Energy

Energy is one of the most fundamental parts of our universe.

We use energy to do work. Energy lights our cities. Energy powers our vehicles, trains, planes and rockets. Energy warms our homes, cooks our food, plays our music, and gives us pictures on television. Energy powers machinery in factories.

Energy is defined as "the ability to do work."

When we eat, our bodies transform the food into energy to do work. When we run or walk, we "burn" food energy in our bodies. When we think or read or write, we are also doing work.

Cars, planes, trolleys, boats and machinery also transform energy into work.

Work means moving something, lifting something, warming something, and lighting something. All these are a few of the various types of work. But where does energy come from?

There are many sources of energy. In this guide, we will be looking at the energy that makes our world work. Energy is an important part of our daily lives.

The forms of energy we will look at include:

- Geothermal Energy
- Fossil Fuels -- Coal, Oil and Natural Gas
- Hydro Power and Ocean Energy
- Nuclear Energy
- Solar Energy
- Wind Energy

What is Energy?

All around us energy is causing things to happen. Look out a window. If it's daytime, the sun is giving out light and heat energy. If it's nighttime, street lamps are using electrical energy to make light.

A car drives by your school or house. It is being powered by gasoline, a type of stored energy.

Our bodies eat food, which has energy in it. We use that food to play or study.

Energy makes everything happen. Energy can be divided into two different types, depending on whether the energy is moving or stored.

Energy that is stored is called potential energy.

Energy that is moving is called kinetic energy.

If you have a pencil on your desk, try this example that shows the two different types of energy.

Put the pencil at the side of the desk and push it off to the floor. The pencil is moving and is using kinetic energy.

Now, pick the pencil back up and put it back on the desk. You used your own energy to lift and move the pencil. Moving it higher than the floor adds energy to it. As it rests on the desk, it has potential energy. The higher it is, the further it could fall, so the pencil has more potential energy the higher you raise it.

Energy is measured in a couple of different ways.

One of the basic measuring blocks is called a Btu. This stands for British thermal unit.

Btu is defined as the amount of heat energy it takes to raise the temperature of one pound of water by one degree Fahrenheit, at sea level.

One Btu equals about: One blue-tip kitchen match

One thousand (1,000) Btu roughly equals: One average candy bar

It takes, for example, about 2,000 Btus to make a pot of coffee.

Energy can also be measured in joules. Joules sounds the same way as the word jewels. It takes 1,000 joules to equal a British thermal unit. So:

1,000 joules = 1 Btu

So, it would take 2 million joules to make a pot of coffee.

Joule is named after an English physicist named James Prescott Joule who lived from 1818 to 1889. He discovered that heat is a type of energy.

One joule is the amount of energy needed to lift one pound about nine inches.

Around the world, scientists measure energy in joules rather than BTUs. It's much like people around the world using the metric system, meters and kilograms, instead of the English system of feet and pounds.

Like in the metric system, you can have kilojoules -- "kilo" means 1,000.

1,000 joules = 1 kilojoule = 1 Btu

A piece of buttered toast contains about 315 kilojoules of energy. With that energy you could:

Jog for 6 minutes
Bicycle for 10 minutes
Walk briskly for 15 minutes
Sleep for 1-1/2 hours

Run a car for 7 seconds at 80 kilometers per hour (about 50 miles per hour)
Light a 60 watt light bulb for 1-1/2 hours

Energy can only be changed into another sort of energy. It cannot be created nor can it be destroyed.

Here are some changes in energy from one form to another.

Stored energy in a flashlight's batteries becomes light energy when turned on.

Food contains energy stored as chemical potential energy. Your body uses the stored energy to do work, kinetic energy.

If you overeat, the food's energy is stored as potential energy in fat.

When you talk on the phone, your voice is changed to electrical energy. The phone on the other end changes the electrical energy into sound energy.

A car uses stored chemical energy in gasoline to move. The engine changes the chemical energy into heat and kinetic energy to power the car.

A toaster changes electrical energy into heat energy.

A television changes electrical energy into light and sound energy.

Heat Energy

Heat is a form of energy. We use it for a lot of things like warming our homes and cooking our food.

Heat energy moves in three ways:

1. Conduction
2. Convection
3. Radiation

Conduction is when energy is passed directly from one item to another. If you stirred a pan of soup on the stove with a metal spoon, the spoon will heat up. The heat is being conducted from the hot area of the soup to the colder area of spoon.

