A CONTENT SECONDARY SCIENCE NEWSLETTER FROM THE SOUTHERN NEVADA REGIONAL PROFESSIONAL DEVELOPMENT PROGRAM

SCIENCE DISSECTED

Southern Nevada RPDP

Renewable and Nonrenewable Resources
Model-Evidence Link Diagram (MEL)

Renewable and non-renewable resources are significant topics in today's world. There is a continued battle between the environmental impacts of non-renewable resources and the high cost associated with renewable resources. As students investigate these ideas, they will be able to form their own ideas while learning how to construct an argument using researched evidence, rather than guesses and feelings.

Renewable resource refers to any resource that can be replenished within several decades or is continually available. Non-renewable resources cannot be easily replaced and may no longer be available. This issue of Science Dissected provides an instructional resource for teachers to present students with the opportunity to examine several pieces of evidence compiled about renewable and non-renewable resources and critically evaluate a models for both.

Model A: Renewable energy resources are the most efficient way to support a community.

Model B: Nonrenewable energy resources are the most efficient way to support a community.

Evidence #1: Solar energy is capable of providing many times the total current energy demand.

Evidence #2: Petroleum products make life easier, but they can harm the environment.

Evidence #3: Of the total energy consumed by Americans, only 7 percent is from renewable resources, while 85 percent is from fossil fuels, predominately oil.

Evidence #4: Wind energy is a clean, renewable resource, but it is inconsistent and intermittent.

Evidence #5: Fossil fuels are a dominant energy source that produces CO_2.

The following is a suggestion for using this MEL with students:

1. Hand out the Model Evidence Link Diagram (page 1). Instruct students to read the directions, descriptions of Model A and Model B, and evidence #1.
2. Handout the evidence text #1, ask the students to read it and draw the lines for that evidence. I would recommend allowing them to work with a neighbor for this.
3. Ask a few students to share the type of line they drew to each model, giving support for their reasons. Try to help students understand that each text could support and/or conflict which both models.
4. Hand out the remaining evidence texts and have them complete the lines for the remaining four texts.
5. Handout page 2 for the students to critically evaluate their links and construct understanding.

Once students have completed page 2, they can then engage in collaborative argumentation as they compare their links and explanations with that of their peers. Students should be given the opportunity to revise the link weighting during the collaborative argumentation exercise. If time permits, have students find additional resources to support the models. This can then be extended into an argumentation paper, a debate, or a Socratic Seminar.

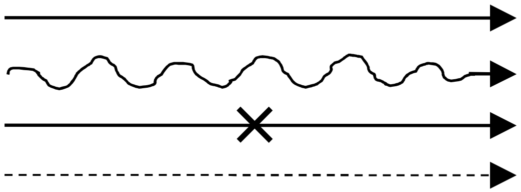
Archived Issues of Science Dissected, http://www.rpdp.net/link.news.php?type=sciencedis. Instructional Resource resulting from Plausibility, It's All About Connecting the Models Workshop co-sponsored by CPDD and SNRPDP Science March 6, 2012

Written by: Andrea Carver

Name:____ ____________________ **Period:**________________

Directions: draw two arrows from each evidence box. One to each model. You will draw a total of 10 arrows.

Key:



The evidence **supports** the model

The evidence **STRONGLY supports** the model

The evidence **contradicts** the model (shows its wrong)

The evidence has **nothing to do with** the model

Standard: N.8.B.1 (+E.8.C.7)

Evidence #1
Solar energy is capable of providing many times the total current energy demand.

Evidence #2
Petroleum products make life easier, but they can harm the environment.

Model A
Renewable energy resources are the most efficient way to support a community.

Model B
Nonrenewable energy resources are the most efficient way to support a community.

Evidence #3
Of the total energy consumed by Americans, only 7 percent is from renewable resources, while 85 percent is from fossil fuels, predominately oil.

Evidence #4
Wind energy is a clean, renewable resource, but it is inconsistent and intermittent.

Evidence #5
Fossil fuels are a dominant energy source that produces CO_2.

Provide a reason for three of the arrows you have drawn. **Write your reasons for the three most interesting or important arrows.**

A. Write the number of the evidence you are writing about.
B. Circle the appropriate descriptor (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write the letter of the model you are writing about.
D. Then write your reason.

1. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

2. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

4. Circle the plausibility of each model. [Make two circles. One for each model.]

	Greatly implausible (or even impossible)									Highly Plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

5. Circle the model which you think is correct. [Only circle one choice below.]

Very certain that Model A is correct	Somewhat certain that Model A is correct	Uncertain if Model A or B is correct	Somewhat certain that Model B is correct	Very certain that Model B is correct

Evidence #1: Solar energy is capable of providing many times the total current energy demand.

Solar Basics

Energy from the Sun

The sun has produced energy for billions of years. Solar energy is the sun's rays (solar radiation) that reach the Earth. This energy can be converted into other forms of energy, such as heat and electricity.

Radiant energy from the sun has powered life on Earth for many millions of years.

In the 1830s, the British astronomer John Herschel famously used a solar thermal collector box (a device that absorbs sunlight to collect heat) to cook food during an expedition to Africa. Today, people use the sun's energy for lots of things.

