Encyclopedia of Energy

Scott Bennett

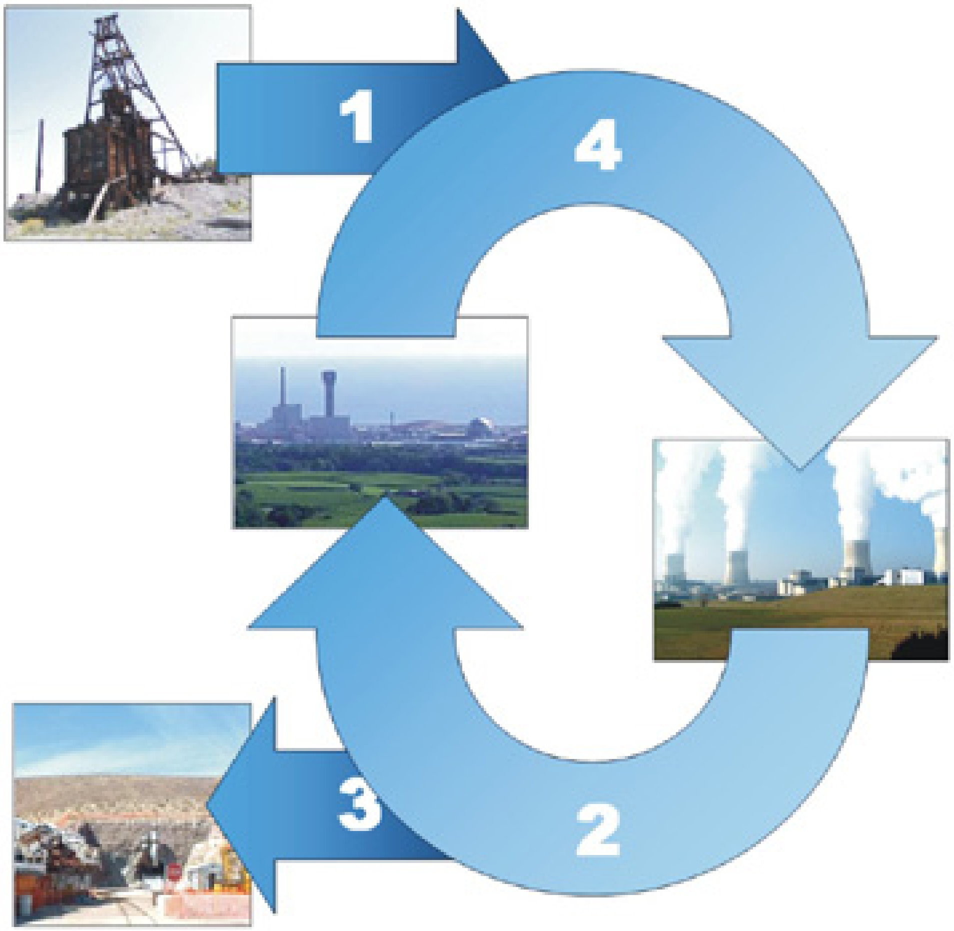

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Table of Contents

ELECTRICITY - A Secondary Energy Source

Electricity is the flow of electrical power or charge. It is a secondary energy source which means that we get it from the conversion of other sources of energy, like coal, natural gas, oil, nuclear power and other natural sources, which are called primary sources. The energy sources we use to make electricity can be renewable or non-renewable, but electricity itself is neither renewable or non-renewable.

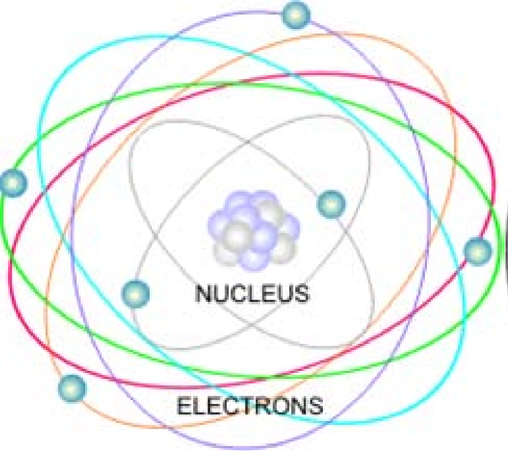
Electricity is a basic part of nature and it is one of our most widely used forms of energy. Many cities and towns were built alongside waterfalls (a primary source of mechanical energy) that turned water wheels to perform work. Before electricity generation began slightly over 100 years ago, houses were lit with kerosene lamps, food was cooled in iceboxes, and rooms were warmed by wood-burning or coal-burning stoves. Beginning with Benjamin Franklin's experiment with a kite one stormy night in Philadelphia, the principles of electricity gradually became understood. Thomas Edison helped change everyone's life -- he perfected his invention -- the electric light bulb. Prior to 1879, direct current (DC) electricity had been used in arc lights for outdoor lighting. In the late-1800s, Nikola Tesla pioneered the generation, transmission, and use of alternating current (AC) electricity, which can be transmitted over much greater distances than direct current. Tesla's inventions used electricity to bring indoor lighting to our homes and to power industrial machines.

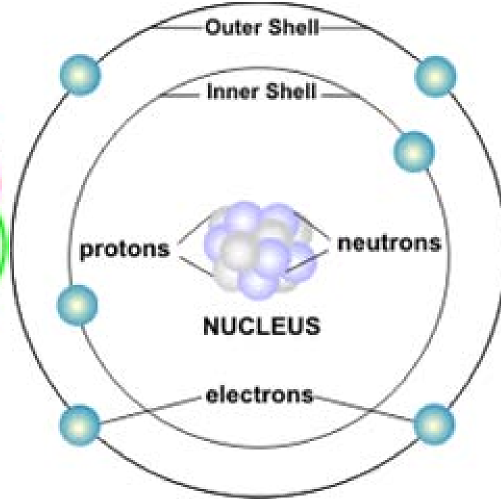
Despite its great importance in our daily lives, most of us rarely stop to think what life would be like without electricity. Yet like air and water, we tend to take electricity for granted. Everyday, we use electricity to do many jobs for us -- from lighting and heating/cooling our homes, to powering our televisions and computers. Electricity is a controllable and convenient form of energy used in the applications of heat, light and power.

THE SCIENCE OF ELECTRICITY

In order to understand how electric charge moves from one atom to another, we need to know something about atoms. Everything in the universe is made of atoms—every star, every tree, every animal. The human body is made of atoms. Air and water are, too. Atoms are the building blocks of the universe. Atoms are so small that millions of them would fit on the head of a pin.

Atoms are made of even smaller particles. The center of an atom is called the **nucleus**. It is made of particles called **protons** and **neutrons**. The protons and neutrons are very small, but electrons are much, much smaller. **Electrons** spin around the nucleus in shells a great distance from the nucleus. If the nucleus were the size of a tennis ball, the atom would be the size of the Empire State Building. Atoms are mostly empty space.





If you could see an atom, it would look a little like a tiny center of balls surrounded by giant invisible bubbles (or shells). The electrons would be on the surface of the bubbles, constantly spinning and moving to stay as far away from each other as possible. Electrons are held in their shells by an electrical force.

The protons and electrons of an atom are attracted to each other. They both carry an **electrical charge**. An electrical charge is a force within the particle. Protons have a positive charge (+) and electrons have a negative charge (-). The positive charge of the protons is equal to the negative charge of the electrons. Opposite charges attract each other. When an atom is in balance, it has an equal number of protons and electrons. The neutrons carry no charge and their number can vary.

The number of protons in an atom determines the kind of atom, or **element**, it is. An element is a substance in which all of the atoms are identical (the Periodic Table shows all the known elements). Every atom of hydrogen, for example, has one proton and one electron, with no neutrons. Every atom of carbon has six protons, six electrons, and six neutrons. The number of protons determines which element it is.

Electrons usually remain a constant distance from the nucleus in precise **shells**. The shell closest to the nucleus can hold two electrons. The next shell can hold up to eight. The outer shells cans hold even more. Some atoms with many protons can have as many as seven shells with electrons in them.

The electrons in the shells closest to the nucleus have a strong force of attraction to the protons. Sometimes, the electrons in the outermost shells do not. These electrons can be pushed out of their orbits. Applying a force can make them move from one atom to another. These moving electrons are electricity.

STATIC ELECTRICITY

Electricity has been moving in the world forever. Lightning is a form of electricity. It is electrons moving from one cloud to another or jumping from a cloud to the ground. Have you ever felt a shock when you touched an object after walking across a carpet? A stream of electrons jumped to you from that object. This is called **static electricity**.

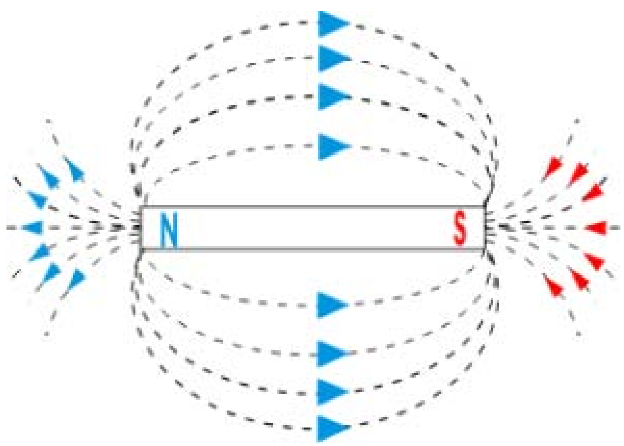
Have you ever made your hair stand straight up by rubbing a balloon on it? If so, you rubbed some electrons off the balloon. The electrons moved into your hair from the balloon. They tried to get far away from each other by moving to the ends of your hair.

They pushed against each other and made your hair move—they repelled each other. Just as opposite charges attract each other, like charges repel each other.

MAGNETS AND ELECTRICITY

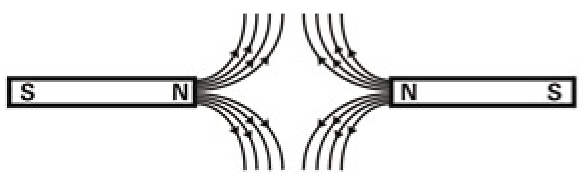
In most objects, all of the forces are in balance. Half of the electrons are spinning in one direction; half are spinning in the other. These spinning electrons are scattered evenly throughout the object.

Magnets are different. In magnets, most of the electrons at one end are spinning in one direction. Most of the electrons at the other end are spinning in the opposite direction.



Bar Magnet

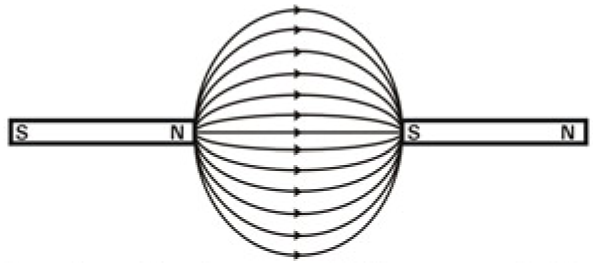
This creates an imbalance in the forces between the ends of a magnet. This creates a **magnetic field** around a magnet. A magnet is labeled with North (N) and South (S) poles. The magnetic force in a magnet flows from the North pole to the South pole.



Like poles of magnets (N-N or S-S) repel each other.

Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the South poles together, they repel each other. Two North poles also repel each other.

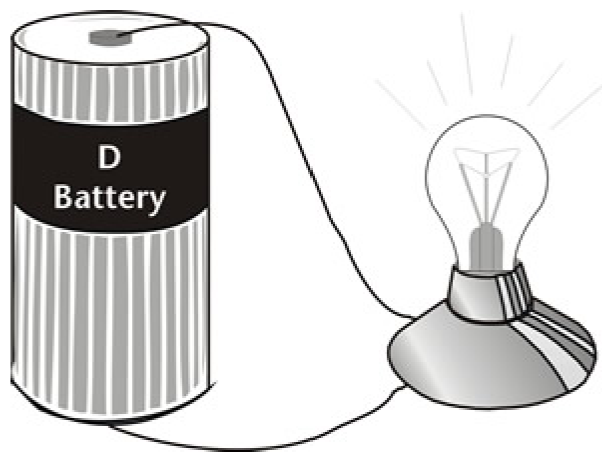
Turn one magnet around and the North (N) and the South (S) poles are attracted to each other. The magnets come together with a strong force. Just like protons and electrons, opposites attract.



Opposite poles of magnets (N-S) attract each other.

These special properties of magnets can be used to make electricity. Moving magnetic fields can pull and push electrons. Some metals, like copper have electrons that are loosely held. They can be pushed from their shells by moving magnets. Magnets and wire are used together in electric generators.

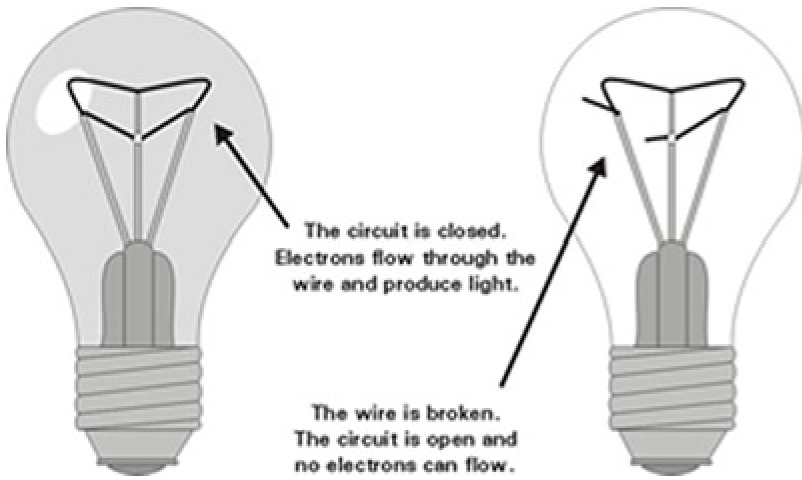
BATTERIES PRODUCE ELECTRICITY



A battery produces electricity using two different metals in a chemical solution. A chemical reaction between the metals and the chemicals frees more electrons in one metal than in the other. One end of the battery is attached to one of the metals; the other end is attached to the other metal. The end that frees more electrons develops a positive charge and the other end develops a negative charge. If a wire is attached from one end of the battery to the other, electrons flow through the wire to balance the electrical charge. A load is a device that does work or performs a job. If a load––such as a lightbulb––is placed along the wire, the electricity can do work as it flows through the wire. In the picture above, electrons flow from the negative end of the battery through the wire to the lightbulb. The electricity flows through the wire in the lightbulb and back to the battery.

ELECTRICITY TRAVELS IN CIRCUITS

Electricity travels in closed loops, or circuits (from the word circle). It must have a complete path before the electrons can move. If a circuit is open, the electrons cannot flow. When we flip on a light switch, we close a circuit. The electricity flows from the electric wire through the light and back into the wire. When we flip the switch off, we open the circuit. No electricity flows to the light. When we turn a light switch on, electricity flows through a tiny wire in the bulb. The wire gets very hot. It makes the gas in the bulb glow. When the bulb burns out, the tiny wire has broken. The path through the bulb is gone. When we turn on the TV, electricity flows through wires inside the set, producing pictures and sound. Sometimes electricity runs motors—in washers or mixers. Electricity does a lot of work for us. We use it many times each day.

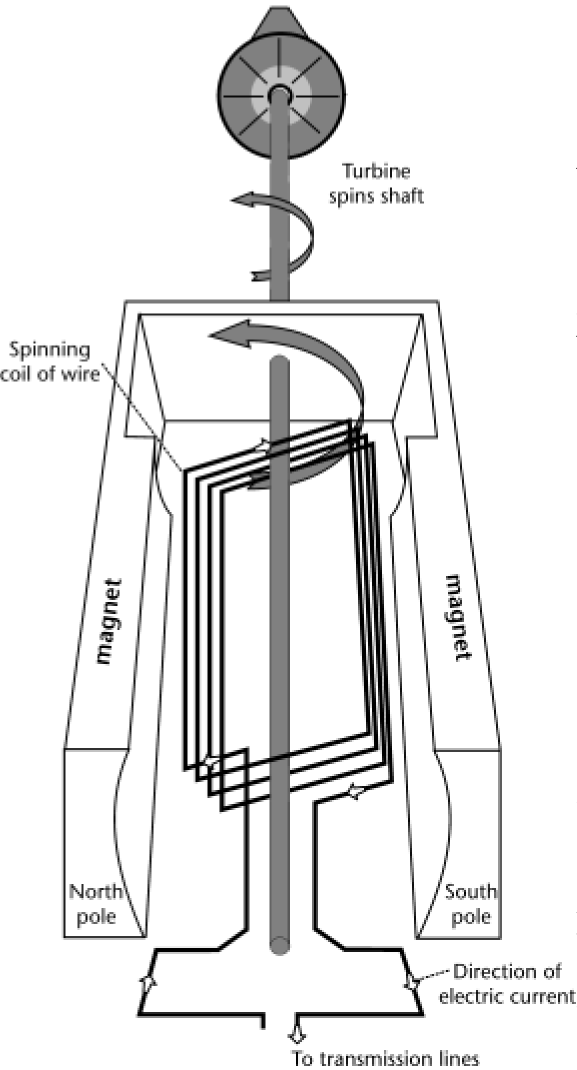


HOW ELECTRICITY IS GENERATED

A generator is a device that converts mechanical energy into electrical energy. The process is based on the relationship between magnetism and electricity. In 1831, Faraday discovered that when a magnet is moved inside a coil of wire, electrical current flows in the wire.

A typical generator at a power plant uses an electromagnet—a magnet produced by electricity—not a traditional magnet. The generator has a series of insulated coils of wire that form a stationary cylinder. This cylinder surrounds a rotary electromagnetic shaft. When the electromagnetic shaft rotates, it induces a small electric current in each section of the wire coil. Each section of the wire becomes a small, separate electric conductor. The small currents of individual sections are added together to form one large current. This current is the electric power that is transmitted from the power company to the consumer.

TURBINE GENERATOR



An electric utility power station uses either a turbine, engine, water wheel, or other similar machine to drive an electric generator or a device that converts mechanical or chemical energy to generate electricity. Steam turbines, internal-combustion engines, gas combustion turbines, water turbines, and wind turbines are the most common methods to generate electricity. Most power plants are about 35 percent efficient. That means that for every 100 units of energy that go into a plant, only 35 units are converted to usable electrical energy.

Most of the electricity in the United States is produced in steam turbines. A turbine converts the kinetic energy of a moving fluid (liquid or gas) to mechanical energy. Steam turbines have a series of blades mounted on a shaft against which steam is forced, thus rotating the shaft connected to the generator. In a fossil-fueled steam turbine, the fuel is burned in a furnace to heat water in a boiler to produce steam.

Coal, petroleum (oil), and natural gas are burned in large furnaces to heat water to make steam that in turn pushes on the blades of a turbine. Did you know that coal is the largest single primary source of energy used to generate electricity in the United States? In 2005, more than half (51%) of the country's 3.9 trillion kilowatthours of electricity used coal as its source of energy.

Natural gas, in addition to being burned to heat water for steam, can also be burned to produce hot combustion gases that pass directly through a turbine, spinning the blades of the turbine to generate electricity. Gas turbines are commonly used when electricity utility usage is in high demand. In 2005, 17% of the nation's electricity was fueled by natural gas.

Petroleum can also be used to make steam to turn a turbine. Residual fuel oil, a product refined from crude oil, is often the petroleum product used in electric plants that use petroleum to make steam. Petroleum was used to generate about three percent (3%) of all electricity generated in U.S. electricity plants in 2005.

Nuclear power is a method in which steam is produced by heating water through a process called nuclear fission. In a nuclear power plant, a reactor contains a core of nuclear fuel, primarily enriched uranium. When atoms of uranium fuel are hit by neutrons they fission (split), releasing heat and more neutrons. Under controlled conditions, these other neutrons can strike more uranium atoms, splitting more atoms, and so on. Thereby, continuous fission can take place, forming a chain reaction releasing heat. The heat is used to turn water into steam, that, in turn, spins a turbine that generates electricity. Nuclear power was used to generate 20% of all the country's electricity in 2005.

Hydropower, the source for almost 7% of U.S. electricity generation in 2005, is a process in which flowing water is used to spin a turbine connected to a generator. There are two basic types of hydroelectric systems that produce electricity. In the first system, flowing water accumulates in reservoirs created by the use of dams. The water falls through a pipe called a penstock and applies pressure against the turbine blades to drive the generator to produce electricity. In the second system, called run-of-river, the force of the river current (rather than falling water) applies pressure to the turbine blades to produce electricity.

Geothermal power comes from heat energy buried beneath the surface of the earth. In some areas of the country, enough heat rises close to the surface of the earth to heat underground water into steam, which can be tapped for use at steam-turbine plants. This energy source generated less than 1% of the electricity in the country in 2005.

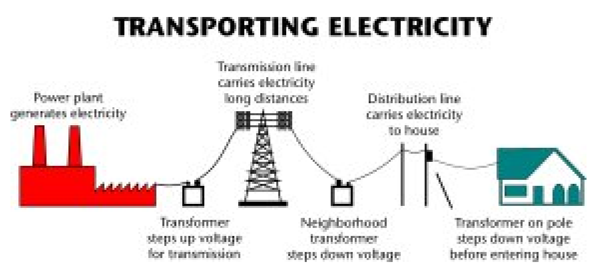
Solar power is derived from the energy of the sun. However, the sun's energy is not available full-time and it is widely scattered. The processes used to produce electricity using the sun's energy have historically been more expensive than using conventional fossil fuels. Photovoltaic conversion generates electric power directly from the light of the sun in a photovoltaic (solar) cell. Solar-thermal electric generators use the radiant energy from the sun to produce steam to drive turbines. In 2005, less than 1% of the nation's electricity was based on solar power.

Wind power is derived from the conversion of the energy contained in wind into electricity. Wind power, less than 1% of the nation's electricity in 2005, is a rapidly growing source of electricity. A wind turbine is similar to a typical wind mill.

Biomass includes wood, municipal solid waste (garbage), and agricultural waste, such as corn cobs and wheat straw. These are some other energy sources for producing electricity. These sources replace fossil fuels in the boiler. The combustion of wood and waste creates steam that is typically used in conventional steam-electric plants. Biomass accounts for about 1% of the electricity generated in the United States.

THE TRANSFORMER - MOVING ELECTRICITY

To solve the problem of sending electricity over long distances, William Stanley developed a device called a transformer. The transformer allowed electricity to be efficiently transmitted over long distances. This made it



possible to supply electricity to homes and businesses located far from the electric generating plant.

The electricity produced by a generator travels along cables to a transformer, which changes electricity from low voltage to high voltage. Electricity can be moved long distances more efficiently using high voltage. Transmission lines are used to carry the electricity to a substation. Substations have transformers that change the high voltage electricity into lower voltage electricity. From the substation, distribution lines carry the electricity to homes, offices and factories, which require low voltage electricity.

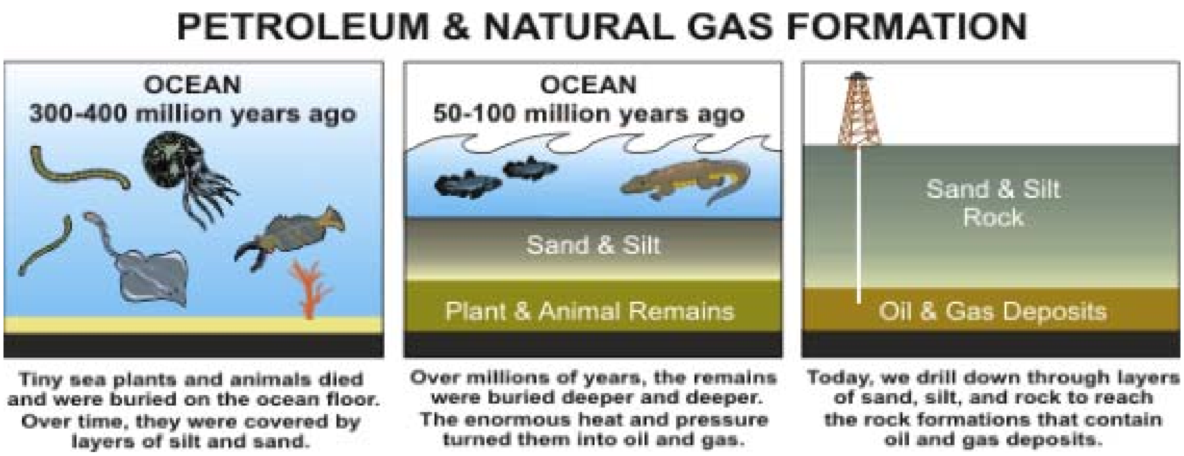
MEASURING ELECTRICITY

Electricity is measured in units of power called watts. It was named to honor James Watt, the inventor of the steam engine. One watt is a very small amount of power. It would require nearly 750 watts to equal one horsepower. A kilowatt represents 1,000 watts. A kilowatthour (kWh) is equal to the energy of 1,000 watts working for one hour. The amount of electricity a power plant generates or a customer uses over a period of time is measured in kilowatthours (kWh). Kilowatthours are determined by multiplying the number of kW's required by the number of hours of use. For example, if you use a 40-watt light bulb 5 hours a day, you have used 200 watts of power, or 0.2 kilowatthours of electrical energy. See our Energy Calculator section to learn more about converting units.

Natural Gas -- A Fossil Fuel

HOW NATURAL GAS WAS FORMED

Millions of years ago, the remains of plants and animals decayed and built up in thick layers. This decayed matter from plants and animals is called organic material -- it was once alive. Over time, the mud and soil changed to rock, covered the organic material and trapped it beneath the rock. Pressure and heat changed some of this organic material into coal, some into oil (petroleum), and some into natural gas -- tiny bubbles of odorless gas. The main ingredient in natural gas is methane, a gas (or compound) composed of one carbon atom and four hydrogen atoms.



In some places, gas escapes from small gaps in the rocks into the air; then, if there is enough activation energy from lightning or a fire, it burns. When people first saw the flames, they experimented with them and learned they could use them for heat and light.

HOW WE GET NATURAL GAS

The search for natural gas begins with geologists (people who study the structure of the earth) locating the types of rock that are usually found near gas and oil deposits.

Today their tools include seismic surveys that are used to find the right places to drill wells. Seismic surveys use echoes from a vibration source at the earth's surface (usually a vibrating pad under a truck built for this purpose) to collect information about the rocks beneath. Sometimes it is necessary to use small amounts of dynamite to provide the vibration that is needed.

Scientists and engineers explore a chosen area by studying rock samples from the earth and taking measurements. If the site seems promising, drilling begins. Some of these areas are on land but many are **offshore**, deep in the ocean. Once the gas is found, it flows up through the well to the surface of the ground and into large pipelines. Some of the gases that are produced along with methane, such as butane and **propane** (also known as 'by-products'), are separated and cleaned at a gas processing plant. The by-products, once removed, are used in a number of ways. For example, propane can be used for cooking on gas grills.

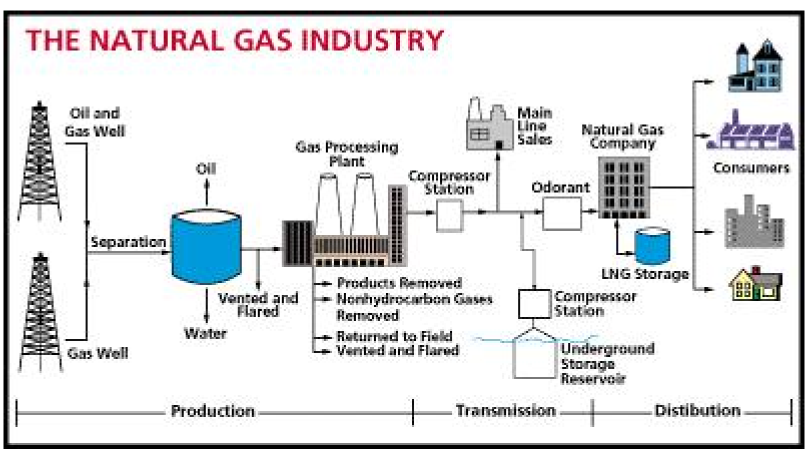
Because natural gas is colorless, odorless and tasteless, mercaptan (a chemical that has a sulfur like odor) is added before distribution, to give it a distinct unpleasant odor (smells like rotten eggs). This serves as a safety device by allowing it to be detected in the atmosphere, in cases where leaks occur.

Most of the natural gas consumed in the United States is produced in the United States. Some is imported from Canada and shipped to the United States in pipelines. Increasingly natural gas is also being shipped to the United States as liquefied natural gas(LNG).

We can also use machines called **"digesters"** that turn today's organic material (plants, animal wastes, etc.) into natural gas. This replaces waiting for thousands of years for the gas to form naturally.

HOW NATURAL GAS IS STORED AND DELIVERED

The gas companies collect it in huge storage tanks, or underground, in old gas wells. The gas remains there until it is added back into the pipeline when people begin to use more gas, such as in the winter to heat homes.



Natural gas is moved by pipelines from the producing fields to consumers. Since natural gas demand is greater in the winter, gas is stored along the way in large underground storage systems, such as old oil and gas wells or caverns formed in old salt beds. The gas remains there until it is added back into the pipeline when people begin to use more gas, such as in the winter to heat homes.

When chilled to very cold temperatures, approximately -260 degrees Fahrenheit, natural gas changes into a liquid and can be stored in this form. Liquefied natural gas (LNG) can be loaded onto tankers (large ships with several domed tanks) and moved across the ocean to deliver gas to other countries. Once in this form, it takes up only 1/600th of the space that it would in its gaseous state. When this LNG is received in the United States, it can be shipped by truck to be held in large chilled tanks close to users or turned back into gas to add to pipelines.

When the gas gets to the communities where it will be used(usually through large pipelines), the gas is measured as it flows into smaller pipelines called "MAINS". Very small lines, called "SERVICES", connect to the mains and go directly to homes or buildings where it will be used.

HOW NATURAL GAS IS MEASURED

We measure and sell natural gas in cubic feet (volume) or in **British Thermal Units** (heat content). Heat from all energy sources can be measured and converted back and forth between British thermal units (Btu) and metric units. See the Energy Calculator for help with converting natural gas units.

One Btu is the heat required to raise the temperature of one pound of water one degree Fahrenheit. Ten burning kitchen matches release 10 Btu. One cubic foot of natural gas has about 1031 Btu. A box 10 feet deep, 10 feet long, and 10 feet wide would hold one thousand cubic feet of natural gas.

For example, a candy bar has about 1000 Btu.

Pipeline companies buy natural gas in thousands of cubic feet or Mcf. M = one thousand.

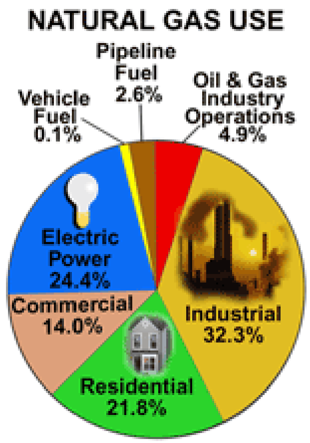
WHAT NATURAL GAS IS USED FOR

Approximately 23 percent of the energy consumption of the U.S. comes from natural gas. Over one-half of the homes in the U.S. use natural gas as their main heating fuel.

Natural gas is also an essential raw material for many common products, such as: paints , fertilizer, plastics, antifreeze, dyes, photographic film, medicines, and explosives. We also get propane, a fuel we use in many of our backyard barbecue grills, when we process natural gas.

Industry depends on it. Natural gas has thousands of uses. It's used to produce steel, glass, paper, clothing, brick, electricity and much more!

Homes use it too. More than 62.5 million homes use natural gas to fuel stoves, furnaces, water heaters, clothes dryers and other household appliances. It is also used to roast coffee, smoke meats, bake bread and much more.



NATURAL GAS AND THE ENVIRONMENT

Natural gas burns more cleanly than other fossil fuels. It has fewer emissions of sulfur, carbon, and nitrogen than coal or oil, and it has almost no ash particles left after burning. Being a clean fuel is one reason that the use of natural gas, especially for electricity generation, has grown so much and is expected to grow even more in the future.

Of course, there are environmental concerns with the use of any fuel. As with other fossil fuels, burning natural gas produces carbon dioxide, which is the most important greenhouse gas. Many scientists believe that increasing levels of carbon dioxide and other greenhouse gases in the earth's atmosphere are changeing the global climate.

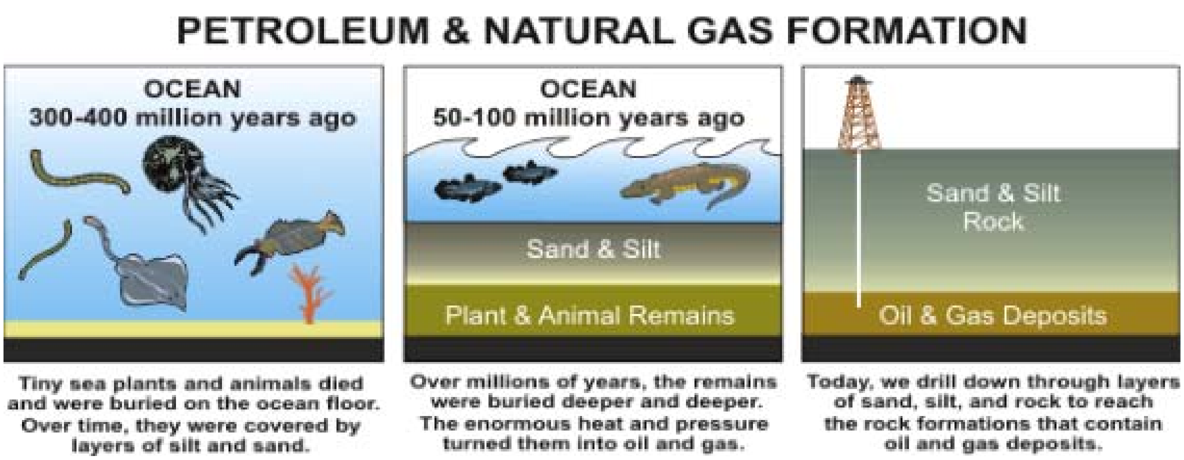
As with other fuels, natural gas also affects the environment when it is produced, stored and transported. Because natural gas is made up mostly of methane (another greenhouse gas), small amounts of methane can sometimes leak into the atmosphere from wells, storage tanks and pipelines. The natural gas industry is working to prevent any methane from escaping. Exploring and drilling for natural gas will always have some impact on land and marine habitats. But new technologies have greatly reduced the number and size of areas disturbed by drilling, sometimes called "footprints." Satellites, global positioning systems, remote sensing devices, and 3-D and 4-D seismic technologies, make it possible to discover natural gas reserves while drilling fewer wells. Plus, the use of horizontal and directional drilling make it possible for a single well to produce gas from much bigger areas.