Metals are excellent conductors of heat energy. Other things like wood or plastics are not good conductors of heat energy. These "bad" conductors are called insulators. That's why a pan is usually made of metal and the handle is made of a strong plastic.

Convection is the movement of gases or liquids from a cooler spot to a warmer spot. If the soup pan above was made of glass, we could see the movement of convection currents in the pan. The warmer soup moves up from the heated area at the bottom of the pan to the top where it is cooler. The cooler soup then moves to take the warmer soup's place. The movement is in a circular pattern within the pan

Convection currents often cause wind. During the daytime, cool air from over water moves to replace the warm air over land that rises. During the nighttime, the direction changes and the water is warmer and the land is cooler.

Radiation is the final form of movement of heat energy. The sun's light and heat cannot reach us by conduction or convention because space is almost completely empty. There is nothing to transfer the energy from the sun to the earth. The sun's rays travel in straight lines called heat rays. When it moves like that, it is called radiation.

When the sunlight hits the earth, its radiation is absorbed or reflected. Darker surfaces absorb more of the radiation and lighter surfaces reflect the radiation. So, if you wear light or white clothes outside during the summer, you would be cooler.

Geothermal Energy

Geothermal Energy has been around for as long as the world existed. "Geo" means earth, and "thermal" means heat. So, geothermal means earth-heat.

Have you ever cut a boiled egg in half without peeling the shell? The egg is what the earth looks like inside. The yellow yolk of the egg is like the core of the earth. The white part is the mantle of the earth. And the thin shell of the egg is like the earth's crust.

Below the crust of the earth, the top layer of the mantle is hot, liquid rock called magma. The crust of the earth floats on this liquid magma mantle. When magma breaks through the surface of the earth in a volcano, it is called lava.

For every 100 meters you go below ground, the temperature of the rock increases about 3 degrees Celsius.

Deep under the surface, water sometimes makes its way close to the hot rock and turns into hot water or into steam. The hot water can reach temperatures of more than 150 degrees Celsius. This is hotter than boiling water.

When this hot water comes up through a crack in the earth, we call it a geyser or hot spring. Sometimes people use the hot water in swimming pools or in health spas.

The hot water from below the ground can warm buildings.

In some places, hot water from below ground is used to heat buildings during the winter. The hot water runs through miles of insulted pipes to dozens of public buildings.

In Iceland, many of the buildings and even swimming pools in the capital of Reykjavik and elsewhere are heated with geothermal hot water. The country has at least 25 active volcanoes, and many hot springs and geysers.

Fossil Fuels

There are three major forms of fossil fuels: coal, oil and natural gas. All three were formed many millions of years ago during the time of the dinosaurs -- hence the name fossil fuels.

Fossil fuels are made up of decomposed plant and animal matter. Plants change energy they receive from the sun into stored energy. This energy is food used by the plant. This is called photosynthesis. Animals eat plants to make energy. And people eat animals and plants to get energy to do work.

When plants and dinosaurs and other ancient creatures died, they decomposed and became buried, layer upon layer under the ground. It took millions of years to form these layers into a hard, black colored rock-like substance called coal, a thick liquid called oil or petroleum, and natural gas. Fossil fuels can be found under the earth in many locations around the country. Each of the fossil fuels is extracted out of the ground differently.

Coal is mined in deep mines or in strip mines closer to the surface and powers small power plants.

Oil or Petroleum

To find oil and natural gas, companies drill through the earth to the deposits deep below the surface. The oil and natural gas are then pumped from below the ground by oilrigs. They then usually travel through pipelines.

Refineries

Oil is stored in large tanks until it is sent to various places to be used.

Oil is also made into many different products -- fertilizers for farms, the clothes you wear, the toothbrush you use, the plastic bottle that holds your milk, the plastic pen that you write with. They all came from oil.

There are thousands of other products that come from oil. Almost all plastic comes originally from oil. Can you think of some things made from oil?

At oil refineries, crude oil is split into various types of products by heating the thick black oil.

The products include gasoline, diesel fuel, aviation fuel, home heating oil, oil for ships and oil to burn in power plants to make electricity.

Natural Gas

Natural gas is lighter than air. Natural gas is mostly made up of a gas called methane. Methane is a simple chemical compound that is made up of carbon and hydrogen atoms. Its chemical formula is CH_4. This gas is highly flammable.