Solar Energy Can Be Used for Heat and Electricity

When converted to **thermal (or heat) energy**, solar energy can be used to:

- Heat water — for use in homes, buildings, or swimming pools
- Heat spaces — inside homes, greenhouses, and other buildings
- Heat fluids — to high temperatures to operate a turbine to generate electricity

Solar energy can be converted to electricity in two ways:

- **Photovoltaic (PV devices) or "solar cells"** change sunlight directly into electricity. Individual PV cells are grouped into panels and arrays of panels that can be used in a wide range of applications ranging from single small cells that charge calculator and watch batteries, to systems that power single homes, to large power plants covering many acres.
- **Solar Thermal/Electric Power Plants** generate electricity by concentrating solar energy to heat a fluid and produce steam that is used to power a generator. In 2010, solar thermal-power generating units were the main source of electricity at 13 power plants in the United States:
  - 11 in California
  - one in Arizona
  - one in Nevada

The main benefits of solar energy are:

- Solar energy systems do not produce air pollutants or carbon-dioxide
- When located on buildings, they have minimal impact on the environment

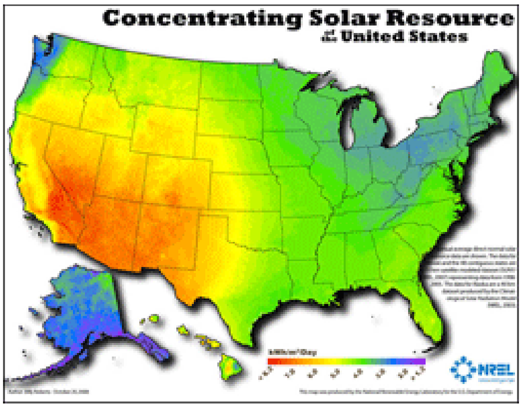
Two limitations of solar energy are:

- The amount of sunlight that arrives at the Earth's surface is not constant. It varies depending on location, time of day, time of year, and weather conditions.

- Because the sun doesn't deliver that much energy to any one place at any one time, a large surface area is required to collect the energy at a useful rate.

Where Solar is Found

Solar Energy Is Everywhere the Sun Shines



Source: National Renewable Energy Laboratory, U.S. Department of Energy

Solar energy is by far the Earth's most available energy source. Solar power is capable of providing many times the total current energy demand. But it is an intermittent energy source, meaning that it is not available at all times. However, it can be supplemented by thermal energy storage or another energy source, such as natural gas or hydropower.

California Has the World's Biggest Solar Thermal Power Plants

Nine solar power plants, in three locations in California's Mojave Desert, comprise the Solar Energy Generating Systems (SEGS). SEGS VIII and IX (each 80 megawatts), located in Harper Lake, are, individually and collectively, the largest solar thermal power generating plants in the world. The SEGS plants are concentrating solar thermal plants.

Concentrating solar power technologies use mirrors to reflect and concentrate sunlight onto receivers that collect the solar energy and convert it to heat. This thermal energy can then be used to produce electricity via a steam turbine or heat engine driving a generator.

Solar Power Can Be Used Almost Anywhere at a Variety of Scales

Low-temperature solar collectors also absorb the sun's heat energy, but instead of making electricity, use the heat directly for hot water or space heating in homes, offices, and other buildings.

Even larger plants than exist today are proposed for construction in the coming years. Covering 4% of the world's desert area with photovoltaics could supply the equivalent of all of the world's electricity. The Gobi Desert alone could supply almost all of the world's total electricity demand.

Weather Affects Photovoltaics

The performance of a photovoltaic array is dependent upon sunlight. Climate conditions (such as clouds or fog) have a significant effect on the amount of solar energy received by a photovoltaic array and, in turn, its performance. The efficiency of most commercially available photovoltaic modules in converting sunlight to electricity ranges from 5% to 15%. Researchers around the world are trying to achieve efficiencies up to 30%.

Solar Thermal Power Plants

Solar Thermal Power Uses Solar Energy Instead of Combustion

Solar thermal power plants use the sun's rays to heat a fluid to very high temperatures. The fluid is then circulated through pipes so it can transfer its heat to water to produce steam. The steam, in turn, is converted into mechanical energy in a turbine and into electricity by a conventional generator coupled to the turbine.

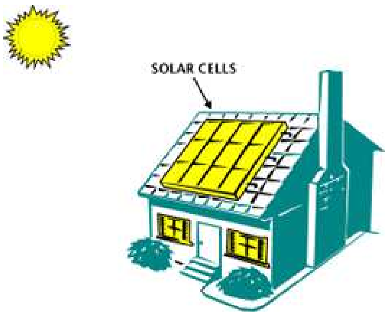
A Parabolic Trough Power Plant

Source: Stock photography (copyrighted)

So solar thermal power generation works essentially the same as generation from fossil fuels except that instead of using steam produced from the combustion of fossil fuels, the steam is produced by the heat collected from sunlight. Solar thermal technologies use concentrator systems to achieve the high temperatures needed to heat the fluid.

Solar Thermal Collectors

Heating With the Sun's Energy



Source: National Energy Education Development Project (Public Domain)

Solar thermal (heat) energy is often used for heating water used in homes and swimming pools and for heating the insides of buildings ("space heating"). Solar space heating systems can be classified as **passive** or **active**.

Passive space heating is what happens to your car on a hot summer day. The sun's rays heat up the inside of your car. In buildings, the air is circulated past a solar heat surface and through the building by convection (meaning that less dense warm air tends to rise while denser cool air moves downward). No mechanical equipment is needed for passive solar heating.