Natural gas pipelines and storage facilities have a very good safety record. This is very important because when natural gas leaks it can cause explosions. Since raw natural gas has no odor, natural gas companies add a smelly substance to it so that people will know if there is a leak. If you have a natural gas stove, you may have smelled this “rotten egg” smell of natural gas when the pilot light has gone out.

Petroleum(Oil) -- A Fossil Fuel

HOW OIL WAS FORMED

Oil was formed from the remains of animals and plants that lived millions of years ago in a marine (water) environment before the dinosaurs. Over the years, the remains were covered by layers of mud. Heat and pressure from these layers helped the remains turn into what we today call crude oil . The word "petroleum" means "rock oil" or "oil from the earth."



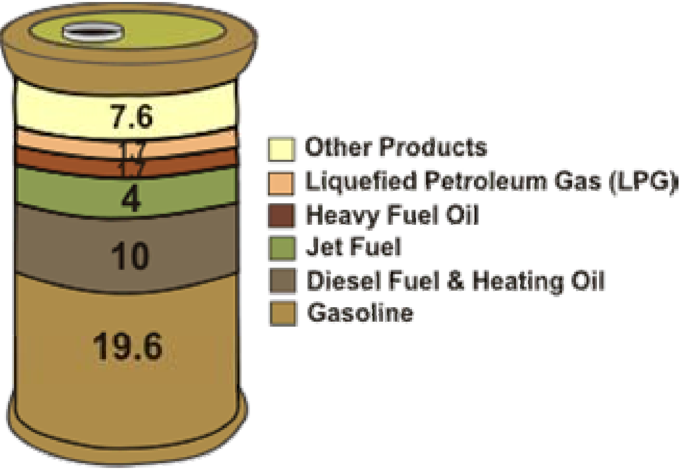
WHERE WE GET OIL

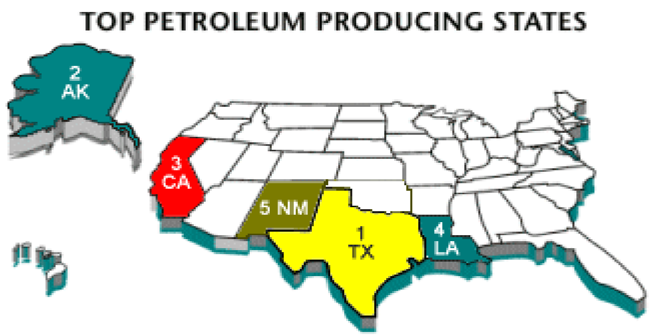
Crude oil is a smelly, yellow-to-black liquid and is usually found in underground areas called reservoirs. Scientists and engineers explore a chosen area by studying rock samples from the earth. Measurements are taken, and, if the site seems promising, drilling begins. Above the hole, a structure called a 'derrick' is built to house the tools and pipes going into the well. When finished, the drilled well will bring a steady flow of oil to the surface.

The world's top five crude oil-producing countries are:

- Saudi Arabia
- Russia
- United States
- Iran
- China

Over one-fourth of the crude oil produced in the United States is produced offshore in the Gulf of Mexico. The top crude oil-producing states are:





- Texas
- Alaska
- California
- Louisiana
- New Mexico

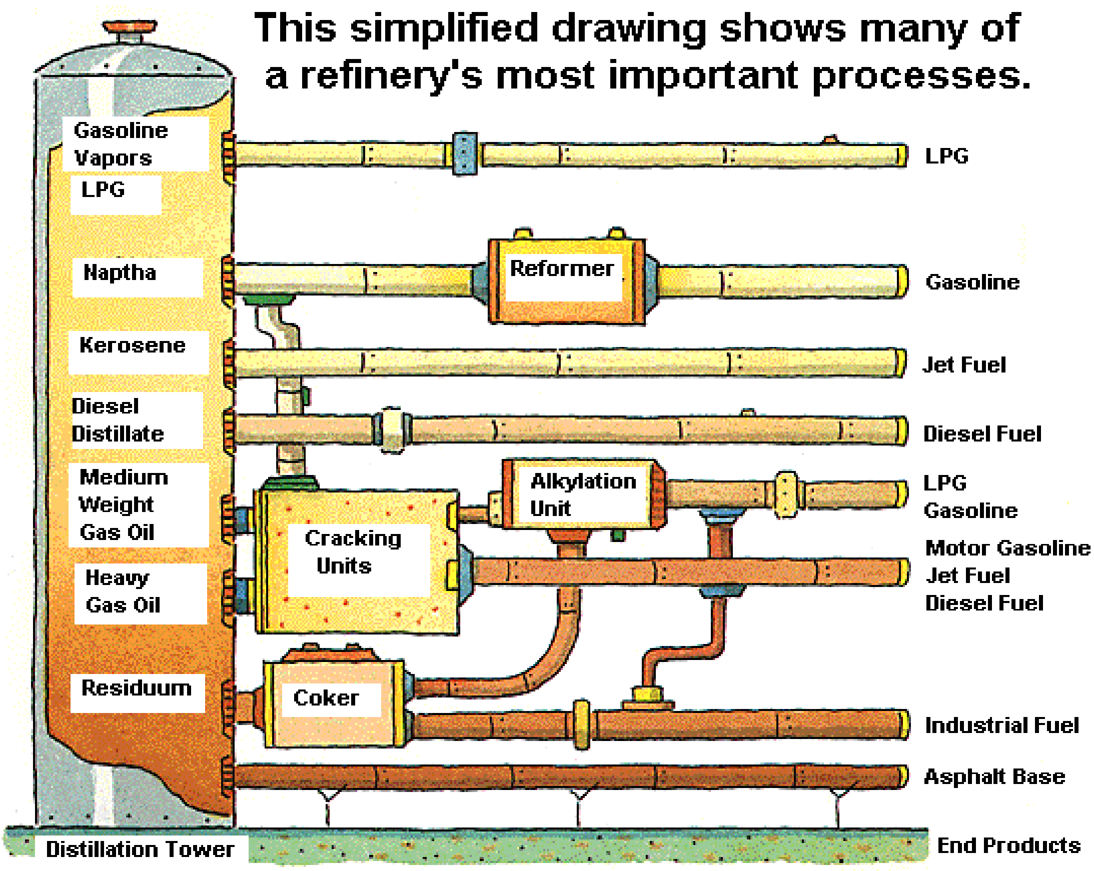
The amount of crude oil produced (domestically) in the United States has been getting smaller each year. However, the use of products made from crude oil has been growing, making it necessary to bring more oil from other countries. About 58 percent of the crude oil and petroleum products used in the United States comes from other countries.

CRUDE OIL IS MADE INTO DIFFERENT FUELS

Products Made from a Barrel of Crude Oil (Gallons)

After crude oil is removed from the ground, it is sent to a refinery by pipeline, ship or barge. At a refinery, different parts of the crude oil are separated into useable petroleum products. Crude oil is measured in barrels (abbreviated "bbls"). A 42-U.S. gallon barrel of crude oil provides slightly more than 44 gallons of petroleum products. This gain from processing the crude oil is similar to what happens to popcorn, it gets bigger after it is popped.

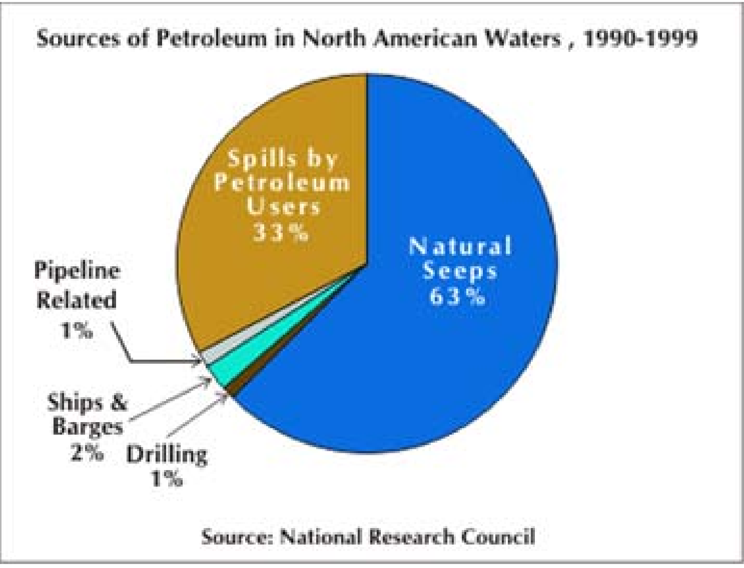
note: The gain from processing is about 5%.



One barrel of crude oil, when refined, produces about 20 gallons of finished motor gasoline, and 7 gallons of diesel, as well as other petroleum products. Most of the petroleum products are used to produce energy. For instance, many people across the United States use propane to heat their homes and fuel their cars. Other products made from petroleum include: ink, crayons, bubble gum, dishwashing liquids, deodorant, eyeglasses, records, tires, ammonia, and heart valves.

OIL AND THE ENVIRONMENT

Products from oil (petroleum products) help us do many things. We use them to fuel our airplanes, cars, and trucks, to heat our homes, and to make products like medicines and plastics. Even though petroleum products make life easier - finding, producing, moving, and using them can cause problems for our environment like air and water pollution. Over the years, new technologies and laws have helped to reduce problems related to petroleum products. As with any industry, the government monitors how oil is produced, refined, stored, and sent to market to reduce the impact on the environment. Since 1990, fuels like gasoline and diesel fuel have also been improved so that they produce less pollution when we use them.



Exploring and drilling for oil may disturb land and ocean habitats. New technologies have greatly reduced the number and size of areas disturbed by drilling, sometimes called "footprints." Satellites, global positioning systems, remote sensing devices, and 3-D and 4-D seismic technologies, make it possible to discover oil reserves while drilling fewer wells. Plus, the use of horizontal and directional drilling make it possible for a single well to produce oil from much bigger areas. Today's production footprints are only about one-fourth the size of those 30 years ago, due to the development of movable drilling rigs and smaller "slimhole" drilling rigs. When the oil in a well is gone, the well must be plugged below ground, making it hard to tell that it was ever there. As part of the "rig-to-reefs" program, some old offshore rigs are toppled and left on the sea floor to become artificial reefs that attract fish and other marine life. Within six months to a year after a rig is toppled, it becomes covered with barnacles, coral, sponges, clams, and other sea creatures.

If oil is spilled into rivers or oceans it can harm wildlife.When we talk about "oil spills" people usually think about oil that leaks from ships when they crash. Although this type of spill can cause the biggest shock to wildlife because so much oil is released at one time, only 2 percent of all oil in the sea comes from ship or barge spills. The amount of oil spilled from ships dropped a lot during the 1990's partly because new ships were required to have a "double-hull" lining to protect against spills. While oil spills from ships are the most well-known problem with oil, more oil actually gets into water from natural oil seeps coming from the ocean floor. Or, from leaks that happen when we use petroleum products on land. For example, gasoline that sometimes drips onto the ground when people are filling their gas tanks, motor oil that gets thrown away after an oil change, or fuel that escapes from a leaky storage tank. When it rains, the spilled products get washed into the gutter and eventually go to rivers and the ocean. Another way that oil sometimes gets into water is when fuel is leaked from motorboats and jet skis.

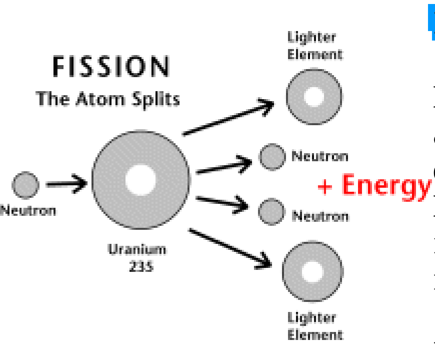
A refinery is a factory where crude oil is processed into petroleum products. Because many different pollutants can escape from refineries into the air, the government monitors refineries and other factories to make sure that they meet environmental standards.

When a leak in a storage tank or pipeline occurs, petroleum products can also get into the ground, and the ground must be cleaned up. To prevent leaks from underground storage tanks, all buried tanks are supposed to be replaced by tanks with a double-lining. This hasn't happened everywhere yet. In some places where gasoline has leaked from storage tanks, one of the gasoline ingredients called methyl tertiary butyl ether (MTBE) has made its way into local water supplies. Since MTBE makes water taste bad and many people are worried about drinking it, a number of states are banning the use of MTBE in gasoline, and the refining industry is voluntarily moving away from using it when blending reformulated gasoline.

Gasoline is used in cars, diesel fuel is used in trucks, and heating oil is used to heat our homes. When petroleum products are burned as fuel, they give off carbon dioxide, a greenhouse gas that is linked with global warming. The use of petroleum products also gives off pollutants - carbon monoxide, nitrogen oxides, particulate matter, and unburned hydrocarbons - that help form air pollution. Since a lot of air pollution comes from cars and trucks, many environmental laws have been aimed at changing the make-up of gasoline and diesel fuel so that they produce fewer emissions. These "reformulated fuels" are much cleaner-burning than gasoline and diesel fuel were in 1990. In the next few years, the amount of sulfur contained in gasoline and diesel fuel will be reduced dramatically so that they can be used with new, less-polluting engine technology.

NUCLEAR ENERGY (URANIUM) ENERGY FROM ATOMS

NUCLEAR ENERGY IS ENERGY FROM ATOMS



Nuclear energy is energy in the nucleus (core) of an atom. Atoms are tiny particles that make up every object in the universe. There is enormous energy in the bonds that hold atoms together.
Nuclear energy can be used to make electricity. But first the energy must be released. It can be released from atoms in two ways: nuclear fusion and nuclear fission.

In **nuclear fusion**, energy is released when atoms are combined or fused together to form a larger atom. This is how the sun produces energy.

In **nuclear fission**, atoms are split apart to form smaller atoms, releasing energy. Nuclear power plants use nuclear fission to produce electricity.

NUCLEAR FUEL - URANIUM

The fuel most widely used by nuclear plants for nuclear fission is uranium. Uranium is nonrenewable, though it is a common metal found in rocks all over the world. Nuclear plants use a certain kind of uranium, U-235, as fuel because its atoms are easily split apart. Though uranium is quite common, about 100 times more common than silver, U-235 is relatively rare. Most U.S. uranium is mined, in the Western United States. Once uranium is mined the U-235 must be extracted and processed before it can be used as a fuel.

During nuclear fission, a small particle called a neutron hits the uranium atom and it splits, releasing a great amount of energy as heat and radiation. More neutrons are also released. These neutrons go on to bombard other uranium atoms, and the process repeats itself over and over again. This is called a chain reaction.

NUCLEAR POWER PLANTS GENERATE ELECTRICITY

Nuclear power accounts for about 19 percent of the total net electricity generated in the United States, about as much as the electricity used in California,Texas and New York, the three states with the most people. In 2005, there were 66 nuclear power plants(composed of 104 licensed nuclear reactors) throughout the United States.

Most power plants burn fuel to produce electricity, but not nuclear power plants. Instead, nuclear plants use the heat given off during fission as fuel. Fission takes place inside the reactor of a nuclear power plant. At the center of the reactor is the core, which contains the uranium fuel.

The uranium fuel is formed into ceramic pellets. The pellets are about the size of your fingertip, but each one produces the same amount of energy as 150 gallons of oil. These energy-rich pellets are stacked end-to-end in 12-foot metal fuel rods. A bundle of fuel rods is called a fuel assembly.

Fission generates heat in a reactor just as coal generates heat in a boiler. The heat is used to boil water into steam. The steam turns huge turbine blades. As they turn, they drive generators that make electricity. Afterward, the steam is changed back into water and cooled in a separate structure at the power plant called a cooling tower. The water can be used again and again.

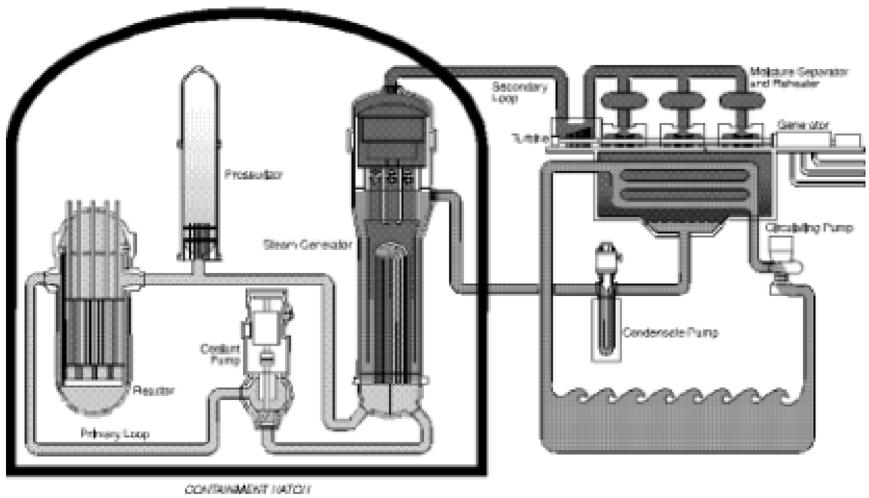
TYPES OF REACTORS

Just as there are different approaches to designing and building airplanes and automobiles, engineers have developed different types of nuclear power plants. Two types are used in the United States: boiling-water reactors (BWRs), and pressurized-water reactors (PWRs).

In the BWR, the water heated by the reactor core turns directly into steam in the reactor vessel and is then used to power the turbine-generator. In a PWR, the water passing through the reactor core is kept under pressure so that it does not turn to steam at all -- it remains liquid. Steam to drive the turbine is generated in a separate piece of equipment called a steam generator. A steam generator is a giant cylinder with thousands of tubes in it through which the hot radioactive water can flow. Outside the tubes in the steam generator, nonradioactive water (or clean water) boils and eventually turns to steam. The clean water may come from one of several sources: oceans, lakes or rivers. The radioactive water flows back to the reactor core, where it is reheated, only to flow back to the steam generator. Roughly seventy percent of the reactors operating in the U.S. are PWR.

Nuclear reactors are basically machines that contain and control chain reactions, while releasing heat at a controlled rate. In electric power plants, the reactors supply the heat to turn water into steam, which drives the turbine-generators. The electricity travels through high voltage transmission lines and low voltage distribution lines to homes, schools, hospitals, factories, office buildings, rail systems and other users.

Figure FE1. Nuclear Steam Supply System
(U-bend Design Steam Generator)



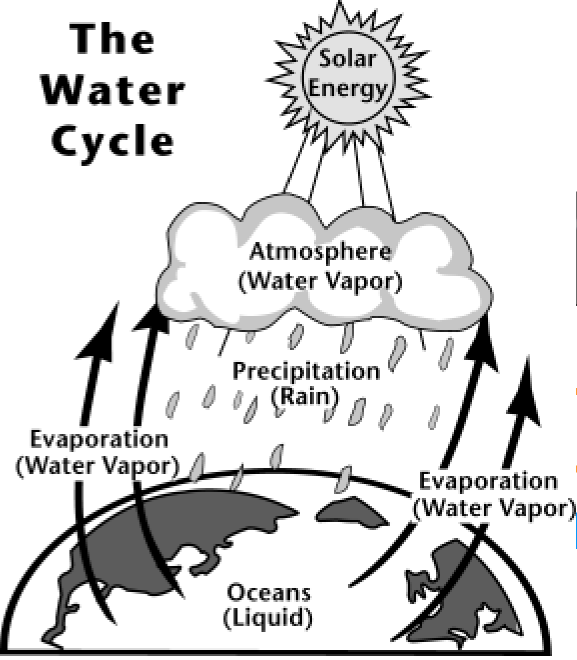
NUCLEAR POWER AND THE ENVIRONMENT

Like all industrial processes, nuclear power generation has by-product wastes: spent (used) fuels, other radioactive waste, and heat. Because nuclear generated electricity does not emit carbon dioxide into the atmosphere, nuclear power plants in the U.S. prevent emissions of about 700 million metric tons of carbon dioxide. This is nearly as much carbon dioxide as is released from all U.S. passenger cars combined.

Spent fuels and other radioactive wastes are the principal environmental concern for nuclear power. Most nuclear waste is low-level radioactive waste. It consists of ordinary tools, protective clothing, wiping cloths and disposable items that have been contaminated with small amounts of radioactive dust or particles. These materials are subject to special regulation that govern their disposal so they will not come in contact with the outside environment.

On the other hand, the spent fuel assemblies are highly radioactive and must initially be stored in specially designed pools resembling large swimming pools (water cools the fuel and acts as a radiation shield) or in specially designed dry storage containers. An increasing number of reactor operators now store their older and less spent fuel in dry storage facilities using special outdoor concrete or steel containers with air cooling. The United States Department of Energy's long range plan is for this spent fuel to be stored deep in the earth in a geologic repository, at Yucca Mountain, Nevada.

Yucca Mountain
Planned site for the nation's first long-term geological repository for nuclear waste.



Hydropower -- Energy from Moving Water

HYDROPOWER GENERATES ELECTRICITY

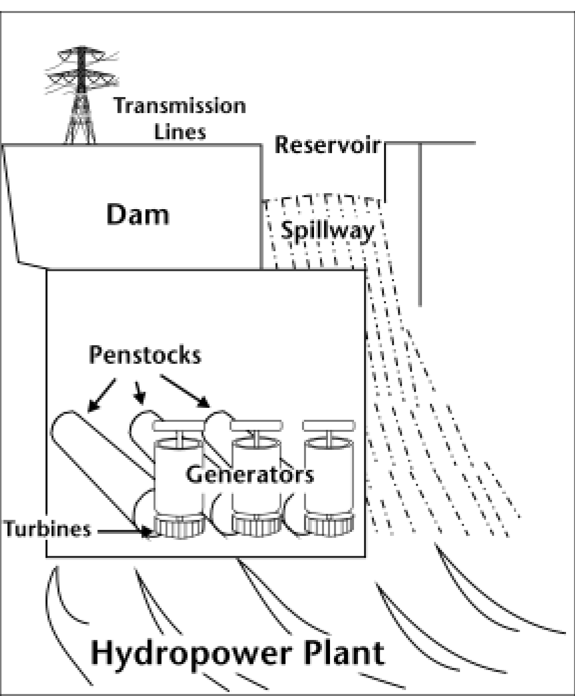
Of the renewable energy sources that generate electricity, hydropower is the most often used. It accounted for 7 percent of total U.S. electricity generation and 75 percent of generation from renewables.

It is one of the oldest sources of energy and was used thousands of years ago to turn a paddle wheel for purposes such as grinding grain. Our nation's first industrial use of hydropower to generate electricity occurred in 1880, when 16 brush-arc lamps were powered using a water turbine at the Wolverine Chair Factory in Grand Rapids, Michigan. The first U.S. hydroelectric power plant opened on the Fox River near Appleton, Wisconsin, on September 30, 1882. Until that time, coal was the only fuel used to produce electricity. Because the source of hydropower is water, hydroelectric power plants must be located on a water source. Therefore, it wasn't until the technology to transmit electricity over long distances was developed that hydropower became widely used.

HOW HYDROPOWER WORKS

Understanding the water cycle is important to understanding hydropower. In the water cycle -

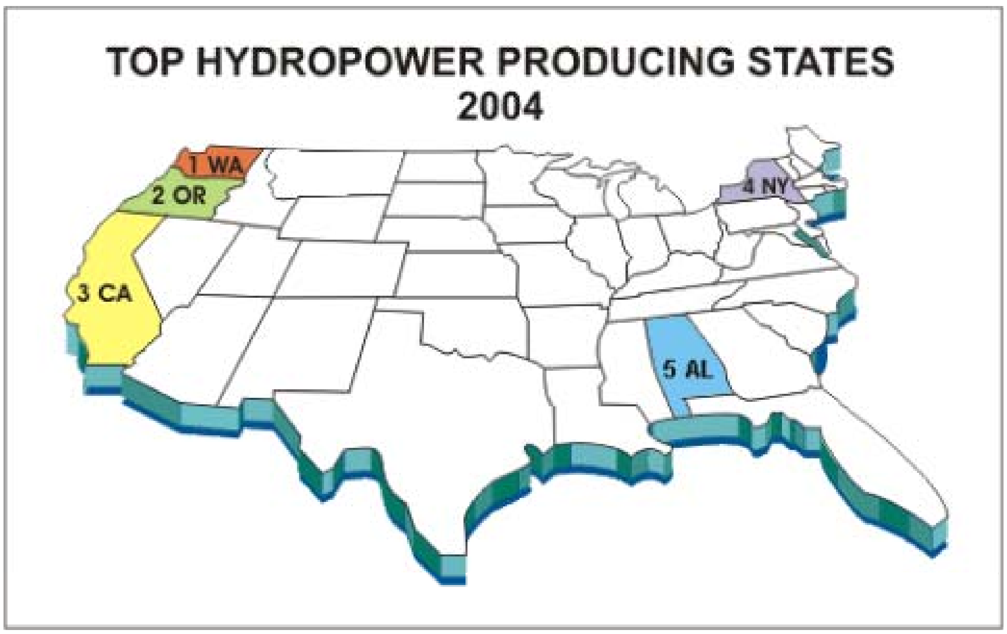
- Solar energy heats water on the surface, causing it to evaporate.
- This water vapor condenses into clouds and falls back onto the surface as precipitation.
- The water flows through rivers back into the oceans, where it can evaporate and begin the cycle over again.



Mechanical energy is derived by directing, harnessing, or channeling moving water. The amount of available energy in moving water is determined by its *flow* or *fall*. Swiftly flowing water in a big river, like the Columbia River along the border between Oregon and Washington, carries a great deal of energy in its flow. So, too, with water descending rapidly from a very high point, like Niagara Falls in New York. In either instance, the water flows through a pipe, or *penstock*, then pushes against and turns blades in a turbine to spin a generator to produce electricity. In a *run-of-the-river system*, the force of the current applies the needed pressure, while in a *storage system*, water is accumulated in reservoirs created by dams, then released when the demand for electricity is high. Meanwhile, the reservoirs or lakes are used for boating and fishing, and often the rivers beyond the dams provide opportunities for whitewater rafting and kayaking. Hoover Dam, a hydroelectric facility completed in 1936 on the Colorado River between Arizona and Nevada, created Lake Mead, a 110-mile-long national recreational area that offers water sports and fishing in a desert setting.

WHERE HYDROPOWER IS GENERATED

Over one-half of the total U.S. hydroelectric capacity for electricity generation is concentrated in three States (Washington, California and Oregon) with approximately 27 percent in Washington, the location of the Nation's largest hydroelectric facility – the Grand Coulee Dam.



It is important to note that only a small percentage of all dams in the United States produce electricity. Most dams were constructed solely to provide irrigation and flood control.

HYDROPOWER AND THE ENVIROMENT

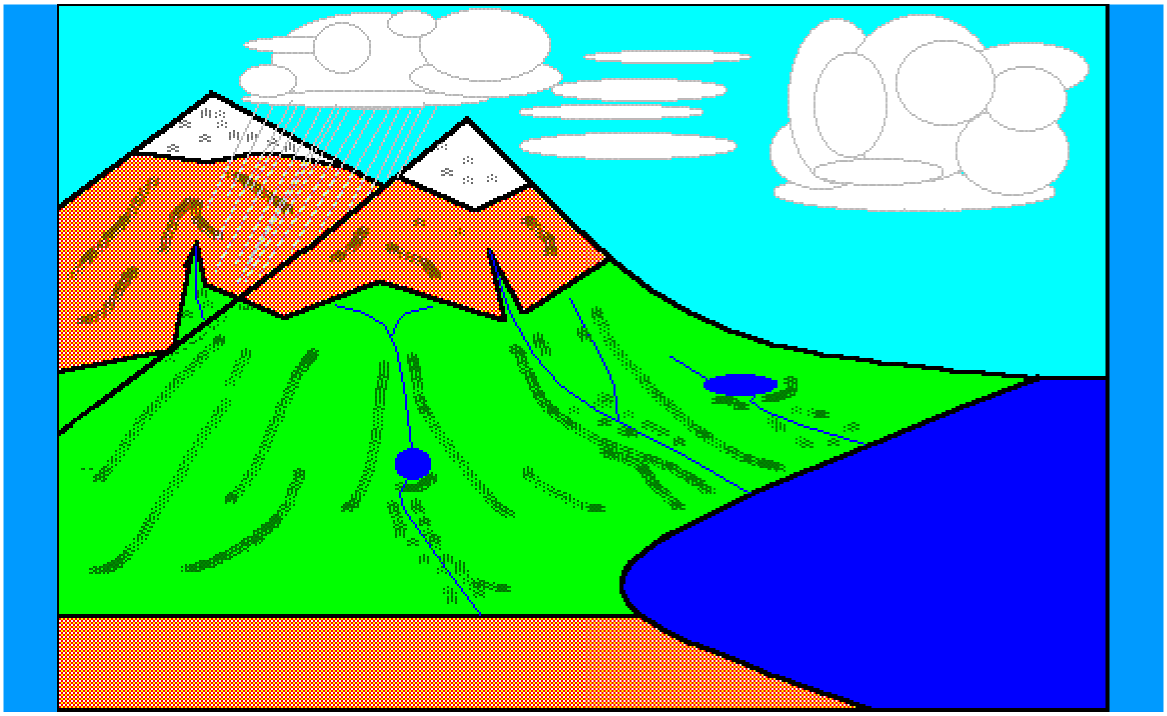
Some people regard hydropower as the ideal fuel for electricity generation because, unlike the nonrenewable fuels used to generate electricity, it is almost free, there are no waste products, and hydropower does not pollute the water or the air. However, it is criticized because it does change the environment by affecting natural habitats. For instance, in the Columbia River, salmon must swim upstream to their spawning grounds to reproduce, but the series of dams gets in their way. Different approaches to fixing this problem have been used, including the construction of "fish ladders" which help the salmon "step up" the dam to the spawning grounds upstream.

Cheap Energy vs the Environment
The Case of Hydroelectric Power

Historical Growth of Hydroelectric power:

- **Currently Hydro power is 7% of the total US Energy Budget. This has been going decreasing with time**
- **This varies considerably with region in the US due to the availability of freely flowing streams**
- **Dam building really was initiated in the 1930's as part of a public works program to combat the depression**
- **Low cost per KWH (see below) caused exponential increase of dam building from 1950-1970 (lots of this on the Columbia)**
- **Since 1970 hydroproduction has levelled off and therefore becomes an increasingly smaller percentage of the US energy budget.**

Hydropower is a natural renewable energy source as it makes use of The Hydrological Cycle:



Hydropower production is sensitive to secular evolution of weather; seasonal snowpacks, etc, etc. Long term droughts (10 years or so) seem to occur frequently in the West

About 30% of the hydropotential in the US has been tapped to date

Why is Hydro so attractive?

- **BECAUSE ITS CHEAP! for the consumer ☞ average price in the PNW is around 4 cents per KWH ☞ this is 3 times less than the national average!**
- **Low cost to the consumer reflect relatively low operating costs of the Hydro Facility. Most of the cost is in building the dam**
- **Operating costs about 0.6 cents per KWH**
- **Coal Plant averages around 2.2 cents per KWH ☞ which reflects costs of mining, transport and distribution.**

Energy density in stored elevated water is high:

So one liter of water per second on a turbine generates 720 watts of power. If this power can be continuously genreated for 24 hours per day for one month then the total number of KWH per month is then:

720 watts x 24 hours/day x 30 days/month = 518 Kwh/month.

Power generating capacity is directly proportional to the height the water falls. For a fall of say only 3 m, 30 times less electricity would be generated (e.g. 17 Kwh/month) - but this is just for a miniscule flow rate of 1 kg/sec.

Capacities of some large dams:

Grand Coulee	1942	6500 MW
John Day	1969	2200 MW
Niagara (NY)	1961	2000 MW
The Dalles	1957	1800 MW
Chief Joseph	1956	1500 MW
McNary	1954	1400 MW
Hoover	1936	1345 MW
Glen Canyon	1964	950 MW
Three Gorges	2000	18000 Mw

Pacific Northwest has 58 hydroelectric dams 63% of total electricity generated. Most of the rest comes from coal fired steam plants (e.g. Centralia Washington).

Note, the Trojan Nuclear Power Plant was relatively easy to shut down because replacement power was immediately available.