Natural gas is usually found near petroleum underground. The natural gas is pumped from below ground and sent in large pipelines.

Natural gas usually has no odor and you can't see it. Before it is sent to the pipelines and storage tanks, it is mixed with a chemical that gives a strong odor. The odor smells almost like rotten eggs. The odor makes it easy to smell if there is a leak.

From the storage tanks natural gas is sent through underground pipes to your home to cook your food and heat your house. Natural gas is also sent to factories and to power plants to make electricity.

Hydro Power

When it rains in hills and mountains, the water becomes streams and rivers that run down to the ocean. The moving or falling water can be used to do work. Energy, you'll remember is the ability to do work. So moving water, which has kinetic energy, can be used as a source of energy.

For hundreds of years, moving water was used to turn wooden wheels that were attached to grinding wheels to grind flour or corn. Today, moving water can also be used to make electricity.

Hydro means water. Hydroelectric means making electricity from water power.

Hydroelectric power uses the kinetic energy of moving water to make electricity. Dams can be built to stop the flow of a river. Water behind a dam often forms a reservoir. Dams are also built across larger rivers but no reservoir is made. The river is simply sent through a hydroelectric power plant.

The water flows through a pipe called a penstock and pushes against blades in a turbine, causing them to turn.
The turbine spins a generator to produce electricity. The electricity can then go to your home, to your school, to factories and businesses.

Nuclear Power

Another major form of energy is nuclear energy, the energy that is trapped inside each atom. One of the laws of the universe is that matter and energy can't be created nor destroyed. But they can be changed in form.

Matter can be changed into energy. The famous scientist Albert Einstein created the mathematical formula that explains this. It is:

$$E = mc^2$$

This equation says:

E [energy] equals m [mass] times c^2 [c stands for the speed of light. c2 means c times c, or the speed of light raised to the second power -- or c-squared.]

Scientists used Einstein's famous equation as the key to unlock atomic energy and also create atomic bombs.

The ancient Greeks said the smallest part of nature is an atom. But they did not know 2,000 years ago about nature's even smaller parts.

Atoms are made up of smaller particles -- a nucleus of protons and neutrons, surrounded by electrons, which swirl around the nucleus much like the earth revolves around the sun.

Nuclear Fission

An atom's nucleus cans be split apart. When this is done, a tremendous amount of energy is released. The energy is both heat and light energy. This energy, when let out slowly, can be harnessed to generate electricity. When it is let out all at once, it makes a tremendous explosion in an atomic bomb. The word fission means to split apart.

A nuclear power plant uses uranium as a "fuel." Uranium is a rare metal that is dug out of the ground. It is processed into tiny pellets that are loaded into very long rods that are put into the power plant's reactor.

Inside the reactor of an atomic power plant, uranium atoms are split apart in a controlled chain reaction.

In a chain reaction, particles released by the splitting of the atom go off and strike other uranium atoms splitting those. Those particles given off split still other atoms in a chain reaction. In nuclear power plants, control rods are used to keep the splitting regulated so it doesn't go too fast.

If the reaction is not controlled, you could have an atomic bomb. But in atomic bombs, almost pure pieces of the element Uranium-235 or Plutonium, of a precise mass and shape, must be brought together and held together, with great force. These conditions are not present in a nuclear reactor.

The reaction also releases nuclear radiation. This is harmful to people, so the power plant's reactor is covered in thick concrete.

This chain reaction gives off heat energy. This heat energy is used to boil water in the core of the reactor. So, instead of burning a fuel, nuclear power plants use the chain reaction of atoms splitting to change the energy of atoms into heat energy.

This water from around the nuclear core is sent to another section of the power plant. Here it heats another set of pipes filled with water to make steam. The steam in this second set of pipes powers a turbine to generate electricity.

Nuclear Fusion

Another form of nuclear energy is called fusion. Fusion means joining smaller nuclei (the plural of nucleus) to make a larger nucleus. The sun uses nuclear fusion of hydrogen atoms into helium atoms. This gives off heat and light and other radiation.

Scientists have been working on controlling nuclear fusion for a long time, trying to make a fusion reactor to produce electricity. But they have been having trouble learning how to control the reaction in a contained space.

What's better about nuclear fusion is that less deadly nuclear radiation is given off.

Solar Power

When we hang laundry outside to dry in the sun, we are using the sun's heat to do work -- drying our clothes.

The sun has always been an energy source.

