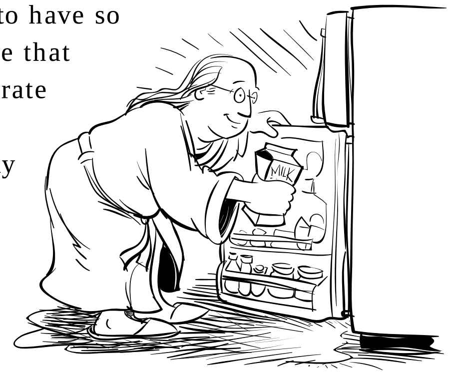
ENERGY SOURCES FOR ELECTRICITY GENERATION
How we use different energy sources to produce electricity

TERMS IN GLOSSARY

alternative energy
biomass
capacity
deplete
fossil fuels
geothermal energy
green energy
hydrogen gas
hydropower
nonrenewable energy
nuclear fuels
ocean energy
regenerate
renewable energy
solar energy
sustainable
wind energy

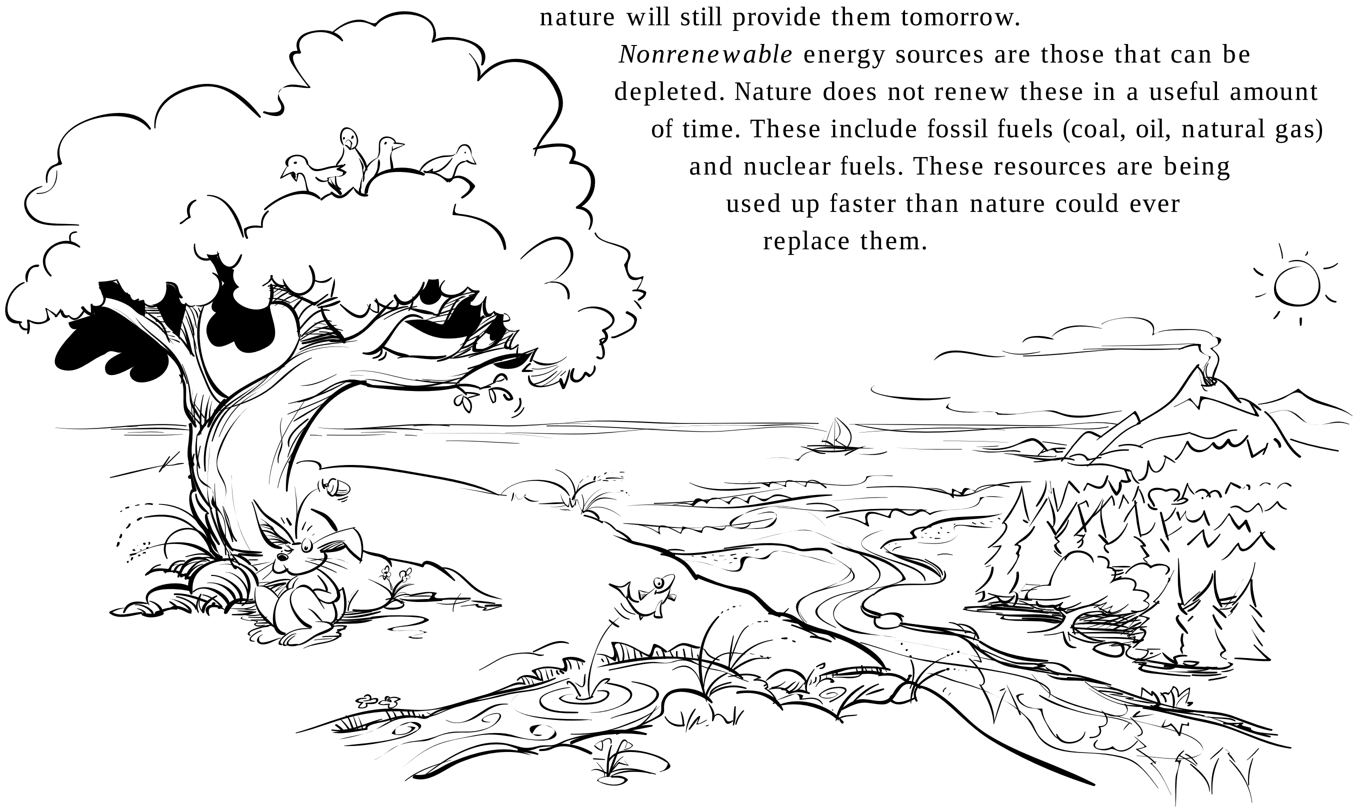
IT'S EASY TO TAKE our seemingly plentiful supply of electricity for granted, especially in the United States. We can flick on our lights or get a cold drink from our refrigerators just about anytime we want. Since we seem to have so much electricity, we might conclude that the energy sources we use to generate this electricity are also found in abundant quantities; but this is only partially true. Renewable energy sources will always be available, but others, the nonrenewables, are being used up.



RENEWABLE AND NONRENEWABLE ENERGY SOURCES

Renewable energy sources are those that are naturally regenerated, or renewed, within a useful amount of time: wood and other substances produced by living things (biomass), natural heat from the earth's interior (geothermal), moving or falling water (hydropower), the wind, the sun, and the ocean. We can use these resources today, and nature will still provide them tomorrow.

Nonrenewable energy sources are those that can be depleted. Nature does not renew these in a useful amount of time. These include fossil fuels (coal, oil, natural gas) and nuclear fuels. These resources are being used up faster than nature could ever replace them.



Renewable energy sources

Energy Resources for Electricity Generation

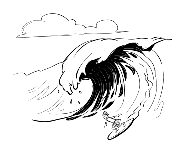
Renewable Energy Resources

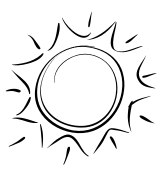
Biomass: Plant material (including wood) or organic waste

Geothermal: The natural heat in the earth

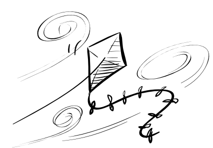
Hydropower: The force of moving water from rivers or storage reservoirs

Ocean: The mechanical energy of ocean tides, currents, and waves, and the sun's heat energy stored in the ocean





Solar: The radiant energy from the sun



Wind: The force of moving air

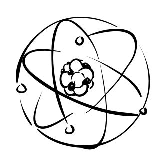
The Renewable and Nonrenewable Resource

Hydrogen: Hydrogen gas produced from other natural resources

Nonrenewable Energy Resources

Fossil Fuels: Coal, oil (petroleum), and natural gas

Nuclear Fuels: Elements with unstable nuclei, such as uranium



RENEWABLE? CLEAN? GREEN?

We sometimes read or hear the terms "clean energy," "green energy," "sustainable energy," and "alternative energy," along with the term "renewable energy." Some people use these terms interchangeably, which can be confusing.

Clean or *green* energy usually refers to energy that is environmentally friendly. When we generate electricity with these resources, very few pollutants, if any, enter our air or water.

Sustainable energy usually refers to a process, system, or technology that does not deplete resources or cause environmental damage. Sustainable energy practices preserve meaningful natural resource choices for future generations.

When people use the term *alternative* energy, they are usually speaking of alternatives to the conventional energy sources: fossil fuels, "large" hydropower, and nuclear. Alternative energy can definitely include renewables. Most often, though, the term alternative is applied to certain transportation fuels — any fuels other than gasoline and diesel — such as ethanol, biodiesel, and hydrogen.

ENERGY AWARENESS, ENERGY CHOICES

Electricity has contributed greatly to our comfort and to our society's development, but we are using up valuable and irreplaceable energy resources. Since the beginning of the Industrial Revolution our use of energy sources, particularly fossil fuels, has increased with each passing year. In the last 30 years alone, their use has tripled.

We are indeed fortunate to have other energy options. In the pages that follow you will find a comprehensive explanation of the energy resources and technologies we use to make electricity.

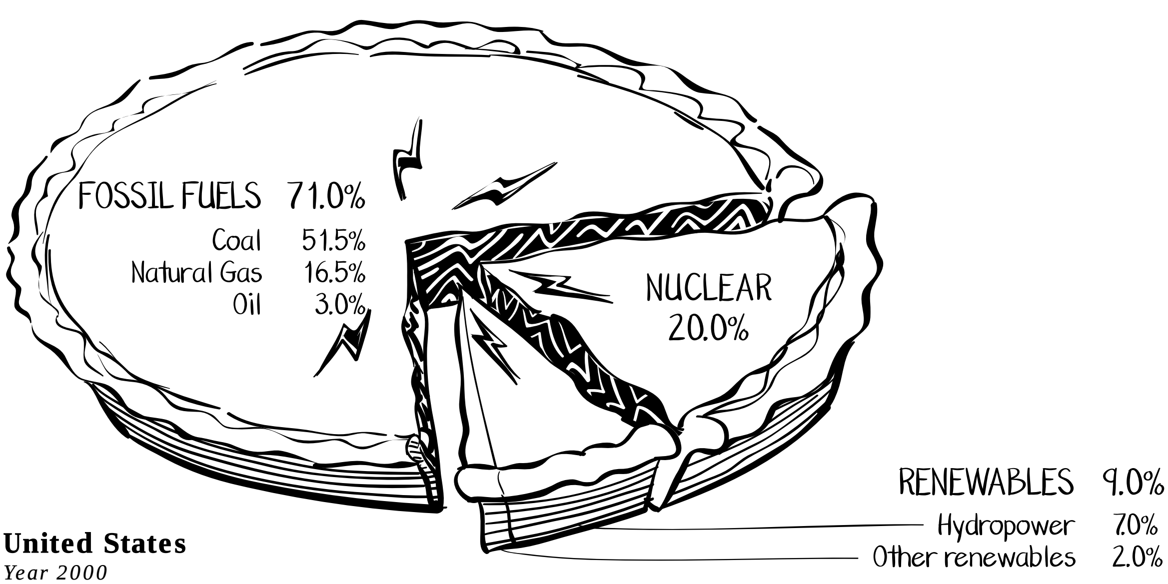
SIZING IT UP

In this chapter, power plant sizes (in kilowatts and megawatts) are given for each energy resource. A power plant's size is the amount of electricity that its turbine(s) can produce at any one time. This is known as a plant's "capacity." But power plants do not always operate at full capacity. The amount of electricity actually produced over time depends on many factors. Some of these factors are addressed in the "Considerations" at the end of each resource section.