Again the main advantages of Hydro are a) its renewable and b) there is a lot of energy available:

Some Real Disadvantages:

Hydroelectric Power - The Risks:

Dams are frequently located upstream from major population centers:

- **1918--1958: 33 Major dam failures resulting in 1680 documented fatalities**
- **1959--1965: 9 major dams failed throughout the world**
- **1976: Teton Dam failure in Idaho**
- **Most of the dams on the columbia have been built since 1950 and are not close to their failure points**
- **The Salmon Problem:**
  - **Extremely Emotional Issue --> icon of the PNW**
  - **Some Federal Dam Licenses can now be lost because of salmon migration problems**
    - **Some studies suggest Federal dams are mostly resonsible for drop from 16 million to 300,000 wild fish per year**
    - **Actual Salmon Count data is available for these dam sites:**
      - **John Day Dam**
      - **Bonneville Dam**
      - **Lower Monumental Dam**
      - **McNary Dam**
      - **The Dalles**
      - **Ice Harbor Dam**
      - **Lower Granite Dam**
      - **Little Goose Dam**
  - **Estimated that to improve migration, utility rates will rise in the PNW by 8%**
  - **There are lots of other factors at work as well:**
    - **El Nino**
    - **Agressive Fishing**

- **Poor logging practices and increased soil erosion**

Note that reservoirs offer expanded habitat for geese, pelicans, eagles, osprey. They also help with flood control thus minimizing soil erosion in the watershed.

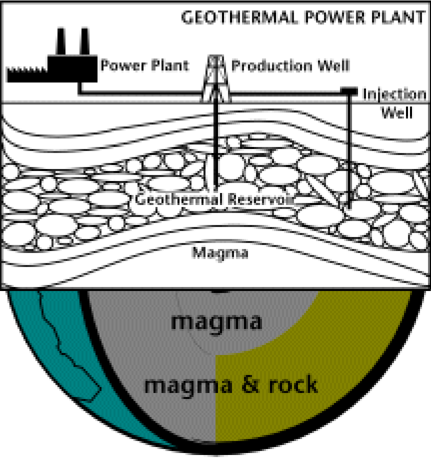
Adverse effects of dams on salmon:

- **migratory barrier**
- **killed in turbines (especially young ones swimming downstream)**
- **supersaturation of air in water (high pressure of water falling down forces air into the solution)**
- **reduced oxygen content if river flow is reduced (summer) due to separation of warm and cold water; cold water doesn't mix to be aerated (this is mostly a problem in the Tennesee Valley)**

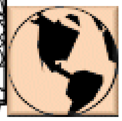
Solutions:

- **Build fish "passages" to direct them towards tributaries this has proven successful for trout in Oregon**
- **Better turbine design and screen systems can help eliminate fishkill on the downstream migration**
- **Minimize turbulence in the operation of the turbine**

  Have better flow control



THE EARTH'S INTERIOR



Geothermal Energy -- Energy from the Earth's Core

The word **geothermal** comes from the Greek words geo (earth) and therme (heat).

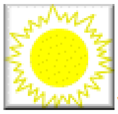
On May 18, 1980, Mt. St. Helens, an active volcano in Washington, erupted (leave this site to see a picture), providing a vivid display of the energy contained within the Earth. Most volcanic activity occurs around the Pacific Ocean's rim, the Ring of Fire.

Volcanic energy cannot be harnessed (controlled and collected), but in a few places heat from the earth, called geothermal energy, can be collected. Usually, engineers try to collect this heat in the rare places where the Earth's crust has trapped steam and hot water. Here, they drill into the crust and allow the heat to escape, either as steam, or as very hot water. Pipes carry the hot water to a plant, where some of the steam is allowed to "flash," or separate from the water. That steam then turns a turbine - generator to make electricity.

Geothermal energy was first used to produce electricity in Italy in 1903. At the end of 2004, there were 43 power plants producing electricity from geothermal energy in the USA. Most of these are located in California and Nevada; Utah has two geothermal plants and Hawaii, formed by volcanic eruptions, has one. Generation from geothermal sources is therefore "site specific," meaning it's only possible in a few places under unique geologic conditions. One such site in California, called The Geysers, can produce almost as much electricity as all the other geothermal sites combined.

Geothermal energy can be used as an efficient heat source in small end-use applications such as greenhouses, but the consumers have to be located close to the source of heat. The capital of Iceland, Reykjavik, is heated mostly by geothermal energy.

Geothermal energy has a major environmental benefit because it offsets air pollution that would have been produced if fossil fuels were the energy source. Geothermal energy has a very minor impact on the soil - the few acres used look like a small light-industry building complex. Since the slightly cooler water is reinjected into the ground, there is only a minor impact, except if there is a natural geyser field close by. For this reason, tapping into the geothermal resources of Yellowstone National Park is prohibited by Law.



Solar Energy -- Energy from the Sun

ENERGY FROM THE SUN

The sun has produced energy for billions of years. Solar energy is the solar radiation that reaches the earth.

Solar energy can be converted directly or indirectly into other forms of energy, such as heat and electricity. The major drawbacks (problems, or issues to overcome) of solar energy are: (1) the intermittent and variable manner in which it arrives at the earth's surface and, (2) the large area required to collect it at a useful rate.

Solar energy is used for heating water for domestic use, space heating of buildings, drying agricultural products, and generating electrical energy.

In the 1830s, the British astronomer John Herschel used a solar collector box to cook food during an expedition to Africa. Now, people are trying to use the sun's energy for lots of things.

Electric utilities are trying photovoltaics, a process by which solar energy is converted directly to electricity. Electricity can be produced directly from solar energy using photovoltaic devices or indirectly from steam generators using solar thermal collectors to heat a working fluid.

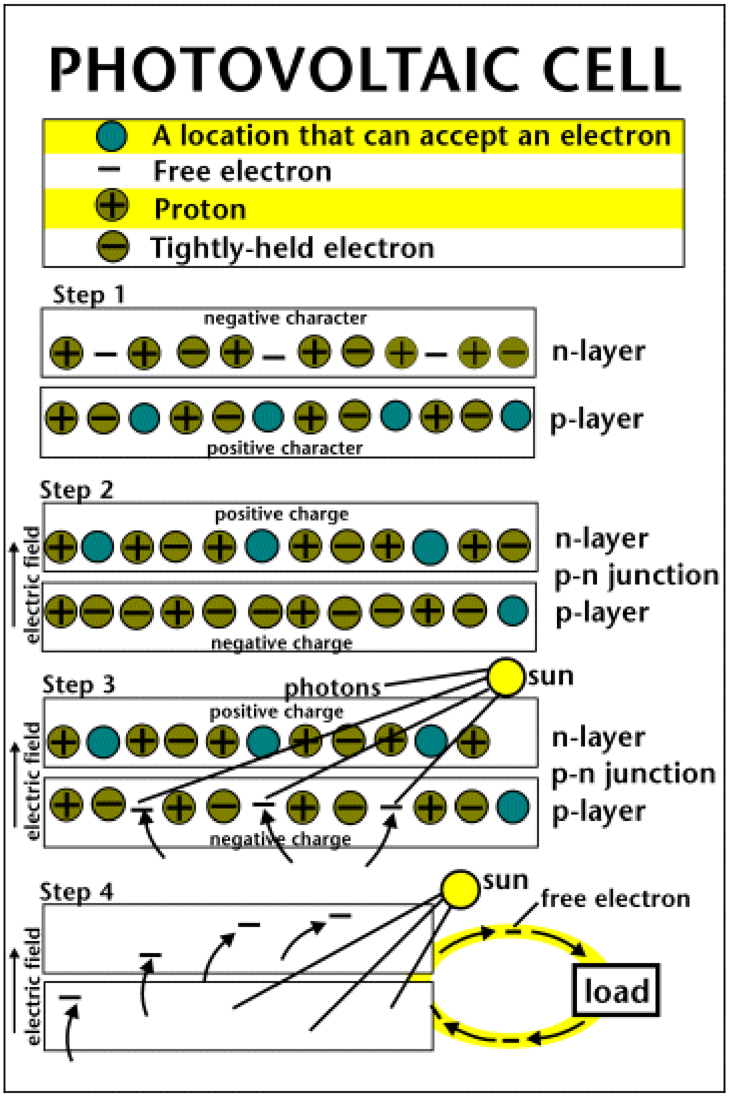
Out of the 14 known solar electric generating units operating in the US at the end of 2004, 10 of these are in California, and 4 in Arizona. No statistics are being collected on solar plants that produce less than 1 megawatt of electricity, so there may be smaller solar plants in a number of other states.

PHOTOVOLTAIC ENERGY

Photovoltaic energy is the conversion of sunlight into electricity through a photovoltaic (PVs) cell, commonly called a solar cell. A photovoltaic cell is a nonmechanical device usually made from silicon alloys.

Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity. When enough sunlight (energy) is absorbed by the material (a semiconductor), electrons are dislodged from the material's atoms.

Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to free electrons, so the electrons naturally migrate to the surface.



When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When the two surfaces are connected through an external load, electricity flows.

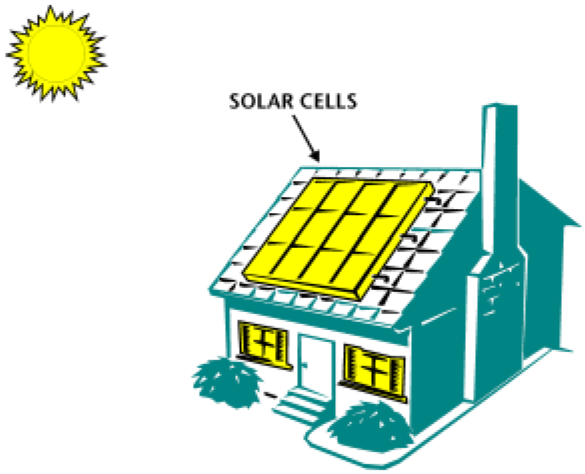
The photovoltaic cell is the basic building block of a PV system. Individual cells can vary in size from about 1 cm (1/2 inch) to about 10 cm (4 inches) across. However, one cell only produces 1 or 2 watts, which isn't enough power for most applications. To increase power output, cells are electrically connected into a packaged weather-tight module. Modules can be further connected to form an array. The term array refers to the entire generating plant, whether it is made up of one or several thousand modules. As many modules as needed can be connected to form the array size (power output) needed.

The performance of a photovoltaic array is dependent upon sunlight. Climate conditions (e.g., clouds, fog) have a significant effect on the amount of solar energy received by a PV array and, in turn, its performance. Most current technology photovoltaic modules are about 10 percent efficient in converting sunlight with further research being conducted to raise this efficiency to 20 percent.

The pv cell was discovered in 1954 by Bell Telephone researchers examining the sensitivity of a properly prepared silicon wafer to sunlight. Beginning in the late 1950s, pvs were used to power U.S. space satellites. The success of PVs in space generated commercial applications for pv technology. The simplest photovoltaic systems power many of the small calculators and wrist watches used everyday. More complicated systems provide electricity to pump water, power communications equipment, and even provide electricity to our homes.

Photovoltaic conversion is useful for several reasons. Conversion from sunlight to electricity is direct, so that bulky mechanical generator systems are unnecessary. The modular characteristic of photovoltaic energy allows arrays to be installed quickly and in any size required or allowed.

Also, the environmental impact of a photovoltaic system is minimal, requiring no water for system cooling and generating no by-products. Photovoltaic cells, like batteries, generate direct current (DC) which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using inverters, solid state devices that convert DC power to AC. Historically, pvs have been used at remote sites to provide electricity. However, a market for distributed generation from PVs may be developing with the unbundling of transmission and distribution costs due to electric deregulation. The siting of numerous small-scale generators in electric distribution feeders could improve the economics and reliability of the distribution system.



SOLAR THERMAL HEAT

The major applications of solar thermal energy at present are heating swimming pools, heating water for domestic use, and space heating of buildings. For these purposes, the general practice is to use flat-plate solar-energy collectors with a fixed orientation (position).

Where space heating is the main consideration, the highest efficiency with a fixed flat-plate collector is obtained if it faces approximately south and slopes at an angle to the horizon equal to the latitude plus about 15 degrees.

Solar collectors fall into two general categories: nonconcentrating and concentrating.

In the nonconcentrating type, the collector area (i.e. the area that intercepts the solar radiation) is the same as the absorber area (i.e., the area absorbing the radiation).

In concentrating collectors, the area intercepting the solar radiation is greater, sometimes hundreds of times greater, than the absorber area. Where temperatures below about 200o F are sufficient, such as for space heating, flat-plate collectors of the nonconcentrating type are generally used.

There are many flat-plate collector designs but generally all consist of (1) a flat-plate absorber, which intercepts and absorbs the solar energy, (2) a transparent cover(s) that allows solar energy to pass through but reduces heat loss from the absorber, (3) a heat-transport fluid (air or water) flowing through tubes to remove heat from the absorber, and (4) a heat insulating backing.

Solar space heating systems can be classified as passive or active. In passive heating systems, the air is circulated past a solar heat surface(s) and through the building by convection (i.e. less dense warm air tends to rise while more dense cooler air moves downward) without the use of mechanical equipment. In active heating systems, fans and pumps are used to circulate the air or the heat absorbing fluid.

SOLAR THERMAL POWER PLANTS

Solar thermal power plants use the sun's rays to heat a fluid, from which heat transfer systems may be used to produce steam. The steam, in turn, is converted into mechanical energy in a turbine and into electricity from a conventional generator coupled to the turbine. Solar thermal power generation is essentially the same as conventional technologies except that in conventional technologies the energy source is from the stored energy in fossil fuels released by combustion. Solar thermal technologies use concentrator systems due to the high temperatures needed for the working fluid. The three types of solar-thermal power systems in use or under development are: parabolic trough, solar dish, and solar power tower.

PARABOLIC TROUGH

The parabolic trough is used in the largest solar power facility in the world located in the Mojave Desert at Kramer Junction, California. This facility has operated since the 1980’s and accounted for the majority of solar electricity produced by the electric power sector in 2004.

A parabolic trough collector has a linear parabolic-shaped reflector that focuses the sun's radiation on a linear receiver located at the focus of the parabola. The collector tracks the sun along one axis from east to west during the day to ensure that the sun is continuously focused on the receiver. Because of its parabolic shape, a trough can focus the sun at 30 to 100 times its normal intensity (concentration ratio) on a receiver pipe located along the focal line of the trough, achieving operating temperatures over 400 degrees Celcius.

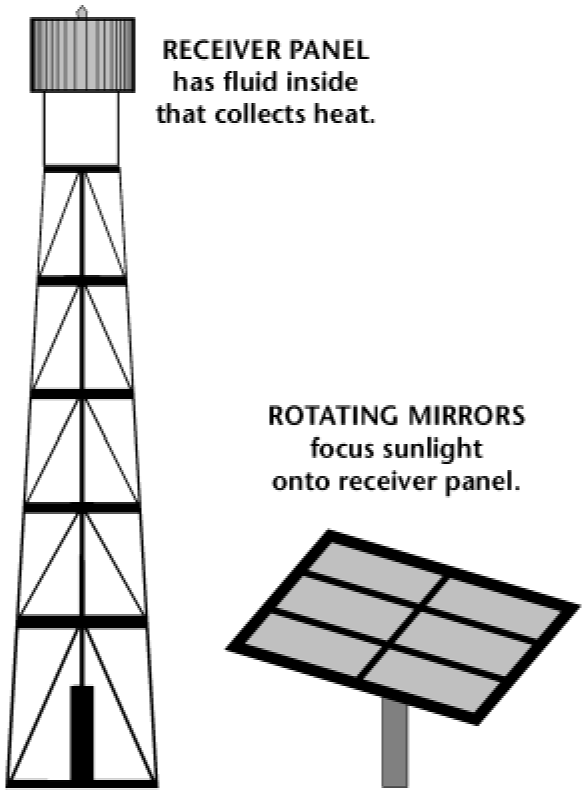
A collector field consists of a large field of single-axis tracking parabolic trough collectors. The solar field is modular in nature and is composed of many parallel rows of solar collectors aligned on a north-south horizontal axis. A working (heat transfer) fluid is heated as it circulates through the receivers and returns to a series of heat exchangers at a central location where the fluid is used to generate high-pressure superheated steam. The steam is then fed to a conventional steam turbine/generator to produce electricity. After the working fluid passes through the heat exchangers, the cooled fluid is recirculated through the solar field. The plant is usually designed to operate at full rated power using solar energy alone, given sufficient solar energy. However, all plants are hybrid solar/fossil plants that have a fossil-fired capability that can be used to supplement the solar output during periods of low solar energy. The Luz plant is a natural gas hybrid.

SOLAR DISH

A solar dish/engine system utilizes concentrating solar collectors that track the sun on two axes, concentrating the energy at the focal point of the dish because it is always pointed at the sun. The solar dish's concentration ratio is much higher that the solar trough, typically over 2,000, with a working fluid temperature over 750^{o}C. The power-generating equipment used with a solar dish can be mounted at the focal point of the dish, making it well suited for remote operations or, as with the solar trough, the energy may be collected from a number of installations and converted to electricity at a central point. The engine in a solar dish/engine system converts heat to mechanical power by compressing the working fluid when it is cold, heating the compressed working fluid, and then expanding the fluid through a turbine or with a piston to produce work. The engine is coupled to an electric generator to convert the mechanical power to electric power.

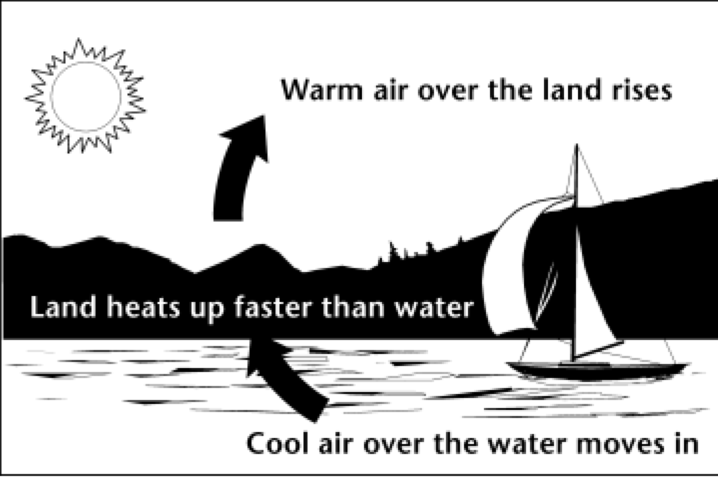
SOLAR POWER TOWER

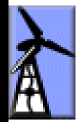
A solar power tower or central receiver generates electricity from sunlight by focusing concentrated solar energy on a tower-mounted heat exchanger (receiver). This system uses hundreds to thousands of flat sun-tracking mirrors called heliostats to reflect and concentrate the sun's energy onto a central receiver tower. The energy can be concentrated as much as 1,500 times that of the energy coming in from the sun. Energy losses from thermal-energy transport are minimized as solar energy is being directly transferred by reflection from the heliostats to a single receiver, rather than being moved through a transfer medium to one central location, as with parabolic troughs. Power towers must be large to be economical. This is a promising technology for large-scale grid-connected power plants. Though power towers are in the early stages of development compared with parabolic trough technology, a number of test facilities have been constructed around the world.



SOLAR POWER TOWER

The U.S. Department of Energy along with a number of electric utilities built and operated a demonstration solar power tower near Barstow, California, during the 1980's and 1990's. Learn more about the history of solar power in the Solar Timeline.





Wind Energy -- Energy from Moving Air

ENERGY FROM WIND

Wind is simple air in motion. It is caused by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of very different types of land and water, it absorbs the sun's heat at different rates.

During the day, the air above the land heats up more quickly than the air over water. The warm air over the land expands and rises, and the heavier, cooler air rushes in to take its place, creating winds. At night, the winds are reversed because the air cools more rapidly over land than over water.

In the same way, the large atmospheric winds that circle the earth are created because the land near the earth's equator is heated more by the sun than the land near the North and South Poles.

Today, wind energy is mainly used to generate electricity. Wind is called a renewable energy source because the wind will blow as long as the sun shines.

The History of Wind

Since ancient times, people have harnessed the winds energy. Over 5,000 years ago, the ancient Egyptians used wind to sail ships on the Nile River. Later, people built windmills to grind wheat and other grains. The earliest known windmills were in Persia (Iran). These early windmills looked like large paddle wheels. Centuries later, the people of Holland improved the basic design of the windmill. They gave it propeller-type blades, still made with sails. Holland is famous for its windmills.

American colonists used windmills to grind wheat and corn, to pump water, and to cut wood at sawmills. As late as the 1920s, Americans used small windmills to generate electricity in rural areas without electric service. When power lines began to transport electricity to rural areas in the 1930s, local windmills were used less and less, though they can still be seen on some Western ranches.

The oil shortages of the 1970s changed the energy picture for the country and the world. It created an interest in alternative energy sources, paving the way for the re-entry of the windmill to generate electricity. In the early 1980s wind energy really took off in California, partly because of state policies that encouraged renewable energy sources. Support for wind development has since spread to other states, but California still produces more than twice as much wind energy as any other state.

The first offshore wind park in the United States is planned for an area off the coast of Cape Cod, Massachusetts (read an article about the Cape Cod Wind Project).

HOW WIND MACHINES WORK

Like old fashioned windmills, today's wind machines use blades to collect the wind's kinetic energy. Windmills work because they slow down the speed of the wind. The wind flows over the airfoil shaped blades causing lift, like the effect on airplane wings, causing them to turn. The blades are connected to a drive shaft that turns an electric generator to produce electricity.

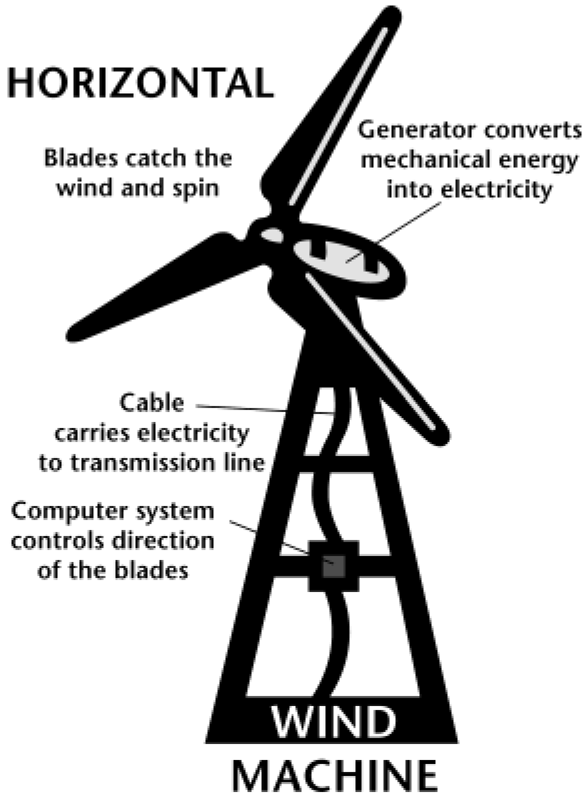
With the new wind machines, there is still the problem of what to do when the wind isn't blowing. At those times, other types of power plants must be used to make electricity.

TYPES OF WIND MACHINES

There are two types of wind machines used today: horizontal–axis wind machines and vertical-axis wind machines. Most windmills are the horizontal-axis type. One wind machine can produce 1.5 to 4.0 million kilowatthours (kWh) of electricity a year. That is enough electricity for to power 150-400 homes.

Horizontal-axis

Horizontal-axis wind machines have blades like airplane propellers. A typical horizontal wind machine stands as tall as a 20-story building and has three blades that span 200 feet across. The largest wind machines in the world have blades longer than a football field! Wind machines stand tall and wide to capture more wind.



Vertical-axis

Vertical–axis wind machines have blades that go from top to bottom and look like giant egg beaters. The typical vertical wind machine stands 100 feet tall and 50 feet wide. Vertical-axis wind machines make up just five percent of the wind machines used today.

The Wind Amplified Rotor Platform (WARP) is a different kind of wind system that is designed to be more efficient and use less land than wind machines in use today. The WARP does not use large blades; instead, it looks like a stack of wheel rims. Each module has a pair of small, high capacity turbines mounted to both of its concave wind amplifier module channel surfaces. The concave surfaces channel wind toward the turbines, amplifying wind speeds by 50 percent or more. Eneco, the company that designed WARP, plans to market the technology to power offshore oil platforms and wireless telecommunications systems.

WIND POWER PLANTS

Wind power plants, or **wind farms** as they are sometimes called, are clusters of wind machines used to produce electricity. A wind farm usually has dozens of wind machines scattered over a large area. The Big Spring Wind Power Project in Texas has 46 wind turbines that generate enough electricity to power 7,300 homes.

Unlike power plants, many wind plants are not owned by public utility companies. Instead they are owned and operated by business people who sell the electricity produced on the wind farm to electric utilities. These private companies are known as Independent Power Producers.

Operating a wind power plant is not as simple as just building a windmill in a windy place. Wind plant owners must carefully plan where to locate their machines. One important thing to consider is how fast and how much the wind blows.

As a rule, wind speed increases with altitude and over open areas with no windbreaks. Good sites for wind plants are the tops of smooth, rounded hills, open plains or shorelines, and mountain gaps that produce wind funneling.

Wind speed varies throughout the country. It also varies from season to season. In Tehachapi, California, the wind blows more from April through October than it does in the winter. This is because of the extreme heating of the Mojave Desert during the summer months. The hot air over the desert rises, and the cooler, denser air above the Pacific Ocean rushes through the Tehachapi mountain pass to take its place. In a state like Montana, on the other hand, the wind blows more during the winter. Fortunately, these seasonal variations are a good match for the electricity demands of the regions. In California, people use more electricity during the summer for air conditioners. In Montana, people use more electricity during the winter months for heating.

WIND PRODUCTION

All together, wind machines in the United States generate 17 billion kWh per year of electricity, enough to serve 1.6 million households. This is enough electricity to power a city the size of Chicago, but it is only a small fraction of the nation's total electricity production, about 0.4 percent. The amount of electricity generated from wind has been growing fast in recent years, tripling since 1998.
New technologies have decreased the cost of producing electricity from wind, and growth in wind power has been encouraged by tax breaks for renewable energy and green pricing programs. Many utilities around the country offer green pricing options that allow customers the choice to pay more for electricity that comes from renewable sources.

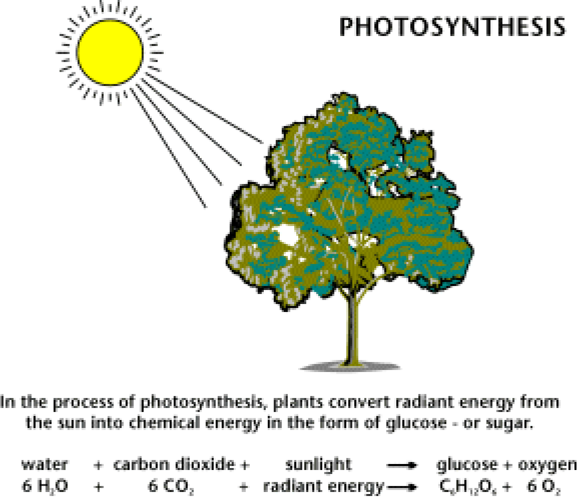
Wind machines generate electricity in 30 different states. The states with the most wind production are California, Texas, Minnesota, Iowa, and Wyoming.

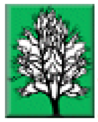
The United States ranks third in the world in wind power capacity, behind Germany and Spain. Most of the wind power plants in the world are located in Europe and in the United States where government programs have helped support wind power development.

WIND AND THE ENVIRONMENT

In the 1970s, oil shortages pushed the development of alternative energy sources. In the 1990s, the push came from a renewed concern for the environment in response to scientific studies indicating potential changes to the global climate if the use of fossil fuels continues to increase. Wind energy offers a viable, economical alternative to conventional power plants in many areas of the country. Wind is a clean fuel; wind farms produce no air or water pollution because no fuel is burned.

The most serious environmental drawbacks to wind machines may be their negative effect on wild bird populations and the visual impact on the landscape. To some, the glistening blades of windmills on the horizon are an eyesore; to others, they're a beautiful alternative to conventional power plants.



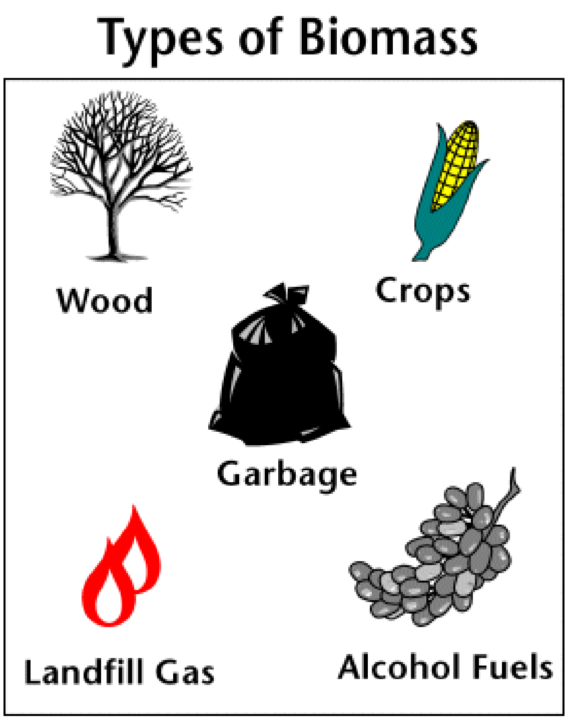


BIOMASS -- Renewable Energy from Plants and Animals

BIOMASS -- ENERGY FROM PLANT AND ANIMAL MATTER

Biomass is organic material made from plants and animals. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. The chemical energy in plants gets passed on to animals and people that eat them. Biomass is a renewable energy source because we can always grow more trees and crops, and waste will always exist. Some examples of biomass fuels are wood, crops, manure, and some garbage.

When burned, the chemical energy in biomass is released as heat. If you have a fireplace, the wood you burn in it is a biomass fuel. Wood waste or garbage can be burned to produce steam for making electricity, or to provide heat to industries and homes.



Burning biomass is not the only way to release its energy. Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Methane gas is the main ingredient of natural gas. Smelly stuff, like rotting garbage, and agricultural and human waste, release methane gas - also called "landfill gas" or "biogas." Crops like corn and sugar cane can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats.

Biomass fuels provide about 3 percent of the energy used in the United States. People in the USA are trying to develop ways to burn more biomass and less fossil fuels. Using biomass for energy can cut back on waste and support agricultural products grown in the United States. Biomass fuels also have a number of environmental benefits.

WOOD AND WOOD WASTE

The most common form of biomass is wood. For thousands of years people have burned wood for heating and cooking. Wood was the main source of energy in the U.S. and the rest of the world until the mid-1800s. Biomass continues to be a major source of energy in much of the developing world. In the United States wood and waste (bark, sawdust, wood chips, and wood scrap) provide only about 2 percent of the energy we use today.

About 81 percent of the wood and wood waste fuel used in the United States is consumed by the industry and commercial businesses. The rest, mainly wood, is used in homes for heating and cooking.

Many manufacturing plants in the wood and paper products industry use wood waste to produce their own steam and electricity. This saves these companies money because they don't have to dispose of their waste products and they don't have to buy as much electricity. The photograph to the right is of biomass fuel, probably wood chips, being stored and dried for later use in a boiler.

MUNICIPAL SOLID WASTE, LANDFILL GAS, AND BIOGAS

Another source of biomass is our garbage, also called municipal solid waste (MSW). Trash that comes from plant or animal products is biomass. Food scraps, lawn clippings, and leaves are all examples of biomass trash. Materials that are made out of glass, plastic, and metals are not biomass because they are made out of non-renewable materials. MSW can be a source of energy by either burning MSW in waste-to-energy plants, or by capturing biogas. In waste-to-energy plants, trash is burned to produce steam that can be used either to heat buildings or to generate electricity.

In landfills, biomass rots and releases methane gas, also called biogas or landfill gas. Some landfills have a system that collects the methane gas so that it can be used as a fuel source. Some dairy farmers collect biogas from tanks called "digesters" where they put all of the muck and manure from their barns. Read about a field trip to a real waste-to-energy plant or learn about the history of MSW.

BIOFUELS -- ETHANOL AND BIODIESEL

"Biofuels" are transportation fuels like ethanol and biodiesel that are made from biomass materials. These fuels are usually blended with the petroleum fuels - gasoline and diesel fuel, but they can also be used on their own. Using ethanol or biodiesel means we don't burn quite as much fossil fuel. Ethanol and biodiesel are usually more expensive than the fossil fuels that they replace but they are also cleaner burning fuels, producing fewer air pollutants.

Ethanol is an alcohol fuel made from the sugars found in grains, such as corn, sorghum, and wheat, as well as potato skins, rice, sugar cane, sugar beets, and yard clippings. Scientists are working on cheaper ways to make ethanol by using all parts of plants and trees. Farmers are experimenting with "woody crops", mostly small poplar trees and switchgrass, to see if they can grow them cheaply and abundantly. Most of the ethanol used in the United States today is distilled from corn. About 99 percent of the ethanol produced in the United States is used to make "E10" or "gasohol" a mixture of 10 percent ethanol and 90 percent gasoline. Any gasoline powered engine can use E10 but only specially made vehicles can run on E85, a fuel that is 85 percent ethanol and 15 percent gasoline.

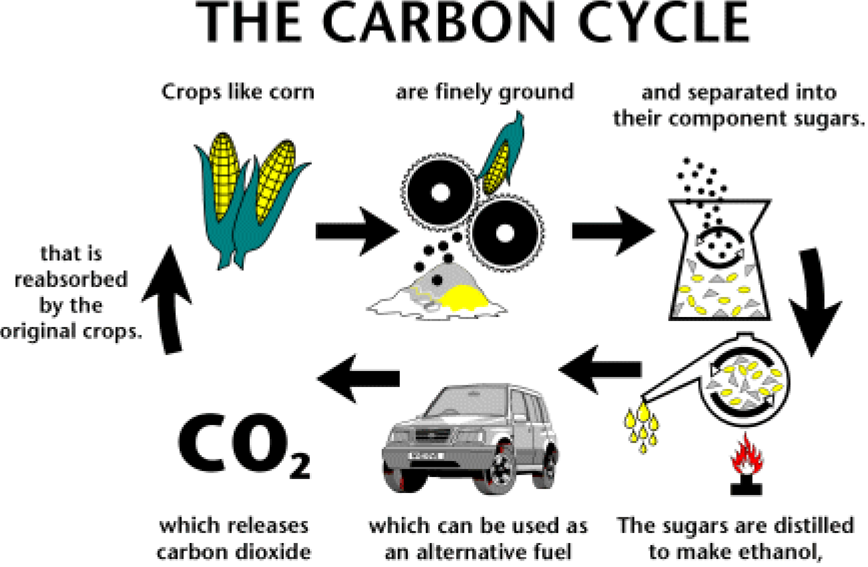
Biodiesel is a fuel made with vegetable oils, fats, or greases - such as recycled restaurant grease. Biodiesel fuels can be used in diesel engines without changing them. It is the fastest growing alternative fuel in the United States. Biodiesel, a renewable fuel, is safe, biodegradable, and reduces the emissions of most air pollutants.

