clean volts

ALTERNATIVE ENERGY USE IN THE PRODUCTION OF ELECTRICITY

WHY ARE WE TALKING ABOUT THIS?

This exhibit highlights the use of renewable energy in the production of electricity. Renewable, also known as "clean," energy has become an increasingly important and controversial topic, prompting spirited discussions nationally and globally. But only 9 percent of the energy used in the production of electricity in the United States is renewable. Of that 9 percent, hydroelectric power is the largest source (67 percent), wind energy makes up 14 percent, and solar energy, while growing in use, accounts for a mere 0.2 percent.

Nearly half of our electricity comes from coal, followed by nuclear power and natural gas. The reason that we primarily use these sources is that they are cheaper than clean energy sources. In order for renewables to become truly competitive with coal and other fossil fuels, the government will have to provide incentives and limit the amount of greenhouse gases (gases that trap heat in the atmosphere when they are released) that companies can emit. Government action encourages technological advances.

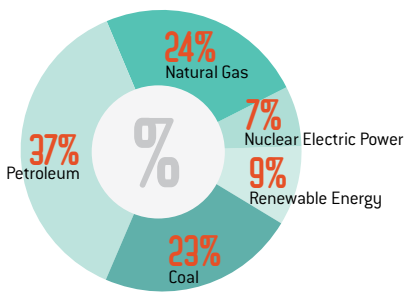
WHAT IS "CLEAN" ENERGY, AND WHY IS IT SO OFTEN IN THE NEWS?

The Energy Information Administration (EIA) defines renewable energy resources as those that are "naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include: biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action."

Renewable energy resources are called clean because they do not emit carbon dioxide (CO_2) and other harmful greenhouse gases (GHGs) into the atmosphere. Unlike clean energy sources, fossil fuels, such as coal (the one most widely used in the production of electricity) and petroleum, emit varying amounts of greenhouse gases into the atmosphere when they are burned. For this reason, they are sometimes referred to as "dirty" fuels.

The Department of Energy (DOE), other US government agencies, and international organizations such as the Intergovernmental Panel on Climate Change (IPCC) agree that global warming is a fact: the overall

U.S. Energy Consumption by Type, 2007



Total U.S. Energy = 99.3 Quadrillion BTU
Source: Energy Information Administration, *Annual Energy Review 2008.* Tables 1.3, 2.1b–2.1f.

temperature of the earth's near-surface air and oceans is rising. This rise in temperature is caused by the burning of fossil fuels, which emit CO_2 and other greenhouse gases into the earth's atmosphere, as well as by other activities such as deforestation (the removal of trees). Trees naturally reduce the buildup of CO_2 in the atmosphere by capturing and storing carbon, and when they are cut down, CO_2 is released into the atmosphere. As the Union of Concerned Scientists states, "When too much global warming pollution is released into the air, it acts like a blanket, trapping heat in our atmosphere and altering weather patterns globally and here in the U.S."

"In the United States, many state governments now require retail electricity providers to use a percentage of renewable energy sources in their mix of source fuels."

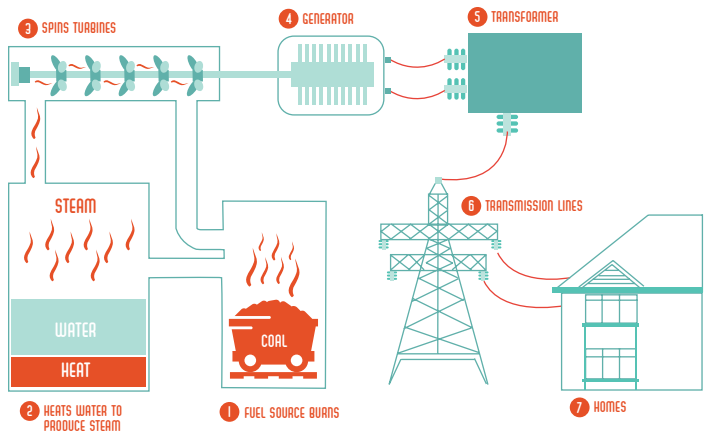
Greenhouse gas production has increased markedly over the past hundred years or so as the demand for electricity and fuels has gone up dramatically with a rise in population and productivity. The two major sources of CO_2 emissions in the United States are coal and petroleum fuel. Coal is burned to produce electricity, and petroleum fuels are burned in vehicles with combustible engines. While there is not universal agreement about the exact rate of global warming, or about the amount of damage each additional degree in temperature will cause, growing concern about global warming has prompted organizations like the United Nations to work toward a global consensus on cutting carbon emissions. Both the Kyoto Protocol, adopted in 1997, and the climate change conference in Copenhagen in December 2009 have as their main goal the reduction of carbon emissions. In the United States, many state governments now require retail electricity providers to use a percentage of renewable energy sources in their mix of source fuels. In Massachusetts, this percentage started at 1 percent in 2003 and will climb to 15 percent in 2020.