Plants use the sun's light to make food. Animals eat plants for food.

And as we found out earlier, decaying plants and animals millions of years ago produced the coal, oil and natural gas that we use today.

So, fossil fuels actually got their start as sunlight many millions of years ago.

The sun can also be used to heat water for hot water in our homes and businesses.

Solar Hot Water

In the 1890s solar water heaters were first used in. They proved to be a big improvement over wood and coal-burning stoves.
Artificial gas made from coal was available too to heat water. But it cost 10 times the price we pay for natural gas today. And electricity was even more expensive!

By 1920, thousands of solar water heaters had been sold. But by then, large deposits of oil and natural gas were discovered. As these low cost fuels became available, solar systems began to be replaced with heaters using fossil fuels.

Panels on the roof of a building, contain water pipes. When the sun hits the panels and the pipes, the sunlight warms them.

That warmed water can then be used in a swimming pool.

Solar Thermal Electricity

Solar can also be used to make electricity.

Some solar power plants use a highly curved mirror called a parabolic trough to focus the sunlight on a pipe running down a central point above the curve of the mirror. The mirror focuses the sunlight to strike the pipe, and it gets so hot that it can boil water into steam. That steam can then be used to turn a turbine to make electricity.

In California's Mojave Desert, there are huge rows solar mirrors arranged in what's called "solar thermal power plants" that use this idea to make electricity for more than 350,000 homes. The problem with solar energy is that it works only when the sun is shining. So, on cloudy days and at night, the power plants can't create energy. Some solar plants, are a hybrid technology. During the daytime they use the sun. At night they use natural gas to boil the water so they can continue to make electricity.

Sunlight is reflected off 1,800 mirrors circling a tall tower. The mirrors are called heliostats and turn to face the sun all day long.

The light is reflected back to the top of the tower in the center of a circle where a fluid is turned very hot by the sun's rays. That fluid can be used to boil water to make steam to turn a turbine and a generator.

This experimental power plant is called Solar II. It is being re-built in California's desert using newer technologies than when it was first built in the early 1980s. Solar II will use the sunlight to change heat into mechanical energy in the turbine.

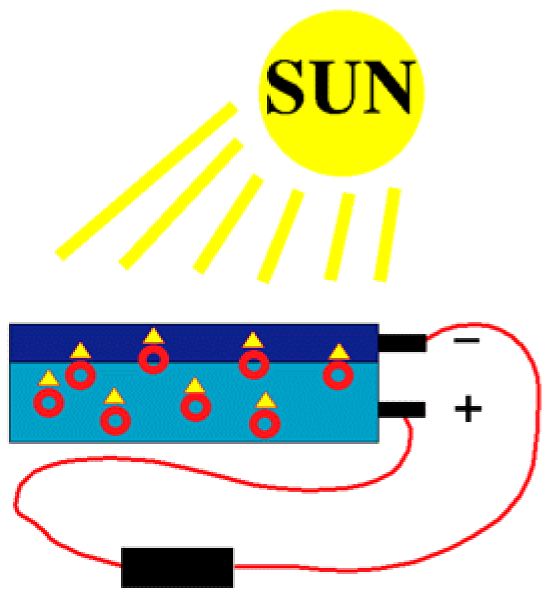
The power plant will make enough electricity to power about 10,000 homes. Scientists say larger central tower power plants will be able to make electricity for 100,000 to 200,000 homes.

Solar Cells or Photovoltaic Energy

We can also change the sunlight directly to electricity using solar cells.

Solar cells are also called photovoltaic cells -- or PV cells for short -- and can be found on many small appliances, like calculators, and even on spacecraft. They were first developed in the 1950s for use on U.S. space satellites. They are made of silicon, a special type of melted sand.

When sunlight strikes the solar cell, electrons (circles) are knocked loose. They move toward the treated front surface (dark shade). An electron imbalance is created between the front and back. When the two surfaces are joined by a connector, like a wire, a current of electricity occurs between the negative and positive sides.



These individual solar cells are arranged together in a PV module. Some of the modules are set on special tracking devices to follow sunlight all day long.

The electrical energy from solar cells can then be used directly. It can be used in a home for lights and appliances. It can be used in a business. Solar energy can be stored in batteries to light a roadside billboard at night. Or the energy can be stored in a battery for an emergency roadside cellular telephone when no telephone wires are around.