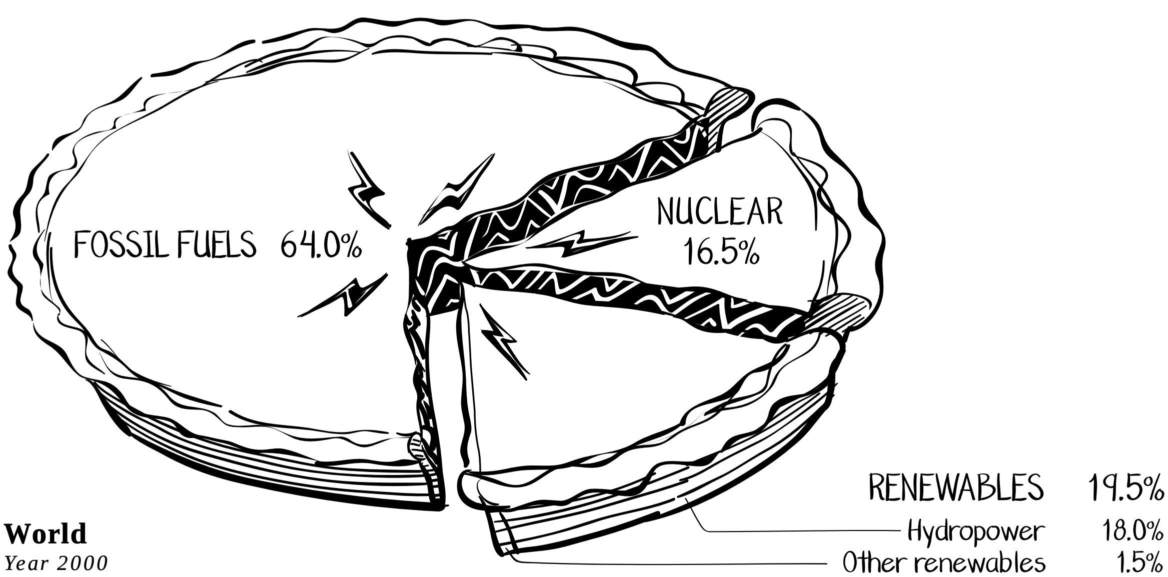
The percentages in the pie charts on the next page are from actual electricity produced.

RESOURCES BEING USED TO GENERATE ELECTRICITY

These pie charts show the percentages of electricity produced from different energy resources in the United States* and around the world.



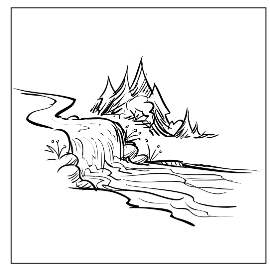
United States
Year 2000

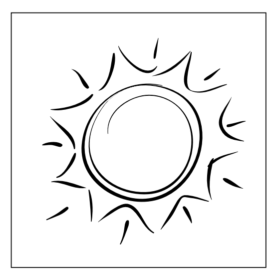


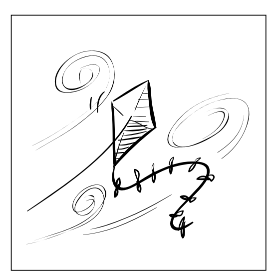
World
Year 2000

**Watch www.energyforkeeps.org for more information about energy resource use.*

Renewable Energy Sources



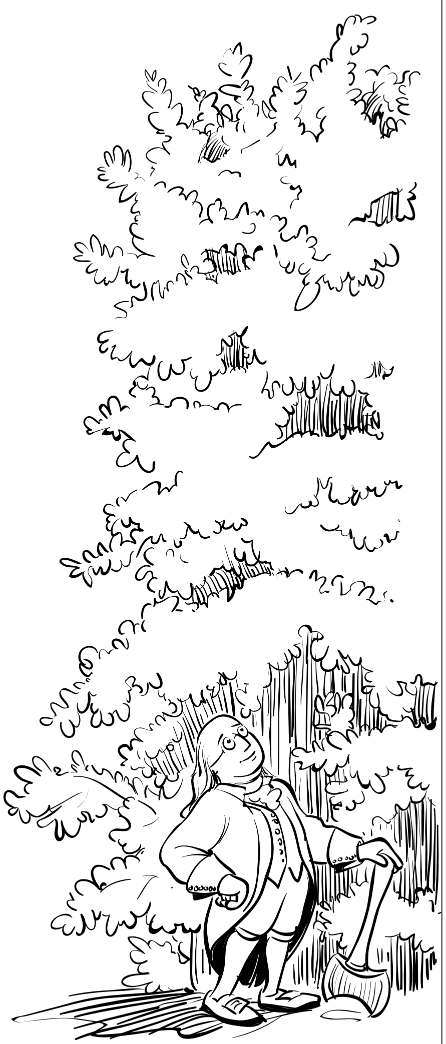




Renewable Energy Source: BIOMASS

TERMS IN GLOSSARY

byproduct
carbon cycle
decompose
energy farm
gasification
green waste
methane gas
microbe
soil erosion



Fast-growing trees are ready to be harvested for use in a biomass power plant.

BIOMASS WAS ONE OF THE FIRST energy resources ever used by humans. It includes anything that is or was once alive. Ever since the discovery of ways to create fire, humans have been burning wood and other organic material to create heat and light.

In the United States, biomass, mostly from trees, was the premier energy source until the 1830s. It was displaced by fossil fuels (mainly coal) when the Industrial Revolution took hold. Recently, however, the use of biomass, in a widening range of forms, has begun to increase. Today it is an important energy source for many processes, including the generation of electricity.*

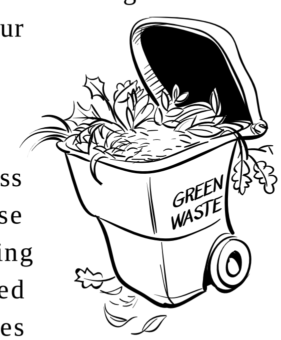
THE BIOMASS RESOURCE

Most living things receive and store energy from the sun. This energy is released when the organic material is digested, burned, or decomposed. This released energy can be used to produce electricity. Today, many kinds of biomass are used as energy resources.

Solid Biomass

Solid biomass is anything organic that has not yet broken down into a gas or a liquid. There are many kinds of solid biomass. Chipped wood, whole trees, energy crops, and agricultural wastes are examples. Other solid biomass sources are trimmings from forests and orchards; wastes from building construction, food processing, and paper industries; animal manure; and plain old garbage.

At home and at work people produce tons of waste each year, much of which is organic. Many of us produce a lot of this “green” waste just from cutting our lawns and trimming our trees and bushes.

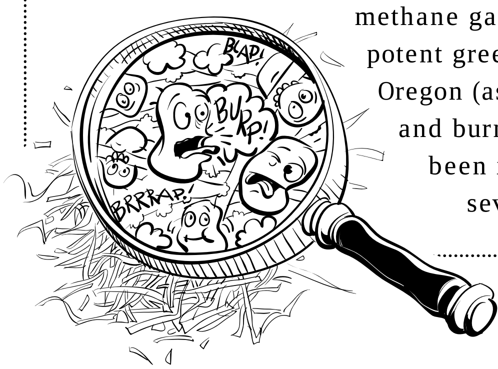


Until recently, all garbage (including organic waste) was dumped into landfills or burned without any pollution controls. Today, many biomass power plants (complete with pollution controls) use solid biomass to produce electricity. Instead of going to landfills much of our green waste is now trucked directly to biomass plants. A plant in Michigan uses 300,000 tons per year of wood waste from local timber industries (and puts wastewater to use in its cooling towers). A plant in Wisconsin uses 250,000 tons of wood wastes, shredded railroad ties, and even scrap tires.

**Biomass can also be used a fuel for space heating and factory processing, and to produce liquid transportation fuel such as ethanol.*

POWER SKETCH: Munching Microbes

Picture a landfill teeming with rotting, long-buried waste. Microbes gobble this decaying quagmire of leftover stuff that originally came from living things. As the microbes munch, they burp methane gas. Methane gas is normally released into the atmosphere and is a potent greenhouse gas (see Glossary). However, at a landfill near Eugene, Oregon (as at many others around the United States), the gas is collected and burned for heat to generate electricity. This biomass power plant has been in operation since 1992 and continues to send electrical power to several thousand homes.



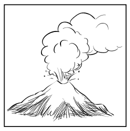
Biofuels and Biogas

We can produce both liquid and gas fuels from solid biomass. This is not a new idea. The production of biomass gas, called gasification, is based on a method developed in the early 1800s to produce gas from coal for town streetlights in both England and the United States. And since the 1940s, in over a million homes in India, people have cooked with biomass gas made in their own small gasifiers.