THE PRODUCTION OF ELECTRICITY

Electricity is defined as “the flow of electrical power or charge. It is both a basic part of nature and one of our most widely used forms of energy.”

Electricity is called a “secondary power source” because it is not itself a power source. A fuel or energy power of some kind is needed in order to produce electricity. Many different sources of energy can be used in the production of electricity. As the Department of Energy explains, “The energy sources we use to make electricity can be renewable or nonrenewable, but electricity itself is neither renewable nor nonrenewable.”

The simplest way to generate electricity is with a turbine. With this method, a fuel such as coal is burned to heat water to produce steam to spin the turbines. The turbines have strong magnets at each end, and when the magnets spin, they pass over coils of fine copper wire, moving the electrons from one copper atom to another. This movement of electrons causes an electrical current.



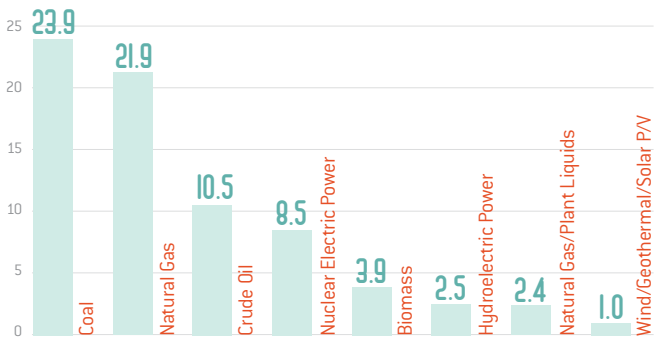
Simplified drawing of electricity production and transmission

A BIT OF HISTORY: PRODUCTION AND CONSUMPTION OF ELECTRICITY IN THE UNITED STATES

During the late 1800s, various inventions converged to be able to bring electric lighting to industry, commercial businesses, streets, and finally into people's homes. Thomas Edison developed the first commercially viable electric lightbulb in 1887, and Nikola Tesla patented the first alternating current (AC) generator in 1888. It wasn't long before people started looking for a way to transmit electrical energy produced at a power plant to locations several miles away. The first attempts made use of the direct current system, and the transmission was extremely limited. But with Tesla's AC generator, the first successful transmission of electricity took place in 1891, when electrical power was transmitted from Niagara Falls to Buffalo, New York, about twenty miles away.

The first use of electrical power at the end of the nineteenth century was for manufacturing; it was used to power machines that had previ-

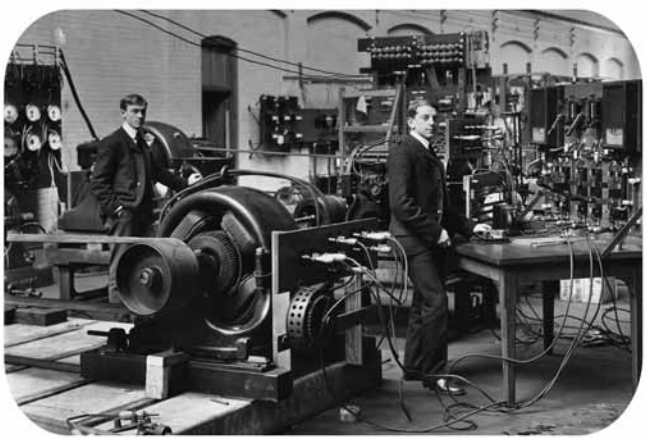
U.S. Overall Energy Production
by Major Resource (2008)



Source: Energy Information Administration, *Annual Energy Review 2008.* Table 1.2.