BIOMASS AND THE ENVIRONMENT

Biomass can pollute the air when it is burned, though not as much as fossil fuels. Burning biomass fuels does not produce pollutants like sulfur, that can cause acid rain. When burned, biomass does release carbon dioxide, a greenhouse gas. But when biomass crops are grown, a nearly equivalent amount of carbon dioxide is captured through photosynthesis. Each of the different forms and uses of biomass impact the environment in a different way:

Burning wood - Because the smoke from burning wood contains pollutants like carbon monoxide and particulate matter, some areas of the country won't allow the use of wood burning fireplaces or stoves on high pollution days. A special clean-burning technology can be added to wood burning fireplaces and stoves so that they can be used even on days with the worst pollution.

Burning Municipal Solid Waste (MSW) or Wood Waste - Burning municipal solid waste (MSW or garbage) and wood waste to produce energy, means that less of it has to get buried in landfills. Plants that burn waste to make electricity must use technology to prevent harmful gases and particles from coming out of their smoke stacks. The particles that are filtered out are added to the ash that is removed from the bottom of the furnace. Because the ash may contain harmful chemicals and metals, it must be disposed of carefully.



Sometimes the ash can be used for road work or building purposes. Learn more about MSW or waste-to-energy plants.

Collecting landfill gas or biogas - Collecting and using landfill and biogas reduces the amount of methane that is released into the air. Methane is one of the greenhouse gases associated with global climate change. Many landfills find it cheaper to just burn-off the gas that they collect because the gas needs to be processed before it can be put into natural gas pipelines. Learn more about landfills.

Ethanol- Since the early 1990s ethanol has been blended into gasoline to reduce harmful carbon monoxide emissions. Blending ethanol into gasoline also reduces toxic pollutants found in gasoline but causes more "evaporative emissions" to escape. In order to reduce evaporative emissions, the gasoline requires extra processing before it can be blended with ethanol. When burned, ethanol does release carbon dioxide, a gree house gas. But growing plants for ethanol may reduce greenhouse gases, since plants use carbon dioxide and produce oxygen as they grow. Learn more on our Ethanol Page.

Biodiesel- Biodiesel is much less polluting than petroleum diesel. It results in much lower emissions of almost every pollutant: carbon dioxide, sulfur oxide, particulates, carbon monoxide, air toxics and unburned hydrocarbons. Biodiesel does have nitrogen oxide emissions that are about 10 percent higher though. Blending biodiesel into petroleum diesel can help reduce emissions. Biodiesel contains almost no sulfur and can help reduce sulfur in diesel fuel used throughout the country. Learn more on our Biodiesel Page.

DIESEL -- A PETROLEUM PRODUCT

DIESEL FUEL REFINED FROM OIL

Diesel is a petroleum fuel that contains energy. At refineries, crude oil is separated into different fuels including gasoline, jet fuel/kerosene, lubricating oil, heating oil, and diesel. Heating oil and diesel fuel are closely related products. The main difference between the two fuels is that diesel fuel contains less sulfur than heating oil. Approximately 7 gallons of diesel are produced from each 42-gallon barrel of crude oil. Diesel can only be used in a diesel engine, a type of internal combustion engine used in many cars, boats, trucks, trains, buses, and farm and construction vehicles.

HISTORY OF DIESEL

Rudolf Diesel originally designed the diesel engine to use coal dust as fuel, then experimented with vegetable oil (biodiesel) before the petroleum industry came out with the product now known as diesel fuel. The first diesel-engine automobile trip was completed on January 6, 1930. The trip was from Indianapolis to New York City, a distance of nearly 800 miles. This feat helped prove the usefulness of the diesel engine design. It has been used in millions of vehicles since that time.

USES OF DIESEL

Diesel fuel is important to America’s economy, quality of life and national security. As a transportation fuel, it offers a wide range of performance, efficiency and safety features. Diesel fuel contains between 18 and 30 percent more energy per gallon than gasoline. Diesel technology also offers a greater power density than other fuels, so it packs more power per volume.

Diesel fuel is used for many tasks. In agriculture, diesel fuels more than two-thirds of all farm equipment in the U.S., because diesel engines can perform demanding work. In addition, it is the most widely used fuel for public buses and school buses throughout the U.S.

America's construction industry depends on diesel's power. Diesel engines are able to do demanding construction work, like lifting steel beams, digging foundations and trenches, drilling wells, paving roads and moving soil - safely and efficiently. Diesel also powers the movement of America's freight in trucks, trains, boats and barges; 94 percent of our goods are shipped using diesel-powered vehicles. No other fuel can match diesel in its ability to move freight economically.

DIESEL AND THE ENVIRONMENTAL

When diesel fuel is used, carbon dioxide is a byproduct. Carbon dioxide is a greenhouse gas that is linked to global climate change. Diesel-powered cars achieve 20-40 percent better fuel economy than gasoline powered cars, especially in sport utility vehicles (SUVs) and light trucks, which now make up more than half of all new vehicle sales in the United States. Safety is another advantage of diesel fuel; it is less flammable than gasoline and other alternatives.

The major disadvantage of diesel fuel is its harmful emissions. Significant progress has been made in reducing emissions from diesel engines. With new clean diesel technologies, today's trucks and buses are eight times cleaner than those built just a dozen years ago. In the future, diesel engines must become even cleaner in order to meet tightening environmental standards.

New diesel fuels—some of which have lower sulfur content—can also help diesel vehicles achieve lower emissions. Ultra low sulfur diesel (ULSD) fuel is highly refined for clean, complete combustion and low emissions. ULSD is necessary for new engine technologies to work properly, and will eventually replace regular diesel fuel. Using low sulfur diesel fuel and adding exhaust control systems can reduce particulate emissions by up to 90 percent and nitrogen compounds (NOx)by 25-50 percent.

Even with these advances, diesel still contributes significantly to air pollution in the United States. It will take a long time for the new cleaner burning diesel vehicles to replace older ones.

Famous People in Energy

Isaac Newton (1642)

Isaac Newton was born in 1642 in England. His father had died two months before his birth. When Isaac was three his mother remarried, and Isaac remained with his grandmother. He was not interested in the family farm.

Isaac was born just a short time after the death of Galileo, one of the greatest scientists of all time. Galileo had proved that the planets revolve around the sun, not the earth as people thought at the time. Isaac Newton was very interested in the discoveries of Galileo and others. Isaac thought the universe worked like a machine and that a few simple laws governed it. Like Galileo, he realized that mathematics was the way to explain and prove those laws. Isaac Newton was one of the world's great scientists because he took his ideas, and the ideas of earlier scientists, and combined them into a unified picture of how the universe works.

Isaac explained the workings of the universe through mathematics. He formulated laws of motion and gravitation. These laws are math formulas that explain how objects move when a force acts on them. Isaac published his most famous book, Principia, in 1687 while he was a mathematics professor at Trinity College, Cambridge. In the Principia, Isaac explained three basic laws that govern the way objects move. He then described his idea, or theory, about gravity. Gravity is the force that causes things to fall down. If a pencil falls off a desk, it will land on the floor, not the ceiling. In his book Isaac also used his laws to show that the planets revolve around the suns in orbits that are oval, not round.

Isaac Newton used three laws to explain the way objects move. They are often call Newton's Laws. The First Law states that an object that is not being pushed or pulled by some force will stay still, or will keep moving in a straight line at a steady speed. It is easy to understand that a bike will not move unless something pushes or pulls it. It is harder to understand that an object will continue to move without help. Think of the bike again. If someone is riding a bike and jumps off before the bike is stopped what happens? The bike continues on until it falls over. The tendency of an object to remain still, or keep moving in a straight line at a steady speed is called inertia.

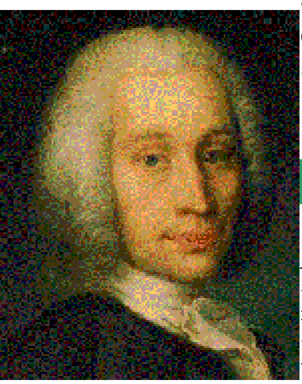
The Second Law {force = mass x acceleration; f = ma} explains how a force acts on an object. An object accelerates in the direction the force is moving it. If someone gets on a bike and pushes the pedals forward the bike will begin to move. If someone gives the bike a push from behind, the bike will speed up. If the rider pushes back on the pedals the bike will slow down. If the rider turns the handlebars, the bike will change direction.

The Third Law states that if an object is pushed or pulled, it will push or pull equally in the opposite direction. If someone lifts a heavy box, they use force to push it up. The box is heavy because it is producing an equal force downward on the lifter's arms. The weight is transferred through the lifter's legs to the floor. The floor presses upward with an equal force. If the floor pushed back with less force, the person lifting the box would fall through the floor. If it pushed back with more force the lifter would fly into the air.

When most people think of Isaac Newton, they think of him sitting under an apple tree observing an apple fall to the ground. When he saw the apple fall, Newton began to think about a specific kind of motion—gravity. Newton understood that gravity was the force of attraction between two objects. He also understood that an object with more matter –mass- exerted the greater force, or pulled smaller object toward it. That meant that the large mass of the earth pulled objects toward it. That is why the apple fell down instead of up, and why people don't float in the air.

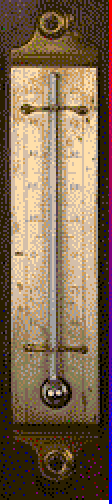
Isaac thought about gravity and the apple. He thought that maybe gravity was not just limited to the earth and the objects on it. What if gravity extended to the moon and beyond? Isaac calculated the force needed to keep the moon moving around the earth. Then he compared it with the force the made the apple fall downward. After allowing for the fact that the moon is much farther from the earth, and has a much greater mass, he discovered that the forces were the same. The moon is held in an orbit around earth by the pull of earth's gravity.

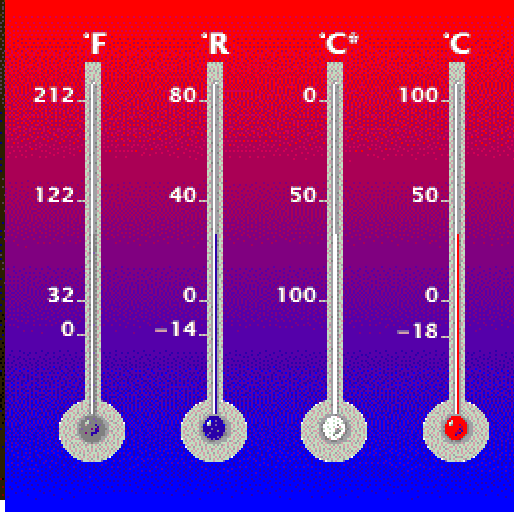
Isaac Newton's calculations changed the way people understood the universe. No one had been able to explain why the planets stayed in their orbits. What held them up? Less that 50 years before Isaac Newton was born it was thought that the planets were held in place by an invisible shield. Isaac proved that they were held in place by the sun's gravity. He also showed that the force of gravity was affected by distance and by mass. He was not the first to understand that the orbit of a planet was not circular, but more elongated, like an oval. What he did was to explain how it worked.



Anders Celsius (1701)

Anders Celsius was born in 1701 in Sweden. He succeeded his father as professor of astronomy at the University of Uppsala in 1730. It was there that he built Sweden's first observatory in 1741. One of the major questions of that time was the shape of the Earth. Isaac Newton had proposed that the Earth was not completely spherical, but rather flattened at the poles. Cartographic measuring in France suggested that it was the other way around - the Earth was elongated at the poles. In 1735, one expedition sailed to Ecuador in South America, and another expedition traveled to Northern Sweden. Celsius was the only professional astronomer on that expedition. Their measurements seemed to indicate that the Earth actually was flattened at the poles.





Celsius was not only an astronomer, but also a physicist. He and an assistant discovered that the aurora borealis had an influence on compass needles. However, the thing that made him famous is his temperature scale, which he based on the boiling and melting points of water. Celsius' fixed scale for measuring temperature defines zero degrees as the temperature at which water freezes, and 100 degrees as the temperature at which water boils. This scale, an inverted form of Celsius' original design, was adopted as the standard and is used in almost all scientific work.

Anders Celsius died in 1744, at the age of 42. He had started many other research projects, but finished few of them. Among his papers was a draft of a science fiction novel, situated partly on the star Sirius.

John Dalton (1766)

John Dalton was born in England in 1766, ten years before the U.S. Declaration of Independence was signed. His family lived in a small thatched cottage. As a small child, John worked in the fields with his older brother, and helped his father in the shop where they wove cloth. Although they had enough to eat, they were poor. Most poor boys at that time received no education, but John was lucky to attend a nearby school. In 1766, only about one out of every 200 people could read.

John was a good student and loved learning. His teachers encouraged him to study many things. When he was twelve, he opened his first school in a nearby town, but there was very little money. He had to close his school and work in his uncle's fields.

Three years later, he joined his older brother and a friend to run a school in Kendall, England. They taught English, Latin, Greek, French, and 21 math and science subjects. John studied the weather and the nature around him. He collected butterflies, snails, mites, and maggots. He measured his intake of food and compared it to his production of waste. He discovered he was color-blind and studied that, too.

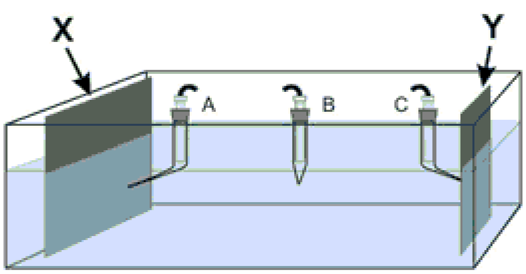
In 1793, John moved to Manchester as a tutor at New College, and began observing the behavior of gases. He began to think about different elements and how they are made. He had a theory that each element is made up of identical atoms and that all elements are different because they are each made of different atoms.  He thought that each element had a different weight, because it was made of different atoms.

In 1808, Dalton published a book, A New System of Chemical Philosophy, which listed the atomic weights of many known elements. His weights were not all accurate, but they formed the basis for the modern periodic table. Not everyone accepted Dalton's theory of atomic structure at the time, however. He had to defend his theory with more research.

When John Dalton died in 1844, he was buried with honors in England. More than 400,000 people viewed his body as it lay in state. As his final experiment, he asked that an autopsy be performed to find out the cause of his color-blindness. He proved that it was not caused by a problem with his eyes, but with his perception-the way his brain worked. Even in death, he helped expand scientific knowledge.

Today, scientists everywhere accept Dalton's theory of atomic structure. A simple country boy showed the world a new way of thinking about the universe and how it is made.

Georg Simon Ohm (1787)



Georg Simon Ohm was born in 1787 in Germany. His father, Johann Wolfgang Ohm, was a locksmith and his mother, Maria Elizabeth Beck, was the daughter of a tailor. Although his parents had not been formally educated, Ohm's father was a remarkable man who had educated himself and was able to give his sons an excellent education through his own teachings.

In 1805, Ohm entered the University of Erlangen and received a doctorate. He wrote elementary geometry books while teaching mathematics at several schools. Ohm began experimental work in a school physics laboratory after he had learned of the discovery of electromagnetism in 1820.

In two important papers in 1826, Ohm gave a mathematical description of conduction in circuits modeled on Fourier's study of heat conduction. These papers continue Ohm's deduction of results from experimental evidence and, particularly in the second, he was able to propose laws which went a long way to explaining results of others working on galvanic electricity.

The basic components of an electrochemical cell are:

1) Electrodes (X and Y) that are made of electrically conductive materials: metals, carbon, composites ...

2) Reference electrodes (A, B, C) that are in electrolytic contact with an electrolyte
3) The cell itself or container that is made of an inert material: glass, Plexiglass, ... and
4) An electrolyte that is the solution containing ions.

Using the results of his experiments, Georg Simon Ohm was able to define the fundamental relationship between voltage, current, and resistance. What is now known as Ohm's law appeared in his most famous work, a book published in 1827 that gave his complete theory of electricity.

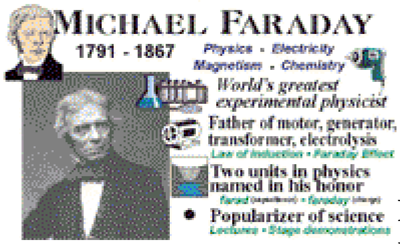
The equation I = V/R is known as "Ohm’s Law". It states that the amount of steady current through a material is directly proportional to the voltage across the material divided by the electrical resistance of the material. The ohm (R), a unit of electrical resistance, is equal to that of a conductor in which a current (I) of one ampere is produced by a potential of one volt (V) across its terminals. These fundamental relationships represent the true beginning of electrical circuit analysis.

Michael Faraday (1791)

Born in 1791 to a poor family in England, Michael Faraday was extremely curious, questioning everything. He felt an urgent need to know more. At age 13, he became an errand boy for a bookbinding shop in London. He read every book that he bound, and decided that one day he would write a book of his own. He became interested in the concept of energy, specifically force. Because of his early reading and experiments with the idea of force, he was able to make important discoveries in electricity later in life. He eventually became a famous chemist and physicist.

Faraday built two devices to produce what he called electromagnetic rotation: that is a continuous circular motion from the circular magnetic force around a wire. Ten years later, in 1831, he began his great series of experiments in which he discovered electromagnetic induction. These experiments form the basis of modern electromagnetic technology.

In 1831, using his "induction ring", Faraday made one of his greatest discoveries - electromagnetic induction: the "induction" or generation of electricity in a wire by means of the electromagnetic effect of a current in another wire. The induction ring was the first electric transformer. In a second series of experiments in September he discovered magneto-electric induction: the production of a steady electric current. To do this, Faraday attached two wires through a sliding contact to a copper disc. By rotating the disc between the poles of a horseshoe magnet he obtained a continuous direct current. This was the first generator. From his experiments came devices that led to the modern electric motor, generator and transformer.



Faraday continued his electrical experiments. In 1832 he proved that the electricity induced from a magnet, voltaic electricity produced by a battery, and static electricity were all the same. He also did significant work in electrochemistry, stating the First and Second Laws of Electrolysis. This laid the basis for electrochemistry, another great modern industry.

Michael Faraday, one of the world's greatest experimental physicist, is known as the father of the electric motor, electric generator, electric transformer, and electrolysis. He wrote the "Law of Induction" and is known for the "Faraday Effect". Two units in physics were named in his honor, the farad (for capacitance) and the faraday (as a unit of charge).

James Prescott Joule (1818)

Joule was born in 1818 in England. A physicist, he shared in discovering the law of the conservation of energy. The law states that energy used in one form reappears in another and is never lost. In 1840, he stated a law, now called Joule's Law, that heat is produced in an electrical conductor. The international unit of energy, the joule, is named in his honor.

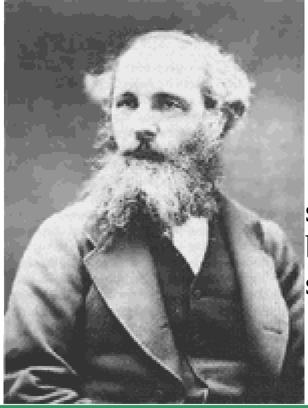
Edwin Laurentine Drake (1819)

Edwin Laurentine Drake was born in 1819 in Greenville, New York. Drake is considered the petroleum entrepreneur of the oil industry. A former railroad conductor, his success was based on his belief that drilling was the best way to obtain petroleum from the earth. He organized Seneca Oil Co., leased land, and on August 27, 1859, struck oil at a depth of 69 feet near Titusville, Pennsylvania.

Most historians trace the start of the oil industry on a large scale to this first venture. Drake used an old steam engine to power the drill. After his well began to produce oil, other prospectors drilled wells nearby. Oil created riches for many people and for many countries, but not for Drake. His poor business sense eventually impoverished him. In 1876, he was granted an annuity by the State of Pennsylvania, where he remained until his death in Bethlehem, Pennsylvania.

An industry which brought great riches to so many, finally honored him by bringing his body back to Titusville and interring it in a fine tomb replete with

$$\mathrm{div}\mathbf{D} = \rho$$
$$\mathrm{div}\mathbf{B} = 0$$
$$\mathrm{curl}\mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\mathrm{curl}\mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

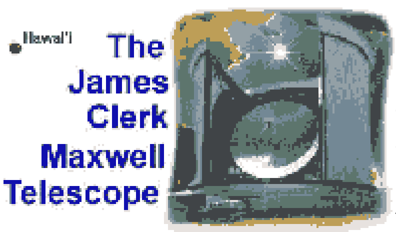


symbolic bronze sculpture. The oil industry honors its birthplace with a museum and memorial park at the site where Drake struck oil in his pioneer well.

James Clerk Maxwell (1831)

James Clerk Maxwell was born in Scotland in 1831. He is generally considered the greatest theoretical physicist of the 1800s, if not the century's most important scientist. He combined a rigorous mathematical ability with great insight into the nature of science. This ability enabled him to make brilliant advances in the two most important areas of physics at that time (electromagnetism and a kinetic theory of gases), in astronomy, and in biology as well.

Maxwell was a physicist who is best known for his work on the connection between light, electricity, magnetism, and electromagnetic waves (traveling waves of energy). "Maxwell's Equations" are the group of four equations that



show his greatness. This simple group of equations, together with the definitions of the quantities used in them and auxiliary relations defining material properties, fully describe classical electromagnetism. He discovered that light consists of electromagnetic waves. He not only explained how electricity and magnetism are really electromagnetism, but also paved the way for the discovery and application of the whole spectrum of electromagnetic radiation that has characterized modern physics. Physicists now know that this spectrum also includes radio, infrared, ultraviolet, and X-ray waves, to name a few.

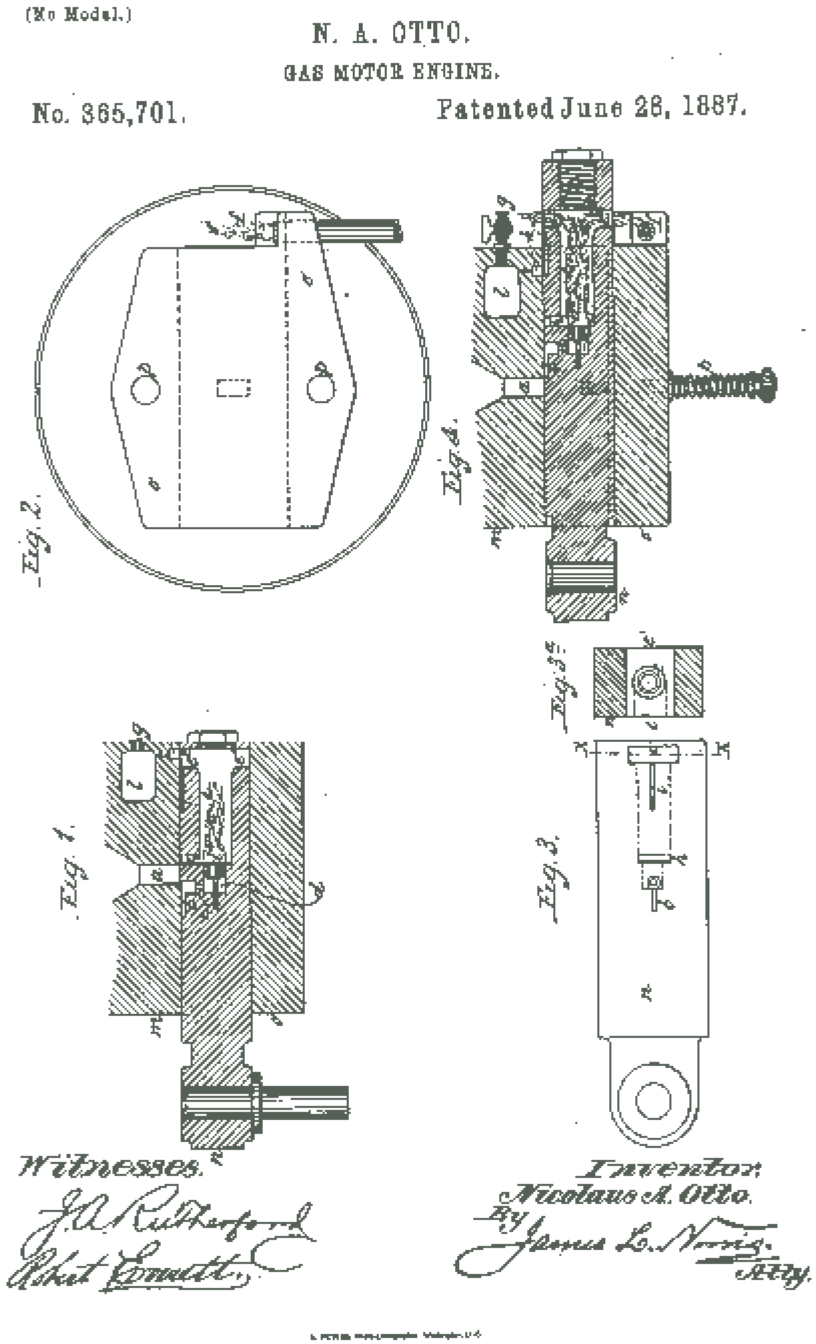
Maxwell's second greatest contribution was his kinetic theory, especially the part dealing with the distribution of molecular speeds. In developing the kinetic theory of gases, Maxwell gave the final proof that the nature of heat resides in the motion of molecules. The kinetic theory of gases explains the relationship between the movement of molecules in a gas and the gas's temperature and other properties.

Maxwell also made important contributions in several other theoretical and experimental fields. Early in his career he figured out and then demonstrated the principles governing color, color vision, and how eyes work. He used a green, red and blue striped bow in making the world's first color photograph of an object. He hypothesized that the rings of the planet Saturn were made up of many small particles, and was proven right when satellites visited Saturn in the 1970's and later.

Nicolaus Otto (1832)

Born in 1832 in Germany, Nicolaus August Otto invented the first practical alternative to the steam engine - the first successful four-stroke cycle engine. Otto built his first four-stroke engine in 1861. Then, in partnership with German industrialist Eugen Langen, they improved the design and won a gold medal at the World Exposition in Paris of 1867.

In 1876, Otto, then a traveling salesman, chanced upon a newspaper account of the Lenoir internal combustion engine. Before year's end, Otto had built an internal combustion engine, utilizing a four-stroke piston cycle. Now called the 'Otto cycle' in his honor, the design called for four strokes of a piston to draw in and compress a gas-air mixture within a cylinder resulting in an internal explosion. He received patent #365,701 for his gas-motor engine. Because of its reliability, efficiency, and relative quietness, more than 30,000 Otto cycle engines were built in the next 10 years. He also developed low-voltage magneto ignition systems for his engines, allowing a much greater ease in starting.



Thomas Edison (1847)

Thomas Edison was born in 1847 in Milan, Ohio. Young Tom didn't do very well in school, so his mother decided to teach him at home. She gave him lots of books to read. Tom was a curious boy. He always wanted to know how things worked. He liked to see if he could make them work better. His mother let him set up a laboratory in the house where he could experiment with things.

As a young man, Tom set up a lab of his own, where he could try out his ideas. He invented lots of things in his laboratory. Guess what his favorite invention was? It was the phonograph. Before the phonograph, if you wanted to hear music, you had to play it yourself or go to a concert.




Edison's most famous invention was the light bulb. At the time, people used gas or oil lamps to light their homes. Edison knew it would be cheaper and easier to use electricity. The trouble was, nobody knew how to do it. Edison worked on his idea a long time . He tried lots of things that didn't work. But he didn't give up. He kept trying until one day it worked! Today, you can flip a switch and have light any time you want it.

Edison also built the first power plant. Edison's Pearl Street Power Station opened in 1882 in New York City. It sent electricity to 85 customers and made enough power to light 5,000 lamps.

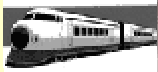
Edison also invented the movie camera. When you go to the movies or watch TV, you can thank him for his ideas and hard work. Many of the electric machines you see at home or at school came from his ideas.

Inventing things was what Edison liked best. He thought about how things worked. Then he thought about how he could do it better. That is called inspiration. The hard part came next. Edison had to make his ideas work. He tried all kinds of things until he found exactly what would work. He called that perspiration. He said that invention was "one percent inspiration and ninety-nine percent perspiration."

Lewis Latimer (1848)

Lewis Howard Latimer was born in 1848 in Chelsea, Massachusetts. As a young man, Latimer learned mechanical drawing while working for a Boston patent office. In 1880, he was hired by Hiram Maxim of the U.S. Electric Lighting Company to help develop a commercially viable electric lamp. In 1882, Latimer invented a device for efficiently manufacturing the carbon filaments used in electric lamps and shared a patent for the "Maxim electric lamp". He also patented a threaded wooden socket for light bulbs and supervised the installation of electric streetlights in New York City, Philadelphia, Montreal, and London.

In 1884, Latimer became an engineer at the Edison Electric Light Company where he had the distinction of being the only African American member of "Edison's Pioneers" - Thomas Edison's team of inventors. While working for Edison, Latimer wrote Incandescent Electric Lighting, the first engineering handbook on lighting systems. Although today's incandescent light bulbs use filaments made of tungsten rather than carbon, Latimer's work helped to make possible the widespread use of electric lights.


Granville Woods (1856)

Born in Columbus, Ohio in 1856, Granville Woods literally learned his skills on the job. Attending school in Columbus until age 10, he served an apprenticeship in a machine shop and learned the trades of machinist and blacksmith. During his youth he also went to night school and took private lessons. Although he had to leave formal school at age ten, Granville Woods realized that learning and education were essential to developing critical skills that would allow him to express his creativity with machinery.

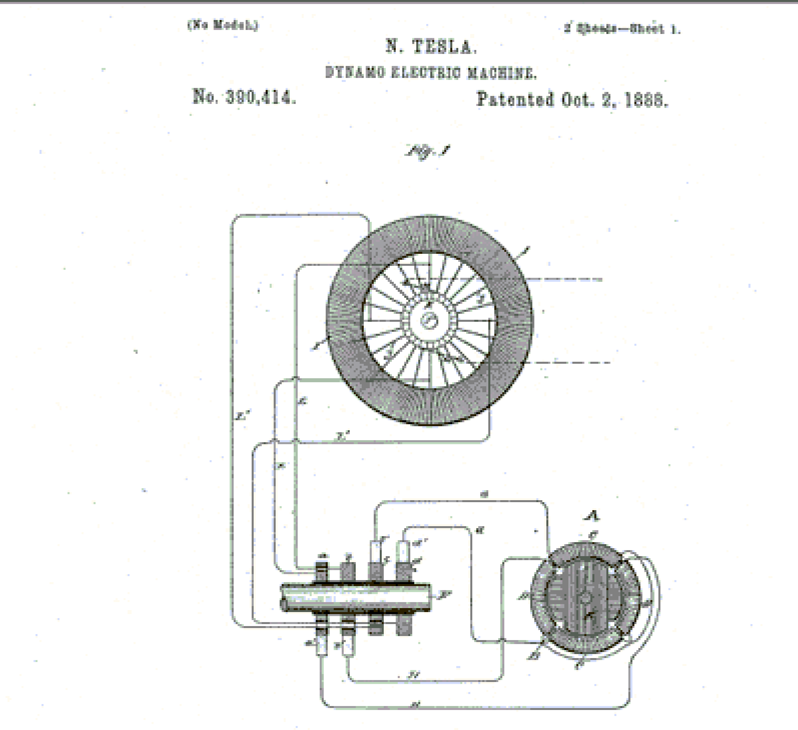
In 1872, he obtained a job as a fireman on the Danville and Southern railroad in Missouri, eventually becoming an engineer. He invested his spare time in studying electronics. In 1874, Woods moved to Springfield, Illinois, and worked in a rolling mill. In 1878, he took a job aboard the Ironsides, a British steamer, and, within two years, became Chief Engineer of the steamer. Finally, his travels and experiences led him to settle in Cincinnati, Ohio, where he became the person most responsible for modernizing the railroad.

In 1888, Woods developed a system for overhead electric conducting lines for railroads, which aided in the development of the overhead railroad system found in cities such as Chicago, St. Louis, and New York City. In his early thirties, he became interested in thermal power and steam-driven engines. And, in 1889, he filed his first patent for an improved steam-boiler furnace. In 1892, a complete Electric Railway System was operated at Coney Island, NY. In 1887, he patented the Synchronous Multiplex Railway Telegraph, which allowed communications between train stations from moving trains. Woods' invention made it possible for trains to communicate with the station and with other trains so they knew exactly where they were at all times. This invention made train movements quicker and prevented countless accidents and collisions.

Nikola Tesla (1856)

Nikola Tesla was born in 1856 in Austria-Hungary and emigrated to the U.S. in 1884 as a physicist. He pioneered the generation, transmission, and use of alternating current (AC) electricity, which can be transmitted over much greater distances than direct current.