Active heating systems require a **collector** to absorb and collect solar radiation. Fans or pumps are used to circulate the heated air or heat absorbing fluid. Active systems often include some type of energy storage system.

Solar Energy & the Environment

An Array of Solar Panels Supplies Energy for Use at Marine Corps Air Ground Combat Center in Twentynine Palms, California

Source: U.S. Marine Corps photo by Pfc. Jeremiah Handeland/Released (Public Domain)

Using solar energy produces no air or water pollution and no greenhouse gases, but does have some indirect impacts on the environment. For example, there are some toxic materials and chemicals, and various solvents and alcohols that are used in the manufacturing process of photovoltaic cells (PV), which convert sunlight into electricity. Small amounts of these waste materials are produced.

In addition, large solar thermal power plants can harm desert ecosystems if not properly managed. Birds and insects can be killed if they fly into a concentrated beam of sunlight, such as that created by a "solar power tower." Some solar thermal systems use potentially hazardous fluids (to transfer heat) that require proper handling and disposal.

Concentrating solar systems may require water for regular cleaning of the concentrators and receivers and for cooling the turbine-generator. Using water from underground wells may affect the ecosystem in some arid locations.

Original Source: www.eia.gov (adapted for length and content)

Evidence #2: Petroleum products make life easier, but they can harm the environment.

Nonrenewable Basics

The four nonrenewable energy sources used most often are:

- Oil and petroleum products — including gasoline, diesel fuel, and propane
- Natural gas
- Coal
- Uranium (nuclear energy)

Nonrenewable energy sources come out of the ground as liquids, gases, and solids. Crude oil (petroleum) is the only commercial nonrenewable fuel that is naturally in liquid form. Natural gas and propane are normally gases, and coal is a solid.

Fossil Fuels Are Nonrenewable, but Not All Nonrenewable Energy Sources Are Fossil Fuels

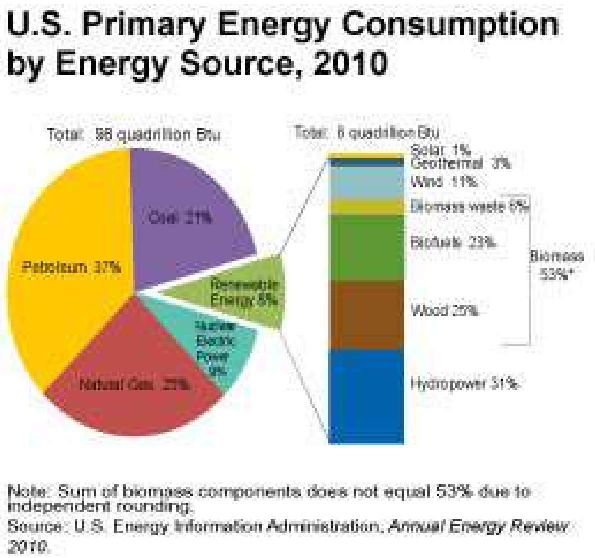
Coal, petroleum, natural gas, and propane are all considered fossil fuels because they were formed from the buried remains of plants and animals that lived millions of years ago.

Uranium ore, a solid, is mined and converted to a fuel used at nuclear power plants. Uranium is not a fossil fuel, but is a nonrenewable fuel.

Renewable Basics

What Is Renewable Energy?

Renewable energy sources can be replenished.



The five renewable sources used most often are:

- Biomass — including: wood and wood waste, municipal solid waste, landfill gas and biogas, ethanol, biodiesel
- Water (hydropower)
- Geothermal
- Wind
- Solar

Many paper mills use wood waste to produce steam and electricity

Source: Stock photography (copyrighted)

What Role Does Renewable Energy Play in the United States?

The use of renewable energy is not new. More than 150 years ago, wood, which is one form of biomass, supplied up to 90% of our energy needs. As the use of coal, petroleum, and natural gas expanded, the United States became less reliant on wood as an energy source. Today, we are looking again at renewable sources to find new ways to use them to help meet our energy needs.

In 2010, consumption of renewable sources in the United States totaled about 8 quadrillion Btu — 1 quadrillion is the number 1 followed by 15 zeros — or about 8% of all energy used nationally. About 10% of U.S. electricity was generated from renewable sources.

Over half of renewable energy goes to producing electricity. The next largest use of renewable energy is biomass (wood and waste) for the production of heat and steam for industrial purposes and for space heating, mostly in homes. Biomass also includes biofuels, such as ethanol and biodiesel, used for transportation.

Renewable energy plays an important role in the supply of energy. When renewable energy sources are used, the demand for fossil fuels is reduced. Unlike fossil fuels, non-biomass renewable sources of energy (hydropower, geothermal, wind, and solar) do not directly emit greenhouse gases.

Why Don’t We Use More Renewable Energy?

In the past, renewable energy has generally been more expensive to produce and use than fossil fuels. Renewable resources are often located in remote areas, and it is expensive to build power lines to the cities where the electricity they produce is needed. The use of renewable sources is also limited by the fact that they are not always available — cloudy days reduce solar power; calm days reduce wind power; and droughts reduce the water available for hydropower.

The production and use of renewable fuels has grown more quickly in recent years as a result of higher prices for oil and natural gas, and a number of State and Federal Government incentives, including the Energy Policy Acts of 2002 and 2005. The use of renewable fuels is expected to continue to grow over the next 30 years, although EIA projects that we will still rely on non-renewable fuels to meet most of our energy needs.