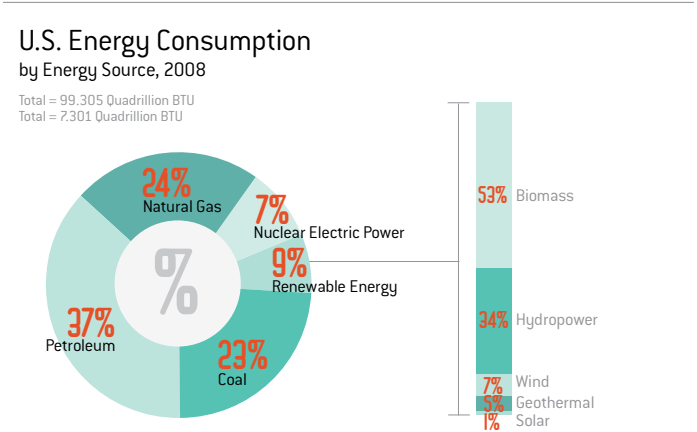
ously been powered by water, wind, or animals. At the 1893 World's Fair in Chicago, an entire building was devoted to electrical exhibits, and the public got to see for the first time many potential uses for electricity. They were dazzled by spectacular displays of different kinds of lighting and electrical generators and convertors.

In the late nineteenth century, electricity did not exist in homes. Some large urban areas had small electrical stations, but these stations could power only a very small area, and service was unreliable. Street



Courtesy of the MIT Museum

Students at the Massachusetts Institute of Technology at the turn of the 20th century.



Note: Sum of components may not equal 100% due to independent rounding.
Source: EIA, Renewable Energy Consumption and Electricity 2008 Statistics, Table 1: U.S. Energy Consumption by Energy Source. (July 2009)

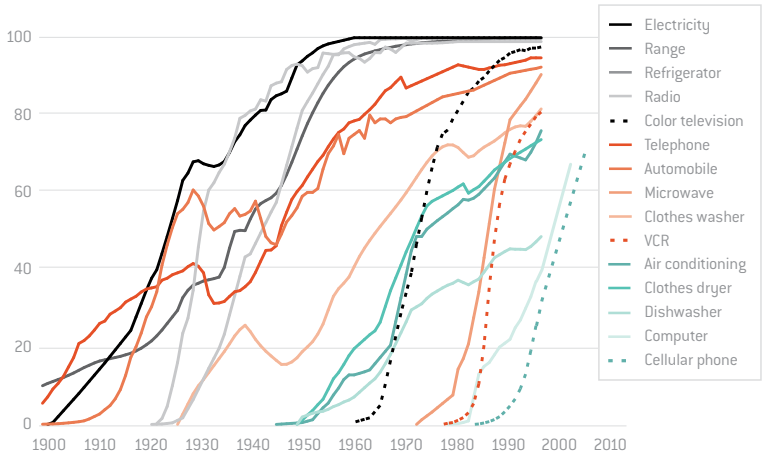
lighting, fueled by gas, was intermittent at best, and the availability of electricity was primarily restricted to urban areas. At the beginning of the twentieth century, residential lighting was introduced, but it wasn't until the 1930s that most people living in larger towns and cities had electricity. Few people in rural areas had electrical power yet, and farms continued to be powered by working animals. In the mid-twentieth century, electrical power finally reached the rural farmlands.

Nowadays, not only do we take electric lights for granted and feel shocked when there is an occasional power outage, but we don't generally think about the electrical aspect of many items that we use on a daily basis. We rely on our computers, iPods, vacuums, cell phones, refrigerators, heating and cooling devices, and much more, but we seldom even consider the power that is needed for them to function.

Per capita consumption of electricity in the United States has grown at an astonishing rate. In the 1920s, when the commonly used electrical appliances were electric brooms and vacuums, the average annual kilowatt=hour use by residence was around 340 —by 2000 it was up to nearly 11,000. As you can see in the graph, the use of electrical appliances and other items that we consider essential today has increased markedly. This increase is due to both our rising population and the fact that we constantly find new uses for electrical power. For example, computers in the 1960s were for business use only; minicomputers such as the PDP-8, which was introduced in 1965, were the size of copying machines and were almost exclusively used in businesses. According to the 2000 Census, one half of U.S. households own a computer, and according to Neilsen, 40 percent of households own a video game machine that is similar in power to computers.