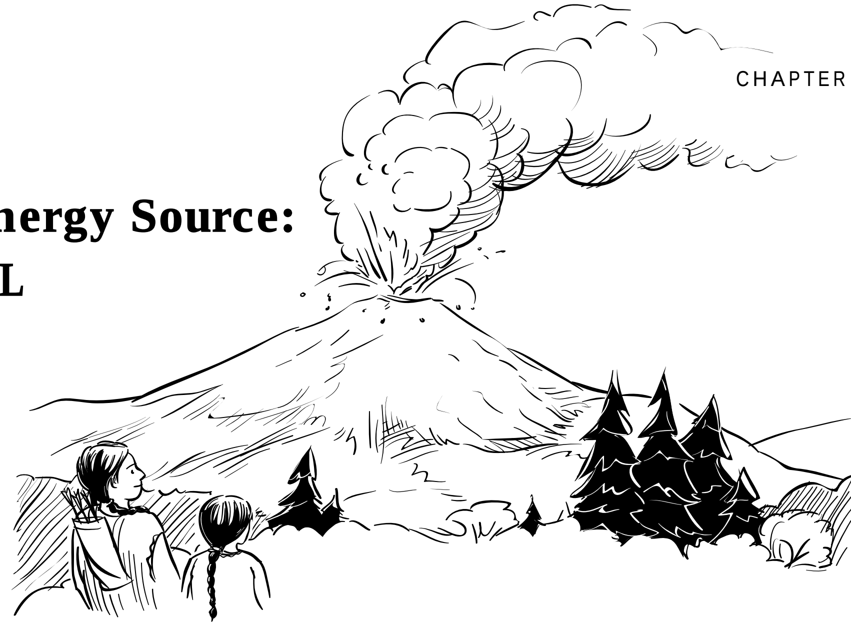
Today, gasifiers use high-tech processes to produce a gas from solid biomass by heating it under very controlled conditions. This gas can then be converted to a liquid. Gasification facilities can be large or small, serving power plants that range from just a few kilowatts to 50 MW or more.

WASTE TO ENERGY

A biomass power plant in Shasta County, California, processes about 90 tons of solid waste from timber mills, forests, and orchards every hour, producing enough electricity to power 50,000 homes. Each day at a biomass power plant in Vermont, about 200 tons of waste wood from local forests are converted to gas, which is burned to produce "homegrown" electricity.



Renewable Energy Source: GEOTHERMAL



TERMS IN GLOSSARY

binary power plant
conduction
crust
dry steam power plant
fissure
flash power plant
fumarole
geothermal reservoir
groundwater
heat exchanger
hot dry rock
hydrogen sulfide
magma
mantle
modular
mud pot
porous
subducting
tectonic plates
wastewater

PEOPLE HAVE ALWAYS BEEN FASCINATED with volcanoes and their fiery displays of nature's power. Many ancient societies once thought volcanoes were home to temperamental gods or goddesses. Today we know that volcanoes result from the immense heat energy — geothermal energy — found in Earth's interior. This heat also causes hot springs, steam vents (fumaroles), and geysers.

Over the ages, humans have benefited from Earth's geothermal energy by using the hot water that naturally rises up to the earth's surface. We have soaked in hot springs for healing and relaxation and have even used them as instant cooking pots. Hot springs have also been an important part of cultural life, especially in Japan and Europe.

Today we drill wells deep underground to bring hot water and steam to the surface. We use the geothermal water to heat buildings, to speed the growth of plants and fish, and to dry lumber, fruits and vegetables. (See Direct Use Geothermal, page 119.) We use the really hot water and steam to generate electricity.

POWER SKETCH: Fine Neighbor

Set amidst the open vistas and forests of the eastern Sierra Nevada of California, a power plant churns out enough electricity for about 40,000 homes. The natural setting is not marred by smoky emissions, because there are none. This geothermal power plant uses hot water resources from an underground geothermal reservoir to power its turbine generators. Many tourists and residents of nearby Mammoth Lakes don't even realize the power plant is there beside the main highway. Those who do, say it is a fine neighbor indeed.

Mammoth Lakes geothermal power plant

THE GEOTHERMAL RESOURCE

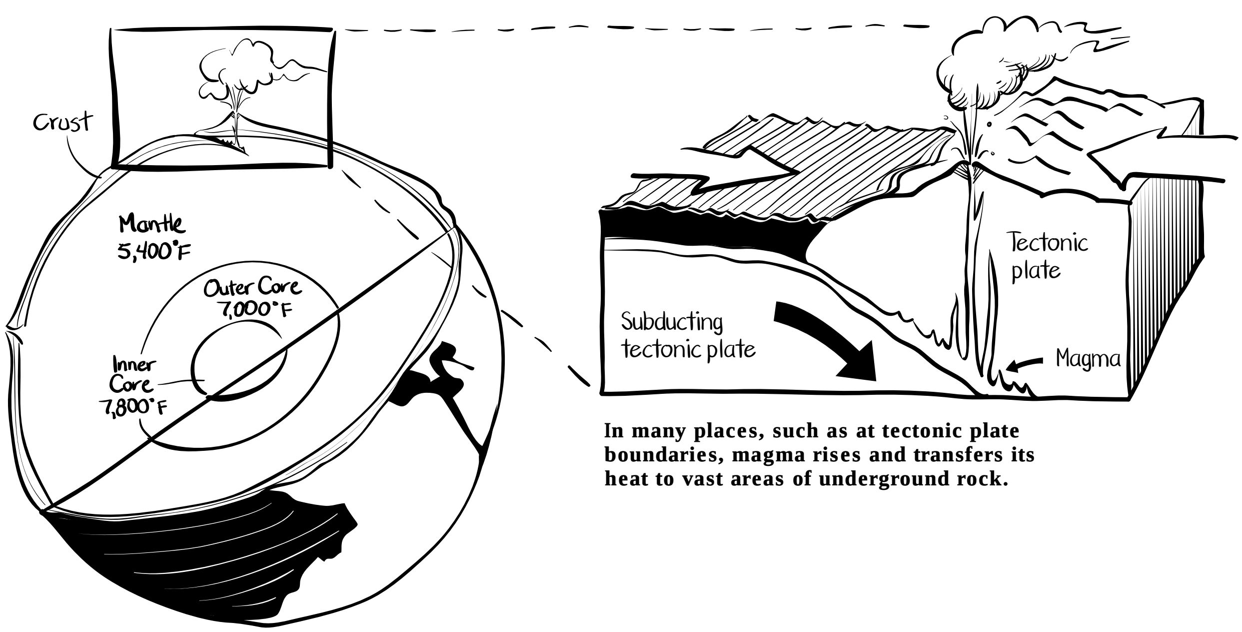
Geo means earth and *thermal* means heat. So geothermal energy is the heat energy of the earth.

The Inner Earth: Hot, Hot, Hot!

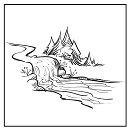
Billions of years ago Earth was a fiery ball of liquid and gas. As the planet cooled, an outer rocky crust formed over the hot interior. This relatively thin crust “floats” on top of a massive layer of very hot rock called the mantle. Some of the mantle rock is actually melted, or molten, forming magma.

Heat from the mantle and the magma continuously transfers up into the crust. (Heat is also being generated in the crust itself by the natural decay, or breakdown, of radioactive elements found in all rock.)

The crust is broken into enormous slabs — tectonic plates — that are actually moving very slowly (about the rate your fingernails grow) over the mantle, separating from, crushing into, or sliding (subducting) under one another. The edges of these huge plates are often restless with volcanic and earthquake activity (see page 36, Hot Locations). At these plate boundaries, and in other places where the crust is thinned or fractured, magma is closer to the surface than it is elsewhere. Sometimes the magma emerges above ground — where we know it as lava. But most of it stays below ground where, over time, it creates large regions of hot rock.



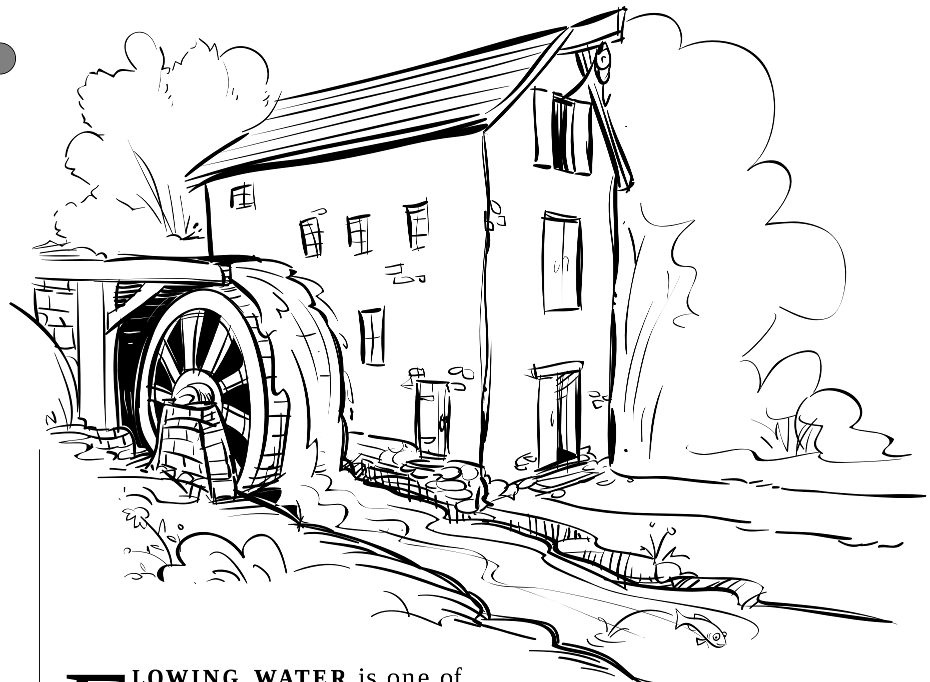
In many places, such as at tectonic plate boundaries, magma rises and transfers its heat to vast areas of underground rock.



Renewable Energy Source: HYDROPOWER

TERMS IN GLOSSARY

flow
head
horsepower
impoundment
penstock
pumped storage
run-of-river (diversion)
tailrace
water cycle



FLOWING WATER is one of nature's most powerful forces. Humans began harnessing this energy force several thousand years ago. By the first century B.C., waterwheels were working in many parts of the world, including Greece. (In fact, the term hydro comes from an ancient Greek word for water.) For centuries waterwheels in many countries provided the energy to grind grain and saw lumber. By the 1700s, more than 10,000 waterwheels were hard at work in colonial New England alone.

