fission

A nuclear power plant consists basically of fuel (uranium), control rods that regulate fission in the fuel, a *moderator* such as water or graphite that slows down neutrons so the uranium can absorb them, and a cooling system that carries off the heat energy produced. The heat is used to make steam, and the steam to generate electricity.

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. For several years the federal government has been developing a disposal site at Yucca Mountain in Nevada.

A new program of the U.S. Department of Energy, called *Nuclear Power 2010*, seeks to find locations for new nuclear power plants and to conduct research into new, safer, and more efficient plant designs.

Geothermal electrical generation accounted for about 17 percent of electricity from renewable sources in 2003.

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## Nuclear Fusion

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

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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.

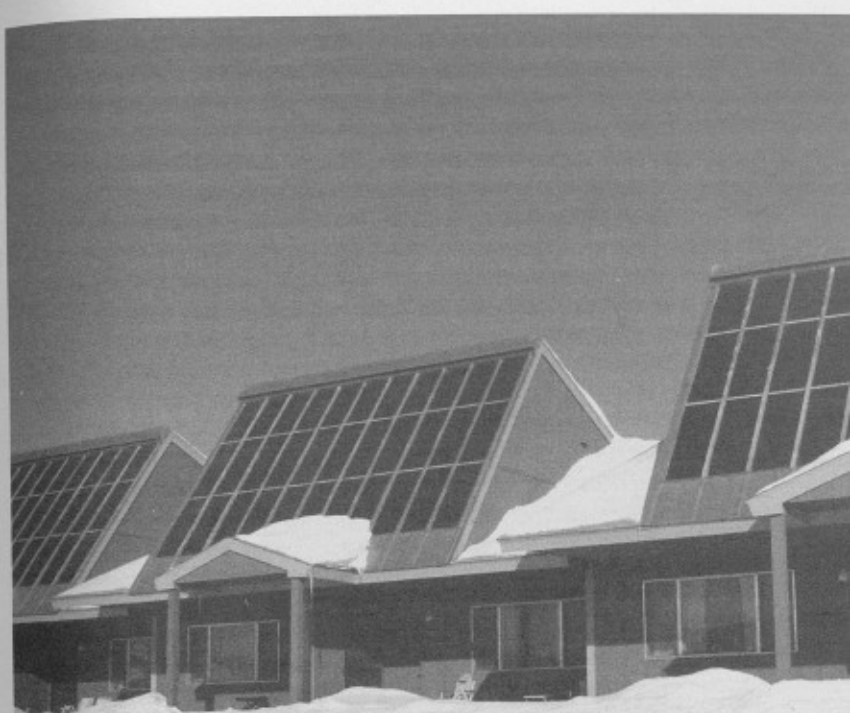
Even after we learn to control the process, it will take years to develop power plants to deliver substantial amounts of energy to people. Engineers will need to design systems to transfer the heat to fluids that could power turbines and generators. Separate plants will be needed to produce *deuterium* (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.

## Solar Energy

Solar energy can be used directly for heating, or sunlight can be converted into electricity. Solar panels that heat water are common throughout the United States. Many homes and other buildings use passive solar-energy systems for heating. These buildings generally have large windows facing south. During the day, sunlight passes through the windows and heats walls and floors made of stone or brick. During the cooler nighttime hours, the walls and floors release the heat to warm the building.

*Photovoltaics* is the technology for converting solar energy directly into electricity. Photovoltaic (solar) cells are not complicated and do not fail often. However, compared to other forms of generating electricity, solar cells are expensive. The cost of solar electricity is about 20 to 30 cents per kilowatt-hour. This cost must be reduced to about 5 or 6 cents per kilowatt-hour for solar cells to be competitive.



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.

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).

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## Ocean Energy

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.

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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 percent 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 Turbines

Modern high-tech wind turbines capture the energy of wind to produce electricity or pump water. The most efficient placement for a wind turbine usually is about 100 feet high, where winds are stronger and steadier than at ground level. *Wind farms* are areas where strong and consistent winds make it desirable to install several wind turbines together. Utility companies run most wind farms. Single turbines can be used in remote locations and by individual homeowners.

In the past 20 years, the price of wind-generated electricity has dropped by about 80 percent. In the American West, the Great Plains, and New England, good wind sites provide excellent potential for future wind-power development.



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.

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

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# 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.

## 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.

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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.

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

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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.

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

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# 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!"