Household Ownership and Use of Products

Percent of Households with



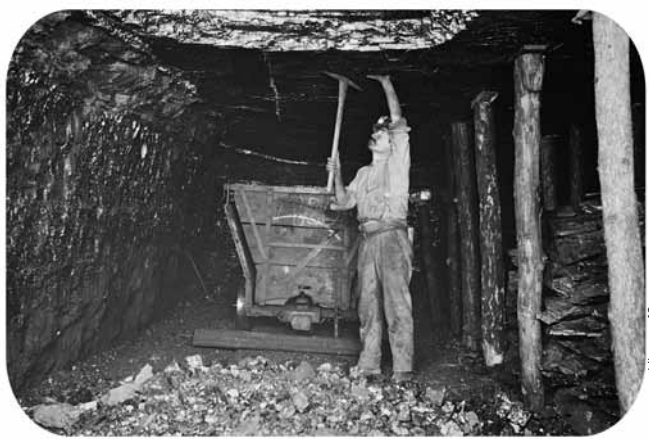
Source: The Federal Reserve Bank of Dallas, Annual Report 1997 (updated for computers and cell phones)

SOURCES OF FUEL: PROS AND CONS

COAL

Coal is the primary source fuel in the production of electricity in the United States today and has been since the 1890s. In the late nineteenth century, coal was also used as the main home heating fuel, and as the chief fuel for locomotives. The principal advantages to coal are that it is cheap compared with other fuels and that it is an abundant native fuel source; more than a quarter of the world's coal reserves are found within the United States, so it does not have to be imported. It has also been relatively easy to mine. Electrical plants that are coal-powered are able to run at an efficiency rate of around 40 percent, and they supply more than half of the electricity consumed in the United States.

Coal-fired electrical plants can run continuously, which means that there is continuity in the production of electricity, and it is possible to project accurately the production of electricity. In fact, according to the DOE, it is a cumbersome and expensive process to stop and restart a coal plant. It is much easier and more cost-effective to keep a plant "on line." And coal is a fuel source that the EIA expects to last 150 years, even with projected increases in consumption of electricity.



Library of Congress

Miner from 1910. Coal became the most important source of fuel in the production of electricity beginning in the 1890s.

A major disadvantage of coal is that it is a dirty fuel; it indisputably adds CO_2 to the atmosphere and contributes to global warming. In addition, many people experience serious health issues related to coal mining and production from the toxic elements emitted by burning coal and the spillage of contaminated groundwater. And while alternative cleaner coal options are being studied, such as methods for capturing and sequestering the carbon dioxide so that it is not released into the atmosphere, and ways to place coal combustion residues back in the mines from which the coal was extracted, they haven't yet been fully examined or even proven viable in terms of cost.

23% of all energy used in the United States is natural gas.

NATURAL GAS

Natural gas ranks third in sources of fuel used in the United States. It supplies about 23 percent of all the energy used. Among the advantages of natural gas are that it burns cleaner than coal, so it causes less pollution and emits lower amounts of carbon. About 85 percent of the natural gas used in the United States is produced domestically, so it doesn't have to be imported, and it can also be transported over large distances.

Even though natural gas burns cleaner than coal, it is still a nonrenewable resource, so its availability is not unlimited. Other disadvantages include potential serious health issues if its toxic flames are inhaled. In addition, natural gas is highly combustible. If the gas builds up in an enclosed space, it can explode.

RENEWABLE SOURCES OF ENERGY: PROS AND CONS

Renewable sources of energy are significantly more expensive than non-renewable. Without state or federal subsidies or government policies to force the development and use of renewable energies, they will languish.

SOLAR

The main advantages to solar energy are that sunshine is abundant and free and clean. However, the sun does not shine constantly, and solar power is less efficient when the day is cloudy. To convert the sun's energy into electricity, solar panels are used to collect radiation from the sun. These panels need to be oriented in a particular way to absorb the maximum radiant energy. When solar power was first being developed, the efficiency of the silicon chips used for the panels was at only 15 percent, but the search for an improved efficiency has been ongoing. By the late 1990s, efficiency had risen to about 40 percent.

iStockphoto

Solar farm in the countryside.

Without government incentives, solar power is prohibitively expensive for most homeowners. It requires a significant investment up front. Some companies are beginning to offer lease-to-own options that require a very small initial investment on the part of the homeowner. Solar power is not an option for every home; only dwellings that are oriented in a southeasterly direction can use solar energy, and there cannot be adjacent buildings or trees blocking the light.