During the Industrial Revolution, waterwheels were also used to run textile mills and other factories. By the late 1800s water turbines were driving a new device – the generator – to produce electricity. Before the end of that century the world's first commercial water-driven electrical station opened at Niagara Falls, New York, and the era of hydroelectric power was born.

THE HYDROPOWER RESOURCE

The hydropower resource is the force of flowing water, provided to us naturally by the earth's water cycle and by gravity. The force of the flow of a medium-size river is equal to several million horsepower. (One million horsepower, if converted to electricity, would equal the power of 746 MW.) You can imagine how easily this much force can be put to work driving waterwheels or water turbines.

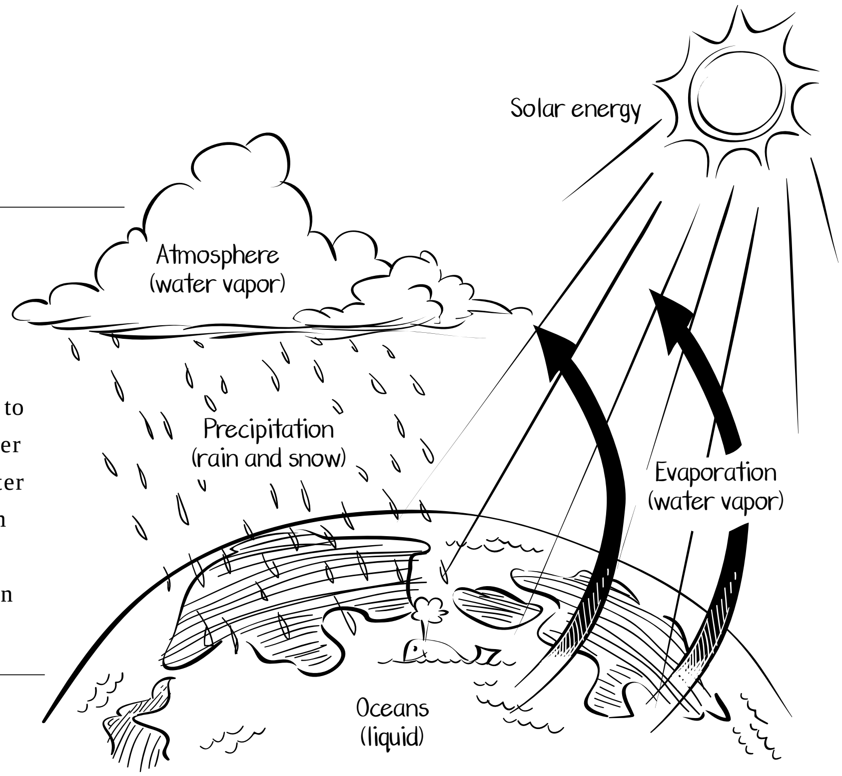
REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt can serve about 1,000 homes in the United States.

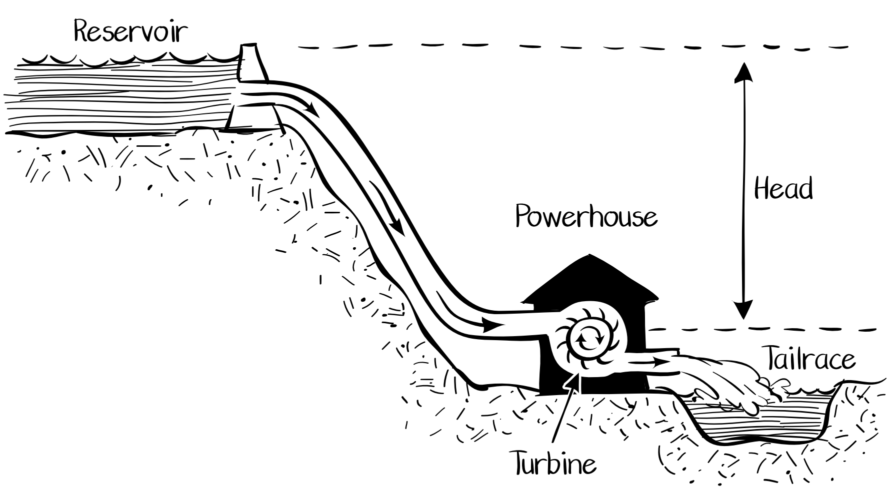
THE WATER CYCLE

Energy from the sun (solar energy) causes evaporation of water from the land and from the oceans, rivers, and lakes. This puts water vapor into the atmosphere where it can condense to form clouds, which then return the water to the earth as rain, snow, and ice. Water runoff is pulled down by gravity to form streams and rivers, which flow to lakes and to the sea. This cycle of evaporation and precipitation is continuous.

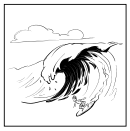


The Steeper the Better

The amount of force that water can impart depends on two factors: the head, the vertical distance the water falls; and the flow, the volume (amount or mass) of the water. The greater the head and the flow, the more water energy is available. So hydropower systems work best with a steep drop (high head) and a large flow. One gallon (3.8 liters) of water falling 100 feet (30 meters) per second can generate about 1 kW of electric power. No wonder waterfall areas, with their naturally steep drops, were chosen as the sites for the world's first hydroelectric power plants.



