Wind

2002 Facts at a Glance

Classification: Renewable Energy Source

Percent of energy produced in US: 0.1% (0.1 Q)
Percent of energy consumed in US: 0.1% (0.1 Q)

Major use: electricity

What Is Wind?

Wind is air in motion. It is produced by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of various land and water formations, it absorbs the sun's radiation unevenly.

When the sun is shining during the day, the air over landmasses heats more quickly than the air over water. The warm air over the land expands and rises, and the heavier, cooler air over water moves in to take its place, creating local winds. At night, the winds are reversed because the air cools more rapidly over land than over water.

Similarly, the large atmospheric winds that circle the earth are created because the surface air near the equator is warmed more by the sun than the air over the North and South Poles.

Wind is called a **renewable** energy source because wind will continually be produced as long as the sun shines on the earth. Today, wind energy is mainly used to generate electricity.

The History of Wind

Throughout history, people have harnessed the wind in many ways. Over 5,000 years ago, the ancient Egyptians used wind power to sail their ships on the Nile River. Later, people built windmills to grind their grain. 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 made of fabric sails and invented ways for it to change direction so that it could continually face the wind. Windmills helped Holland become one of the world's most industrialized countries by the 17th century.

American colonists used windmills to grind wheat and corn, pump water, and cut wood. 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 environment more open to alternative energy sources, paving the way for the re-entry of the windmill into the American landscape to generate electricity.

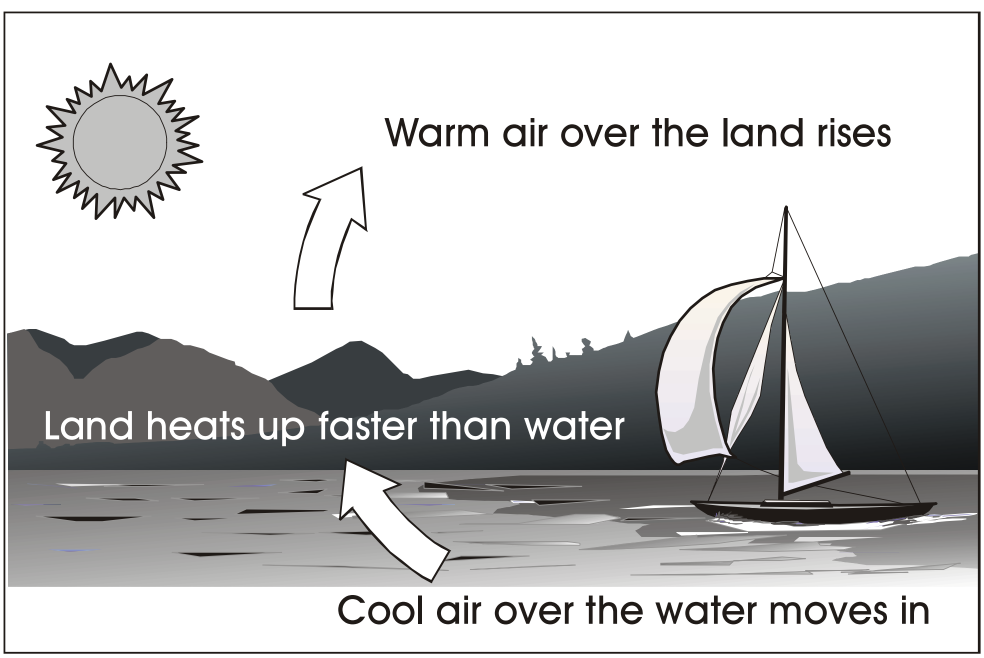
Windmill Mechanics

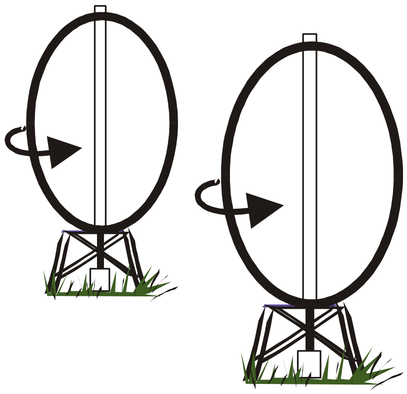
Windmills work because they slow down the speed of the wind. The wind flows over the airfoil shaped blades causing lift, like the effect on airplane wings, causing them to turn. The blades are connected to a drive shaft that turns an electric generator to produce electricity.