Some experimental cars also use PV cells. They convert sunlight directly into energy to power electric motors on the car.

Wind Power

Wind can be used to do work.

The kinetic energy of the wind can be changed into other forms of energy, either mechanical energy or electrical energy.

When a boat lifts a sail, it is using wind energy to push it through the water. This is one form of work.

Farmers have been using wind energy for many years to pump water from wells using windmills.

In Holland, windmills have been used for centuries to pump water from low-lying areas.

Wind is also used to turn large grinding stones to grind wheat or corn, just like a water wheel is turned by water power.

Today, the wind is also used to make electricity.

Blowing wind spins the blades on a wind turbine -- just like a large toy pinwheel. The blades are attached to a hub that is mounted on a turning shaft. The shaft goes through a gear transmission box where the turning speed is increased. The transmission is attached to a high speed shaft which turns a generator that makes electricity.

If the wind gets too high, the turbine has a brake that will keep the blades from turning and being damaged.

The only problem with wind is that it is not windy all year long. It is usually windier during the summer months when wind rushes inland from cooler areas, like the ocean to replace hot rising air in warm areas.

And wind speeds must be above 12 to 14 miles per hour to turn the turbines fast enough to generate electricity. The turbines usually produce about 50 to 300 kilowatts of electricity each. A kilowatt is 1,000 watts (kilo means 1,000). You can light ten 100-watt light bulbs with 1,000 watts. So, a 300-kilowatt (300,000 watts) wind turbine could light up 3,000 light bulbs that use 100 watts.

About 30 percent of the world's wind-generated electricity is found in California. Other countries that use a lot of wind energy are Denmark and Germany.

Energy: Advantages & Disadvantages

As the world's population increases and there is continued comparison to the current western European, Japanese, and North American living standards, there is likely to be demand for more electrical power. Energy sources available in the world include coal, nuclear, hydroelectric, gas, wind, solar, refuse-based, and biomass. In addition, fusion had been originally proposed as the long-term source.

Every form of energy generation has advantages and disadvantages as shown in the table below.

Source	Advantages	Disadvantages
Coal	• Inexpensive • Easy to recover (in U.S. and Russia)	• Requires expensive air pollution controls • Significant contributor to acid rain and global warming • Requires extensive transportation system

Nuclear	• Fuel is inexpensive • Energy generation is the most concentrated source • Waste is more compact than any source • Extensive scientific basis for the cycle • Easy to transport as new fuel • No greenhouse or acid rain effects	• Requires larger capital cost because of emergency, containment, radioactive waste and storage systems • Requires resolution of the long-term high level waste storage issue in most countries • Potential nuclear proliferation issue
Hydroelectric	• Very inexpensive once dam is built • Government has invested heavily in building dams, particularly in the Western U.S.	• Very limited source since depends on water elevation • Many dams available are currently exist (not much of a future source[depends on country]) • Dam collapse usually leads to loss of life • Dams have affected fish (e.g. salmon runs) • Environmental damage for areas flooded (backed up) and downstream
Natural Gas	• Good distribution system for current use levels • Easy to obtain • Better as space heating energy source	• Very limited availability as shown by shortages during winters several years ago • Could be major contributor to global warming • Expensive for energy generation • Large price swings with supply and demand
Wind	• Wind is free if available • Good source for periodic water pumping demands of farms as used earlier in 1900's	• Need 3x the amount of installed generation to meet demand • Limited to few areas of U.S. • Equipment is expensive to maintain • Need expensive energy storage (e.g. batteries) • Highly climate dependent - wind can damage during windstorms or not turn during still summer days. • Can affect endangered birds.
Solar	• Sunlight is free when available	• Limited to southern areas of U.S. and other sunny areas throughout the world • Does require special materials for mirrors/panels that can affect environment • Current technology requires large amounts of land for small amounts of energy generation
Refuse Based Fuel	• Fuel can have low cost • Could create jobs because smaller plants would be used • Low sulfur dioxide emissions	• Inefficient if small plants are used • Could be significant contributor to global warming because fuel has low heat content • Flyash can contain metals as cadmium and lead • Contain dioxins and furans in air and ash releases
Nuclear Fusion	• Hydrogen and tritium could be used as fuel source • Higher energy output per unit mass than fission Low radiation levels associated with process than fission-based reactors	• Breakeven point has not been reached after about 40 years of expensive research and commercially available plants not expected for at least 35 years.