The steeper the drop, the greater the force of falling water



Renewable Energy Source: OCEAN

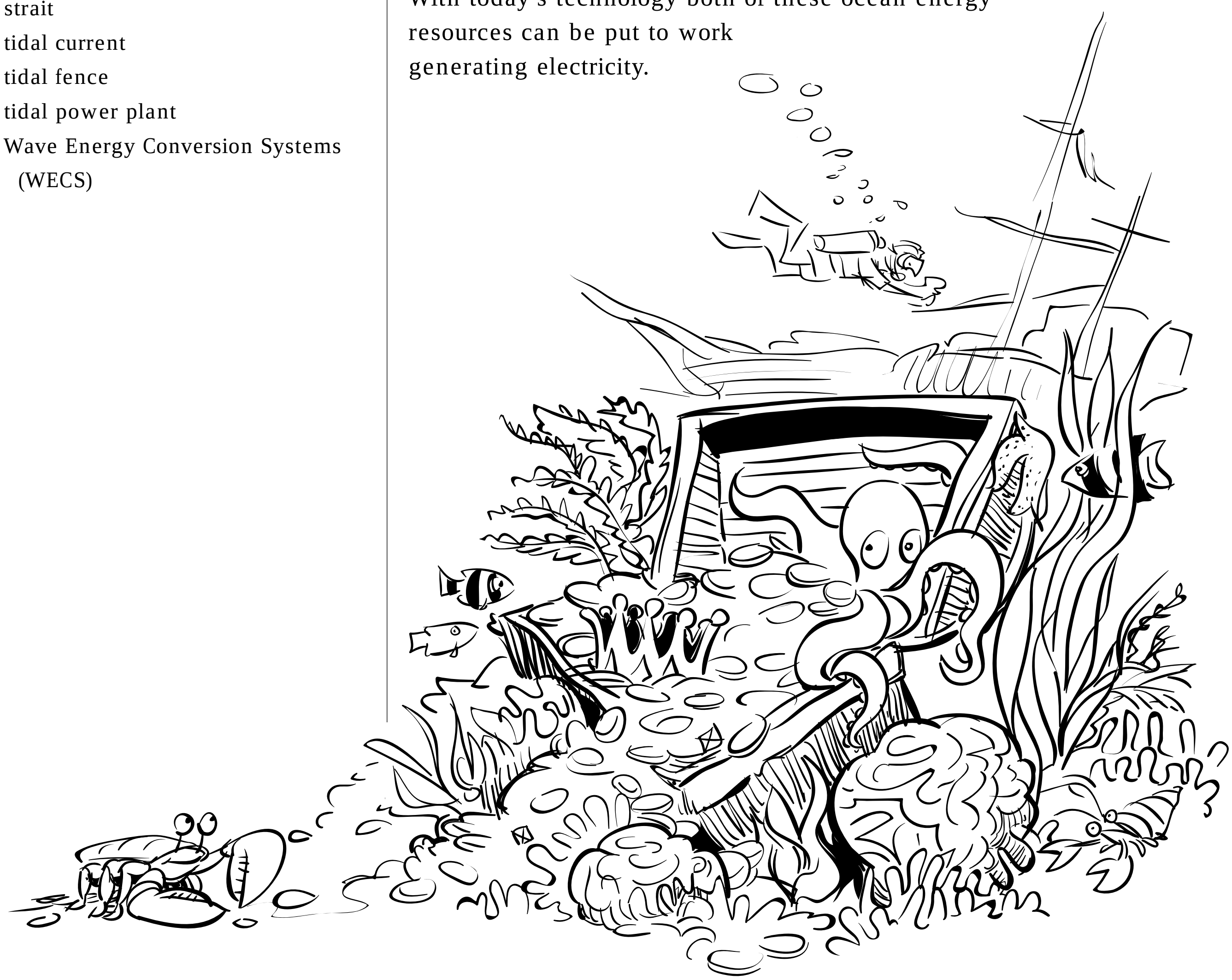
TERMS IN GLOSSARY

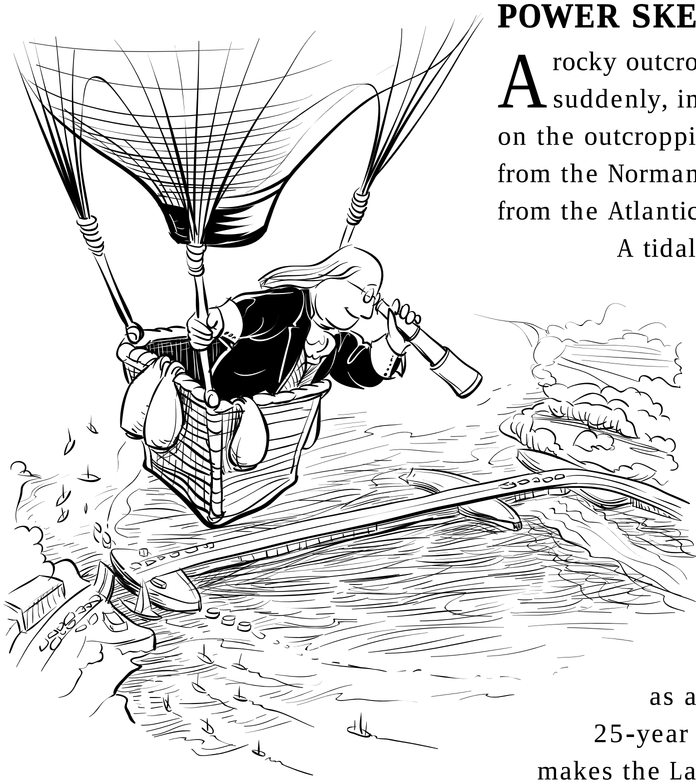
aquafarming
barrage
current
ebb
estuary
high and low tide
marine current
Ocean Thermal Energy Conversion (OTEC)
one-way marine current
sluice
strait
tidal current
tidal fence
tidal power plant
Wave Energy Conversion Systems (WECS)

SINCE EARLIEST TIMES, the ocean has been a vast resource for travel, food, pearls, minerals, oil, and much more. Some say that the ocean is the last remaining frontier on earth. Much of the deep seafloor, with its many marvels, remains to be explored. And there's the lure of undiscovered shipwrecks and the riches they might contain. However, there is yet another ocean frontier that some think is much more valuable than buried treasure. This is the ocean's energy frontier, one that we are just beginning to understand and put to work.

THE OCEAN RESOURCE

Oceans have tremendous energy in the movement of their currents and waves. And the oceans store a vast amount of heat from the sun. With today's technology both of these ocean energy resources can be put to work generating electricity.





POWER SKETCH: Vive La Rance

A rocky outcropping of France's Atlantic coast is transformed, suddenly, into an island. Twice a day the single structure on the outcropping, the abbey of Mont-Saint-Michel, is cut off from the Normandy mainland by the tide, which sweeps in from the Atlantic to the La Rance estuary.

A tidal power plant here captures energy from the dramatic rise and fall of the sea. Built in 1966, the plant at La Rance supplies about 240 MW of electricity to French homes and workplaces. The facility uses a dam stretched across the opening of the estuary. Inside the dam's powerhouse are 24 hydroelectric turbines, specially engineered to capture the force of both incoming and outgoing tides.

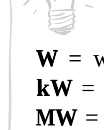
The crest of this dam doubles as a roadway, and the reservoir behind it serves as a recreation area. This, combined with a 25-year history of reliable electricity generation, makes the La Rance power plant an energy-wise winner.

Marine Currents

There are two kinds of marine currents: two-way (tidal) currents, and one-way currents.

Two-way currents are the ocean tides, caused by gravitational pull of the moon and sun. Each heavenly body pulls on the part of the ocean nearest to it, causing bulges in water height. As the earth rotates, those bulges move in relation to the world's coastlines, pulling water onto and away from the shore. So the turning of the earth causes a moving pattern in the ocean: at every coast in turn, the level rises and falls, resulting in two high tides and two low tides daily.

One-way currents are like massive "rivers" of ocean water flowing within the ocean for hundreds — sometimes thousands — of miles.



REMINDER

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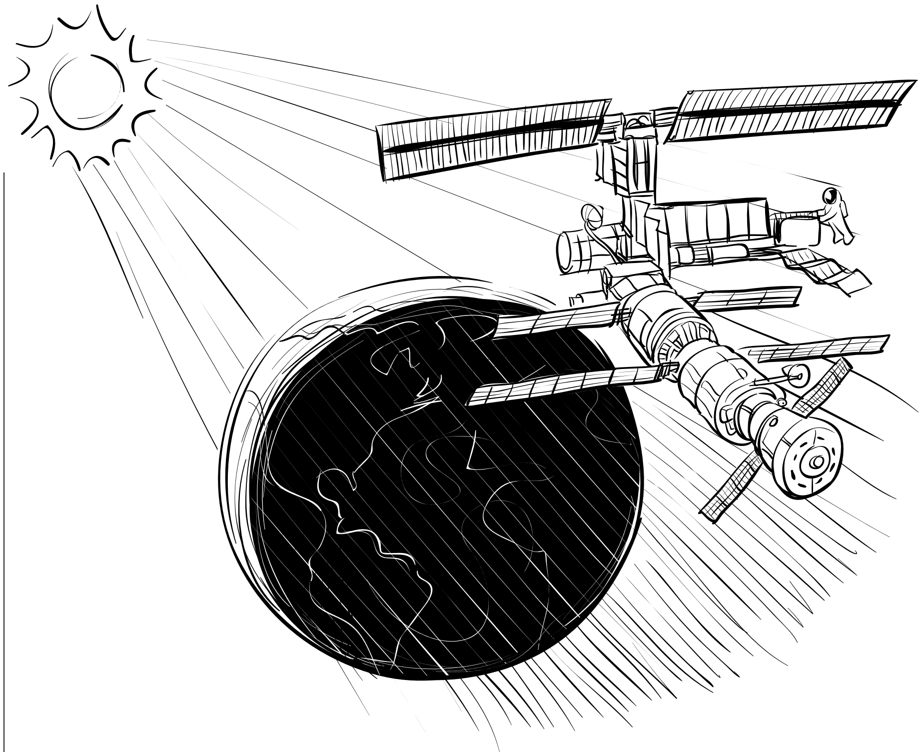
Renewable Energy Source: SOLAR



TERMS IN GLOSSARY

array
central receiving tower
Concentrating Solar Power (CSP)
electromagnetic spectrum
heliostat
infrared
module
parabolic trough
photon
photoelectric effect
photovoltaic
radiant energy
silicon
solar cell
solar dish engine
solar panel
spectrum
ultraviolet

WITH SOLAR ENERGY, THE SKY'S THE LIMIT. Our sun is the world's most widely used energy resource. Plants began capturing the sun's energy millions of years ago, and members of the animal kingdom have always basked in its warmth. Human dwellings have long included openings that let in the sun's light and heat. Glass windows were used as early as 79 A.D., as revealed in the archeological ruins of Pompeii and Herculaneum (Roman cities completely preserved under layers of ash from a volcanic eruption). Now, our use of windows to admit the sun's radiation is such a common practice that we don't even think about it. And today, with technology ranging from tiny solar cells to huge power plants shimmering with rows of curved mirrors, we use solar energy to make electricity.

THE SOLAR RESOURCE

We all know that our sun gives off radiating waves of heat and light energy. Without these, our planet would not have life. The sun's waves move rapidly as tiny bundles of energy called photons. These photons travel vast distances from the sun through the vacuum of space and bathe our planet with solar energy every day.

Shedding Light on the Solar Spectrum

All the sun's radiant energy waves form the electromagnetic, or solar, spectrum. Forty-five percent of the radiation of the solar spectrum that reaches the earth's surface is visible light. Almost all the rest we do not see (although we can detect and measure it), yet it all delivers energy. For example, ultraviolet radiation, though we can't see it, can tan or burn our skin. And we're all familiar with the sun's infrared, or thermal (heat), radiation. Infrared radiation is what keeps the earth (and us) warm.

Some parts of the earth receive more solar radiation than others. In general, the areas at or near the equator receive the most. For example, the tropics get about two and a half times more infrared radiation than the poles. However, any area that receives a steady supply of solar radiation, whether a little or a lot, can make use of the energy pouring in from our sun.

We use just a fraction of our enormous solar resource.* More energy from sunlight strikes Earth in one hour than all the energy consumed on the planet in a year.

GENERATING ELECTRICITY FROM SOLAR RESOURCES

In this section we discuss solar energy only as a source of electricity. In Chapter 5 we discuss direct (non-electric) uses of solar energy — active direct uses such as heating water, and passive direct uses such as designing sun-friendly homes.

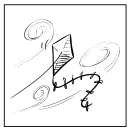
Photovoltaics (PV)

In the 1950s, American engineers sought a method to power U.S. space satellites. They found it in a process called photovoltaics (PV). We still use photovoltaics to energize orbiting satellites, space stations, and the Hubble telescope. Back on the earth, PV is widely used for everything from roadside call boxes to large power plants.

UP ON THE ROOFTOP

Today there is a slimmer version of PV technology, something called thin film PV. Thin film PV can be used to replace some of the regular shingles on a building's rooftop. Operating in the same way that flat plate PV does, thin film shingles are as durable and protective as regular asphalt shingles. These solar shingles are textured to fit right in with the architectural design of buildings.