Tesla patented a device to induce electrical current in a piece of iron (a rotor) spinning between two electrified coils of wire. This rotating magnetic field device generates AC current when it is made to rotate by using some form mechanical energy, like steam or hydropower. When the generated current reaches its user and is fed into another rotating magnetic field device, this second device becomes



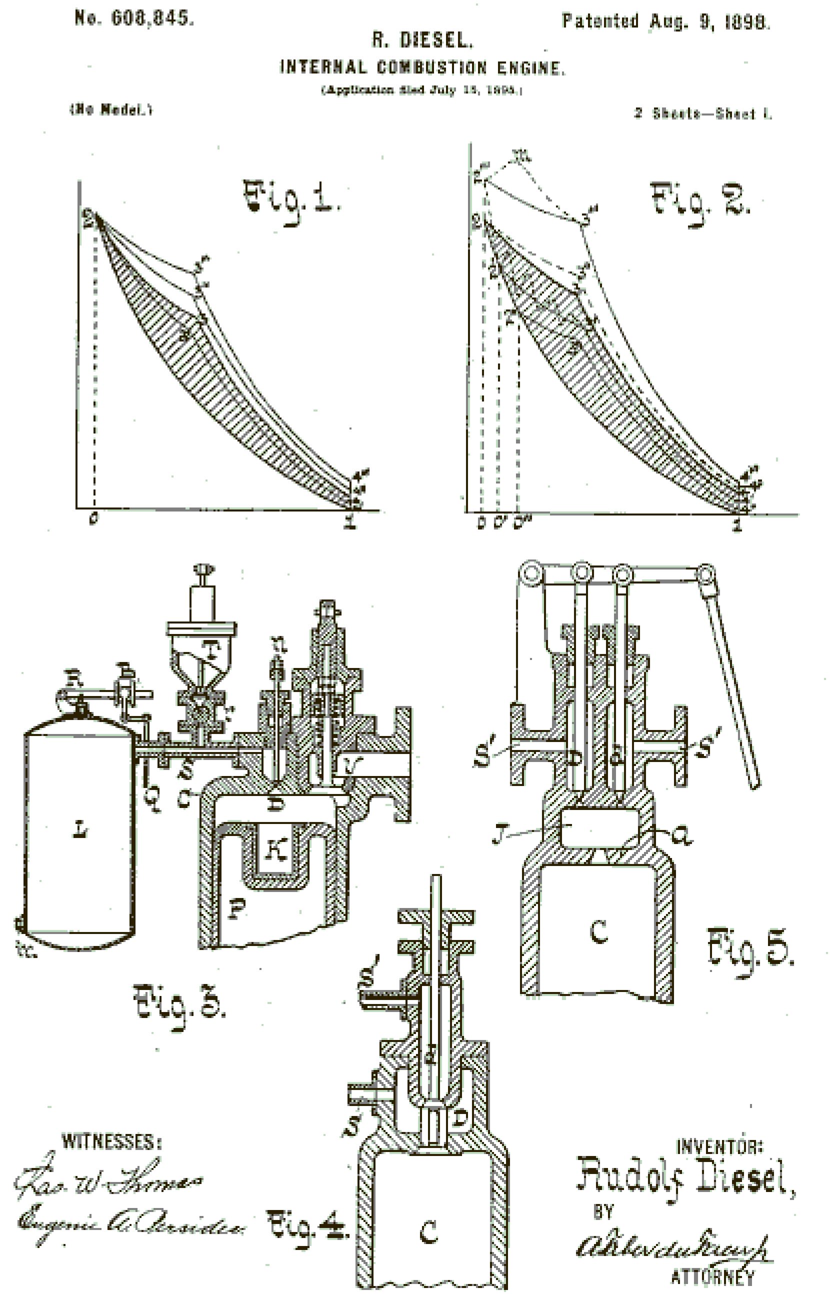
an AC induction motor that produces mechanical energy. Induction motors run household appliances like clothes washers and dryers. Development of these devices led to widespread industrial and manufacturing uses for electricity.

The induction motor was only part of Tesla's overall conception. In a series of history-making patents, he demonstrated a polyphase alternating-current system, consisting of a generator, transformers, transmission layout, and motor and lights. From the power source to the power user, it provided the basic elements for electrical production and utilization. Our AC power system remains essentially unchanged today.

In 1888, George Westinghouse, head of the Westinghouse Electric Company, bought the patent rights to Tesla's system of dynamos, transformers and motors. Westinghouse used Tesla's alternating current system to light the World's Columbian Exposition of 1893 in Chicago. Then in 1896, Tesla's system was used at Niagara Falls in the world's first large hydroelectric plant. The Tesla coil, invented in 1891, is still used in radio and television sets, car starters, and a wide variety of electronic equipment.

Tesla's work with radio-frequency waves laid the foundation for today's radio. He experimented with wireless transmission of electrical power, and received 112 patents for devices ranging from speedometers to extremely efficient electrical generators to a bladeless turbine still in use today. He suggested that it was possible to use radio waves to detect ships (later developed as RADAR), and his work with special gas-filled lamps set the stage for the creation of fluorescent lighting.

Tesla was Thomas Edison's rival at the end of the 19th century - in fact, he was more famous than Edison throughout the 1890's. His invention of polyphase AC electric power earned him worldwide fame but not fortune. At his zenith his circle of friends included poets and scientists, industrialists and financiers. Yet Tesla died alone and almost penniless in a New York hotel room in 1943. During his life, Tesla created a legacy of genuine invention that still fascinates today. After his death, the world honored him by naming the unit of magnetic flux density the "tesla."



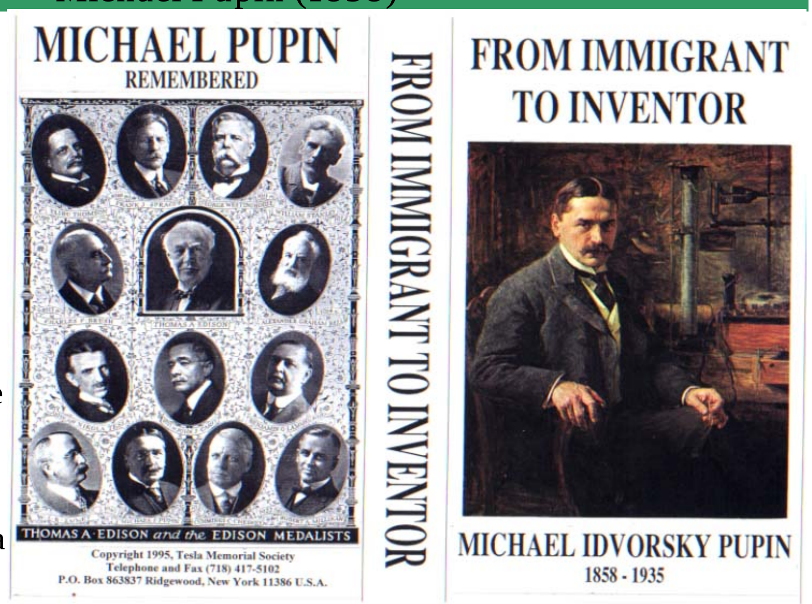
Rudolf Diesel (1858)

Rudolf Diesel was born in 1858 in France and began his career as a refrigerator engineer. For ten years he worked on various heat engines, including a solar-powered air engine. Diesel's ideas for an engine where the combustion would be carried out within the cylinder were published in 1893, one year after he applied for his first patent. Rudolf Diesel received patent #608845 for the diesel engine.The diesel engines of today are refined and improved versions of Rudolf Diesel's original concept. They are often used in submarines, ships, locomotives, and large trucks and in electric generating plants.

Though best known for his invention of the pressure-ignited heat engine that bears his name, Diesel was also a well-respected thermal engineer and a social theorist. Diesel's inventions have three points in common: They relate to heat transference by natural physical processes or laws; they involve markedly creative mechanical design; and they were initially motivated by the inventor's concept of sociological needs. Diesel originally conceived the diesel engine to enable independent craftsmen and artisans to compete with large industry.

At Augsburg, on August 10, 1893, Diesel's prime model, a single 10-foot iron cylinder with a flywheel at its base, ran on its own power for the first time. Diesel spent two more years making improvements and in 1896 demonstrated another model with the theoretical efficiency of 75 percent, in contrast to the ten percent efficiency of the steam engine. By 1898, Diesel was a millionaire. His engines were used to power pipelines, electric and water plants, automobiles and trucks, and marine craft, and soon after were used in mines, oil fields, factories, and transoceanic shipping.

Michael Pupin (1858)



Michael Pupin, American physicist and inventor, was born in Austria-Hungary in 1858. He immigrated to the United States in 1874, graduated from Columbia University in physics in 1883, and obtained his Ph.D. at the University of Berlin in 1889. Pupin taught at Columbia for more than 40 years, 30 of them as a professor of electromechanics.

Pupin improved the quality of long-distance telephone and telegraph transmission by inserting coils in the long lines at intervals; he discovered that matter struck by X-rays is stimulated to radiate other X-rays (secondary radiation) and invented an electrical resonator. He received 34 patents for his inventions, and he won the Pulitzer Prize in 1924 for his autobiography, *From Immigrant to Inventor*.

Marie Curie (1867)

Marie Curie was born in Poland in 1867. As a child, she amazed people with her great memory. She learned to read when she was only four years old.

Her father was a professor of science. The instruments that he kept in a glass case fascinated Marie. She dreamed of becoming a scientist, but that would not be easy. Her family became very poor, and at the age of 18, Marie became a governess. She helped pay for her sister to study in Paris. Later, her sister helped Marie with her education.

In those days, there were no universities for girls in Poland. So, in 1891, Marie went to the Sorbonne University in Paris. She was so poor, she ate only bread and butter, and drank tea. She wore old clothes she had brought with her from Warsaw.

Every day, she would study in the library until 10:00 p.m., then go to her cold little room, and read until 2 or 3 o'clock in the morning.

After four years at the Sorbonne, Marie married Pierre Curie, a well-known physicist. (A physicist is a scientist who studies the physical nature of the world -- what things are made of and why they do what they do.)

Together the Curies began looking for new elements. They took uranium ore, ground it up, and boiled it. They treated it with acids and other chemicals. Finally, after four years of hard work and tons of ore, they had one-tenth of a gram of pure radium. They had discovered the first radioactive element!

In 1903, Marie, Pierre, and another scientist, Henry Becquerel, were awarded the Nobel Prize in Physics for their discovery of radium and their study of radioactivity. Marie Curie was the first woman to win a Nobel Prize in Physics. Later, she won a second Nobel Prize in Chemistry.

During World War I, Marie worked to develop x-rays. She believed they could help treat diseases like cancer. She never tried to make money from her discoveries, because she believed in helping others.

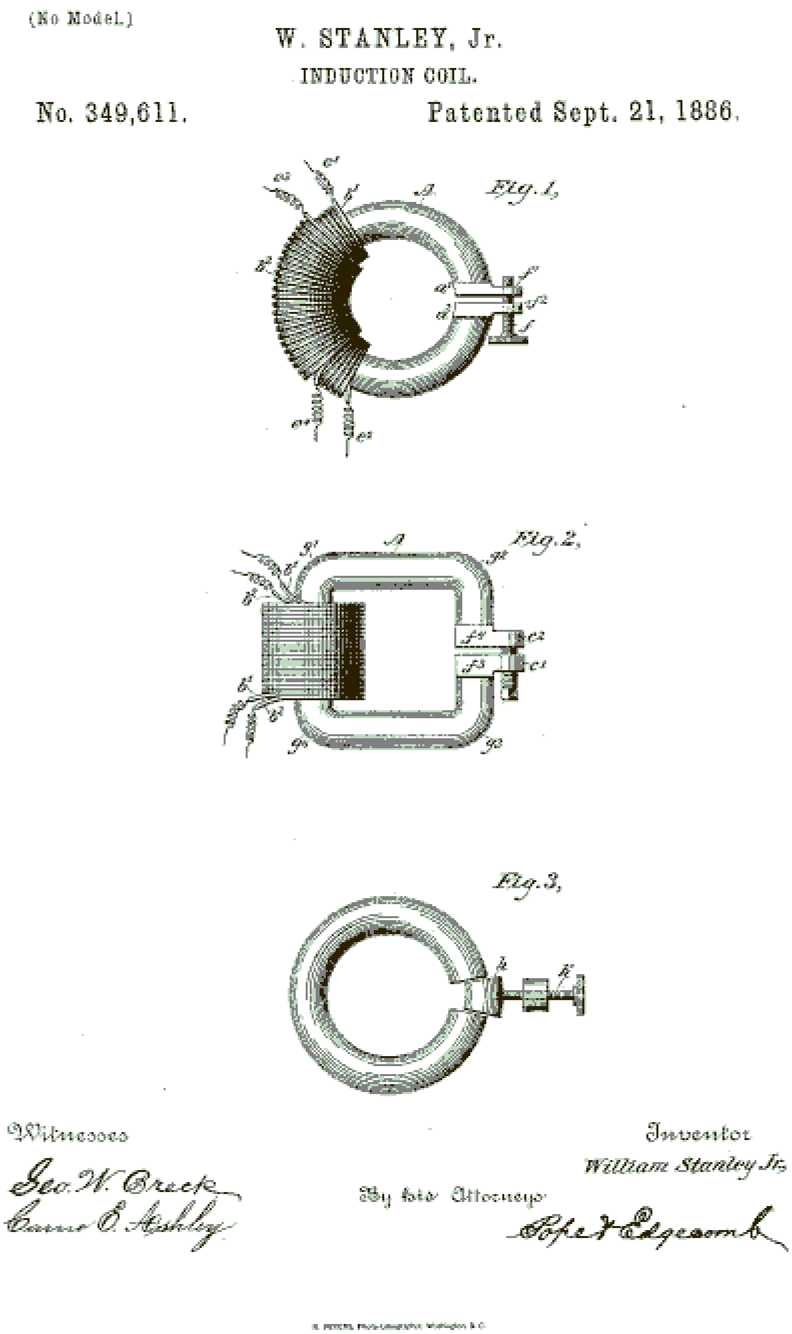
William Stanley (1858)

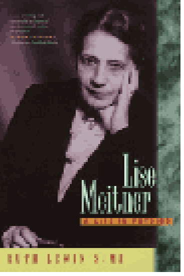
William Stanley was born in 1858. During his lifetime he was granted 129 patents covering a wide range of electric devices. The most notable of these is the induction coil, a transformer that creates alternating current electricity. In the 1880s every electricity distribution system used direct current (DC). The problem is that DC transmission over long distances is impractical, requires thick wires, is dangerous and could not be used for lighting. On the other hand, alternating current (AC) systems did not have these drawbacks. AC voltage systems could be varied by use of induction coils, but no practical coil system had been invented. Stanley's patent #349,611 changed all this and became the prototype for all future transformers.

Born in Brooklyn, New York, Stanley attended private schools before enrolling at Yale University. He began to study law at age 21 but less than a semester later left school to look for a job in the emerging field of electricity.

Stanley's first job was as an electrician with one of the early manufacturers of telegraph keys and fire alarms. He designed one of the country's first electrical installations for a store on New York's Fifth Avenue. After inventor and industrialist George Westinghouse learned of Stanley's accomplishments, he hired Stanley as his chief engineer at his Pittsburgh factory. It was during this time that Stanley began work on the transformer.

After Stanley left Pittsburgh, in 1886 he built the first AC system, providing lighting for offices and stores on the Main Street of Great Barrington, Massachusetts. He made transformers, auxiliary electrical equipment, and electrical appliances. The Stanley Electric Manufacturing Company was purchased by General Electric in 1903.





Lise Meitner (1878)

Lise Meitner was born in Austria in 1878. As a young girl, she had a love for mathematics and physics, and adopted Madame Curie and Florence Nightingale as her heroines. After private schooling, she entered the University of Vienna and received her doctorate in physics in 1906. She had to get used to being the only woman in a room full of one hundred students.

She worked at the Kaiser-Wilhelm Institute with radiochemist, Otto Hahn. They discovered the element protactinium and studied the effects of neutron bombardment on uranium. Meitner became joint director of the institute and was appointed head of the Physics Department in 1917. After leaving Nazi Germany in 1938, she found a post at the Nobel Physical Institute in Stockholm. She continued her research there, and, together with her nephew Otto Frisch, realized that they had split the uranium nucleus. They called the process "fission." During the war, she refused to work on the atomic bomb. In 1947, a laboratory was established for her by the Swedish Atomic Energy Commission, and she worked on an experimental nuclear reactor.

Albert Einstein (1879)

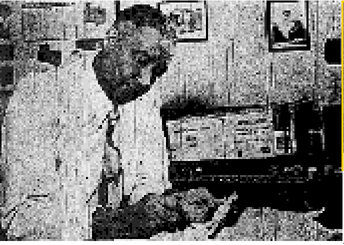
Albert Einstein was born in Germany in 1879. He enjoyed classical music and played the violin. One story Einstein liked to tell about his childhood was of a wonder he saw when he was four or five years old: a magnetic compass. The needle's invariable northward swing, guided by an invisible force, profoundly impressed the child. The compass convinced him that there had to be "something behind things, something deeply hidden."

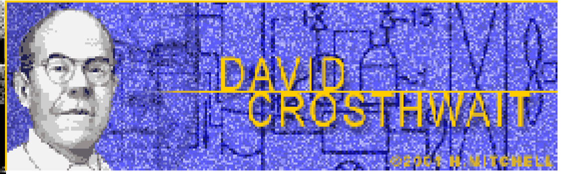
Even as a small boy Einstein was self-sufficient and thoughtful. According to family legend he was a slow talker, pausing to consider what he would say. His sister remembered the concentration and perseverance with which he would build houses of cards.

In 1933, he joined the staff of the newly created Institute for Advanced Study in Princeton, New Jersey. He accepted this position for life, living there until his death. Einstein is probably familiar to most people for his mathematical equation about the nature of energy, $E = mc^2$.

Einstein wrote a paper with a new understanding of the structure of light. He argued that light can act as though it consists of discrete, independent particles of energy, in some ways like the particles of a gas. A few years before, Max Planck's work had contained the first suggestion of a discreteness in energy, but Einstein went far beyond this. His revolutionary proposal seemed to contradict the universally accepted theory that light consists of smoothly oscillating electromagnetic waves. But Einstein showed that light quanta, as he called the particles of energy, could help to explain phenomena being studied by experimental physicists. For example, he made clear how light ejects electrons from metals.

There was a well-known kinetic energy theory that explained heat as an effect of the ceaseless motion of atoms; Einstein proposed a way to put the theory to a new





and crucial experimental test. If tiny but visible particles were suspended in a liquid, he said, the irregular bombardment by the liquid's invisible atoms should cause the suspended particles to carry out a random jittering dance. One should be able to observe this through a microscope, and if the predicted motion were not seen, the whole kinetic theory would be in grave danger. But just such a random dance of microscopic particles had long since been observed. Now the motion was explained in detail. Einstein had reinforced the kinetic theory, and he had created a powerful new tool for studying the movement of atoms.

Frederick M. Jones (1892)

Frederick M. Jones was born in Cincinnati, Ohio in 1892. After returning from France after serving in World War I, Mr. Jones worked as a garage mechanic. His mastery of electronic devices was largely self-taught, through work experience and the inventing process. With his experience as a mechanic he developed a self-starting gasoline motor. In the late 1920's Frederick Jones designed a series of devices for the developing movie industry, which adapted silent movie projectors to use talking movie stock. He also developed an apparatus for the movie box-office that delivers tickets and returns change to customers.

Frederick M. Jones was granted more than 40 patents in the field of refrigeration. In 1935 he invented the first automatic refrigeration system for long-haul trucks. The system was, in turn, adapted to a variety of other common carriers, including ships and railway cars. The invention eliminated the problem of food spoilage during long shipping times. The ability to provide fresh produce across the United States during the middle of summer or winter changed the American consumer's eating habits. Jones' inspiration for the refrigeration unit was a conversation with a truck driver who had lost a shipment of chickens because the trip took too long and the truck's storage compartment overheated. Frederick Jones also developed an air-conditioning unit for military field hospitals and a refrigerator for military field kitchens. Frederick Jones received over 60 patents in his career.

David Crosthwait (1898)

David Crosthwait was born in Nashville, Tennessee, in 1898. He received a B.S. from Purdue University (1913) and a Masters of Engineering in 1920. Mr. Crosthwait was considered an authority on heat transfer, ventilation and air conditioning. He was a Research Engineer, Director of Research Laboratories for C.A. Dunham Company in Marshalltown, Iowa, from 1925 to 1930. He was the Technical Advisor of Dunham-Bush, Inc. from 1930 to 1971. He served as the past president of the Michigan City Redevelopment.

Mr. Crosthwait was responsible for designing the heating system for Radio City Music Hall at Rockefeller Center in New York City. Mr. Crosthwait was the author

of a manual on heating and cooling with water and guides, standards, and codes that dealt with heating, ventilation, refrigeration, and air conditioning systems. David Crosthwait received 39 patents relating to the design, installing, testing, and service of HVAC power plants, heating, and ventilating systems. After retiring from industry in 1969, Mr. Crosthwait taught a course on steam heating theory and control systems at Purdue University.

Louis Roberts (1913)

Louis W. Roberts was born in Jamestown, New York, in 1913. He was educated at Fisk University, where he received a Bachelor of Arts in 1935, and a Master of Science from the University of Michigan in 1937. Roberts served as a research assistant for Standard Oil of New Jersey from 1935 to 1936. He was a graduate assistant from 1936-37 while at the University of Michigan. He served as Instructor of Physics at St. Augustine's College from 1937-39. Roberts was appointed Professor of Mathematics and Physics at St. Augustine's College from 1941 to 1943 and Associate Professor of Physics at Howard University, 1943-44. Roberts holds eleven patents for electronic devices and is the author of papers on electromagnetism, optics, and microwaves.

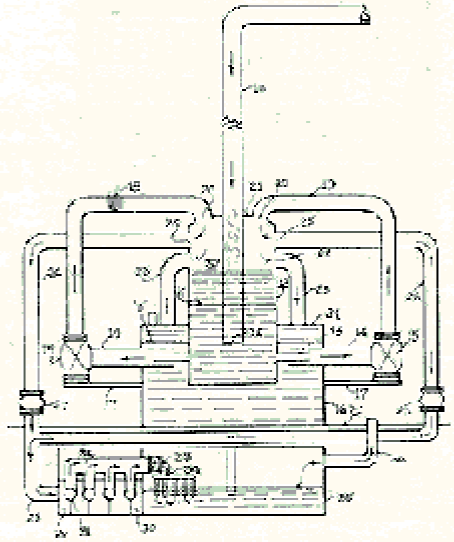
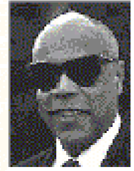
Roberts served as Director of Research for Microwave Associates from 1950 to the present. He is also the Director of Energy and Environment at the Transportation System Center in Cambridge, Massachusetts, from 1977 to the present. The Transportation System Center, as part of the U.S. Department of Transportation, develops energy conservation practices for the transportation industries. Currently, transportation accounts for over half of the United States' consumption of petroleum. However, the Energy Conservation Policy Act requires the transportation sector to reduce fuel consumption in all types of vehicles.

During Roberts' career, he has served as chief of the Optics and Microwave Laboratory in the Electronics Research Center of the National Aeronautics and Space Administration. He founded and was president of a microwave company. His research interests focus on microwave and optical techniques and components, plasma research, solid state component and circuit development.

Roscoe L. Koontz (1922)

Roscoe L. Koontz was born in St. Louis, Missouri in 1922. He graduated from Vashon High School in St. Louis. His college education at Stowes Teachers College was interrupted by a three-year hitch in the U.S. Army during World War II. While in the army, he received technical training through a special pre-engineering army training program at West Virginia State College. Upon discharge from the army in 1946, he returned to Tennessee State University and graduated with a Bachelor of Science in Chemistry.



through his Atomic Energy Fellowship sponsored at Rochester in pinhole gamma collimator and fabricate

Roscoe Koontz was among the first formally trained health physicists participation in the first Health Physics Training Program, the University of 1948. He designed a ray camera and helped to design and automatic air and water sampling equipment and radiation activity measuring devices.

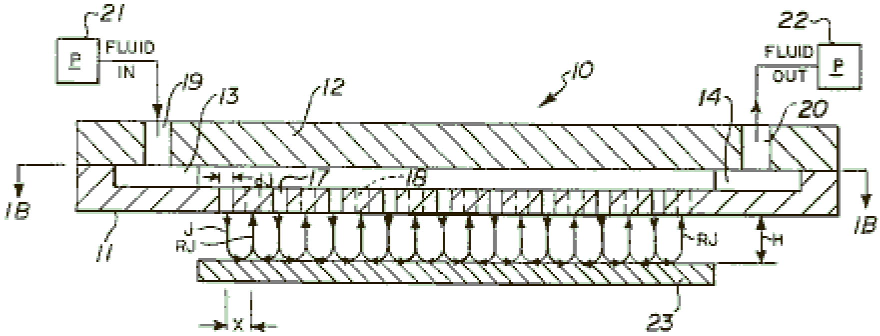
Health physics became a recognized profession around 1942. When Koontz entered the field, there were few rules and guidelines and procedures for health physicists to follow. Together with their instructors, the early students, like Koontz, originated many of today's practices, instrumentation and techniques to protect people from the hazards of ionizing radiation.

Rufus Stokes (1924)

Rufus Stokes was born in Alabama in 1924. He later moved to Illinois, where he worked as a machinist for an incinerator company. In 1968, he was granted a patent on an air-purification device to reduce the gas and ash emissions of furnace and powerplant smokestack emissions. The filtered output from the stacks became almost transparent. Stokes tested and demonstrated several models of stack filters, termed the "clean air machine", in Chicago and elsewhere to show its versatility. The system benefited the respiratory health of people, but also eased the health risks to plants and animals. A side-effect of reduced industrial stack emissions was the improved appearance and durability of buildings, cars, and objects exposed to outdoor pollution for lengthy periods.

Meredith C. Gourdine (1929)

Meredith C. Gourdine was born in Newark, New Jersey in 1929. He received a B.S. in Engineering Physics from Cornell University in 1953 and a Ph.D. in Engineering Physics from the California Institute of Technology in 1960. Dr. Gourdine pioneered the research of electrogasdynamics. He was responsible for the engineering technique termed Incineraid for aiding in the removal of smoke from buildings. His work on gas dispersion developed techniques for dispersing fog from airport runways.

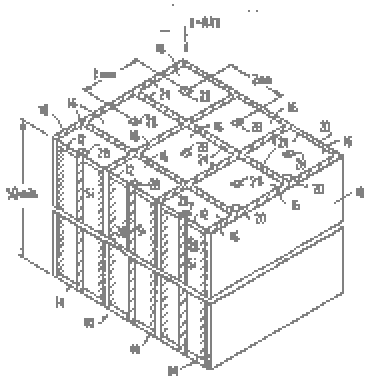


Dr. Gourdine served on the technical staff of the Ramo-Woolridge Corporation from 1957-58. He then became a Senior Research Scientist at the Caltech Jet Propulsion Laboratory from 1958-60. He became a Lab Director of the Plasmodyne Corporation from 1960-62 and Chief Scientist of the Curtiss-Wright Corporation from 1962 to 1964. Dr. Gourdine established a research laboratory, Gourdine Laboratories, in Livingston, New Jersey, with a staff of over 150. Dr. Gourdine has been issued several patents on gasdynamic products as a result of his work. He received patent #5,548,907 for a method and apparatus for transferring heat, mass, and momentum between a fluid and a surface. Dr. Gourdine served as president of Energy Innovation, Inc. of Houston, Texas.

George Edward Alcorn, Jr.

George Edward Alcorn, Jr. was born in 1940. He received a four-year academic scholarship to Occidental College in Los Angeles, where he graduated with a Bachelor of Science in Physics. He received his degree with honors while earning eight letters in basketball and football. George Alcorn earned a Master of Science in Nuclear Physics in 1963 from Howard University, after nine months of study. During the summers of 1962 and 1963, George Alcorn worked as a research engineer for the Space Division of North America Rockwell. He was involved with the computer analysis of launch trajectories and orbital mechanics for Rockwell missiles, including the Titan I and II, Saturn IV, and the Nova.

In 1967 George Alcorn earned a Ph.D. in Atomic and Molecular Physics from Howard University. Between 1965-67 Alcorn conducted research on negative ion formation under a NASA-sponsored grant. Dr. Alcorn holds eight patents in the United States and Europe on semiconductor technology, one of which is a method of fabricating an imaging X-ray spectrometer. His area of research includes: adaptation of chemical ionization mass spectrometers for the detection of amino acids and development of other experimental methods for planetary life detection; classified research involved with missile reentry and missile defense; design and building of space instrumentation, atmospheric contaminant sensors, magnetic mass spectrometers, mass analyzers; and development of new concepts of magnet design and the invention of a new type of x-ray spectrometer.



Henry Ford (1863)

Henry Ford is often incorrectly thought of as the inventor of the automobile. (That distinction belongs to Karl Benz of Germany.) Henry Ford was an innovative man who revolutionized the automobile industry. Ford was born on July 30, 1863 in Dearborn, Michigan. As a child he worked on the family farm. In his spare time, he experimented in the farm's machine shop. At the age of 17, Ford left the family farm and moved to Detroit where he worked in continued his work in machine shops, specifically with steam engines. In 1882 Henry Ford became a certified machinist and was hired by Westinghouse Company to set up and repair steam engines.

In 1891 Ford designed a small engine that burned gasoline. Thomas Edison then offered Henry Ford a job and Ford became the chief engineer for Edison Illuminating Company. Three years later, Ford built a gasoline-powered car known as the "horseless carriage". He quit his job with Edison to pursue interests with cars. Over the next few years, Henry Ford continued to develop his car designs, including the Model A and the Model T. He increased both speed and fuel efficiency. Efficiency was a trademark of Ford. He developed the assembly line to help produce cars quickly and economically. It was Ford's goal to make cars available to average Americans. During both World War I and World War II, the Ford plant was used in the war effort to build equipment. During the last portion of Henry Ford's life, he served as chairman of the Ford Foundation, a charitable organization. Henry Ford died on April 7, 1947.

Robert Goddard (1882)

Robert Goddard is given credit as being one of the fathers of modern rocketry. Though not given credit during his lifetime, he is now recognized as a significant modern scientist. Robert Goddard was born on October 5, 1882 in Worchester, Massachusetts. As a young boy he displayed an interest and ability in science. He experimented with electricity. He became fascinated with fireworks, the beginning of his interest in rockets. Goddard attended public school in both Boston and Worchester. He attended Worchester Polytechnic Institute, a practical engineering school. He regularly journaled new ideas and inventions. After earning his degree, he taught at the institute and later at Clark University.

In 1920 Goddard wrote a paper describing sending an unmanned rocket to the moon. He was ridiculed by the press for this idea. Charles Lindberg became interested though and began to finance Goddard's work. Goddard moved his operation to New Mexico. During this time, he worked with parachute systems, stabilizing fins, and gyroscopes. Though his work was not widely known in the United States, Goddard's work was taken very seriously in Germany. During World War II, the Germans developed Goddard's theories further. Goddard was a faithful American and worked with the U.S. military to create and build the bazooka, an antitank weapon. He worked with the U.S. Navy to develop jet takeoff devices. Goddard died on August 10, 1945. After his death the U.S. Patent Office recognized Goddard for 214 patents regarding rocket designs. Today's rockets are based on Robert Goddard's designs and theories.

Benjamin Franklin (1706)

Benjamn Franklin was a diplomat, politician, printer, and scientist. He invented bifocals, the Franklin stove, and experimented with electricity. Franklin was born in 1706 in Boston, Massachusetts. He showed his intelligence and interest early on in reading and writing. At the age of ten though, he was taken out of school to learn his father's trade of candle making. Young Benjamin hated this work and two years later became an apprentice in his brother James' print shop. After five years Franklin left his brother's shop and went to New York. There was no work in New York so he moved to Philadelphia. Philadelphia was a much bigger city at the time. Franklin became very successful as a printer. Wealth brought him time to work on his inventions and interests. Franklin recognized that common fireplaces were inefficient. He designed the Franklin stove to use heat better. His stove drew in cool air, heated the air, and then circulated the heated air. These stoves became very popular in American and Europe. Electricity had recently been discovered in Europe. Franklin became extremely interested in it and spent six years trying to generate electricity. Franklin began to focus on lightning and the idea that it was caused by electric charges. Franklin suggested the use of lightning rods to redirect electricity away from buildings to keep them from burning down. By tying an iron key to a kite string during a storm, he was able to identify the electrical charge as being the same as in a Leyden Jar. This proved lightning was electricity. Benjamin Franklin spent the later part of his life pursuing his interests and working for the colonies and the creation for the United States. Franklin died in 1790 in the country he helped form and improve.

Guglielmo Marconi (1874)

Guglielmo Marconi was an Italian inventor and electrical engineer. He is recognized for his development of wireless telegraphy, also known as radio. Prior to Marconi's work, telegraph signals were sent through wires. Marconi was born on April 25, 1874 in Bologna, Italy. He showed an interest for science early in his life. Much of his studies were done privately. In 1894 Marconi began experimenting with wireless telegraphy. He based his work on Heinrich Hertz's work with electromagnets. Beginning with transmitting signals across a room, Marconi eventually was able to transmits signals across miles by grounding the transmitter and receiver. The Italian government was not interested in his work, so Marconi moved to England. During this time, he received his first patent regarding radio. Marconi's next goal was to send a message across the Atlantic. This was accomplished on December 12, 1901. He transmitted the letter "S" in Morse code. The success of this transmission opened scientific study in the atmosphere and the idea of an ionosphere. This technology became more well known as it was used in saving many lives aboard the troubled ships the Republic and the Titanic. This wireless technology became required on passenger ships. Marconi then began working on short-wave and microwave transmissions. Short-wave signals were cheaper and easier to operate.