Wind Machines Today

Today's wind machines are much more technologically advanced than those early windmills. They still use blades to collect the wind's kinetic energy, but the blades are made of fiberglass or other high-strength materials.

Modern wind machines are still wrestling with the problem of what to do when the wind isn't blowing. Large turbines are connected to the utility power network—some other type of generator picks up the load when there is no wind. Small turbines are sometimes connected to diesel/electric generators or sometimes have a battery to store the extra energy they collect when the wind is blowing hard.





VERTICAL AXIS WIND MACHINES

Types of Windmills

Two types of wind machines are commonly used today, the horizontal–axis with blades like airplane propellers and the vertical–axis, which looks like an egg-beater.

Horizontal-axis wind machines are more common because they use less material per unit of electricity produced. About 95 percent of all wind machines are horizontal-axis. 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 wind machines make up just five percent of the wind machines used today. The typical vertical wind machine stands 100 feet tall and 50 feet wide.

Each wind machine has its advantages and disadvantages. Horizontal-axis machines need a way to keep the rotor facing the wind. This is done with a tail on small machines. On large turbines, either the rotor is located downwind of the tower to act like a weather vane, or a drive motor is used. Vertical-axis machines can accept wind from any direction.

Both types of turbine rotors are turned by air flowing over their wing shaped blades. Vertical-axis blades lose energy as they turn out of the wind, while horizontal-axis blades work all the time. At many sites, the wind increases higher above the ground, giving an advantage to tall horizontal-axis turbines. The small tower and ground-mounted generators on vertical-axis turbines make them cheaper and easier to maintain.

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.

Unlike coal or nuclear 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 (IPPs)**.

Operating a wind power plant is not as simple as plunking down machines on a grassy field. Wind plant owners must carefully plan where to locate their machines. They must consider wind availability (how much the wind blows), local weather conditions, proximity to electrical transmission lines, and local zoning codes.

Wind plants also need a lot of land. One wind machine needs about two acres of land to call its own. A wind power plant takes up hundreds of acres. On the plus side, farmers can grow crops or graze cattle around the machines once they have been installed.

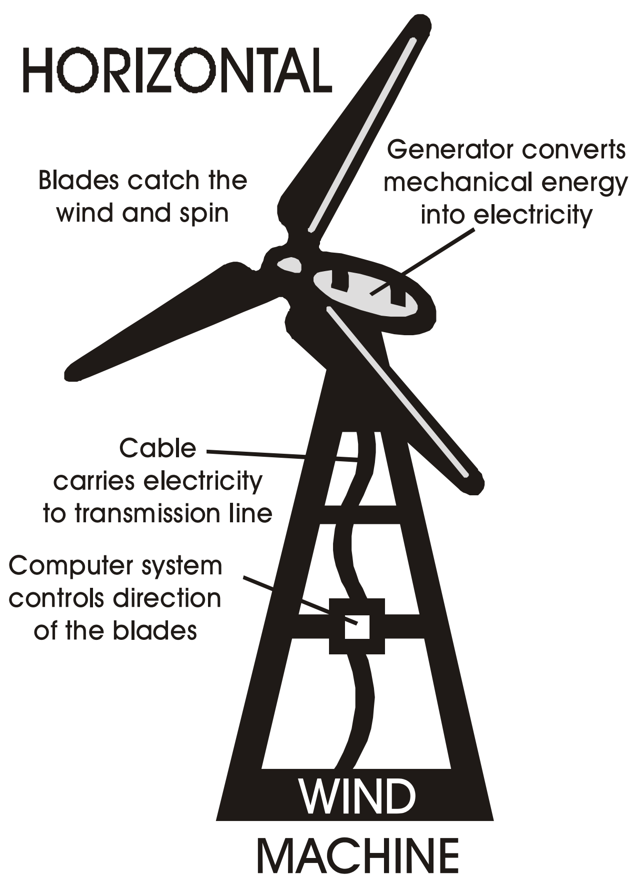
After a plant has been built, there are still maintenance costs. In some states, maintenance costs are offset by tax breaks given to power plants that use renewable energy sources. The Public Utility Regulatory Policies Act, or PURPA, also requires utility companies to purchase electricity from independent power producers at rates that are fair and nondiscriminatory.