WIND

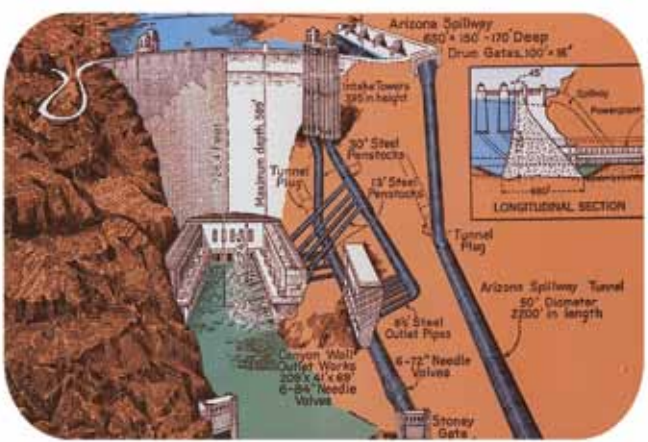
Like solar energy, the main advantages to wind are that it is abundant and free and clean. Wind turbines do not produce emissions, so they are nonpolluting. Also like the sun, the wind is an infinite source of power; it cannot be used up. However, also like the intermittent sunshine, the wind does not always blow, so sometimes it is not available to meet the demands of electricity. Another disadvantage is that ideal wind sites are often far from cities, where the demand for electricity is high, and as a result, there is the added cost of constructing transmitting lines to bring the wind from the wind farms to the cities.

HYDROELECTRIC

Well before electricity, water, or hydro, was a source of power used to run gristmills, sawmills, and, in New England, the textile mills. Falling or rushing water was also used to create electricity at the end of the nineteenth century. As applications for electricity grew over the course of the twentieth century, hydroelectricity production grew until the 1950s; at its peak it was the primary source fuel. Today its place has diminished to about 10 percent with the advent of other technologies.

Hydro is a replenishable source of power that is nonpolluting. It is also relatively easy to control the production of electricity. Once the dam is in place, the amount of electricity generated can easily be adjusted by letting in water to spin the turbines or by shutting it off.

Disadvantages include the massive costs involved in building a dam, the flooding of large areas while creating a lake, and the disruption of wildlife habitats. In the United States most of the optimal sites for hydroelectric plants are already being used.



Courtesy of the Bureau of Reclamation.

Hoover Dam cutaway.

PARTING THOUGHTS

We hope that you have found the exhibit interesting and informative and have learned or been reminded that the choices we make when it comes to our sources of energy do matter. Every energy source has its pros and cons, but nonrenewable sources such as coal and natural gas have lasting environmental consequences. Greenhouse gas production has increased dramatically over the past hundred years due to the emissions from the nonrenewable energy sources we use, and scientists agree that greenhouse gases contribute to global warming.

Clean energy sources will be an increasingly important topic over the next decade—on the local, national, and global level. Both the Kyoto Protocol and the recent Copenhagen climate conference aim to reduce carbon emissions on a global level. But even without global or even national consensus, we see the landscape around us gradually changing to take advantage of renewable sources of energy such as wind turbines and solar panels, and we will no doubt see new technologies developing in the years to come.

To learn more, please visit our web site: **www.economicadventure.org**

Other web sites that might be of interest are:

www.doe.gov

www.epa.gov/climatechange

www.oe.energy.gov

www.eia.doe.gov

www.nrel.gov

GLOSSARY

ALTERNATING CURRENT (AC): An electric current that reverses its direction at regularly recurring intervals.

BRITISH THERMAL UNITS (BTUs): The quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit).

BRUSH ARC LAMP: A device for producing light by maintaining an electric arc across a gap between two conductors

CURRENT (ELECTRIC): A flow of electrons in an electrical conductor. The strength or rate of movement of electricity is measured in amperes ("amps").

ELECTRIC CURRENT: See "Current (electric)."

ELECTRIC ENERGY: The capacity of an electric current to produce work, heat, light, or other forms of energy. It is measured in kilowatt-hours.

ELECTRIC EXPENSES: The expenses incurred (e.g., for labor and materials) in operating a facility's prime movers, generators, auxiliary apparatus, switching gear, and other electrical equipment for each of the points where electricity enters the transmission or distribution power grid.

ELECTRIC GENERATION: The process of creating electricity from an energy source.

GROSS ELECTRIC GENERATION: The total amount of electricity produced by a generating station.