** Statistics buffs, take note: The total amount of solar radiation received by the earth is 1.73 x 10^{17} watts at any one time. This is enough to warm our entire globe, fuel all of the earth's photosynthesizing plants, and create global climatic systems that drive the winds, the waves, and the water cycle.*



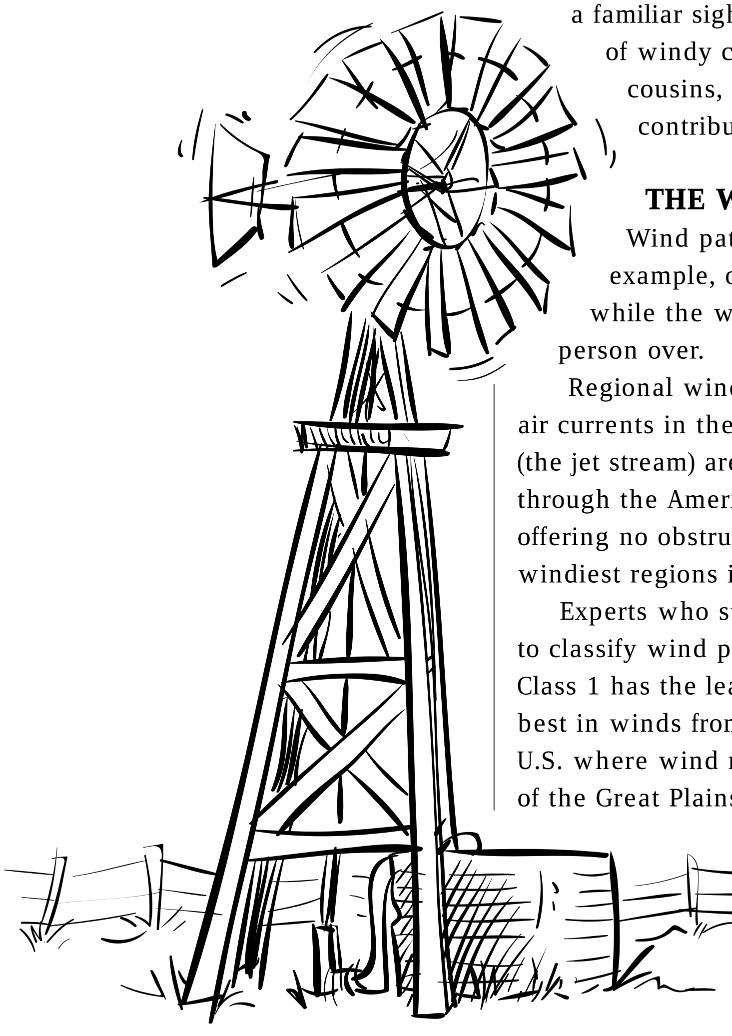
Renewable Energy Source: WIND

TERMS IN GLOSSARY

- air current
- anemometer
- controller
- fixed-speed wind turbine
- jet stream
- multi-megawatt turbine
- nacelle
- rotor
- stand-alone wind turbine
- terrain
- variable-speed wind turbine
- wind farm

THE POWER OF WIND has been helping humans do work for centuries. As early as 5000 B.C. boats propelled by wind sailed along the Nile River. Windmills may have been used in China by 200 B.C., and by 900 A.D. large windmills were grinding grain on the plains of Persia. The windmill spread to England as early as 1100 A.D. and was a common sight throughout medieval Europe. In the 1800s the American West was settled with the help of thousands of water-pumping windmills.

The first wind turbines for generating electricity were designed in Europe around 1910. These soon appeared in the United States, bringing electricity to rural homes and farms. Beginning in the late 1930s, the widespread installation of power lines made these small wind turbines obsolete. However, this was not the wind turbine's last appearance "down on the farm." Today, the wind turbine is once again a familiar sight — on open plains, along mountain passes, even off of windy coastlines. Far advanced from their creaky windmill cousins, today's wind turbines are sleek and powerful contributors to today's electricity scene.



THE WIND RESOURCE

Wind patterns vary greatly from one place to the next. For example, one area in the middle of Ohio is consistently calm, while the winds off nearby Lake Erie can almost knock a person over.

Regional wind patterns are greatly affected by terrain and by air currents in the upper atmosphere. For example, upper-level winds (the jet stream) are a primary factor in the weather systems that bluster through the American Great Plains. The flat terrain in this area, offering no obstruction to the wind, also helps make this one of the windiest regions in the United States.

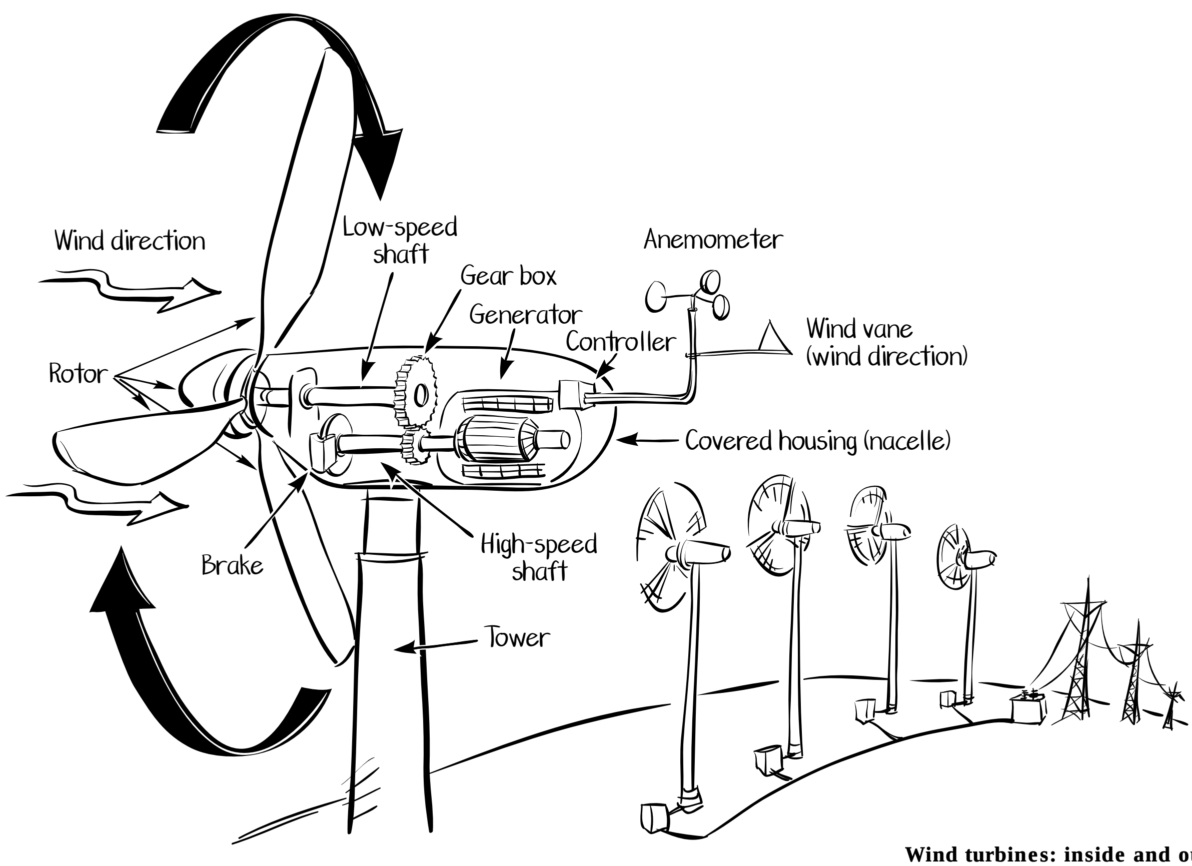
Experts who study wind patterns have developed a scale of 1 to 7 to classify wind power (wind speed, wind height, and other factors). Class 1 has the least power; Class 7, the highest. Wind turbines operate best in winds from Classes 3 through 7. There are many places in the U.S. where wind resources are Class 3 or above, including large parts of the Great Plains, the windy passes of the large mountain ranges, sections of both coasts, and portions of Alaska and Hawaii. Some wind experts believe that U.S. wind resources, if developed, could match total current U.S. electricity generation.

GENERATING ELECTRICITY FROM WIND RESOURCES

The basic machinery that converts wind power to electricity is called a wind turbine. The force of the wind spins blades attached to a hub that turns as the blades turn. Together, the blades and hub are called the rotor. The turning rotor spins a generator, producing electricity.

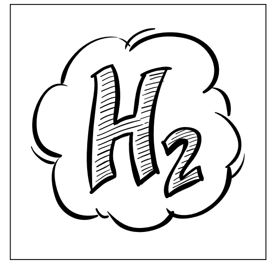
There is also a controller that starts and stops the rotation of the turbine blades. The generator, controller, and other equipment are found inside a covered housing (nacelle) directly behind the turbine blades. Outside, an anemometer measures wind speed and feeds this information to the controller.

Wind turbines begin to turn with wind speeds of between 10 and 15 miles per hour (15 and 23 kilometers per hour). They automatically shut off at 55-60 mph (100 km/h), since anything above this speed is too hard on the machinery. Some wind turbine models run at a fixed speed no matter how fast the wind is blowing. Newer models are "variable speed." Their turning speed changes as wind speeds change, making them more efficient and allowing them to withstand gusty gales.