Adapted/Shortened from the original source www.eia.gov

Evidence #3: Of the total energy consumed by Americans, only 7 percent is from renewable resources, while 85 percent is from fossil fuels, predominately oil.

Renewable and nonrenewable resources

Category: Environment, conservation, and resource management

Nature provides numerous energy resources. Nonrenewable resources were the primary source of energy for the twentieth century. However, with the depletion of nonrenewables, interest in renewable forms of energy has generated increasing research and development of renewables.

Background

Nonrenewable resources cannot be readily replaced after consumption. A renewable resource is one that is continuously available, such as solar energy, or one that can be replaced within several decades, such as wood.

A man hauls aluminum stoves through a street in Kabul, Afghanistan. Aluminum is a nonrenewable resource.

(Zabi Tamanna/Xinhua/Landov)

Nonrenewable Energy Sources

Nonrenewable resources may be subdivided into four categories: metals (such as copper and aluminum), industrial minerals (such as lime and soda ash), construction materials (sand and gravel), and energy resources (coal, oil, and uranium). Of the nonfuel substances, metals are most prone to depletion by overproduction, but recycling can prolong their useful lifetime almost indefinitely.

Construction materials, although not readily recyclable, are abundant and ubiquitous in the Earth's crust, rendering them a virtually unlimited resource. Although less plentiful, the most widely used industrial minerals are unlikely to be depleted in the near future; on the scale of centuries, however, they are an endangered resource if current levels of production are maintained. It is probable that environmental concerns will reduce future production.

The major forms of nonrenewable energy production are fossil fuel combustion (using oil and coal) and nuclear fission (using uranium). Of the total energy consumed by Americans, only 7 percent is from renewable resources, while 85 percent is from fossil fuels, predominantly oil.

Coal was the first fossil fuel to be used extensively, and it remains the most abundant. Coal can be burned directly or converted into petroleum or petroleum products, through the expenditure of additional energy. When used as fuel, coal creates many problems. Mines are environmentally destructive, and coal is the most difficult fossil fuel to transport. When coal is burned, vast quantities of sulfur compounds (which form sulfuric acid in the atmosphere) are released, while the carbon in the coal becomes carbon dioxide, a greenhouse gas believed to contribute to global warming. The carbon in coal also has many other valuable (nonpolluting) uses in the chemical industry.

Oil is the world's major source of energy because it is abundant and relatively inexpensive. Its high rate of use will result in its depletion during the twenty-first century. When burned as gasoline in cars, it releases carbon dioxide; various dangerous air pollutants, such as carbon monoxide and nitrogen oxides; and uncombusted hydrocarbons (a major cause of photochemical smog). Natural gas, formed when organic materials decompose, is usually found with petroleum reservoirs. Its supply, rate of consumption, and probable future are comparable to those of petroleum. It is widely used because it is relatively inexpensive, clean, and nonpolluting (although it does add carbon to the atmosphere).

Tar sands, principally found in Canada, are a low-grade source of petroleum that is feasible to mine and process only when oil prices are relatively high. Two additional problems limit this source: About as much energy is required to extract usable oil as is created when it is combusted, and the process has raised environmental concerns. Oil shales, abundant in the western United States, appear theoretically to be a major source of future petroleum products. The amount of oil tied up in shale exceeds the remaining total world reserve of oil. To extract oil, however, the shale must be mined and heated by processes requiring large quantities of water in regions where water is scarce. Additionally, the total energy required for extraction exceeds the energy created when the oil is burned.

Nuclear reactors produce energy through controlled fission of uranium 235. No air pollution is produced, the mining operations are relatively small and safe, and the resource being consumed has no other known use. On the other hand, reactor technology is sophisticated and elaborate, and complicated devices are prone to breakdowns. A reactor breakdown can have disastrous consequences if radioactive materials are released into the environment. Of equal or greater concern is how the by-products of nuclear power production—nuclear waste—should be disposed of over the long term.

Renewable Energy Sources

The most abundant renewable energy resource is solar energy, the source of most other renewables as well as the original source of fossil fuels. The supply is enormous and inexhaustible, but most is wasted because it occurs in a dilute form that requires expensive hardware to concentrate. Also, it reaches Earth in its most dilute form during the winter, when it is most needed for heating. In cloudy regions it is not even available when demand for it is greatest.

Like solar energy, wind represents a large and potentially inexhaustible source of energy. However, when wind energy is used to generate electricity, expensive collectors are required. Wind energy is not feasible everywhere, and even when feasible it is not always available. Power derived from moving water, such as that provided by hydroelectric dams, makes an important contribution to the world's energy supply. Many of the best sites have already been dammed, however, and development of a number of other sites is unwise because of ecological reasons or the sites' scenic beauty.

Tidal energy utilizes the ebb and flow of tides to create electricity by trapping seawater at the extremes of high and low tide and releasing it through turbines. Although a potentially large energy source, it is economically feasible only where there are naturally high tides (4.5 meters or more) and where a narrow inlet encloses a large bay.

Geothermal energy uses the heat from natural hot springs to create steam to power turbines, which are used to create electricity. Because the heat must be close to the surface, there are few known sites from which geothermal electrical energy can be extracted economically. Also, because pipelines must be run over many hectares to collect steam, the power-generating stations tend to be ugly and noisy.