NET ELECTRIC GENERATION: The total amount of electricity produced by a generating station minus the amount that is used to operate the station.

ELECTRIC GENERATION INDUSTRY: Stationary and mobile generating units that are connected to the electric power grid and can generate electricity. The electric generation industry includes the "electric power sector" (utility generators and independent power producers) and industrial and commercial power generators, including combined-heat-and-power producers, but it excludes units at single-family dwellings.

ELECTRIC GENERATOR: A facility that produces only electricity, commonly expressed in kilowatt-hours (kWh) or megawatt-hours (MWh). Electric generators include electric utilities and independent power producers.

FOSSIL FUELS: Naturally occurring substances deep in the earth that are made from decomposed plants and animals. Over time, the decomposing remains turn into fuels, and these fuels are burned to release energy.

GENERATING UNIT: Any combination of physically connected generators, reactors, boilers, combustion turbines, and other prime movers operated together to produce electric power.

GENERATION: The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in kilowatt-hours.

GENERATOR CAPACITY: The maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, adjusted for ambient conditions.

GLOBAL WARMING: An increase in the near-surface temperature of the earth. Global warming occurred in the distant past as the result of natural influences, but today the term is most often used to refer to the warming that occurs as a result of human-caused emissions of greenhouse gases.

GREENHOUSE EFFECT: The warming that results when solar radiation is trapped in the lower levels of the atmosphere. This happens because gases in the atmosphere allow the sun's short-wave radiation to pass through on its way to earth but then trap the long-wave radiation instead of allowing it to escape into space. Water vapor and carbon dioxide are the chief gases responsible for this phenomenon.

GREENHOUSE GASES: Those gases such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving the earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

HYDROELECTRIC POWER: The use of flowing water to produce electrical energy. The first industrial use of hydropower to generate electricity in the United States was in 1880, when sixteen brush-arc lamps were powered using a water turbine at the Wolverine Chair Factory in Grand Rapids, Michigan.

KILOWATT (KW): A standard unit of electrical power equal to 1,000 watts. The term "kilowatt" (in addition to the measurements of "watt" and "megawatt") is commonly used to describe the capacity of an electric generator, particularly in reference to small solar photovoltaic and other generating systems.

KILOWATT-HOUR (KWH): 1,000 watts or 1 kilowatt acting over a period of 1 hour. One kilowatt-hour is equal to 1,000 watt-hours and is equal to 3600 kilojoules. The primary difference between a kilowatt and a kilowatt-hour is that "kilowatt" measures the capacity of an electric generator and "kilowatt-hour" measures the actual amount of electricity it produces over a certain period of time.

MEGAWATT (MW): A standard unit of electrical power equal to 1,000 kilowatts, or 1 million watts. Like watts and kilowatts, the term "megawatt" is used as a standard measure of electric power plant generating capacity. It is most commonly used for large systems such as wind turbines, biomass plants, and coal, natural gas, and nuclear plants.

MEGAWATT-HOUR (MWH): 1 megawatt acting over a period of 1 hour. One megawatt-hour is equal to 1,000 kilowatt-hours or 1 million watt-hours. The primary difference between a megawatt and a megawatt-hour is that "megawatt" measures the capacity of an electric generator and "megawatt-hour" measures the actual amount of electricity it produces over a certain period of time.

PHOTOVOLTAIC AND SOLAR THERMAL ENERGY (AS USED AT ELECTRIC UTILITIES): Energy radiated by the sun as electromagnetic waves (electromagnetic radiation) that is converted at electric utilities into electricity by means of solar (photovoltaic) cells or concentrating (focusing) collectors.

SOLAR ENERGY: The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

TURBINE: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

VOLT (V): The volt is the International System of Units (SI) measure of electric potential or electromotive force. A potential of 1 volt appears across a resistance of 1 ohm when a current of 1 ampere flows through that resistance. Reduced to SI base units, $1\ V = 1kg \times m^2 \times s^{-3} \times A^{-1}$ (kilogram meter squared per second cubed per ampere).

VOLTAGE: The difference in electrical potential between any two conductors or between a conductor and ground. It is a measure of the electric energy per electron that electrons can acquire and/or give up as they move between the two conductors.

WIND ENERGY: Kinetic energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.

WIND TURBINE: A wind energy conversion device that produces electricity; typically three blades rotating about a horizontal axis and positioned upwind of the supporting tower.

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