In 1909 Marconi was awarded the Noble Prize in physics, which he shared with Karl F. Braun. In 1914 King George gave Marconi an honorary title of Knight Grand Cross of the Royal Victoria Order. Marconi also received John Fritz Medal, an American engineering award. He died on July 20, 1937.

J. Robert Oppenheimer (1908)

J. Robert Oppenheimer is considered the father of the atomic bomb. He was the director of the team who designed and built the first atomic bomb. Oppenheimer was born in 1908 in New York City. In 1925 he graduated from Harvard University. In 1927 Oppenheimer earned his doctorate degree from the

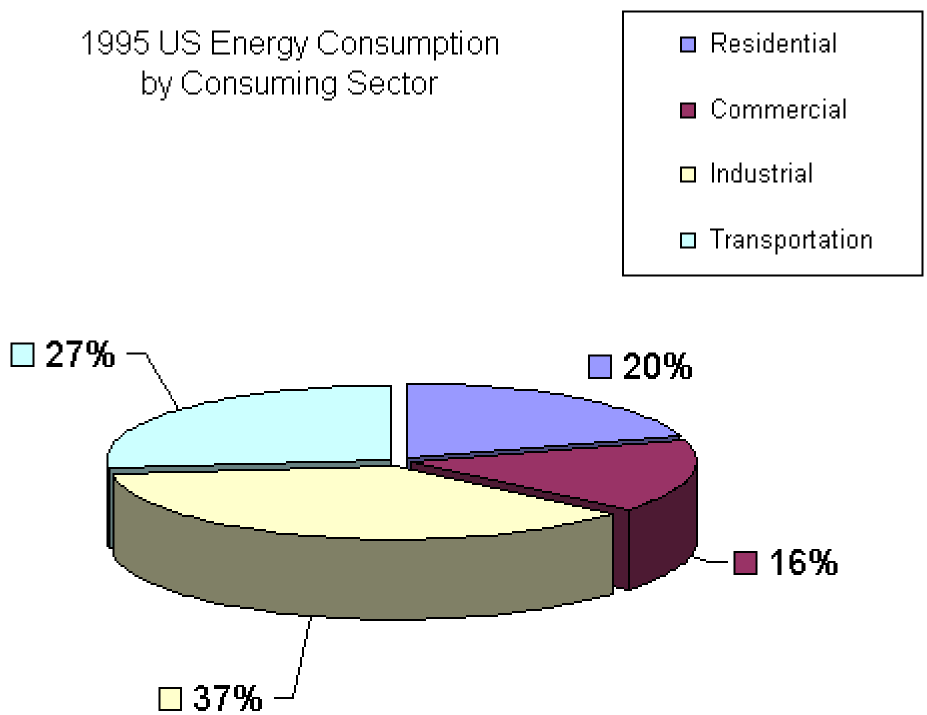
University of Gottingen in Germany. Two years later he became a professor at the University of California at Berkley and worked on theoretical physics. From 1943-1945, Oppenheimer led a team of scientists who designed and built the first atomic bomb. Over several of the following years, Oppenheimer headed the advisory committee of the United States Atomic Energy Commission (AEC). He worked with the U.S. Department of Defense and worked internationally for control of atomic energy.

Oppenheimer's loyalty to the United States was questioned in 1953. He held opposition to the hydrogen bomb and had some connections with Communists. This led to an investigation by the AEC security panel. He was cleared of all charges but the allegations caused him to be denied further access to secret information. Oppenheimer was awarded the Enrico Fermi Award for contributions to theoretical physics. J. Robert Oppenheimer spent the last years of his life as the director of the Institute for Advanced Study in Princeton, New Jersey. He died in 1967.

How will potential lost power be compenstated for?

- energy conservation?
- sale of hydro to the US by Canada?
- Coal-fired plants?
- wind?
- solar?
- nukes?

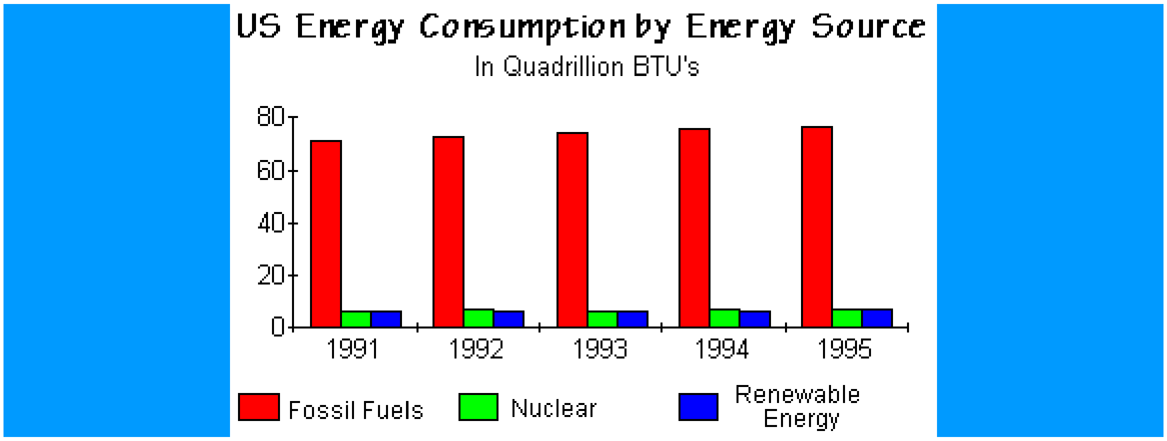
Total Energy Usage



Our total energy use can be divided into three principal areas each of which consume approximately equal amounts of energy on an annual basis:

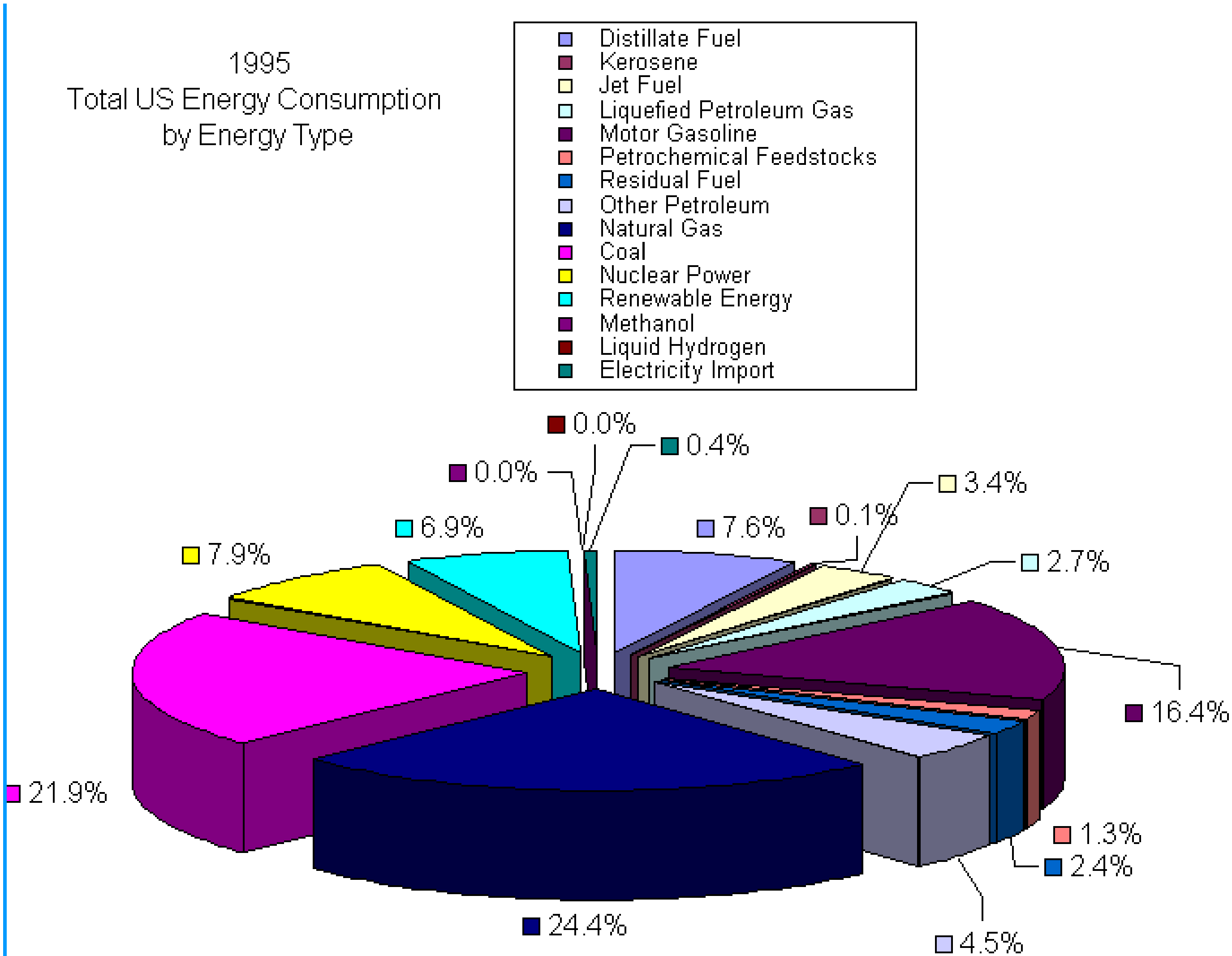
- Electricity Generation
- Space Heating
- Transportation

This energy use has been roughly constant over the last 5 years and is dominated (90%) by the use of fossil fuels.



Fossil Fuels come in 3 principal forms from which many other products are derived:

- **Coal**
- **Natural Gas**
- **Crude Oil**



Most traditional Energy production comes about via steam driven turbines so the heating of water is what is essential.

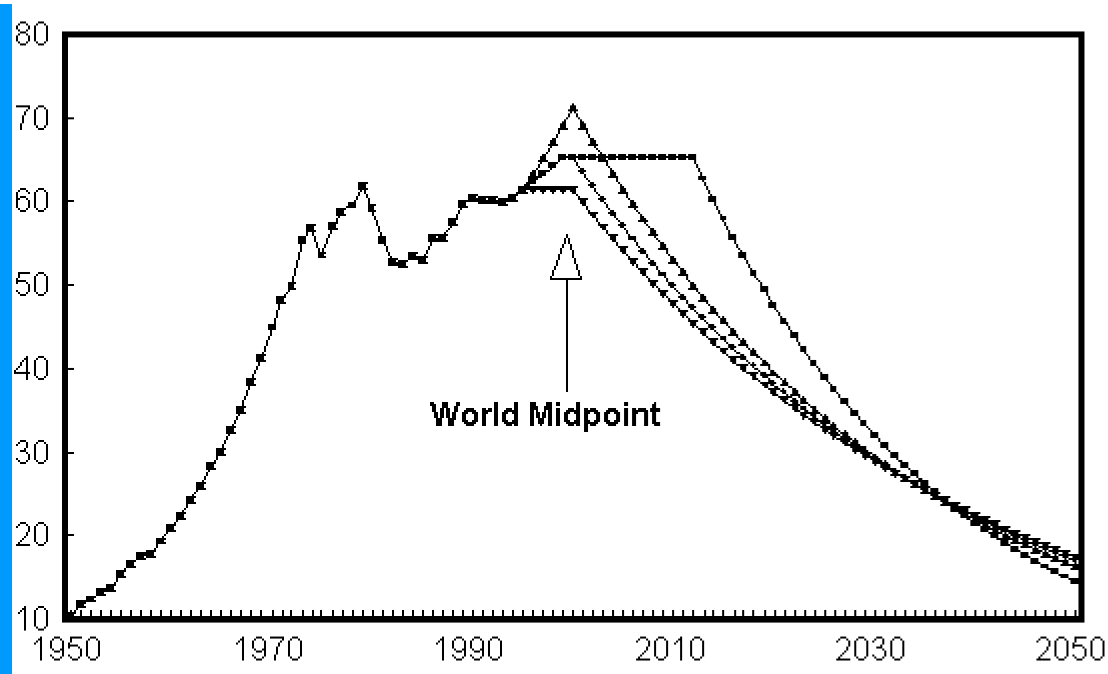
- **Coal Fired Steam Plants**
- **Nuclear Fired Steam Plants**
- **Oil/Natural Gas Fired Steam Plants**

The Need for Alternative Energy

- **Basic concept of alternative energy sources relates to issues of sustainability, renewability and pollution reduction.**
- **In reality, Alternative Energy means any thing other than deriving energy via Fossil Fuel combustion**
- **Basic Barrier to all forms of alternative energy lies in initial costs!**
- **Currently we have no significant production line alternative energy source operating anywhere in the US!**

The simple problem is that there are simply not enough fossil fuels left to sustain its usage as the foundation of our energy production. Forget about global warming for the moment, the issue is more basic than that.

We have about 50 more years of production from known reserves , after that we will either have to discover more reserves are shift away from our fossil fuel based energy economy.



Campbell World Oil Production Plot

Forms of Alternative Energy:

- **Solar:**

Advantages: Always there; no pollution

Disadvantages: Low efficiency (5-15%); Very high initial costs; lack of adequate storage materials (batteries); High cost to the consumer

- Hydro:

Advantages: No pollution; Very high efficieny (80%); little waste heat; low cost per KWH; can adjust KWH output to peak loads; recreation dollars

Disadvantages: Fish are endangered species; Sediment buildup and dam failure; changes watershed characteristics; alters hydrological cycle

- Wind:

Advantages: none on large scale; supplemental power in windy areas; best alternative for individual homeowner

Disadvantages: Highly variable source; relatively low efficiency (30%); more power than is needed is produced when the wind blows; efficient energy storage is thus required

- Geothermal:

Advantages: very high efficiency; low initial costs since you already got steam

Disadvantages: non-renewable (more is taken out than can be put in by nature); highly local resource

- **Ocean Thermal Energy Conversion:**

  Advantages: enormous energy flows; steady flow for decades; can be used on large scale; exploits natural temperature gradients in the ocean

  Disadvantages: Enormous engineering effort; Extremely high cost; Damage to coastal environments?

- **Tidal Energy:**

  Advantages: Steady source; energy extracted from the potential and kinetic energy of the earth-sun-moon system; can exploit bore tides for maximum efficiency

  Disadvantages: low duty cycle due to intermittent tidal flow; huge modification of coastal environment; very high costs for low duty cycle source

- **Hydrogen Burning:**

  Advantages: No waste products; very high energy density; good for space heating

  Disadvantages: No naturally occurring sources of Hydogren; needs to be separated from water via electrolysis which takes a lot of energy; Hydrogen needs to be liquified for transport - takes more energy. Is there any net gain?

- **Biomass Burning:**

  Advantages: Biomass waste (wood products, sewage, paper, etc) are natural by products of our society; reuse as an energy source would be good. Definite co-generation possibilities. Maybe practical for individual landowner.

  Disadvantages: Particulate pollution from biomass burners; transport not possible due to moisture content; unclear if growing biomass just for burning use is energy efficient. Large scale facilities are likely impractical.

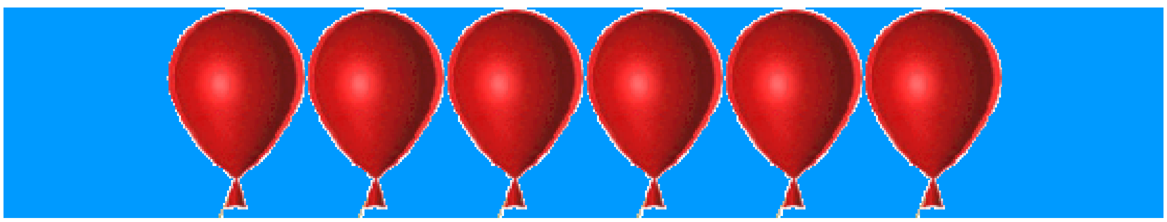
- **Nuclear Fusion: --> Forget it, we aren't smart enough yet.**

  But suppose we become smart enough in a few hundred years. Can adoption of sustainable energy technology get us to this point?

This is ultimately limited by some basic physics, some of which we understand (Thermodyanmics) and some of which we don't (Chaos).

Even though a system may appear to be very simple, the behavior of that system might be chaotic. The elements of this theory are hard to describe but some neutrally buoyant helium balloons floating around class today can serve as an example.

In Class Chaos Demo



Helium balloons and a demonstration of the principles of chaos:

- **Unstable equilibrium (a perturbation in either direction causes an irrecoverable situation)**
- **No predicative power, our neutrally buoyant helium ballon can go in any direction**
- **Random interactions will occur that would not otherwise occur (e.g. whose head is this balloon going to fall on).**
- **These random interactions will increase the chaos of the system (student x bats balloon in some direction).**
- **An external event which is not in the interactions reduces the chaos (e.g. the helium runs out and the balloon falls on the floor).**
- **The nature of the chaotic system is continuously changing --> i.e. its difficult to maintain the neutral buoyancy of the balloon. When its not neutrally buoyant, its less chaotic and more deterministic.**

- **In principle, the motions of the ballon are entirely governed by physics, hence if we knew all the physics we would have predictive power. However, the amount of information which is required to be known is nearly infinite.**

So even though the helium balloon is a simple system, its motion and its interaction with other elements is chaotic.

Chaos seems to exist in a variety of natural systems to some extent or another

- **The Flow of the McKenzie River**
- **The Greenhouse effect**
- **Hurricane evolution**
- **Planetary orbits**
- **Evolution of species**

THERMODYNAMIC LAWS

You can not subvert or change these laws:

The Zeroth Law (0): Systems are in equilibrium when they are at the same temperature.

- **System is in it lowest energy state**
- **No more energy can be extracted from it**
- **All systems of different temperature will tend to equilibrium when they are no longer thermally isolated.**

Modelling Thermodynamic Equilibrium: (

Warning, JAVA applets Page (might kill some browsers); Suggest using Netscape 4.04 or IE 4.0 for this. Netscape 3.0 might not completey work.

)

The First Law (1): Energy is Conserved in a closed system:

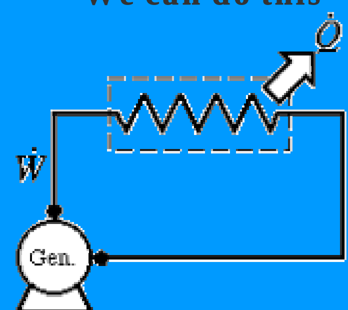
- The net flow of energy across some system is equal to the change in energy of that system
- We usually consider work and heat flow as the two kinds of energy

The Second Law (2): The Law of Entropy:

- It is not possible to extract heat-energy from a reservoir and perform work without creating waste heat that does no work.
- The amount of disorder increases
- Things tend toward a state of randomness(this is not the same as chaos)
- You can not go from a disordered system to an ordered system without inputting more energy (this is the most important attribute of the second law)

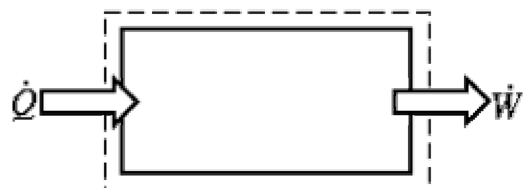
Example:

We can do this



100% of electrical energy converted to heat by pushing a current through a resistive element.

We can not reverse that process to do this:



In the course of doing the original work we have increased the disorder to the system by heating it. In no way can we recover work of that this disordered

system without putting energy into the system.

To decrease local entropy requires work (energy).

- Your dorm room - it takes a lot of work to decrease the amount of disorder
- Iron Ore is originally concentrated in mountains - has a low disorder. Eventually it becomes mined and ends up distributed in the nations landfills.
- This combination of letters is readable and hence of low order but

ticmiainflteriraaladecolwrerdoohsobntoftrsdbne

is not and would require a lot of work to rearrange into the previous sentence

- Rich fossil fuel deposits are stored in a state of low order. when we liberate all of that so that the individual atoms become randomly distributed, where will society find the energy to maintain local order?

Energy From the Oceans

More promising technology is OTEC (Ocean Thermal Energy Generation). This takes advantage of the fact that the ocean is an enormous heat engine.

Physics of Heat Engines:

- efficiency = work done/energy input
- it can be shown that this is equivalent to

efficiency (in %) = 1 - T1/T2 ; T1 < T2

T is measured in Kelvins

- So, in principle any two reservoirs with different temperatures T1 and T2 can produce energy. There will be a demonstration of this principle in class today.
    - Boiling water T = 373K
    - Ice Water T=273K
    - Liquid Nitrogen T=77K
- Efficiency of Boiling water and Ice water: 1 - (273/373) = 27%
- Efficienty of Ice water and LN_2: 1 - (77/273) = 72%
- What is efficiency of Boiling water and LN_2?

Thermodynamic Constraints:

- Systems are in equilibrium when they are at the same temperature
- energy is conserved within a closed system
- it is not possible to extract heat energy from a reservoir and perform work without transferring heat to a reservoir of lower temperature. In other words, all thermodynamic systems must tend towards equilibrium. Some energy goes towards performing work and some is lost as waste heat.

To get the highest efficiency one wants to maximize the difference between T1 and T2 but then their are material problems (containers melt, freeze, etc)

Typical Case:

- Coal-fired burner: T = 825K
- Cooling tower: T = 300 K
- efficiency = 1 - 300/825 = 64%

How this all works:

- Exhaust steam is condensed back into liquid thereby decreasing its total volume by a factor of 1000

- Therefore the work done by the pump is down by a factor of 1000 compared to if it had to pump steam directly back into the system

Heat Energy from the Ocean

Do this:

Basic principle is that heat difference is used to condense a steam into a liquid then return it to be reheated.

Since heat differences in the ocean will be smaller, then one must substitute ammonia for water as the working fluid.

Example Calculations:

- **Surface Ocean temperature is 25 degrees C (298K)**
- **At 1000 meters depth the temperature is 5 degrees C (278K)**
- **Efficiency = 1 - 278/298 = .067 (6.7%)**
- **Power in cooling 1000 gallons of water per second by 2 degrees C is 32 MegaWatts (because water has such high heat capacity/storage)**
- **using 6.7% efficiency would then yield 2 Megawatts (1/500 typical coal-fired plant)**
- **But this is only for 1000 measly little gallons per second**

OTEC Potential Sites:

- **Florida, Puerto Rico, and Hawaii**
- **Indian Ocean**
- **Northeast Australia, Indonesia and Mexico**

Above sites typically have thermal gradients higher then 22 degrees C

Energy extracted comes from the cooling of the warmer water ☞ this is transferred to the ammonia which does the actual work of turning the turbine (as ammonia steam)

Energy extracted proportional to the volume of water and the temperature it drops.

Principal energy loss is when the warmer water meets the cooler water in the condenser.

Review of OTEC (Ocean Thermal Energy Conversion)

- **Thermal gradients of greater than 22 C can be exploited and used as a heat engine**
- **Energy is derived from cooling warm surface water to the temperature of the water at approximately 500-1000 feet depth.**
- **The maximum surface temperature of ocean water is 25 C and its minimum value is of course 0 C**
- **efficiency is then 1 -(273+0)/(273+25) = 1 - 273/298 = 7%**
- **Energy is derived from the cooling water via transfer to a working fluid such as ammonia which when mixed with warm water vaporizes to steam and powers a turbine**
- **Ammonia returns (condenses) to liquid when mixed with cooler water at depth and then the cycle repeats itself**
- **Since the volume of water in the oceans is huge, the capacity in just the Gulf Coast Waters alone is several 10's of Giga**

More on OTEC

Hawaii Facility

Ocean Power also comes in 2 other forms:

  - **Tidal Energy**
  - **Current Flow Energy**

The ocean is a huge reservoir for storing the energy of the sun that is incident on the earth. How huge is huge?

Incident flux on ocean surface area is 10^{17} Watts or 0.1 Billion Billion Watts (its a large number)

The oceans are a huge heat engine. Temperature differences, caused by differences in insolation both in latitude and in depth.

- Equatorial waters warmer than higher latitude waters
- surface layers warmer than deeper layers
- This sets up an enormous circulation network

Major currents are shaped by:

- Temperature differences (driven mostly by tilt of earth's axis)
- Prevailing wind patterns interacting with the surface waters (again driven mostly by tilt of earth's axis)
- the rotation of the earth the Coriolis Force
- shorelines of continental masses

Tapping the Current for Energy:

- Gulf current has 1000 times the flow of the Mississippi River(!)
- Current averages about 5 mph
- Density of water is higher as well
- Its always there - no intermittency problem no need for energy storage
- Build Turbines for underwater use
- Anchor a foundation to the ocean floor
- hundreds of miles long rigged with turbines
- cables on ocean floor to shore deliver the electricity
- An engineering challenge but there are few bad side effects from producing energy this way
- Obviously the capital costs are huge in this case but this does represent a Large Scale Solution

Tidal Energy from the Ocean

Extracts energy from the kinetic energy of the earth-moon-sun system.

Variations in water level along coastlines can be used to drive turbines
technology is the same as low-head hydro power

Vertical tides on US coast range from 2 feet in Florida to more than 18 feet in Maine

To enhance efficiency of turbines driven by tidal currents, it is desireable to build a damlike structure across the mouth of a tidal basin in order to direct the flow to a turbine

Turbines designed for work at both high and low tide (inflow or outflow)

Intermittent tidal flow is major problem. Tidal facility produces about 1/3 the electrical energy of a hydro facility of the same peak capacity

Two tidal plants in the world:

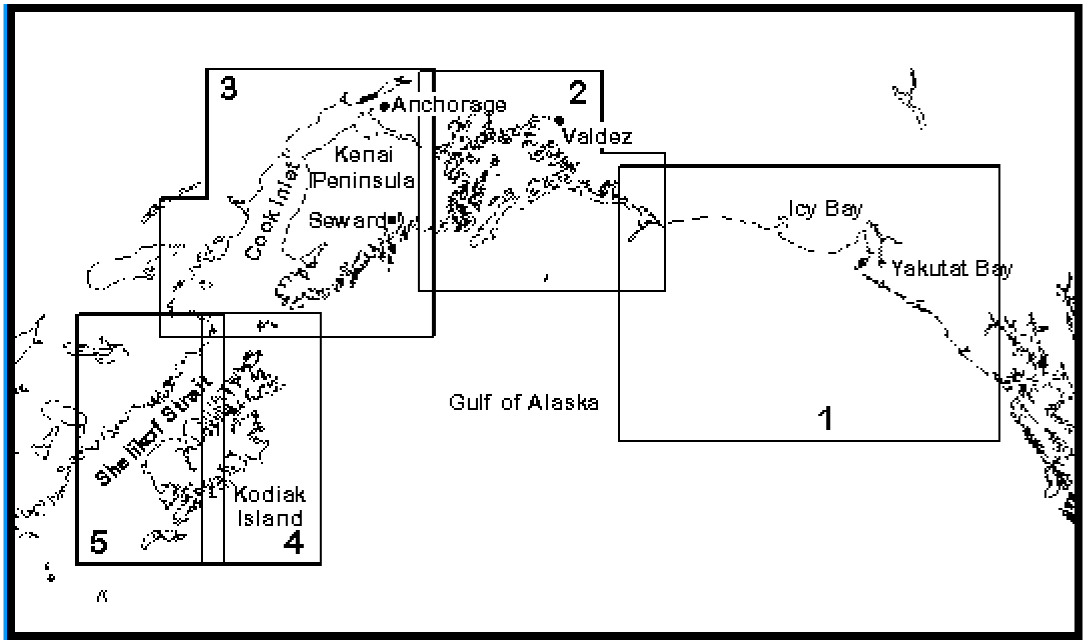
- **1 MW facility on the White Sea in Russia (1969)**
- **240-MW on the Rance River, St. Malo France (1967)**
  has 750 meter long dike to impound tides that can be as high as 13 meters (!)

Proposed New Facilities:

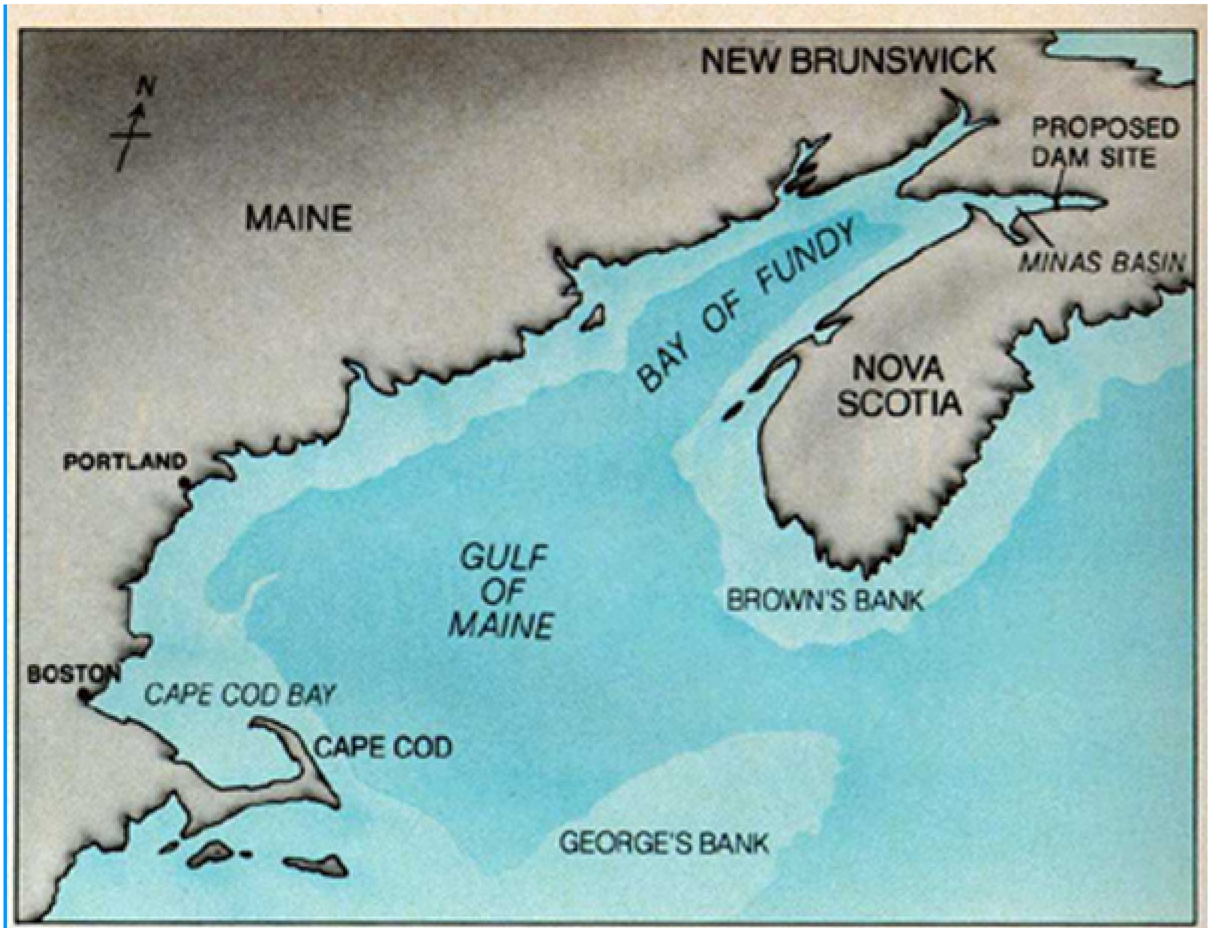
- Phillipines
- Apsley Strait, Australia
- A serious commercial venture
- Large Scale production in the UK

Potential Sites in the US

- Alaska (Cook Inlet)



- **Bay of Funday (US-Canadian Border; NE Coast of US) ☞ most favorable site in the World ☞ would produce about 30,000 MW in total (1/2 for the US)**



A power plant in Minas Basin could raise tides in Cape Cod Bay

- **A 20 MW demonstration plant has been built here**
- **Locally (New England) this is a potential important source of power but on national scale is just a few percent of our (insatiable) need for power**

Bottom Line: There aren't many favorable sites in the world for tidal power and the estimated capacity is 50 times smaller than the world's hydroelectric power capacity.

Electric Power Glossary

- **Above-market Cost -** The cost of a service in excess of the price of comparable services in the market.
- **Access Charge -** A charge for a power supplier, or its customer, for access to a utility's transmission or distribution system. It is a charge for the right to send electricity over another's wires.
- **Actual Peak Load Reductions -** Reduction in annual peak load by consumers who participate in a DSM program that reflect changes in demand.
- **Affiliate -** A company that is controlled by another or that has the same owner as another company.
- **Affiliated Power Producer -** A generating company that is affiliated with a utility.
- **After-Market -** Broad term that applies to any change after the original purchase, such as adding equipment not a part of the original purchase. As applied to alternative fueled vehicles, it refers to conversion devices or kits for conventional fuel vehicles.
- **Aggregation -** The process of organizing small groups, businesses or residential customer into a larger, more effective bargaining unit that strengthens their purchasing power with utilities.
- **Aggregator -** An entity that puts together customers into a guying group for the purchase of a commodity service. The vertically integrated investor owned utility, municipal utilities and rural electric cooperatives perform this function in today's power market. Other entities such as buyer cooperatives or brokers could perform this function in a restructured power market.
- **Alaskan System Coordination Council (ASCC) -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Allowance for Funds Used During Construction (AFUD -** Construction activities may be financed from internally generated funds (primarily earnings retained in the business), or from funds provided by other external sources (short- and long-term debt). The allowance for funds used during construction is intended to recognize the cost of these funds dedicated to construction activities during the construction period. To arrive at the "allowance", a common procedural method makes use of a formula that is based on the assumption that short-term debt is the first source of construction funds. The cost rate for short-term debt is based on current costs. Since a utility plant is subject to depreciation, the allowance for funds used during construction is recovered in the form of depreciation from ratepayers over the service life of the plant to which it applies.
- **Alternating Current (AC) -** Flow of electricity that constantly changes director between positive and negative sides. Almost all power produced by electric utilities in the United States moves in current that shifts direction at a rate of 60 times per second.