Vegetation (biomass) energy uses plants or animal products derived from plants as a source of fuel. This source includes wood, organic wastes, ethanol, and methane gas from biodigestion. This type of renewable resource is renewable only if harvesting is controlled and if resources exist to cultivate the source. Thus, trees must be given sufficient time to mature, and corn must be cultivated before ethanol can be produced. Although vegetation has a long history as a source of fuel, efficient and sustainable techniques have yet to be introduced.

Plitnik, George R. "Renewable and nonrenewable resources." *Encyclopedia of Global Resources*. Ed. Craig W. Allin. 4 vols. Salem Press, 2010. *Salem Science* Web. 13 Mar. 2012.

Evidence #4: Wind energy is a clean, renewable resource, but it is inconsistent and intermittent.

Wind energy

Category: Energy resources

Wind energy has been a significant energy resource in human history, from its use by ancient sailboats to its employment in modern large-scale electrical generators. In the twenty-first century, it is one of the fastest-growing energy sources in the world. Wind energy is a clean, renewable, and free power source that is a viable alternative to fossil fuels, which pollute the environment and promote global warming.

Background

The energy of the wind was captured by humans as early as the fourth century b.c.e., when the Egyptians used wind to propel sailboats on the Nile River. Soon, there were sailing vessels in the Mediterranean Sea. Windmills, machines that convert wind into mechanical power, were used to pump water and mill grain in ancient times. In a windmill, wind blows on sails or blades radiating from a windshaft (cylindrical part on which the sails turn), which produces mechanical energy when it rotates. The first documented wind device was a Persian windmill shown in drawings from about 500 c.e. This windmill was the horizontal axis type, with a horizontal wheel holding the sails, a vertical windshaft, and vertical sails made of bundles of reeds or wood. These windmills spread throughout the Middle East and into China.

The Green Mountain Energy Wind Farm at Brazos in Texas was completed in 2003 and contains 160 wind turbines.

During the twelfth century, the first European windmills appeared in England and France. These wooden machines were called post mills, because they had a central vertical post. They had a horizontal windshaft, had a revolving platform atop the post, and were rotated by hand. In the fourteenth century, a larger and sturdier windmill called the tower mill was developed. The tower mill had a stationary body that supported a rotatable wooden cap, to which the rotor was attached. The blades faced the wind, and there was storage space for the grain at the base. This windmill was popular in Holland, where windmills were used for land drainage. Between 1300 and 1850 c.e., windmills provided about 25 percent of Europe's industrial power. They were used for grinding dyes, spices, and paint pigment as well as for irrigation and grain milling.

In the nineteenth and early twentieth centuries, windmills played an essential role in the development of the western and Great Plains regions of the United States. In 1854, Daniel Halladay designed small, multibladed, and inexpensive windmills that were sturdy enough for the Great Plains. American farmers and homesteaders used windmills to pump underground water to the surface. Windmill-generated water was crucial for livestock, human use, crop irrigation, and steam locomotives. Windmills made the arid Great Plains bloom, opening up the West to towns, farms, and most important, the transcontinental railroad. Windmills were responsible for changing cattle ranching from a nomadic to a stable business and transforming the Great Plains into a breadbasket. Between 1880 and 1930, approximately 6 million windmills were installed in the western United States and the Great Plains.

As Europe and the United States became industrialized, the steam engine gradually replaced water-pumping windmills in Europe, and electricity replaced wind power in rural America. The Rural Electrification Act of 1936 provided low-cost federal loans for bringing electricity into rural areas. Low-cost power from town and regional electric generators became available, and power lines were extended to remote areas of the country. In 1935, only 11 percent of the farms in the United States had electric service, but by the early 1970's, about 98 percent did.

Meanwhile, scientists developed larger windmills, called wind turbines, that could generate electricity. In 1890, in Denmark, P. LaCour built the first windmill capable of generating electricity. In 1941, Palmer Putnam built the world's largest wind turbine on a windy mountaintop called Grandpa's Knob in Vermont. This nearly 230-metric-ton generator served an entire town by feeding electric power into the existing local utility grid.

Energy from fossil fuels (coal, natural gas, and oil) was in abundance and had essentially displaced wind power. The Atomic Energy Act of 1954 allowed private companies to develop nuclear energy for peaceful purposes. However, Europe was developing more wind-power technologies. For instance, from 1956 to 1957 in Denmark, Johannes Juul built the world's first alternating current (AC) wind turbine, the very efficient Gedser wind turbine. The 1973 oil crisis, the environmental movement, and the dangers of atomic energy led to renewed interest in wind energy, which is a renewable energy source. Electricity generated by renewable energy sources (solar, wind, hydro, geothermal, and biomass energy) is called "green" power. During the 1990's, wind power was one of the fastest-growing sources of energy.

Wind Energy Technology

When the Sun warms areas of the Earth at different rates and the various surfaces absorb or reflect the radiation differently, there are differences in air pressure. As hot air rises, cooler air comes in to replace it. Wind, or air in motion, is the result. Air has mass, and moving air contains kinetic energy, the energy of that motion.

Windmills convert wind energy into mechanical power or electricity. The modern electricity windmills are called wind turbines or wind generators. In the wind turbine, wind turns two or three propeller-like rotor blades, which are the sails of the system. When the blades move, energy is transferred to the rotor. The wind shaft is connected to the rotor's center, so both the rotor and shaft spin. The rotational energy is thus transferred to the shaft, which spins an electrical generator at the other end.