Wind Resources

Where is the best place to build a wind plant? There are many good sites for wind plants in the United States including California, Alaska, Hawaii, the Great Plains, and mountainous regions. Scientists say there is enough wind in 37 states to produce electricity. An average wind speed of 14 mph is needed to convert wind energy into electricity economically. The average wind speed in the U.S. is 10 mph. Because of the availability of consistent wind, some companies are considering installing wind machines offshore.

Scientists use an instrument called an anemometer to measure how fast the wind is blowing. An anemometer looks like a modern-style weather vane. It has three spokes with cups that spin on a revolving wheel when the wind blows. It is hooked up to a meter that tells the wind speed. A weather vane shows the direction of the wind, not the speed.

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. The three biggest wind plants in California are located at mountain gaps.



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.

These seasonal variations are a good match for the electricity demands of the regions. In California, people use more electricity during the summer when air conditioners are used for cooling. Conversely, more people use electricity in Montana during winter heating months.

OPERATING TIME OF WIND PLANTS
Annual Average

Wind Production

How much energy can we get from the wind? There are two terms to describe basic electricity production: efficiency and capacity factor.

Efficiency refers to how much useful energy (electricity, in this case) we can get from an energy source. A 100 percent energy efficient machine would change all the energy put into it into useful energy. It would not waste any energy.

There is no such thing as a 100 percent energy efficient machine. Some energy is always lost or wasted when one form of energy is converted to another. The lost energy is usually in the form of heat, which dissipates into the air and cannot be used again economically.

How efficient are wind machines? Wind machines are just as efficient as most other plants, such as coal plants. Wind machines convert 30-40 percent of the wind's kinetic energy into electricity. A coal-fired power plant converts about 30-35 percent of the chemical energy in coal into usable electricity.

Capacity refers to the capability of a power plant to produce electricity. A power plant with a 100 percent capacity rating would run all day, every day at full power. There would be no down time for repairs or refueling, an impossible goal for any plant. Coal plants typically have a 75 percent capacity rating since they can run day or night, during any season of the year.

Wind power plants are different from power plants that burn fuel. Wind plants depend on the availability of wind, as well as the speed of the wind. Therefore, wind machines cannot operate 24 hours a day, 365 days a year.

A wind turbine at a typical wind farm operates 65-80 percent of the time, but usually at less than full capacity, because the wind speed is not at optimum levels. Therefore, its capacity factor is 30-35 percent.

Economics also plays a large part in the capacity of wind machines. Wind machines can be built that have much higher capacity factors, but it is not economical to do so. The decision is based on electricity output per dollar of investment.

One wind machine can produce 1.5 to 4.0 million kilowatt-hours (kWh) of electricity a year. That is enough electricity for 150-400 homes per year. In this country, wind machines produce 10 billion kWh of energy a year. Wind energy provides about 0.1 percent of the nation's electricity, a very small amount. That is enough electricity to serve a million households, as many as in a city the size of Chicago, Illinois.

California produces more electricity from the wind than any other state followed by Texas, Minnesota and Iowa. Some 13,000 wind machines produce more than one percent of California's electricity. (This is about half as much electricity as is produced by one nuclear power plant.) In the next 15 years, wind machines could produce five percent of California's electricity.

Why is California out-producing every other state in developing wind energy? More than any other reason, wind energy has taken off in this state because of California's state policies that support renewable energy sources. Other states have just as good wind resources as California.

Ten years ago, the United States was the king of wind energy. The U.S. produced 90 percent of the world's wind-blown electricity. By 1996, that number had dropped to 30 percent. What happened to the wind industry?

Wind is the fastest growing energy technology in the world today. In the last three years, wind capacity worldwide has more than doubled. Experts expect the production from wind machines to triple in the next few years. India and many European countries are planning major new wind facilities.

In the United States, however, wind capacity grew very slowly in the 1990s. Many new wind projects were put on hold because of deregulation. (See explanation of deregulation in the Electricity Infosheet.)

Utilities were not sure how deregulation would affect many new technologies. Would the government still encourage utilities to invest in renewable energy projects? Would there be a market for the energy produced?

The answers to these questions are still not known. Nevertheless, investment in wind energy is beginning to increase because its cost has come down and the technology has improved. Wind is now one of the most competitive sources for new generation.

Another hopeful sign for the wind industry is consumer demand for green pricing. Many utilities around the country now allow customers to voluntarily choose to pay more for electricity generated by renewable sources.