- **Ampere -** Unit that measures electrical current in a circuit by 1 volt acting through a resistance of 1 ohm.
- **Ancillary Services -** Services necessary for the transmission of energy from resources to loads.
- **Annual Effects -** Effects in energy use and peak load resulting from participation in DSM programs in effect during a given period of time.
- **Annual Equivalent -** An equal cash flow amount that occurs every year.
- **Annual Fuel Utilization Efficiency -** A measure of heating efficiency, in consistent units, determined by applying the federal test method for furnaces. This value is intended to represent the ratio of heat transferred to the conditioned space by the fuel energy supplies over one year.
- **Annual Maximum Demand -** The greatest of all demands of the electrical load which occurred during a prescribed interval in a calendar year.
- **Annuity -** A series of equal cash flows over a number of years.
- **Appliance Saturation -** The percentage of households or buildings in a service area that have the type of equipment to which the demand-side technology applies. For example, if 50 percent of the residential customers have a central air conditioner, the appliance saturation is 50 percent.
- **Applicability Factor -** The percentage of end-use energy and demand used by a technology to which the demand-side management (DSM) measure applies. For example, the high-efficiency fluorescent lighting DSM measure applies to fluorescent lighting but not all lighting. Applicability therefore represents the percent of the lighting end-use attributable to fluorescence for which there could be high-efficiency replacements installed.
- **Area Load -** The total amount of electricity being used at a given point in time by all consumers in a utility's service territory.
- **Attributes -** Attributes are the outcomes by which the relative "goodness" of a particular expansion plan is measured e.g. fuel usage. Some attributes, such as fuel usage, are measured in well-defined parameters. Other attributes (e.g. public perception of a technology) are more subjective. Attributes may be grouped in several ways. Categories include financial, economic, performance, fuel usage, environmental, and socio-economic. The attributes chosen must measure issues that directly concern the utility and have an impact on its planning objectives. Limiting the number of attributes reduces the complexity and cost of a study.
- **Available but not Needed Capability -** Capability of generating units that are operable but not necessary to carry load.
- **Average Cost -** The revenue requirement of a utility divided by the utility's sales. Average cost typically includes the costs of existing power plants, transmission, and distribution lines, and other facilities used by a utility to serve its customers. It also includes operations and maintenance, tax, and fuel expenses.
- **Average Demand -** The energy demand in a given geographical area over a period of time. For example, the number of kilowatt-hours used in a 24-hour period, divided by 24, tells the average demand for that period.

- **Average Revenue per Kilowatt-hour -** Revenue by sector and geographic area calculated by dividing the monthly revenue by monthly sales.
- **Avoided Costs -** These are costs that a utility avoids by purchasing power from an independent producer rather than generating power themselves, purchasing power from another source or constructing new power plants. A Public Utility Commission calculates avoided costs for each utility, and these costs are the basis upon which independent power producers are paid for the electricity they produce. There are two parts to an avoided cost calculation: the avoided capacity cost of constructing new power plants and the avoided energy cost of fuel and operating and maintaining utility power plants.
- **Base Bill -** The base bill is calculated by multiplying the rate from the electric rate by the level of consumption.
- **Base Load -** The minimum load experienced by an electric utility system over a given period of time.
- **Base Load Unit -** A generating unit that normally operates at a constant output to take all or part of the base load of a system.
- **Base Rate -** The portion of the total electric or gas rate covering the general costs of doing business unrelated to fuel expenses.
- **Base Year -** The first year of the period of analysis. The base year does not have to be the current year.
- **Baseline Forecast -** A prediction of future energy needs which does not take into account the likely effects of new conservation programs that have not yet been started.
- **Baseload Capacity -** Generating equipment operated to serve loads 24-hours per day.
- **Basic Service -** The four charges for generation, transmission, distribution and transition that all customers must pay in order to retail their electric service.
- **Bilateral Contract -** A direct contract between the power producer and user or broker outside of a centralized power pool.
- **Biomass -** Plant materials and animal waste used as a source of fuel.
- **Blackout -** A power loss affecting many electricity consumers over a large geographical area for a significant period of time.
- **British Thermal Unit (BTU) -** The standard unit for measuring quantity of heat energy. It is the amount of heat energy necessary to raise the temperature of one pound of water one degree Fahrenheit.
- **Broadband Communications -** The result of utilities forming partnerships to offer consumers "one-stop-shopping" for energy-related and high-tech telecommunications services.
- **Broker -** A retail agent who buys and sells power. The agent may also aggregate customers and arrange for transmission, firming and other ancillary services as needed.
- **Brownout -** A controlled power reduction in which the utility decreases the voltage on the power lines, so customers receive weaker electric current. Brownouts can be used if total power demand exceeds the maximum available supply. The typical household does not notice the difference.

- **Bulk Power Market -** Wholesale purchases and sales of electricity.
- **Bulk Power Supply -** Often this term is used interchangeably with wholesale power supply. In broader terms, it refers to the aggregate of electric generating plants, transmission lines, and related equipment. The term may refer to those facilities within one electric utility, or within a group of utilities in which the transmission lines are interconnected.
- **Buy Through -** An agreement between utility and customer to import power when the customer's service would otherwise be interrupted.
- **Capability -** Maximum load that a generating unit can carry without exceeding approved limits.
- **Capacitor -** This is a device that helps improve the efficiency of the flow of electricity through distribution lines by reducing energy losses. It is installed in substations and on poles. Usually it is installed to correct an unwanted condition in an electrical system
- **Capacity -** The maximum load a generating unit, generating station, or other electrical apparatus is rated to carry by the user or the manufacturer or can actually carry under existing service conditions.
- **Capacity (Purchased) -** Energy available for purchase from outside the system.
- **Capacity Charge -** An assessment on the amount of capacity being purchased.
- **Capacity Factor -** The ratio of the average load on a machine or equipment for a period of time to the capacity rating of the machine or equipment.
- **Capital Recovery Factor (CRF) -** A factor used to convert a lump sum value to an annual equivalent.
- **Captive Customer -** A customer who does not have realistic alternatives to buying power from the local utility, even if that customer had the legal right to buy from competitors.
- **Circuit -** Conductor for electric current.
- **Cogeneration -** Production of heat energy and electrical or mechanical power from the same fuel in the same facility. A typical cogeneration facility produces electricity and steam for industrial process use.
- **Cogenerator -** A facility that produces electricity and/or other energy for heating and cooling.
- **Coincidence Factor -** The ratio of the coincident maximum demand of two or more loads to the sum of their noncoincident maximum demands for a given period. The coincidence factor is the reciprocal of the diversity factor and is always less than or equal to one.
- **Coincidental Demand -** Two or more demands that occur at the same time.
- **Coincidental Peak Load -** Two or more peak loads that occur at the same time.
- **Combined Cycle -** Similar to the combustion turbine simple cycle, but includes a heat recovery steam generator that extracts heat from the combustion turbine exhaust flow to produce steam. This steam in turn powers a steam turbine engine.

- **Combined Cycle Plant -** An electric generating station that uses waste heat from its gas turbines to produce steam for conventional steam turbines.
- **Combustion Turbine -** A fossil-fuel-fired power plant that uses the conversion process known as the Brayton cycle. The fuel, oil, or gas is combusted and drives a turbine-generator.
- **Commercial Operation -** Commercial operation occurs when control of the generator is turned over to the system dispatcher.
- **Commercialization -** Programs or activities that increase the value or decrease the cost of integrating new products or services into the electric sector.
- **Comparability -** When a transmission owner provides access to transmission services at rates, terms and conditions equal to those the owner incurs for its own use.
- **Competitive Bidding -** This is a procedure that utilities use to select suppliers of new electric capacity and energy. Under competitive bidding, an electric utility solicits bids from prospective power generators to meet current or future power demands. When offers from independent power producers began exceeding utility needs in the mid-1908's, utilities and state regulators began using competitive bidding systems to select more fairly among numerous supply alternatives.
- **Competitive Franchise -** A process whereby a municipality (or group of municipalities) issues a franchise to supply electricity in the community to the winner of a competitive bid process. Such franchises can be for bundled electricity and transmission/distribution, or there can be separate franchises for the supply of electricity services and the transmission and distribution function. Franchises can be, but typically are not, exclusive licenses.
- **Competitive Transition Charge (CTC) -** A "nonbypassable" charge generally placed on distribution services to recover utility costs incurred as a result of restructuring (stranded costs - usually associated with generation facilities and services) and not recoverable in other ways.
- **Comprehensive National Energy Policy Act -** Federal legislation in 1992 that opened the U.S. electric utility industry to increase competition at the wholesale level and left authority for retail competition to the states.
- **Conductor -** An object or substance which conducts or leads electric current. A wire, cable, busbar, rod, or tube can serve as a path for electricity to flow. The most common conductor is an electrical wire.
- **Connection -** The connection between two electrical systems that permit the transfer of energy.
- **Conservation -** A foregoing or reduction of electric usage for the purpose of saving natural energy resources and limiting peak demand in order to ultimately reduce the capacity requirements for plant and equipment.
- **Consumer Education -** Efforts to provide consumers with skills and knowledge to use their resources wisely in the marketplace.
- **Consumption (Fuel) -** Amount of fuel used for gross generation.
- **Contract Path -** The most direct physical transmission tie between two interconnected entities. When utility systems interchange power, the transfer is

presumed to take place across the "contract path" , notwithstanding the electric fact that power flow in the network will distribute in accordance with network flow conditions. This term can also mean to arrange for power transfer between systems.

- **Contract Price -** Price marketed on a contract basis for one or more years.
- **Contract Receipts -** Purchases that cover at least one year.
- **Control Area -** A power system or systems to which an automatic control is applied.
- **Converter -** Any technology that changes the potential energy in fuel into a different form of energy such as heat or motion. The term also is used to mean an apparatus that changes the quantity or quality of electric energy.
- **Cooperative Electric Utility -** A utility established to be owned by and operated for the benefit of those using its services.
- **Cross-subsidization -** This refers to the transfer of assets or services from the regulated portion of an electric utility to its unregulated affiliates to produce an unfair competitive advantage. Also, cross-subsidization can refer to one rate class (such as industrial customers) subsidizing the rates of another class (such as residential customers).
- **Current (Electric) -** Flow of electrons in an electric conductor.
- **Current Transformers -** These are used in conjunction with metering equipment. They are designed to permit measurement of currents beyond the range of a meter.
- **Customer Assistance Programs -** Alternative collection program set up between a utility company and a customer that allows customers to pay utility bills on a percentage-of-the-bill they owe or percentage-of-customer-income instead of paying the full amount owed. These programs are for low-income people who can't pay their bills. These customers must agree to make regular monthly payments based on their new payment plans.
- **Customer Class -** A distinction between users of electric energy. Customer class is usually defined by usage patterns, usage levels, and conditions of service. Classes are usually categorized generically by customer activity (e.g. residential, commercial, industrial, agricultural, street lighting).
- **Customer Costs -** Costs that are related to and vary with the number of customers. Customer costs include meters, meter readers, or service equipment costs.
- **Customer Service Charge -** That portion of the customer's bill which remains the same from month to month. The charge is determined separately from the amount of energy used. It is based on the costs associated with connecting a customer to the company's distribution system, including the service connection and metering equipment. This charge also recovers expenses such as meter reading, billing costs, customer accounting expenses records and collections, and a portion of general plant items such as office space for customer service personnel.
- **Customer Service Protection -** The rules governing grounds for denial of service, credit determination, deposit and guarantee practices, meter reading and accuracy, bill contents, billing frequency, billing accuracy, collection practices,

notices, grounds for termination of service, termination procedures, rights to reconnection, late charges, disconnection/reconnection fees, access to budget billing and payment arrangements, extreme weather, illness or other vulnerable customer disconnection protections, and the like. In a retail competition model, would include protections against "slamming" and other hard-sell abuses.

- **Daily Peak -** The maximum amount of energy or service demanded in one day from a company or utility service.
- **Degree-day -** A unit measuring the extent to which the outdoor mean (average of maximum and minimum) daily dry-bulb temperature falls below (in the case of heating) or rises above (in the case of cooling) an assumed base. The base is normally taken as 65 degrees for heating and cooling unless otherwise designated.
- **Demand (electric) -** The rate at which electric energy is delivered to or by a system, part of a system, or a piece of equipment. Demand is expressed in kW, kVA, or other suitable units at a given instant or over any designated period of time. The primary source of "demand" is the power-consuming equipment of the customers.
- **Demand Billing -** The electric capacity requirement for which a large user pays. It may be based on the customer's peak demand during the contract year, on a previous maximum or on an agreed minimum. It is measured in kilowatts.
- **Demand Charge -** The sum to be paid by a large electricity consumer for its peak usage level.
- **Demand Controller -** An electrical, mechanical, or electromechanical device or system that monitors the customer demand and causes that demand to be leveled and/or limited.
- **Demand Ratchet -** This is the minimum billing demand based upon a given percentage of the actual demand use, recorded during the last eleven months of demand history.
- **Demand-Side Management (DSM) -** A technology or program that encourages customers to use electricity differently.
- **Demonstration -** The application and integration of a new product or service into an existing or new system. Most commonly, demonstration involves the construction and operation of a new electric technology interconnected with the electric utility system to demonstrate how it interacts with the system. This includes the impacts the technology may have on the system and the impacts that the larger utility system may have on the functioning of the technology.
- **Departing Member -** A member consumer served at retail by an electric cooperative corporation that hs given notice of intent to receive generation services from another source or that is otherwise in the process of changing generation suppliers. These persons shall nonetheless remain members of the electric distribution cooperative corporation for purposes of distribution service.
- **Dependable Capacity -** The system's ability to carry the electric power for the time interval and period specified. Dependable capacity is determined by such factors as capability, operating power factor and portion of the load the station is to supply.

- **Depletable Energy Sources -** This includes: 1) electricity purchased from a public utility and 2) energy obtained from burning coal, oil, natural gas or liquefied petroleum gasses.
- **Depreciation, Straight-line -** Straight-line depreciation takes the cost of the asset less the estimated salvage value and allocates the cost in equal amounts over the asset's estimated useful life.
- **Deregulation -** The elimination of regulation from a previously regulated industry or sector of an industry.
- **Designated Agent -** An agent that acts on behalf of a transmission provider, customer or transmission customer as required under the tariff.
- **Direct Access -** The ability of a retail customer to purchase commodity electricity directly from the wholesale market rather than through a local distribution utility.
- **Direct Current (DC) -** Electric that flows continuously in the same direction.
- **Direct Energy Conversion -** Production of electricity from an energy source without transferring the energy to a working fluid or steam. For example, photovoltaic cells transform light directly into electricity. Direct conversion systems have no moving parts and usually produce direct current.
- **Direct Load Control -** Activities that can interrupt load at the time of peak by interrupting power supply on consumer premises, usually applied to residential consumers.
- **Direct Utility Cost -** A cost identified with one of the DSM categories.
- **Disaggregation -** The functional separation of the vertically integrated utility into smaller, individually owned business units (I.e. generation, dispatch/control, transmission, distribution). The terms "deintegration", "disintegration" and "delimitation" are sometimes used to mean the same thing.
- **Discount/Interest Rate -** The discount rate is used to determine the present value of future or past cash flows. The rate accounts for inflation and the potential earning power of money.
- **Dispatchability -** This is the ability of a generating unit to increase or decrease generation, or to be brought on line or shut down at the request or a utility's system operator.
- **Distributed Generation -** A distributed generation system involves small amounts of generation located on a utility's distribution system for the purpose of meeting local (substation level) peak loads and/or displacing the need to build additional (or upgrade) local distribution lines.
- **Distribution -** The system of wires, switches, and transformers that serve neighborhoods and business, typically lower than 69,000 volts. A distribution system reduces or downgrades power from high-voltage transmission lines to a level that can be used in homes or businesses.
- **Distribution Line -** This is a line or system for distributing power from a transmission system to a customer. It is any line operating at less than 69,000 volts.
- **Distribution System -** That part of the electric system that delivers electric energy to consumers.

- **Distribution Utility (Disco) -** The regulated electric utility entity that constructs and maintains the distribution wires connecting the transmission grid to the final customer. The Disco can also perform other services such as aggregating customers, purchasing power supply and transmission services for customers, billing customers and reimbursing suppliers, and offering other regulated or non-regulated energy services to retail customers. The "wires" and "customer service" functions provided by a distribution utility could be split so that two totally separate entities are used to supply these two types of distribution services.
- **Distributive Power -** A packaged power unit located at the point of demand. While the technology is still evolving, examples include fuel cells and photovoltaic applications.
- **Diversity Exchange -** Exchange of capacity or energy between systems that have peak loads occurring at different times.
- **Diversity Factor -** The ratio of the sum of the non-coincident maximum demands of two or more loads to their coincident maximum demand for the same period.
- **Divestiture -** The stripping off of one utility function from the others by selling (spinning-off) or in most other way changing the ownership of the assets related to that function. Most commonly associated with spinning-off generation assets so they are no longer owned by the shareholders that own the transmission and distribution assets.
- **DSM Measure Technology Program -** Single devices, equipment, or rates as listed in the Reference Data. A demand-side management program is usually a group of DSM measures or technologies. However, a DSM program could in some cases be a single measure.
- **East Central Area Reliability Coordination Agreeme -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Economic Dispatch -** The distribution of total generation requirements among alternative sources for optimum system economy with consideration to both incremental generating costs and incremental transmission losses.
- **Economic Efficiency -** A term that refers to the optimal production and consumption of goods and services. This generally occurs when prices of products and services reflect their marginal costs. Economic efficiency gains can be achieved through cost reduction, but it is better to think of the concept as actions that promote an increase in overall net value (which includes, but is not limited to, cost reductions).
- **Economy Energy -** Energy produced and substituted for the traditional but less economical source of energy. Economic energy is usually sold without capacity and is priced at variable costs plus administration costs.
- **Efficiency Service Company -** A company that offers to reduce a client's electricity consumption with the cost savings being split with the client.
- **Elasticity of Demand -** The ratio of the percentage change in the quantity demanded of a good to the percentage change in price.

- **Electric Capacity -** This refers to the ability of a power plant to produce a given output of electric energy at an instant in time, measured in kilowatts or megawatts (1,000 kilowatts).
- **Electric Distribution Company -** The company that owns the power lines and equipment necessary to deliver purchased electricity to the customer.
- **Electric Plant (Physical) -** A facility that contains all necessary equipment for converting energy into electricity.
- **Electric Power Supplier -** Non-utility provider of electricity to a competitive marketplace.
- **Electric Rate Schedule -** An electric rate and its contract terms accepted by a regulatory agency.
- **Electric Reliability Council of Texas (ERCOT) -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Electric System -** This term refers to all of the elements needed to distribute electrical power. It includes overhead and underground lines, poles, transformers, and other equipment.
- **Electric Utility -** A legal entity that owns and/or operates facilities for the generation, transmission, distribution, or sale of electric energy.
- **Electric Utility Affiliate -** This refers to a subsidiary or affiliate of an electric utility. Many utilities form affiliates to develop, own, and operate independent power facilities.
- **Electric Wholesale Generator -** A power producer who sells power at cost to a customer.
- **Embedded Cost -** A utility's average cost of doing business, which includes the costs of fuel, personnel, plants, poles, and wires.
- **End-Use -** The specific purpose for which electric is consumed (I.e. heating, cooling, cooking, etc.).
- **Energy -** This is broadly defined as the capability of doing work. In the electric power industry, energy is more narrowly defined as electricity supplied over time, express in kilowatt-hours.
- **Energy Charge -** The amount of money owed by an electric customer for kilowatt-hours consumed.
- **Energy Consumption -** The amount of energy consumed in the form in which it is acquired by the user. The term excludes electrical generation and distribution losses.
- **Energy Costs -** Costs, such as for fuel, that are related to and vary with energy production or consumption.
- **Energy Deliveries -** Energy generated by one system delivered to another system.
- **Energy Effects -** Changes at the consumer meter that reflect activities undertaken in response to utility-administered programs.
- **Energy Efficiency -** Programs that reduce consumption.
- **Energy Policy Act of 1992 -** This act which was the first comprehensive federal energy law promulgated in more than a decade will help create a more

competitive U.S. electric power marketplace by removing barriers to competition. By doing so, this act allows a broad spectrum of independent energy producers to compete in wholesale electric power markets. The act also made significant changes in the way power transmission grids are regulated. Specifically, the law gives the Federal Energy Regulatory Commission the authority to order electric utilities to provide access to their transmission facilities to other power suppliers.

- **Energy Receipts -** Energy generated by one utility system that is received by another through transmission lines.
- **Energy Reserves -** The portion of total energy resources that is known and can be recovered with presently available technology at an affordable cost.
- **Energy Resources -** Everything that could be used by society as a source of energy.
- **Energy Services Companies (ESCOs) -** ESCOs would be created in a deregulated, openly competitive electric marketplace. The Energy Services industry would be made up of power aggregators, power marketers and brokers, whose job is to match buyers and sellers, tailor both physical and financial instruments to suit the needs of particular customers, and to allow even the smallest residential customers to form buying groups or cooperatives that will give them the same bargaining power as large industrial customers.
- **Energy Source -** A source that provides the power to be converted to electricity.
- **Energy Use -** Energy consumed during a specified time period for a specific purpose (usually expressed in kWh).
- **Entitlement -** Electric energy or generating capacity that a utility has a right to access under power exchange or sales agreements.
- **Entrance Cable/Service Entrance Conductor -** This is the cable running down the side of a customer's house into the meter. This cable is owned by the customer and its maintenance is the customer's responsibility. Work on this cable should be performed only by a licensed electrician.
- **Environmental Attributes -** Environmental attributes quantity the impact of various options on the environment. These attributes include particulate emissions, SO2 or Nox, and thermal discharge (air and water).
- **Escape Provision -** A contract provision which allows a party, such as an electric customer, to get out of it. Usually, there is a penalty.
- **Exempt Wholesale Generator (EWG) -** An EWG is a category of power producer defined by the Energy Policy Act of 1992. EWG's are independent power facilities that generate electricity for sale in wholesale power markets at market-based rates. The Federal Energy Regulatory Commission is responsible for determining EWG status.
- **Facility -** A location where electric energy is generated from energy sources.
- **Feasibility Factor -** A factor used to adjust potential energy savings to account for cases where it is impractical to install new equipment. For example, certain types of fluorescent lighting require room temperature conditions. They are not feasible for outdoor or unheated space applications. Some commercial applications, such as color-coded warehouses, require good color rendition, so

color distortions could also make certain types of lighting infeasible. The feasibility factor equals 100 percent minus the percent of infeasible applications.

- **Federal Energy Regulatory Commission (FERC) -** The regulatory agency, in the U.S. Department of Energy, that has jurisdiction over interstate electricity sales, wholesale rates, licensing, etc.
- **Federal Power Act -** An act that includes the regulation of interstate transmission of electrical energy and rates. This act is administered by the Federal Energy Regulatory Commission.
- **Feeder -** This is an electrical supply line, either overhead or underground, which runs from the substation, through various paths, ending with the transformers. It is a distribution circuit, usually less than 69,000 volts, which carries power from the substation.
- **Feeder Lockout -** This happens when a main circuit is interrupted at the substation by automatic protective devices and cannot be restored until crews investigate. This indicates a serious problem on the circuit, usually equipment failure or a broken conductor.
- **Financial Attributes -** Financial attributes measure the financial health of the company. Utility management, security analysts, investors, and regulators use these attributes to evaluate a utility's performance against its historic records and industry averages. Key financial attributes include capital requirements, earnings per share of common equity, capitalization ratios, and interest coverage ratios.
- **Firm Energy -** Power or power-producing capacity covered by a commitment to be available at all times during the period.
- **Firm Transmission Service -** Service that is reserved for at least one year.
- **Fixed Costs -** The annual costs associated with the ownership of property such as depreciation, taxes, insurance, and the cost of capital.
- **Flat Rate -** A fixed charge for goods and services that does not vary with changes in the amount used, volume consumed, or units purchased.
- **Flexible Load Shape -** The ability to modify your utility's load shape on short notice. When resources are insufficient to meet load requirements, load shifting or peak clipping may be appropriate.
- **Flexible Retail PoolCo -** This provides a model for the restructured electric industry that features an Independent System Operator (ISO) operating in parallel with a commercial Power Exchange, which allows end-use customers to buy from a spot market or "pool" or to contract directly with a particular supplier.
- **Forced Outage -** An outage that results from emergency conditions and requires a component to be taken out of service automatically or as soon as switching operations can be performed. The forced outage can be caused by improper operation of equipment or by human error. If it is possible to defer the outage, the outage becomes a scheduled outage.
- **Franchise Area -** This is the territory in which a utility system supplies service to customers.
- **Franchise Monopoly -** Under this system, a utility has the right to be the sole or principal supplier of electric power at a retail level in a specific region or area knows as the franchise service territory. In return for its sole supplier privilege, the utility has an obligation to serve anyone who requests service, and agrees to

be accountable to state and/or federal regulatory bodies that regulate the utility's performance, accounting procedures, pricing structures, and plant planning and siting.

- **Fuel -** A substance that can be burned to product heat.
- **Fuel Adjustment -** A clause in the rate schedule that provides for adjustment of the amount of a bill as the cost of fuel varies from a specified base amount per unit. The specified base amount is determined when rates are approved. This item is shown on all customer bills and indicates the current rate for any adjustment in the cost of fuel used by the company. It can be a credit or a debit. The fuel adjustment lags two months behind the actual price of the fuel. For example, the cost of oil in January will be reflected in March's fuel adjustment.
- **Fuel Cell -** An advanced energy conversion device that converts fuels to power very efficiently and with minimal environmental impact.
- **Fuel Diversity -** A utility or power supplier that has power stations using several different types of fuel. Avoiding over-reliance on one fuel helps avoid the risk of supply interruption and price spikes.
- **Fuel Escalation -** The annual rate of increase of the cost of fuel, including inflation and real escalation, resulting from resource depletion, increased demand, etc.
- **Fuel Expenses -** Costs associated with the generation of electricity.
- **Fuel-Use Attributes -** Fuel-use attributes are important to utilities concerned about reliance on a single fuel or reduction in usage of a particular fuel. These attributes include annual fuel consumption by type and percent energy generation by fuel.
- **Full-Forced Outage -** Net capability of generating units unavailable for load for emergencies.
- **Functional Unbundling -** The functional separation of generation, transmission, and distribution transactions within a vertically integrated utility without selling of "spinning off" these functions into separate companies.
- **Generating Station (Generating Plant or Power Plan -** The location of prime movers, electric generators, and auxiliary equipment used for converting mechanical, chemical, and nuclear energy into electric energy.
- **Generating Unit -** Combination of connected prime movers that produce electric power.
- **Generation (Electricity) -** Process of producing electric energy by transforming other forms of energy.
- **Generation Charges -** Part of the basic service charges on every customer's bill for producing electricity. Generation service is competitively priced and is not regulated by Public Utility Commissions. This charge depends on the terms of service between the customer and the supplier.
- **Generation Company (Genco) -** A regulated or non-regulated entity (depending upon the industry structure) that operates and maintains existing generating plants. The Genco may own the generation plants or interact with the short term market on behalf of plant owners. In the context of restructuring the market for electricity, Genco is sometimes used to describe a specialized

"marketer" for the generating plants formerly owned by a vertically-integrated utility.

- **Generation Dispatch and Control -** Aggregation and dispatching (sending off to some location) generation from various generating facilities, providing backup and reliability services.
- **Generator -** Machine used to convert mechanical energy into electrical energy.
- **Geothermal -** An electric generating station in which steam tapped from the earth drives a turbine-generator, generating electricity.
- **Gigawatt -** This is a unit of electric power equal to one billion watts, or one thousand megawatts - enough power to supply the needs of a medium-sized city.
- **Good Utility Practice -** Methods and practices that are approved by a significant portion of the industry.
- **Greenfield Plant -** This refers to a new electric power generating facility built from the ground up.
- **Grid -** Matrix of an electrical distribution system.
- **Gross Generation -** Amount of electric energy produced by generating units as measured at the generator terminals.
- **Heat Rate -** A measure of generating station thermal efficiency and generally expressed as Btu per net k/Wh. The heat rate is computed by dividing the total Btu content of the fuel burned (or of heat released from a nuclear reactor) by the resulting net kWh generated.
- **High Heat Value (HHV) -** The high or gross heat content of the fuel with the heat of vaporization included; the water vapor is assumed to be in a liquid state.
- **Hourly Metering -** Tracking or recording a customer's consumption during specific periods of time that can be tied to the price of energy.
- **Hourly Non-Firm Transmission Service -** Transmission scheduled and paid for on an as-available basis and subject to interruption.
- **Hydroelectric -** An electric generating station in which a water wheel is driven by falling water, thus generating electricity.
- **Incentive -** A rebate or some form of payment used to encourage people to implement a given demand-side management (DSM) technology. The incentive is calculated as the amount of the technology costs that must be paid by the utility for the participant test to equal one and achieve the desired benefit/cost ratio to drive the market.
- **Incremental Effects -** Annual effects in energy use and peak load caused by new participants in existing DSM programs and all participants in new DSM programs during a given year.
- **Independent Power Producers (IPPs) -** These are private entrepreneurs who develop, own or operate electric power plants fueled by alternative energy sources such as biomass, cogeneration, small hydro, waste-energy and wind facilities.
- **Independent System Operator (ISO) -** An ISO is the entity charged with reliable operation of the grid and provision of open transmission access to all market participants on a non-discriminatory basis.

- **Indirect Utility Cost -** Any cost that is not identified with a specific DSM category such as Administration, Marketing, etc.
- **Installed capacity -** The total generating units' capacities in a power plant or on a total utility system. The capacity can be based on the nameplate rating or the net dependable capacity.
- **Intangible Transition Charge -** The amounts on all customer bills, collected by the electric utility to recover transition bond expenses.
- **Integrated Resource Plan (IRP) -** A comprehensive and systematic blueprint developed by a supplier, distributor, or end-user of energy who has evaluated demand-side and supply-side resource options and economic parameters and determined which options will best help them meet their energy goals at the lowest reasonable energy, environmental, and societal cost.
- **Interchange (Electric utility) -** The agreement among interconnected utilities under which they buy, sell and exchange power among themselves. This can, for example, provide for economy energy and emergency power supplies.
- **Interconnection (Electric utility) -** The linkage of transmission lines between two utility, enabling power to be moved in either direction. Interconnections allow the utilities to help contain costs while enhancing system reliability.
- **Interdepartmental Service (Electric) -** Amounts charged by the electric department at specified rates for electricity supplied by other utility departments.
- **Intermediate Load (Electric Systems) -** Range from base load to a point between that and peak load.
- **Intermittent Resources -** Resources whose output depends on some other factory that cannot be controlled by the utility e.g. wind or sun. Thus, the capacity varies by day and by hour.
- **Interruptible Loads -** Loads that can be interrupted in the event of capacity or energy deficiencies on the supplying system.
- **Interruptible Power -** This refers to power whose delivery can be curtailed by the supplier, usually under some sort of agreement by the parties involved.
- **Interruptible Rates -** These provide power at a lower rate to large industrial and commercial customers who agree to reduce their electricity use in times of peak demand.
- **Interval Metering -** The process by which power consumption is measured at regular intervals in order that specific load usage for a set period of time can be determined.
- **Investor-Owned Utility (IOU) -** An IOU is a form of electric utility owned by a group of investors. Shares of IOUs are traded on public stock markets.
- **Jurisdictional -** Utilities, ratepayers and regulators (and impacts on those parties) that are subject to state regulation in a state considering restructuring.
- **Kilovolt ampere (kVA) -** The practical unit of apparent power, which is 1,000 volt-amperes. The volt-amperes of an electric circuit are the mathematical products of the volts and amperes of the client.
- **Kilowatt (kW) -** The electrical unit of power equal to 1,000 watts.

- **Kilowatt-Hour (kWh) -** The basic unit of electric energy equal to one kilowatt of power supplied to or taken from an electric circuit for one hour.
- **Layoff -** Excess capacity of a generating unit, available for a limited time under the terms of a sales agreement.
- **Levelized -** A lump sum that has been divided into equal amounts over period of time.
- **Lightning Arrestor -** This protects lines, transformers, and equipment from lightning surges by carrying the charge to the ground. Lightning arrestors serve the same purpose on a line as a safety valve on a steam boiler.
- **Line -** A line is a system of poles, conduits, wires, cables, transformers, fixtures, and accessory equipment used for the distribution of electricity to the public.
- **Load -** The amount of electric power delivered or required at any specified point or points on a system. Load originates primarily at the power consuming equipment of the customer.
- **Load Building -** Programs aimed at increasing use of existing electric equipment or the addition of new equipment.
- **Load Centers -** A limited geographical area where large amounts of power are used by customers.
- **Load Diversity -** The condition that exists when the peak demands of a variety of electric customers occur at different times. This is the objective of "load molding" strategies, ultimately curbing the total capacity requirements of a utility.
- **Load Duration Curve -** A curve that displays load values on the horizontal axis in descending order of magnitude against percent of time (on the vertical axis) the load values are exceeded.
- **Load Factor -** The ratio of the average load supplied to the peak or maximum load during a designated period. Load factor, in percent, also may be derived by multiplying the kWh in a given period by 100, and dividing by the product of the maximum demand in kW and the number of hours in the same period.
- **Load Forecast -** Estimate of electrical demand or energy consumption at some future time.
- **Load Management -** Influencing the level and shape of demand for electrical energy so that demand conforms to present supply situations and long-run objectives and constraints.
- **Load Profile -** Information on a customer's usage over a period of time, sometimes shown as a graph.
- **Load Ratio Share -** Ratio of a transmission customer's network load to the provider's total load calculated on a rolling twelve-month basis.
- **Load Shape -** A curve on a chart showing power (kW) supplied (on the horizontal axis) plotted against time of occurrence (on the vertical axis), and illustrating the varying magnitude of the load during the period covered.
- **Load Shifting -** A load shape objective that involves moving loads from peak periods to off-peak periods. If a utility does not expect to meet its demand during peak periods but has excess capacity in the off-peak periods, this strategy might be considered.