The ability to generate electricity is measured in units of power called watts. A kilowatt represents 1,000 watts, a megawatt is 1 million watts, and a gigawatt represents 1 billion watts. Electricity consumption and production are described in kilowatt-hours. Multiplying the number of kilowatts by the number of hours equals the kilowatt-hours. One kilowatt-hour equals the energy of one kilowatt produced or used for a period of one hour.

The turbine's size and the speed of the wind through the rotor determine the output of the turbine. As of 2009, the world's largest turbine was the Enercon E-126, the first wind turbine with 6-megawatt rated power. Wind turbines can generate electricity for an individual building or for widespread distribution by connecting to an electricity grid or network.

Wind Farms

A wind farm or wind power plant is a group of large wind turbines (660 kilowatts and up) installed in the same location to jointly capture wind and produce electricity. There can be up to about one hundred individual modules or turbines sited far apart and covering an extended area of hundreds of square kilometers. Turbines can be added as the need arises. Individual modules connect with a medium-voltage (usually 34.5-kilovolt) power collection system. Then a substation transformer increases the medium voltage of electrical current for connection with a high-voltage transmission system. Wind farms are best located in areas with consistent, strong, and unobstructed winds, such as high plains, mountain passes, and coastlines. In rural, agricultural areas, the land between the turbines can still be used for farming.

As of 2009, the world's second largest onshore wind farm was Florida Power and Light's Horse Hollow Wind Energy Center in Taylor and Nolan counties, Texas. Completed in 2006, Horse Hollow has 421 turbines and delivers 735 megawatts of electricity at its peak. The world's largest wind farm, as of October, 2009, was Roscoe Wind Farm in Texas, designed to deliver 781.5 megawatts from 627 turbines.

In 2008, T. Boone Pickens's company, Mesa Power, placed a $2 billion order with General Electric (GE) for 667 wind turbines to be delivered in 2010 and 2011. Pickens, the legendary oil executive and energy investor, planned to build the world's largest wind farm in Texas. He also created the Pickens Plan, which promotes generating up to 22 percent of the nation's electricity from wind, thus freeing up the natural gas supply to be used as transportation fuel and reducing foreign oil dependence.

Wind farms can also be sited offshore in the shallow waters of the oceans in order to capture the stronger winds. As of 2009, the world's biggest offshore wind farm was the Lynn and Inner Dowsing Wind Farm near Skegness, Lincolnshire, England. Each of the fifty-four 3.6-megawatt turbines sits on a pylon driven into the shallow seabed and turns a hub that is more than 80 meters above sea level.

As of 2009, plans existed for even larger offshore farms. When completed, Horns Rev 2 wind farm, sited in the North Sea between 30 and 40 kilometers west of the westernmost tip of Denmark, would become the world's biggest offshore wind farm, delivering 209 megawatts from ninety-five turbines, at a cost of about $670 million. The 1,000-megawatt London Array in the outer Thames Estuary, one of the three strategic areas the United Kingdom government has identified for offshore wind farm development, was scheduled for completion in the early 2010's.

In 2001, the Cape Wind Project was formally proposed. The proposed $1 billion farm would cover 38.6 square kilometers on Horseshoe Shoal in Nantucket, 8 kilometers off Cape Cod in Massachusetts. This location is one of the largest offshore areas with shallow water, which is very cost-effective because wind turbine foundation costs rise with increasing water depth and wave height. The farm's 130 wind turbines would produce up to 420 megawatts of renewable wind energy that would, on average, provide 75 percent of the electricity needed by Cape Cod, Nantucket, and Martha's Vineyard. The farm's energy would be capable of replacing 2.685 million barrels of oil per year. After years of rigorous and comprehensive review from federal and state agencies, the project was approved in 2009.

Advantages and Disadvantages

The first advantage of wind energy is that the fuel is free. The main costs of generating electricity from wind are those of installation, operation, and maintenance. The United States has an abundant supply of wind power that can help promote energy independence from expensive imported energy and thus reduce national economic and security risks. Since 1973, more than $7 trillion has been spent on foreign oil. The wind industry has also created jobs and helped stabilize electricity costs. Since 1980, the cost of wind energy has dropped more than 80 percent.

Wind energy has significant long-term benefits for the environment, human health, and global climate change. Wind is a clean, renewable energy resource that is inexhaustible and easily replenished by nature. Wind power plants do not pollute the air or need waste cleanups like fossil-fuel and nuclear-generation plants, and wind turbines do not emit greenhouse gases or cause acid rain. As of 2009, the wind-energy-generating capacity of the United States was 25,170 megawatts, enough electricity to power almost seven million households. To generate the equivalent of that much energy, 112 million barrels of oil or 31.2 million metric tons of coal (a line of 9-metric-ton trucks more than 22,000 kilometers long) would have to be burned each year.

A significant disadvantage is that wind is inconsistent and intermittent. It is variable power that does not always blow at times of electrical demands. To be cost-effective, wind sites are located where both strong winds and land are available, usually in remote locations, far from large population centers where consumer demand is the greatest. For instance, China’s major wind-energy resources are located in the Northern China wind belt, including the sparsely populated Xinjiang Uygur and the windy grasslands of Nei Monggol. Even in locations where winds are strong, there are wide differences in wind velocities over relatively short distances.