Wind turbines: inside and out

The Renewable and Nonrenewable Resource



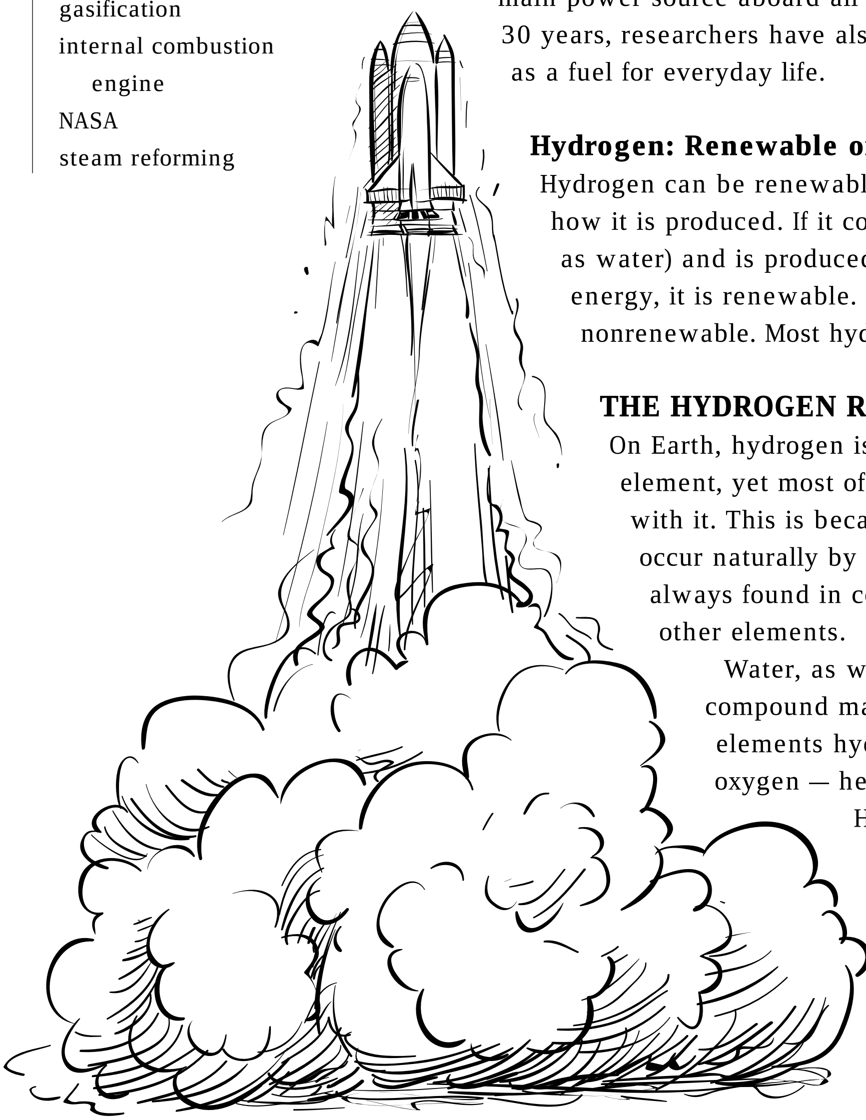
The Renewable and Nonrenewable Resource: HYDROGEN

TERMS IN GLOSSARY

anaerobic digestion
anode
cathode
compound
electrochemical
electrode
electrolysis
electrolyte
element
gasification
internal combustion engine
NASA
steam reforming

HYDROGEN IS ONE OF THE MOST ABUNDANT elements on Earth. Yet it wasn't until the 1700s that scientists first proved its existence, and it was later still that they recognized its value. Finally, by the mid-1800s, people were using hydrogen in "town gas," providing light and heat in cities across the United States and Europe. More recently, it has become useful in the production of ammonia, fertilizers, glass, refined metals, vitamins, cosmetics, cleaners, and much more.

Hydrogen has launched many U.S. rockets into outer space. And hydrogen fuel cells, first used successfully in the 1960s, have been the main power source aboard all of NASA's space shuttles. Over the last 30 years, researchers have also been looking at ways to use hydrogen as a fuel for everyday life.

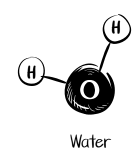


Hydrogen: Renewable or Nonrenewable?

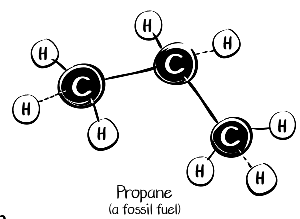
Hydrogen can be renewable or nonrenewable, depending on how it is produced. If it comes from a renewable resource (such as water) and is produced using electricity from renewable energy, it is renewable. Otherwise, the hydrogen is considered nonrenewable. Most hydrogen produced today is nonrenewable.

THE HYDROGEN RESOURCE

On Earth, hydrogen is the third most common element, yet most of us aren't very familiar with it. This is because hydrogen doesn't occur naturally by itself. Instead, it is always found in combination with other elements.



Water, as we know, is a compound made of the elements hydrogen and oxygen — hence the formula H_2O. Hydrogen joins with carbon to make fossil fuels such as natural gas, coal, and petroleum. It is found in the molecules of all living things.



Hydrogen Unbound

In order to use hydrogen we must separate it from the compounds in which it is bound. Once freed, it is a colorless, combustible gas that will release a great deal of energy. Scientists have developed different ways to produce hydrogen. One important method is electrolysis. Other techniques use chemical or biological processes.

Producing *Renewable* Hydrogen

By Electrolysis. Electrolysis was first closely studied in the 1830s by English scientist Michael Faraday. In this process, electricity is passed through water. The electrical charge causes the hydrogen and oxygen in the water molecule to split apart and turn into gases. A chemical called an electrolyte is often added to the water to help conduct electrons through it.

Water used in electrolysis is, of course, a renewable resource, but for the resulting hydrogen to be considered renewable, the electricity for this process must also have come from a renewable source. Any renewable method of generating electricity could be used.

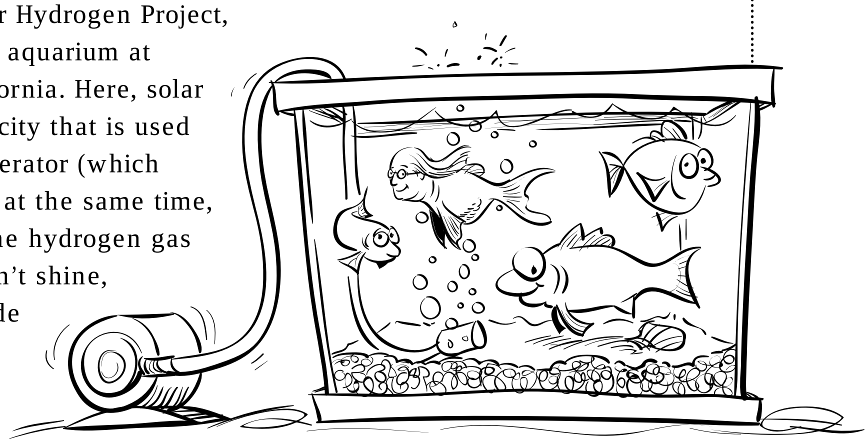
HYDROGEN TO GO

One day some of our cars may operate using hydrogen gas. Already some major car manufacturers have designed engines that burn hydrogen instead of gasoline. The engines of these cars are similar to those in the vehicles we drive today.

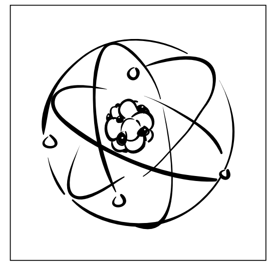
People like the idea of using these engines because burning hydrogen produces few polluting emissions. Researchers are now working on ways to store hydrogen aboard a vehicle, along with ways to make hydrogen "filling stations" widely available. (See also "Fuel Cells," page 80.)

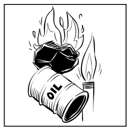
POWER SKETCH: Hydrogen Fuel Cells Keep Aquarium Bubbling

A unique energy system, the Schatz Solar Hydrogen Project, helps keep fish alive in the marine lab aquarium at Humboldt State University in northern California. Here, solar panels mounted on the roof produce electricity that is used for two purposes: to drive the aquarium's aerator (which adds oxygen to the water for the fish) and, at the same time, to produce hydrogen gas by electrolysis. The hydrogen gas is stored and then, whenever the sun doesn't shine, the hydrogen is used in a fuel cell to provide electricity for the aquarium's aerator. This remarkable renewable energy system has been running day and night since 1994.



Nonrenewable Energy Sources





Nonrenewable Energy Source: FOSSIL FUELS

TERMS IN GLOSSARY

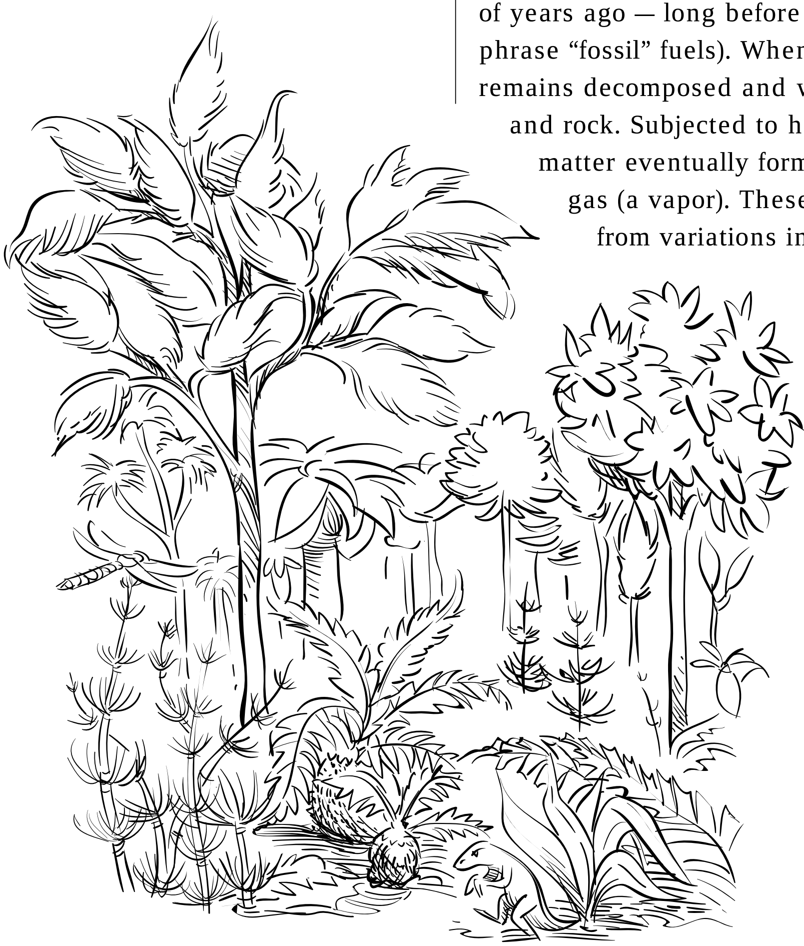
- acid rain
- carbon-based compound
- combined cycle power plant
- crude oil
- gas turbine
- global climate change
- greenhouse gas
- hydrocarbon
- oil rig
- oil refinery
- scrubber
- synthetic

FOSSIL FUELS—COAL, OIL, AND NATURAL GAS—have been highly prized energy sources for centuries. Mining for coal may have first occurred in China as far back as 200 B.C. By 200 A.D. the Romans made wide use of the coal resources they found in the British Isles. In the 1100s, oil wells were being drilled in Europe and along the west coast of the Caspian Sea. It was the Industrial Revolution, however, that launched the widespread use of fossil fuels to power factories and transportation systems. Electricity was first produced using coal in the 1880s. Since that time, fossil fuels have been the dominant source of energy for electrical production, transportation, and industry in the United States and around the world.