The wind industry is poised to make a major comeback. New wind plants are now operating or under construction in Washington, Oregon, Nevada, Montana, Wyoming, Texas, Iowa, Kansas, and other states. The direction is changing for wind energy in the U.S.

Wind Economics

On the economic front, there is a lot of good news for wind energy. First, a wind plant is far less expensive to construct than a conventional energy plant. Wind plants can simply add wind machines as electricity demand increases.

Second, the cost of producing electricity from the wind has dropped dramatically in the last two decades. Electricity generated by the wind cost 30 cents per kWh in 1975, but now costs less than five cents per kWh. New turbines are lowering the cost even more.

Wind Energy & 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.

FUTURE *wind power*

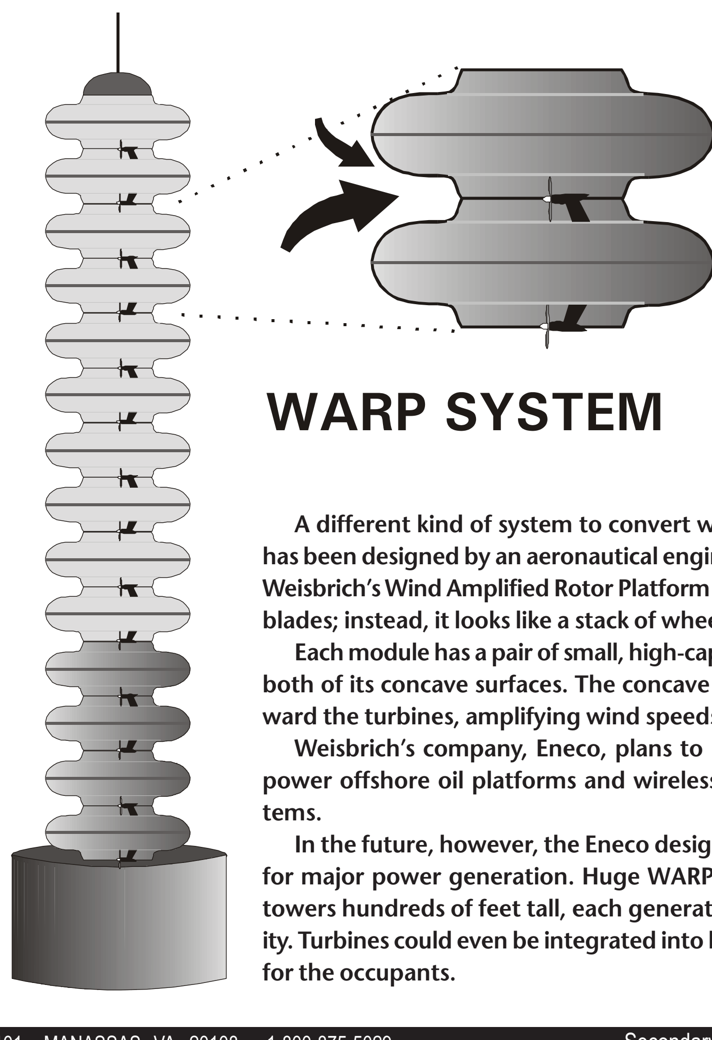
Wind Churner

With a blade that's 144 feet in diameter, the Vestas V44-600 is the largest wind turbine in operation. Perched atop a 160-foot tower west of Traverse City, Michigan, the turbine provides slightly less than one percent of the Traverse City Light and Power Company's total output.

But, that's enough for about 200 residential customers. These patrons, who get all their electricity from wind power, agreed to pay about 20 percent more than other utility customers to support the project.

The turbine was built in Denmark. The blade tips pitch to capture the most energy from the winds and the rotor and generator speed can vary slightly to smooth out power fluctuations.

In average winds of 14 to 15 mph, the annual production from the wind turbine is estimated at between 1.1 and 1.2 million kWh.



WARP SYSTEM

A different kind of system to convert wind energy into electricity has been designed by an aeronautical engineer in Connecticut. Alfred Weisbrich's Wind Amplified Rotor Platform (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 surfaces. The concave surfaces channel wind toward the turbines, amplifying wind speeds by 50 percent or more.

Weisbrich's company, Eneco, plans to market the technology to power offshore oil platforms and wireless telecommunications systems.

In the future, however, the Eneco design could be used by utilities for major power generation. Huge WARP fields could be built with towers hundreds of feet tall, each generating megawatts of electricity. Turbines could even be integrated into buildings to provide power for the occupants.