To meet these challenges, storage of surplus wind energy and electrical distribution systems to transmit this energy to consumers are necessary. Wind power can be stored in batteries, and technology already exists that can convert wind energy into fuels such as ethanol and hydrogen. However, economic feasibility is a major consideration. Enhanced electrical transmission systems improve reliability for consumers, relieve congestion in existing systems, and provide access to new and remote wind-generation sources. Typically, large wind plants are connected to the local electric utility transmission network. In the European Union, there is a proposal for a super grid of interconnected wind farms in Western Europe, including Denmark, England, Ireland, and France.

On a smaller scale, distributed energy is a viable solution. Consumers can make their own wind power with private wind turbine and batteries as backup. As more communities or individual consumers use distributed energy, they lower the costs of central wind power plants and transmission systems. Established in 1987, Southwest Windpower in Arizona is the world’s leading producer of small wind turbines. Applications include offshore platform lighting, remote homes and cabins, utility-connected homes and businesses, water pumping, and telecommunications. Their wind generators often work as part of a hybrid wind-solar battery-charging system. Also, small domestic turbines can complement power from a larger electrical power system, and utility companies buy back any surplus electricity.

There are also aesthetic and environmental concerns surrounding the large-scale implementation of wind energy. Local residents and public advocacy groups have often opposed wind farms because of the rotor noise, visual impact, and potential harm to property values and local wildlife and its habitats. For instance, in 2001, residents concerned about the environment opposed the proposal of the Cape Wind Project, the first offshore wind farm in the country. In many cases, technological advances and the appropriate siting of the wind generators away from populated areas have mitigated the problems.

The Future of Wind Energy

Wind energy is already one of the fastest-growing energy sources, and the market is forecast to expand in the future. Wind power is affordable, readily available, and renewable. Wind energy technology has developed to the point that it can compete successfully with conventional power generation technologies, such as oil, nuclear, coal, and most natural gas-fired generation.

As of 2008, the world's ten largest producers of wind power were the United States, Germany, Spain, China, India, Italy, France, the United Kingdom, Denmark, and Portugal. There is major wind-energy development globally, and in some countries, wind-power generation has been increasing exponentially. In 2008, in Australia, numerous wind farm projects were approved, and wind power is expected to provide more than 20 percent of the country's energy by 2020. China has been rapidly increasing its installed wind-power capacity each year since 2005, and estimates predicted that China would achieve a capacity of 100 gigawatts by 2020.

Utility companies have increased investments in wind farms and wind technology. In 2005, General Electric's turbine business doubled, and by 2009, it was the leading U.S. wind turbine supplier and a world leader, with more than ten thousand wind turbine installations worldwide, comprising more than 15,000 megawatts of capacity. GE operates wind power manufacturing and assembly facilities in Spain, Canada, China, Germany, and the United States. In 2008, GE passed the $4 billion mark in investments in wind farms.

Vestas, the Danish company that is the world's leading wind supplier, had $5.7 billion in revenues in 2008. In Denmark, wind energy equaled 20 percent of total energy consumption. Vestas had installed more than thirty-eight thousand wind turbines in sixty-two countries on five continents to serve an estimated forty-five million people worldwide. By 2009, Vestas was installing an average of one wind turbine every three hours, twenty-four hours a day.

In 2008, the U.S. wind energy industry surpassed previous records for installations and was second only to the natural gas industry in adding new capacity. Enough new wind-power-generating capacity to service more than two million homes, 8,500 megawatts, was installed. These wind projects increased the nation's entire wind-power-generating capacity to more than 25,300 megawatts and equaled 42 percent of the U.S.'s total power-producing capacity that was added. The new wind-energy capacity had the same effect as taking more than seven million cars off the road or preventing almost 40 million metric tons of carbon emissions.

Significantly, there has been increasing federal government support of wind power. In 2008, the U.S. Department of Energy released its groundbreaking technical report *Twenty Percent Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*. More than one hundred people from government, industry, utilities, and nongovernment organizations worked on this report, which supports a scenario in which by 2030, wind power would supply 20 percent of U.S. electricity. Other benefits would be to reduce emissions of greenhouse gases by 25 percent, avoid consumption of 15 trillion liters of water, cut electric sector water consumption by 17 percent, create $2 billion in local annual revenues through jobs and other economic benefits, and reduce nationwide natural gas use by 11 percent with savings of $86-$214 billion for gas consumers. The Department of Energy has also researched the use of wind energy for hydrogen production, water treatment and irrigation, and hydropower applications.

The American Recovery and Reinvestment Act of 2009 provided measures to benefit renewable energy, including a Treasury Department grant program for renewable energy developers, increased funding for research and development, and a manufacturing tax credit. The ARRA also includes an extension of the wind-energy production tax credit to December 31, 2012. Consumers are allowed federal tax credits for energy efficiency, including tax credits of 30 percent of the cost of residential small wind turbines placed in service before December 31, 2016.

Weber, Thomas W. "Wind energy." *Encyclopedia of Global Resources*. Ed. Craig W. Allin. 4 vols. Salem Press, 2010. *Salem Science* Web. 13 Mar. 2012.

Evidence #5: Fossil fuels are a dominant energy source that produces CO_2.