- **Loss of Load Probability (LOLP) -** A measure of the probability that system demand will exceed capacity during a given period; this period is often expressed as the expected number of days per year over a long period, frequently taken as ten consecutive years. An example of LOLP is one day in ten years.
- **Losses -** The general term applied to energy (kWh) and capacity (kW) lost in the operation of an electric system. Losses occur principally as energy transformations from kWh to waste-heat in electrical conductors and apparatus. This waste-heat in electrical conductors and apparatus. This power expended without accomplishing useful work occurs primarily on the transmission and distribution system.
- **Low Heat Value (LHV) -** The low or net heat of combustion for a fuel assumes that all products of combustion, including water vapor, are in a gaseous state.
- **Marginal Cost -** The cost to the utility or providing the next (marginal) kilowatt-hour of electricity, irrespective of sunk costs.
- **Marginal Cost -** The sum that has to be paid the next increment of product of service. The marginal cost of electricity is the price to be paid for kilowatt-hours above and beyond those supplied by presently available generating capacity.
- **Market Eligibility -** The percentage of equipment still available for retrofit to the demand-side management measure. For example, if 20 percent of customers where demand controllers are feasible have already purchased demand controllers, then the eligible market eligibility factor is 80 percent.
- **Market-Based-Price -** A price set by the mutual decisions of many buyers and sellers in a competitive market.
- **Marketer -** An agent for generation projects who markets power on behalf of the generator. The marketer may also arrange transmission, firming or other ancillary services as needed. Though a marketer may perform many of the same functions as a broker, the difference is that a marketer represents the generator while a broker acts as a middleman.
- **Maximum Demand -** Highest demand of the load within a specified period of time.
- **Maximum Demand -** Highest demand of the load occurring within a specified period of time.
- **Measure Life -** The length of time that the demand-side management technology will last before requiring replacement. The measure life equals the technology life. These terms are used synonymously.
- **Megawatt -** One million watts.
- **Megawatt-hour (MWh) -** One thousand kilowatt-hours or one million-watt hours.
- **Member System -** An eligible customer operating as part of an agency composed exclusively of other eligible customers.
- **Meter Constant -** This represents the ratio between instrument transformers (CTs, PTs) and the meter. It is used as a multiplier of the difference between meter readings to determine the kWh used. The meter constant is also used as a multiplier of the demand reading to determine the actual demand.

- **Mid-America Interconnected Network (MAIN -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Mid-Atlantic Area Council (MAAC) -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Mid-Continent Area Power Pool (MAPP); -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Mill -** One mill is equal to one-thousandth of a dollar.
- **Mobile Substation -** This is a movable substation which is used when a substation is not working or additional power is needed.
- **Monopoly -** The only seller with control over market sales.
- **Monopsony -** The only buyer with control over market purchases.
- **Municipal Electric Utility -** A power utility system owned and operated by a local jurisdiction.
- **Municipal Solid Waste -** A Biomass resource that can be used to produce energy by the process of incineration.
- **Municipalization -** The process by which a municipal entity assumes responsibility for supplying utility service to its constituents. In supplying electricity, the municipality may generate and distribute the power or purchase wholesale power from other generators and distribute it.
- **Native Load Customers -** Wholesale and retail customers that the transmission provider constructs and operates a system to provide electric needs.
- **Net Capability -** Maximum load carrying ability of the equipment, excluding station use.
- **Net Generation -** Gross generation minus plant use.
- **Net Generation -** Gross generation minus the energy consumed at the generating station for its use.
- **Network -** A system of transmission and distribution lines cross-connected and operated to permit multiple power supply to any principal point on it. A network is usually installed in urban areas. It makes it possible to restore power quickly to customers by switching them to another circuit.
- **Network Customers -** Customers receiving service under the terms of the Transmission Provider's Network Integration Tariff.
- **Network Integration Transmission Service -** A service that allows the customer to integrate, plan, dispatch, and regulate its Network Resources.
- **Network Load -** Designated load of a transmission customer.
- **New England Power Exchange (NEPEX) -** This is the operating arm of the New England Power Pool.
- **New England Power Pool (NEPOOL) -** A regional consortium of 98 utilities who coordinate, monitor and direct the operations of major generation and transmission facilities in New England.
- **Non-basic Service -** Any category of service not related to basic services (generation, transmission, distribution and transition charges).

- **Non-bypassable Wires Charge -** A charge generally placed on distribution services to recover utility costs incurred as a result of restructuring (stranded costs - usually associated with generation facilities and services) and not recoverable in other ways.
- **Non-Firm Power -** Power supplied or available under terms with limited or no assured availability.
- **Non-Firm Transmission Service -** Point-to-point service reserved and/or scheduled on an as-available basis.
- **Non-jurisdictional -** Utilities, ratepayers and regulators (and impacts on those parties) other than state-regulated utilities, regulators and ratepayers in a jurisdiction considering restructuring. Examples include utilities in adjacent state and non-state regulated, publicly owned utilities within restructuring states.
- **Non-utility Generator -** Independent power producers, exempt wholesale generators and other companies in the power generation business that have been exempted from traditional utility regulation.
- **Noncoincidental Peak Load -** The sum of two or more peak loads on individual systems, not occurring in the same time period.
- **Nonutility Power Producer -** A legal entity that owns electric generating capacity, but it not an electric utility.
- **North American Electric Reliability Council (NERC) -** Council formed by electric utility industry in 1968 to promote the reliability and adequacy of bulk power supply in utility systems of North America. NERC consists of ten regional reliability councils: Alaskan System Coordination Council (ASCC); East Central Area Reliability Coordination Agreement (ECAR); Electric Reliability Council of Texas (ERCOT); Mid-America Interconnected Network (MAIN); Mid-Atlantic Area Council (MAAC); Mid-Continent Area Power Pool (MAPP); Northeast Power Coordinating Council (NPCC); Southeastern Electric Reliability Council (SERC); Southwest Power Pool (SPP); Western systems Coordinating Council (WSCC).
- **North/South -** Technology factors are provided for North and South because some equipment and technologies are temperature sensitive. A North designation generally represents a utility that experiences cold winters and has average annual heating degree days of at least 5,000 (based on a 65 degree base). A South designation has relatively mild winters but a significant saturation of air conditioning. This geographical designation is very general, but it is intended to separate out areas that are warmer than others.
- **Northeast Power Coordinating Council (NPCC) -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Notice of Proposed Rulemaking -** A designation used by the Federal Energy Regulatory Commission for some of its dockets.
- **Nuclear Regulatory Commission -** This is the federal agency responsible for the licensing of nuclear facilities. They oversee these facilities and make sure regulations and standards are followed.
- **Obligation to Serve -** The obligation of a utility to provide electric service to any customer who seeks that service, and is willing to pay the rates set for that

service. Traditionally, utilities have assumed the obligation to serve in return for an exclusive monopoly franchise.

- **Off-peak -** Periods of relatively low system demands.
- **Ohm -** Unit of measure of electrical resistance.
- **On-Peak Energy -** Energy supplied during periods of relatively high system demand as specified by the supplier.
- **Open Access -** Access to the electric transmission system by any legitimate market participant, including utilities, independent power producers, cogenerators, and power marketers.
- **Operation and Maintenance Expenses -** Costs that relate to the normal operating, maintenance and administrative activities of a business.
- **Options -** Options are potential decisions over which a utility has a reasonable degree of control. One option might be to build a new coal-fired power plant; another option might be to refurbish an old power plant. Each option has one of more values to be specified. A specified option has a specified value such as year of implementation or size of plant. A plan is a set of specified options. A plan contains a set of decisions or commitments the utility can make, given the options available.
- **Outage -** Time during which service is unavailable from a generating unit, transmission line, or other facility.
- **Overload -** The flow of electricity into conductors or devices when normal load exceeds capacity.
- **Parallel Path Flow -** This refers to the flow of electric power on an electric system's transmission facilities resulting from scheduled electric power transfers between two other electric systems. (Electric power flows on all interconnected parallel paths in amounts inversely proportional to each path's resistance.)
- **Partial Load -** An electrical demand that uses only part of the electrical power available.
- **Payback -** The length of time it takes for the savings received to cover the cost of implementing the technology.
- **Peak -** Periods of relatively high system demands.
- **Peak Clipping -** Peak clipping reduces a utility's system peak, reducing the need to operate peaking units with relatively high fuel costs. Peak clipping is typically pursued only for the days the system peak is likely to occur, and the resources are not expected to meet the impending load requirements.
- **Peak Demand -** Maximum power used in a given period of time.
- **Peak Load Power plant -** A power generating station that is normally used to produce extra electricity during peak load times.
- **Peaking Capacity -** Generating equipment normally operated only during the hours of highest daily, weekly, or seasonal loads; this equipment is usually designed to meet the portion of load that is above base load.
- **Peaking Unit -** A power generator used by a utility to produce extra electricity during peak load times.

- **Performance Attributes -** Performance attributes measure the quality of service and operating efficiency. Loss of load probability, expected energy curtailment, and reserve margin are all performance attributes.
- **Period of Analysis -** The number of years considered in the study.
- **Phase -** One of the characteristics of the electric service supplied or the equipment used. Practically all residential customers have single-phase service. Large commercial and industrial customers have either two-phase or three-phase service.
- **Photovoltaics -** A technology that directly converts light into electricity. The process uses modules, which are usually made up of many cells (thin layers of semiconductors).
- **Pilot -** A utility program offering a limited group of customers their choice of certified or licensed energy suppliers on a one year minimum trial basis.
- **Planned Generator -** Proposal to install generating equipment at an existing or planned facility or site.
- **Plant -** A facility containing prime movers, electric generators, and other equipment for producing electric energy.
- **Point(s) of Delivery -** Point(s) for interconnection on the Transmission Provider's System where capacity and/or energy are made available to the end user.
- **Point(s) of Receipt -** Point(s) of connection to the transmission system where capacity and/or energy will be made available to the transmission providers.
- **Point-to-Point Transmission Service -** Reservation and/or transmission of energy from point(s) of receipt to point(s) of delivery.
- **PoolCo -** This will serve as a model for the restructured electric industry that combines the functions of an ISO and a Power Exchange. In its least flexible form, a PoolCo also prohibits direct transactions between buyers and sellers (I.e. all producers selling to the Pool and all consumers buy from the Pool.)
- **Power -** The rate at which energy is transferred.
- **Power Exchange -** This is a commercial entity responsible for facilitating the development of transparent spot prices for energy capacity, and/or ancillary services.
- **Power Grid -** A network of power lines and associated equipment used to transmit and distribute electricity over a geographic area.
- **Power Marketers -** Entities engaged in buying and selling electricity.
- **Power Plant -** A generating station where electricity is produced.
- **Power Pool -** Two or more interconnected electric systems that agree to coordinate operations.
- **Power Purchase Agreement -** This refers to a contract entered into by an independent power producer and an electric utility. The power purchase agreement specifies the terms and conditions under which electric power will be generated and purchased. Power purchase agreements require the independent power producer to supply power at a specified price for the life of the agreement. While power purchase agreements vary, their common elements include:

specification of the size and operating parameters of the generation facility; milestones in-service dates, and contract terms; price mechanisms; service and performance obligations; dispatchability options; and conditions of termination or default.

- **Present Value -** The amount of money required to secure a specified cash flow on a future date at a given rate of return.
- **Present Worth Factor -** The adjustment factor that discounts a sum of future dollars back to the current year.
- **Price Cap -** Situation where a price has been determined and fixed.
- **Primary Circuit -** This is the distribution circuit (less than 69,000 volts) on the high voltage side of the transformer.
- **Prime Mover -** A device such as an engine or water wheel that drives an electric generator.
- **Production -** The act or process of generating electric energy.
- **Production Costing -** A method used to determine the most economical way to operate a given system of power resources under given load conditions.
- **Program Life -** The length of time that the utility will be actively involved in promoting a demand-side management program (I.e. financing the marketing activities and the incentives of the program.)
- **Program Maturity -** The time it takes for the full benefits of a demand-side management measure or program to be realized.
- **Project Financing -** This is the most commonly used method to finance the construction of independent power facilities. Typically, the developer pledges the value of the plant and part or all of its expected revenues as collateral to secure financing from private lenders.
- **Prorated Bills -** The computation of a bill based upon proportionate distribution of the applicable billing schedule. A prorated bill is less than 25 days ore more than 38 days.
- **Provider of Last Resort -** A legal obligation (traditionally given to utilities) to provide service to a customer where competitors have decided they do not want that customer's business.
- **Public Authority Service to Public Authorities -** Electric services supplied to public entities such as municipalities or divisions of state or federal governments.
- **Public Utility -** A utility operated by a non-profit governmental or quasi-governmental entity. Public utilities include municipal utilities, cooperatives, and power marketing authorities.
- **Public Utility Commissions -** State regulatory agencies that provide oversight, policy guidelines and direction to electric public utilities.
- **Public Utility Holding Company Act of 1935 (PUHCA) -** PUHCA was enacted by the U.S. Congress to regulate the large interstate holding companies that monopolized the electric utility industry during the early 20th century.
- **Public Utility Regulatory Policies Act of 1978 (PU -** PURPA promotes energy efficiency and increased use of alternative energy sources by encouraging companies to build cogeneration facilities and renewable energy

projects using wind power, solar energy, geothermal energy, hydropower, biomass, and waste fuels.

- **Publicly Owned Utilities -** Municipal utilities (utilities owned by branches of local government) and/or co-ops (utilities owned cooperatively by customers).
- **Pumped Storage -** A facility designed to generate electric power during peak load periods with a hydroelectric plant using water pumped into a storage reservoir during off-peak periods.
- **Purchased Power Adjustment -** A clause in a rate schedule that provides for adjustments to a bill when energy from another system is acquired.
- **Qualifying Facility -** A cogeneration of small production facility that meets criteria established by the Federal Energy Regulatory Commission.
- **Ramp Rate -** The rate at which you can increase load on a power plant. The ramp rate for a hydroelectric facility may be dependent on how rapidly water surface elevation on the river changes.
- **Ramp Up (Supply Side) -** Increasing load on a generating unit at a rate called the ramp rate.
- **Ramp-Up (Demand-Side) -** Implementing a demand-side management program over time until the program is considered fully installed.
- **Rate Base -** Value of property upon which a utility is permitted to earn a specific rate of return.
- **Rate Class -** A group of customers identified as a class and subject to a rate different from the rates of other groups.
- **Rate Structure -** The design and organization of billing charges by customer class to distribute the revenue requirement among customer classes and rating period.
- **Rate-Basing -** The practice by utilities of allotting funds invested in utility Research Development Demonstration and Commercialization and other programs from ratepayers, as opposed to allocating these costs to shareholders.
- **Rate-of-Return Rates -** Rates set to the average cost of electricity as an incentive for regulated utilities to operate more efficiently at lower rates where costs are minimized.
- **Ratemaking Authority -** The utility commission's authority as designated by a State or Federal legislature to fix, modify, and/or approve rates.
- **Ratepayer -** This is a retail consumer of the electricity distributed by an electric utility. This includes residential, commercial and industrial users of electricity.
- **Real-time Pricing -** The instantaneous pricing of electricity based on the cost of the electricity available for use at the time the electricity is demanded by the customer.
- **Receiving Party -** Entity receiving the capacity and/or energy transmitted by the transmission provider to the point(s) of delivery.
- **Recovered Energy -** Reused heat or energy that otherwise would be lost. For example, a combined cycle power plant recaptures some of its own waste heat and reuses it to make extra electric power.

- **Regional Power Exchange -** An entity established to coordinate short-term operations to maintain system stability and achieve least-cost dispatch. The dispatch provides back-up supplies, short-term excess sales, reactive power support, and spinning reserve. The pool may own, manager and/or operate the transmission lines or be an independent entity that manages the transactions between entities.
- **Regional Reliability Councils -** Regional organizations charged with maintaining system reliability even during abnormal bulk power conditions such as outages and unexpectedly high loads.
- **Regional Transmission Group -** An organization approved by a Commission to coordinate transmission planning (and expansion), operation, and use on a regional basis.
- **Regulation -** An activity of government to control or direct economic entities by rulemaking and adjudication.
- **Regulatory Compact -** Under this compact, utilities are granted service territories in which they have the exclusive right to serve retail customers. In exchange for this right, utilities have an obligation to serve all consumers in that territory on demand.
- **Reliability -** Electric system reliability has two components - adequacy and security. Adequacy is the ability of the electric system to supply the aggregate electric demand and energy requirements of the customers at all times, taking into account scheduled and unscheduled outages of system facilities. Security is the ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system facilities.
- **Reliability Councils -** Regional reliability councils were organized after the 1965 northeast blackout to coordinate reliability practices and avoid or minimize future outages. They are voluntary organizations of transmission-owning utilities and in some cases power cooperatives, power marketers, and non-utility generators. Membership rules vary from region to region. They are coordinated through the North American Electric Reliability Council.
- **Renewable Energy -** Energy that is capable of being renewed by the natural ecological cycle.
- **Replacements -** The substitution of a unit for another unit generally of a like or improved character.
- **Repowered Plant -** This is an existing power facility that has been substantially rebuilt to extend its useful life.
- **Reregulation -** The design and implementation of regulatory practices to be applied to the remaining regulated entities after restructuring of the vertically-integrated electric utility. The remaining Regulated entities would be those that continue to exhibit characteristics of a natural monopoly, where imperfections in the market prevent the realization of more competitive results, and where, in light of other policy considerations, competitive results are unsatisfactory in one or more respects. Reregulation could employ the same or different regulatory practices as those used before restructuring.
- **Resellers -** Companies that purchase utility service from a wholesaler and resell it to consumers.

- **Reserve Capacity -** Capacity in excess of that required to carry peak load.
- **Reserve Generating Capacity -** The amount of power that can be produced at a given point in time by generating units that are kept available in case of special need. This capacity may e used when unusually high power demand occurs, or when other generating units are off-line for maintenance, repair or refueling.
- **Reserve Margin -** The percentage of installed capacity exceeding the expected peak demand during a specified period.
- **Restructuring -** The reconfiguration of the vertically-integrated electric utility. Restructuring usually refers to separation of the various utility functions into individually-operated and-owned entities.
- **Retail -** Sales of electric energy to the ultimate customer.
- **Retail Company -** A company that is authorized to sell electricity directly to industrial, commercial and residential end-users.
- **Retail Competition -** A system under which more than one electric provider can offer to sell to retail customers, and retail customers are allowed to choose more than one provider from whom to purchase their electricity.
- **Retail Transaction -** The sale of electric power from a generating company or wholesale entity to the customer.
- **Retail Wheeling -** This refers to the ability of end-use customers of any size to purchase electric capacity, energy or both from anyone other than the local electric utility by moving or wheeling such power over the local utility's transmission and/or distribution lines.
- **Rolling Blackouts -** A controlled and temporary interruption of electrical service. These are necessary when a utility is unable to meet heavy peak demands because of an extreme deficiency in power supply.
- **Running and Quick-Start Capability -** Generally refers to generating units that can be available for load within a 30-minute period.
- **Rural Electric Cooperative -** A nonprofit, customer-owned electric utility that distributes power in a rural area.
- **Sales for Resale -** Energy supplied to other utilities and agencies for resale.
- **Savings Fraction -** The percentage of consumption from using the old technology that can be saved by replacing it with the new, more efficient demand-side management technology. For example, if a 60-watt incandescent lamp were replaced with a 15-watt compact fluorescent lamp, the savings fraction would be 75 percent because the compact fluorescent lamp uses only 25 percent of the energy used by the incandescent lamp.
- **Scheduled Outage -** An outage that results when a component is deliberately taken out of service at a selected time, usually for the purposes of construction, maintenance, or testing.
- **Securitization -** The act of pledging assets to a creditor through a note, lien or bond. This is a mechanism to allow a utility to recover stranded costs up front in a single lump sum payment. Under a securitization scheme, the legislature or utility commission orders customers to pay a surcharge as part of their electric

bill. That surcharge must be paid within the utility's original service territory, regardless of who supplies the electricity to customers.

- **Self-Generation -** A generation facility dedicated to serving a particular retail customer, usually located on the customer's premises. The facility may either be owned directly by the retail customer or owned by a third party with a contractual arrangement to provide electricity to meet some or all of the customer's load.
- **Service Agreement -** an agreement entered into by the transmission customer and transmission provider.
- **Service Area -** The territory a utility system is required or has the right to supply electric service to ultimate customers.
- **Service Drop -** The lines running to a customer's house. Usually a service drop is made up of two 120 volt lines and a neutral line, from which the customer can obtain either 120 or 240 volts of power. When these lines are insulated and twisted together, the installation is called triplex cable.
- **Service Life -** The length of time a piece of equipment can be expected to perform at its full capacity.
- **Service Territory -** This is the state, area or region served exclusively by a single electric utility.
- **Single Phase Line -** This carriers electrical loads capable of serving the needs of residential customers, small commercial customers, and streetlights. It carrier a relatively light load as compared to heavy duty three phrase constructs.
- **Small Power Producer -** Refers to a producer that generates at least 75% of its energy from renewable sources.
- **Solar Thermal Electric -** A process that generates electricity by converting incoming solar radiation to thermal energy.
- **Source Energy -** All the energy used in delivering energy to a site, including power generation and transmission and distribution losses, to perform a specific function, such as space conditioning, lighting, or water heating. Approximately three watts (or 10.239 Btus) of energy is consumed to deliver one watt of usable electricity.
- **Southeastern Electric Reliability Council (SERC -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Southwest Power Pool (SPP) -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Spinning Reserve -** Reserve generating capacity running at zero load.
- **Split-the-savings -** The basis for settling economy-energy transactions between utilities. The added cost of the supplier are subtracted from the avoided costs of the buyer, and the difference is evenly divided.
- **Spot Purchases -** Single shipment of fuel purchased for delivery within 1 year.
- **Stable Prices -** Prices that do not vary greatly over short time periods.
- **Standard Rate -** The basic rate customers would take service under if they were not on real-time pricing.

- **Standby Facility -** A facility that supports a system and generally running under no load.
- **Stocks -** A supply of fuel accumulated for future use.
- **Stranded Benefits -** Special collection programs, renewable energy and demand side management programs, lifeline rates and other utility resources funded by a monopoly utility that may not be funded if the utility's competition does not have smaller costs.
- **Stranded Commitment -** Assets and contracts associated with shifting to competition which are above market prices and result in non-competitive conditions for the utility.
- **Stranded Investments/Costs -** Utility investments in facilities built to serve customers under traditional regulation may become unrecoverable or "stranded" if those assets are deregulated and their cost of generation exceeds the actual price of power in a competitive market. These include prior investments allowed by regulators that are currently being recovered through regulated rates.
- **Stranded/Strandable Costs -** These are costs inherent in the existing electric utility industry rendered potentially unrecoverable in a competitive market.
- **Strategic Conservation -** Strategic conservation results from load reductions occurring in all or nearly all time periods. This strategy can be induced by price of electricity, energy-efficient equipment, or decreasing usage of equipment.
- **Strategic Load Growth -** A form of load building designed to increase efficiency in a power system. This load shape objective can be induced by the price of electricity and by the switching of fuel technologies (from gas to electric).
- **Substation -** A facility used for switching and/or changing or regulating the voltage of electricity. Service equipment, line transformer installations, or minor distribution or transmission equipment are not classified as substations.
- **Summer Peak -** The greatest load on an electric system during any prescribed demand interval in the summer.
- **Supplier -** A person or corporation, generator, broker, marketer, aggregator or any other entity, that sells electricity to customers, using the transmission or distribution facilities of an electric distribution company.
- **Supply-Side -** Technologies that pertain to the generation of electricity.
- **Surplus -** Excess firm energy available from a utility or region for which there is no market at the established rates.
- **Switching Station -** Facility used to connect two or more electric circuits through switches.
- **System (Electric) -** Physically connected generation, transmission, and distribution facilities operating as a single unit.
- **System Peak Demand -** The highest demand value that has occurred during a specified period for the utility system.
- **Systems Benefits Charge -** This is a per-customer charge intended to recover the costs of utility demand-side management reach and development, renewable resources or low-income programs.

- **Target Market -** A specific group of people or geographical area that has been identified as the primary buyers of a product or service.
- **Tariff -** A document, approved by the responsible regulatory agency, listing the terms and conditions, including a schedule or prices, under which utility services will be provided.
- **Tax Credits -** Credits established by the federal and state government to assist the development of the alternative energy industry.
- **Three Phase Line -** This is capable of carrying heavy loads of electricity, usually to larger commercial customers.
- **Time-of-Use Rates -** Electricity prices that vary depending on the time periods in which the energy is consumed. In a time-of-use rate structure, higher prices are charged during utility peak-load times. Such rates can provide an incentive for consumers to curb power use during peak times.
- **Tipping Fee -** A credit received by municipal solid waste companies for accepting and disposing of solid waste.
- **Total DSM Cost -** Total utility and nonutility costs.
- **Total Incentives -** The incentive a utility offers is expressed as a percentage of the technology cost. The utility can assume any level between 0 and 100 percent. A value greater than 100 percent is possible if the utility decides to pay for all the equipment and give a rebate as an additional incentive. You can calculate the required incentive by setting the participant test to one by using the following formula: Total Incentives = (Technology Costs - Bill Reductions)/2.
- **Total Nonutility Costs -** Cash expenditures incurred through participation in a DSM program that are not reimbursed by the utility.
- **Total Resource Cost (TRC) Test -**

A ratio used to assess the cost effectiveness of a demand-side management program. Although this economic desirability test provides information about the relative merits of different DSM programs, several important issues are not addressed in this analysis. First, this cost-effectiveness test does not indicate the level of program participation that will be achieved. Second, the most cost-effective mix of DSM technologies is not determined by this test because this methodology only evaluates one specific measure at a time. Finally, these tests are static; they do not include a feedback mechanism to account for changes in demand due to the DSM program. The TRC Test measures the ratio of total benefits to the costs incurred by both the utility and the participant. The TRC test is applicable to conservation, load management, and fuel substitution technologies. For fuel substitution technologies, the test compares the impact from the fuel not selected to the impact of the fuel that is chosen as a result of implementing the technologies. The TRC Test includes benefits occurring to both participants and nonparticipants. Benefits include avoided supply costs (I.e.

transmission, distribution, generation, and capacity costs). Costs include those incurred by both the utility and program participant.

- **Total Utility Costs -** Total direct and indirect utility costs.
- **Tower -** A steel structure found along transmission lines which is used to support conductors.
- **Transfer -** To move electric energy from one utility system to another over transmission lines.
- **Transformer -** A device for changing the voltage of alternating current.
- **Transition Charge -** A charge on every customer's bill designed to recover an electric utility's transition or stranded costs as determined by a Public Utility Commission.
- **Transition Costs -** Costs incurred by electric utilities to meet obligations, which required the utilities to meet current and future load demand. The utilities ensured sufficient power generating capacity by building additional power plants, whose debts are currently recovered through a regulated rate of return that would not continue in a competitive marketplace. They could be recovered with a special charge during the transition to competition.
- **Transmission -** The act or process of transporting electric energy in bulk.
- **Transmission and Distribution (T&D) Losses -** Losses the result from the friction that energy must overcome as it moves through wires to travel from the generation facility to the customer. Because of losses, the demand produced by the utility is greater than the demand that shows up on the customer bills.
- **Transmission and Distribution (T&D) System -** An interconnected group of electric transmission lines and associated equipment for the movement or transfer or electric energy in bulk between points of supply and points at which it is transformed for delivery to the ultimate customers.
- **Transmission Charge -** Part of the basic service charges on every customer's bill for transporting electricity from the source of supply to the electric distribution company. Public Utility Commissions regulate retail transmission prices and services. The charge will vary with source of supply.
- **Transmission Lines -** Heavy wires that carry large amounts of electricity over long distances from a generating station to places where electricity is needed. Transmission lines are held high above the ground on tall towers called transmission towers.
- **Transmitting Utility -** This is a regulated entity which owns, and may construct and maintain, wire used to transmit wholesale power. It may or may not handle the power dispatch and coordination functions. It is regulated to provide non-discriminatory connections, comparable service and cost recovery. Any electric utility, qualifying cogeneration facility, qualifying small power production facility, or Federal power marketing agency which owns or operates electric power transmission facilities which are used for the sale of electric energy at wholesale.
- **Transparent Price -** The most recent price contract available to any buyer or seller in the market.
- **U.S. Department of Energy (DOE) -** The DOE managers programs of research, development and commercialization for various energy technologies,

and associated environmental, regulatory and defense programs. DOE announces energy policies and acts as a principal advisor to the President on energy matters.

- **U.S. Environmental Protection Agency (EPA) -** The EPA administers federal environmental policies, enforces environmental laws and regulations, performs research, and provides information on environmental subjects. The agency also acts as chief advisor to the President on U.S. environmental policy and issues.
- **Ultrahigh Voltage Transmission -** Transporting electricity over bulk-power lines at voltage greater than 800 kilovolts.
- **Unbundling -** Disaggregating electric utility service into its basic components and offering each component separately for sale with separate rates for each component. For example, generation, transmission and distribution could be unbundled and offered as discrete services.
- **Uncertainties -** Uncertainties are factors over which the utility has little or no foreknowledge, and include load growth, fuel prices, or regulatory changes. Uncertainties are modeled in a probabilistic manner. However, in the Detailed Workbook, you may find it is more convenient to treat uncertainties as "unknown but bounded" variables without assuming a probabilistic structure. A specified uncertainty is a specific value taken on by an uncertainty factor (e.g. 3 percent per year for load growth). A future uncertainty is a combination of specified uncertainties (e.g. 3 percent per year load growth, 1 percent per year real coal and oil price escalation, and 2.5 percent increase in housing starts).
- **Unit Energy Consumption (UEC) -** The annual amount of energy that is used by the electrical device or appliance.
- **Universal Service -** Electric service sufficient for basic needs (an evolving bundle of basic services) available to virtually all members of the population regardless of income.
- **Unserved or Unmet Energy -** The average energy that will be demanded but not served during a specified period due to inadequate available generating capacity.
- **Upgrade -** Replacement or addition of electrical equipment resulting in increased generation or transmission capability.
- **Uprate -** An increase in the rating or stated measure of generation or transfer capability.
- **Utility -** A regulated entity which exhibits the characteristics of a natural monopoly. For the purposes of electric industry restructuring "utility" refers to the regulated, vertically-integrated electric company. "Transmission utility" refers to the regulated owner/operator of the transmission system only. "Distribution utility" refers to the regulated owner/operator of the distribution system which serves retail customers.
- **Utility-Earned Incentives -** Costs paid to a utility for achieving consumer participation in DSM programs.
- **Utilization Factor -** The ratio of the maximum demand of a system or part of a system to the rated capacity of the system or part of the system.

- **Valley Filling -** Valley filling is a form of load management that increases or builds, off-peak loads. This load shape objective is desirable if a utility has surplus capacity in the off-peak hours. If this strategy is combined with time-or-use rates, the average rate for electricity can be lowered.
- **Variable Costs -** Costs, such as fuel costs, that depend upon the amount of electric energy supplied.
- **Variable Prices -** Prices that vary frequently. Prices that are not stable.
- **Vertical Integration -** An arrangement whereby the same company owns all the different aspects of making, selling, and delivering a product or service. In the electric industry, it refers to the historically common arrangement whereby a utility would own its own generating plants, transmission system, and distribution lines to provide all aspects of electric service.
- **Volt -** A unit of electrical pressure. It measures the force or push of electricity. Volts represent pressure, correspondent to the pressure of water in a pipe. A volt is the unit of electromotive force or electric pressure analogous to water pressure in pounds per square inch. It is the electromotive force which, if steadily applied to a circuit having a resistance of one ohm, will produce a current one ampere.
- **Volt-amperes -** The volt-amperes of an electric circuit are the mathematical products of the volts and emperes of the client.
- **Voltage -** Measure of the force of moving energy.
- **Waste-to-Energy -** This is a technology that uses refuse to generate electricity. In mass burn plants, untreated waste is burned to produce steam, which is used to drive a steam turbine generator. In refuse-derived fuel plants, refuse is pre-treated, partially to enhance its energy content prior to burning.
- **Watt -** The electric unit of power or rate of doing work. One horsepower is equivalent to approximately 746 watts.
- **Watt-Hour -** One watt of power expended for one hour.
- **Western systems Coordinating Council (WSCC) -** One of the ten regional reliability councils that make up the North American Electric Reliability Council (NERC).
- **Wheeling -** The use of the transmission facilities of one system to transmit power for another system.
- **Wholesale Bulk Power -** Very large electric sales for resale from generation sources to wholesale market participants and electricity marketers and brokers.
- **Wholesale Competition -** A system whereby a distributor of power would have the option to buy its power from a variety of power producers, and the power producers would be able to compete to sell their power to a variety of distribution companies.
- **Wholesale Power Market -** The purchase and sale of electricity from generators to resellers (who sell to retail customers) along with the ancillary services needed to maintain reliability and power quality at the transmission level.
- **Wholesale Transition -** The sale of electric power from an entity that generates electricity to a utility or other electric distribution system through a utility's transmission lines.

- **Wholesale Transmission Services -** The transmission of electric energy sod, or to be sold, at wholesale in interstate commerce.
- **Wind Energy Conversion -** A process that uses energy from the wind and converts it into mechanical energy and then electricity.
- **Winter Peak -** The greatest load on an electric system during any prescribed demand interval in the winter season or months.
- **Wires Charge -** A broad term which refers to charges levied on power suppliers or their customers for the use of the transmission or distribution wires.