THE FOSSIL FUEL RESOURCE

All fossil fuels are formed from plants and animals that lived millions of years ago — long before the days of the dinosaurs (hence, the phrase “fossil” fuels). When these plants and animals died, their remains decomposed and were eventually buried under tons of soil and rock. Subjected to heat and pressure over time, this organic matter eventually formed coal (a solid), oil (a liquid), and natural gas (a vapor). These three different fossil fuel types resulted from variations in the underground conditions.

Fossil fuels are nonrenewable resources. That is because today’s fossil fuel resources formed so very long ago, when much of the land was covered with swamps and the climate was very warm. These conditions were perfect for many living things, including huge ferns, trees, and other plants. The swamps and seas were teeming with algae and other small organisms. These lush conditions are not nearly as widespread today. Small amounts of fossil fuels may still be forming, but not in significant quantities. And, they will not form in a useful amount of time.



Plants and animals of long ago formed the fossil fuels we use today.

Living things are carbon-based, so all fossil fuels are made of molecules that contain carbon. They also contain hydrogen, giving rise to the name “hydrocarbons.” Hydrocarbons burn easily. They are a reliable source of heat energy and are convenient to transport.

When fossil fuels are burned, carbon combines with oxygen, resulting in emissions of carbon dioxide gas. Fossil fuels contain other substances in addition to hydrocarbons. Sulfur, nitrogen, mercury and other impurities are found in varying amounts in each fossil fuel. When burned, these recombine with other materials and form air pollutants.

Coal

Coal is a solid hydrocarbon that we excavate from underground, just as we mine for minerals. One age-old method is to mine coal from tunnels dug deep underground. The other, and more recent, method is called surface- or strip-mining. Here, deposits within about 200 feet of the surface are exposed by removing the overlaying rock and soil. Once topside, coal is easy to transport, usually in large containers aboard ships or on trains.

There are abundant supplies of coal in the United States, with coal deposits in states across the continent. The top coal-producing states are West Virginia, Kentucky and Pennsylvania. Globally, Australia, India, and South Africa produce the most coal.

Oil

Oil, also known as petroleum or crude oil, is a thick black liquid hydrocarbon found in reservoirs hundreds to thousands of feet below the surface. We extract it by drilling wells deep into the underground rock and then inserting pipes. Natural pressure can bring the oil shooting to the surface when wells are new; but, in most cases, pumps are needed to bring the oil to the surface. These oil field pumping units are common sights on land and at sea (on offshore platforms) in oil-producing areas.

Once captured, crude oil is taken to refineries and processed into various products. These include gasoline, diesel, aviation fuel, home heating oil, asphalt, and oil burned for electrical power. Oil products are sent from refineries through pipelines directly to consumers, or are delivered in large tanks aboard trains, trucks, or tanker ships.

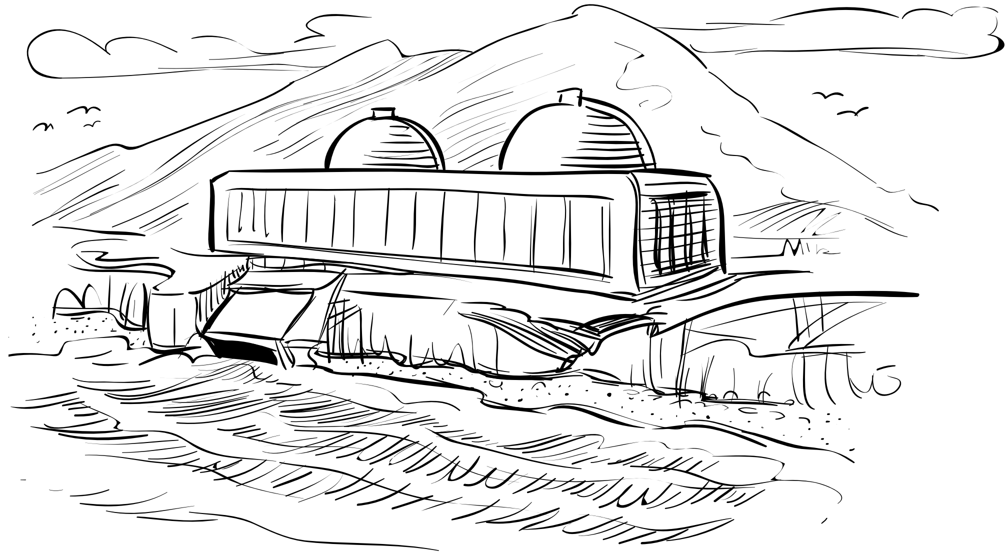
MAKING AMERICA GO

Though less commonly used for producing electricity than coal, oil is still the most widely used fossil fuel. Why? Because for decades it has been refined into gasoline, diesel, and aviation fuel to power our cars, trains, trucks, and planes. It is also used extensively for heating homes and businesses, for industrial process heat, and to make fertilizers, machinery lubricants, medicines, and many types of plastics.

Nonrenewable Energy Source: NUCLEAR

TERMS IN GLOSSARY

chain reaction
containment vessel
control rod
fissionable
fuel rod
nuclear fission
nuclear fusion
nuclear reactor
radioactive
reactive
reactor core
spent fuel
subatomic particle
uranium



This nuclear power plant uses ocean water for cooling; it does not need traditional cooling towers.

THE ATOMIC AGE WAS BORN in 1939 when physicists burst apart the nucleus of a uranium atom, releasing a tremendous amount of energy as heat and light. They called this reaction nuclear fission (fission means "to split").

Nuclear fission's first job was to make atomic bombs during World War II (in the 1940s). However, we soon learned how to control the energy from nuclear fission so we could use it to produce electricity. Today, nuclear energy is used widely for electricity generation. It is also used to power nuclear submarines and aircraft carriers.

THE NUCLEAR RESOURCE

Nuclear energy is the energy trapped inside atoms, those tiny particles from which all matter is made.

The Energy of Atoms and Molecules

In nature, atoms are bonded together into molecules, which in turn are bonded into various types of matter. It takes a great deal of energy to hold these molecules together.

Every atom is made up of even tinier "subatomic" particles, including the protons and neutrons in the atom's nucleus (central part). The energy that holds these subatomic nuclear particles together is significantly greater than the energy that holds molecules together.

POWER SKETCH: A Natural Nuclear Reactor

Nuclear power plants depend on fissionable materials, which include radioactive elements. These materials will release the energy bound in their atoms in a nuclear chain reaction. In most cases, the radioactive element used is uranium. Uranium is so reactive that it will, under very special circumstances, produce its own atomic reaction without any human help. At the Oklo mine in the West African country of Gabon, a deposit of "spent" uranium was found deep underground. This uranium had at one time spontaneously become a natural "nuclear reactor." Millions of years ago, it began its own self-sustaining chain reaction that lasted about 500,000 years!

Making nuclear energy can be roughly compared to burning wood. When we burn wood, we produce energy by breaking the electron bonds between molecules. If we stand beside a blazing bonfire we feel the energy as heat and see the energy as light. Similarly, when we produce a nuclear reaction we break the bonds between protons and neutrons within the nucleus of each atom, releasing enormous amounts of energy — considerably more than our bonfire.

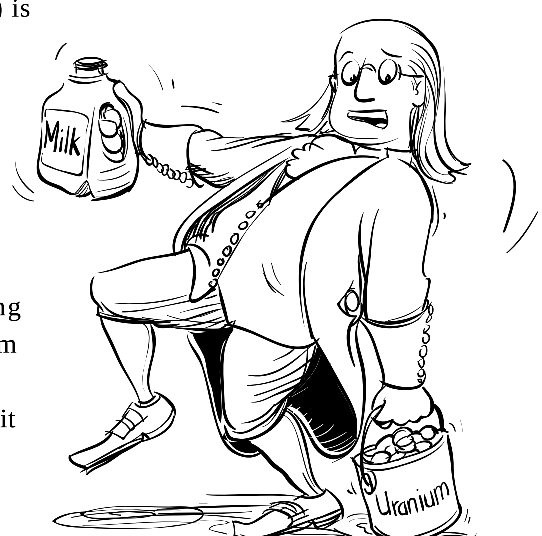
Uranium Nucleus is "Easy" to Split

Most of the elements found on Earth have stable nuclei. This means they don't split apart easily. But some elements, such as uranium, have unstable nuclei, which causes these elements to give off small particles (to "radiate"). One type of uranium, Uranium 235 (U-235) is especially unstable.*

Uranium: Fuel for Nuclear Power

Uranium is very hard and very dense. That is, it has a lot of mass per given quantity. Whereas one gallon of milk weighs about 8 pounds, one gallon of uranium weighs 150 pounds.

Uranium is found in many parts of the world, including the United States. We dig uranium-bearing rock (ore) from the ground just as we mine other minerals. There is a limited supply — though scarcity is less of an issue than it is for fossil fuels, since uranium is used in much smaller quantities. Uranium is, nevertheless, a nonrenewable resource.



**Elements other than uranium, notably plutonium, can also be used for nuclear fission. In most parts of the world plutonium is only used in weapons and not for the production of electricity.*