Fossil fuels

Category: Energy

The coal-burning steam engine stimulated the Industrial Revolution, leading to the nineteenth century's vast commercial productivity. The invention of affordable automobiles in the twentieth century created a huge market for oil, which became America's dominant energy source. When a fossil fuel is burned, its emissions include CO_2, the main anthropogenic contributor to global warming.

Background

Fossil fuels store the chemical energy created over hundreds of millions of years as accumulated layers of plant and animal remains were subjected to heat and pressure. These organic residues transformed into coal beds, pools of oil, and pockets of gas. They include coal, oil, natural gas, oil shale, and tar sands. Since these fuels are no longer being created, they are nonrenewable resources. Equally important, when burned, the carbon unites with oxygen in the atmosphere to produce carbon dioxide (CO_2), the main culprit responsible for anthropogenic global warming.

Coal

Coal is fossilized plant material, deposited 300 million years ago when Earth was warmer and wetter. Preserved and altered by geological forces over eons of time, this material was compacted into carbon-rich fuel.

Coal mining is dirty and dangerous, because underground mines are subject to cave-ins, accumulations of carbon monoxide, and fires caused by explosive gases such as methane. In the United States alone, tens of thousands of miners have died in accidents over the past century, and even more have died or been disabled by respiratory diseases caused by the accumulation of fine dust particles in the lungs. Although strip mining is a safer and less expensive alternative, the land remaining after the overburden is removed is rendered unfit for any other use. Restoration and reclamation are now mandated by U.S. law, but the efforts expended by mining companies are often superficial and ineffective. Coal mining also contributes to water pollution, because sulfur and other soluble minerals in mine drainage and runoff from mine tailing are acidic and highly toxic.

People search a cinder dump in Changzhi, China, for bits of usable coal.

(Reuters/Landov)

Coal burning releases, in addition to CO_2, many toxic metals and radioactive elements formed into gaseous compounds. Coal combustion is responsible for about 25 percent of all atmospheric mercury pollution in the United States.

Oil, Oil Shale, and Tar Sands

Oil is formed from phytoplankton, microorganisms that lived in warm, shallow seas hundreds of million of years ago. When they died, they sank to the bottom and were buried in sediments. Over eons of time heat from the Earth and the pressure of overlying layers of sedimentary rocks transformed this into kerogen deposits containing a mixture of oil, gas, and solid tarlike substances.

Drilling for oil leads to environmental degradation at the drill site, but even more problematic are water pollution due to leaks during transportation and the major oil spills caused by accidents. Such accidents have been known to contaminate shorelines and estuaries, fouling beaches and murdering waterfowl and aquatic life.

Oil shale and tar sands are unconventional resources with a large potential if they can be recovered with reasonable social, economic, and environmental costs. Western Canada has an estimated 270 billion cubic meters of tar sands from which liquid petroleum can be extracted, but the process is expensive and the environmental problems severe. A typical site yielding 125,000 barrels daily leaves 15 million cubic meters of toxic sludge and contaminates billions of liters of water each year.

Vast deposits of oil shale, rich in kerogen, are located in the United States' intermountain west. When heated to about 482° Celsius, the kerogen liquefies and can be separated from the stone. If the deposits could be extracted at a reasonable price and with acceptable environmental impact, the amount would be the equivalent of several trillion barrels of oil. The mining and extraction requires huge amounts of water (a scarcity in the west), creates air pollution, contaminates water, and leaves mountains of loose, rocky waste.

Natural Gas

After oil and coal, natural gas is the world's third largest commercial fuel, accounting for 24 percent of global consumption. It is also the most rapidly increasing fossil fuel energy source because it is convenient, inexpensive, and cleaner burning than coal or oil. When combusted it releases half the CO_2 as an equivalent amount of coal; substituting gas for coal thus helps reduce global warming. Although it is difficult to ship across oceans, the U.S. has an abundant easily available supply and the pipelines to transport it from source to end user. Natural gas, often released when oil is extracted, is burned off when no easy mechanism exists to deliver it to a user. Although transportation is problematic for some recoverable natural gas deposits, the world resources are estimated to be about 300 trillion cubic meters, a sixty-year supply at current rates of use.

An unconventional and as yet untapped source of natural gas is the methane hydrate deposits located in arctic permafrost and beneath deep ocean sediments. At least fifty ocean deposits and a dozen land deposits, containing about 9 trillion metric tons of methane, are known to exist. This is twice the combined amount of all coal, oil and natural gas reserves. Although this is a possible future energy source, the complex technologies required to extract, store, and ship the methane hydrates are formidable.

Context

Fossil fuels promoted the Industrial Revolution, increased industrial productivity, contributed to capitalizing industry and farming, and still provide 85 percent of the world's energy. These resources, however, are nonrenewable; eventually the production rate will decline to the point where it is no longer economically feasible to extract the remaining fuel. When a production peak occurs and decline begins, about half of the total resource has been recovered. Assuming a modest 1 percent or 2 percent annual increase in consumption, the number of years remaining until production peaks for the three main fossil fuels is hundreds of years for coal, up to sixty years for natural gas, and no more than forty years for oil. Given the eminent end of fossil fuel dependence, the contamination of air and water caused by their extraction and combustion, and the hazards posed by global warming, alternate renewable resources must be developed and incorporated into the energy mix expeditiously.

Plitnik, George R. "Fossil fuels." *Encyclopedia of Global Warming*. Ed. Steven I. Dutch. 3 vols. Salem Press, 2009. *Salem Science* Web. 13 Mar. 2012.