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## Wind Energy--How Does It Work?

Wind energy is a form of solar energy, created by circulation patterns in the Earth's atmosphere that are driven by heat from the sun.

People have made use of wind energy for thousands of years, fashioning sails and attaching them to boats for transportation or to wind mills to grind grain. The energy that the wind contains can either be **used directly**, as in these examples, or it can be **converted** into that high-value, highly flexible and useful form of energy we call **electricity**.

Perhaps the simplest way to describe a wind-electric turbine generator (or "wind turbine," as it is usually called) is to say that it works just like a hydroelectric generator. At hydropower stations throughout the U.S. and the world, the energy that is contained in falling or flowing water is used to spin the rotor of a turbine (a rotor that looks quite a bit like an everyday electric fan), and the turbine rotor drives the shaft of a generator to produce electricity.

Wind energy actually works in very similar fashion, especially similar to "run-of-the-river" hydro stations that make use of the flowing water in a river or stream. In the case of wind, of course, the "river" is an invisible one made of air, but the principle is the same. As the air flows past the rotor of a wind turbine (a rotor that looks a lot like an airplane propeller), the rotor spins and drives the shaft of an electric generator.

### What's different about wind?

First and most importantly, the fluid (air) that drives the rotor is much less dense than water, and so the diameter of the rotor must be much larger than the rotor of a hydro turbine. A hydro turbine capable of generating one megawatt (MW) of power would be several feet in diameter--a 1-MW wind turbine's rotor would be roughly 175 feet across.

Second, wind energy is available over a much larger geographical range than hydropower--about one-third of the U.S. (an area stretching from Minnesota to Texas to Wyoming) has enough wind almost everywhere to generate electricity economically, and there are many hills and passes in other states that are windy enough as well. Altogether, 46 of the 50 states have some wind resources that could be developed.

Wind turbines come in all sizes, from those with rotors measuring a few feet across (often used for battery charging on sailboats or vacation homes) to those with rotors hundreds of feet in diameter (used to generate "bulk" electricity that is fed into the utility transmission and distribution system). Turbine subsystems include:

- ❑ a rotor, or blades, which convert the wind's energy into rotational shaft energy;
- ❑ a nacelle containing a drive train, usually including a gearbox\* and a generator;
- ❑ a tower, to support the rotor and drive train; and
- ❑ electronic equipment such as controls, electrical cables, ground support equipment, and interconnection equipment.

\*Some turbines operate without a gearbox.

Household wind systems have rotors up to perhaps 25 feet in diameter, and can be an attractive choice if you live in a windy area or have high electricity prices (one often-quoted rule of thumb is that it is worth looking into a household system if you have average winds of 10 miles per hour and are paying 10 cents or more per kilowatt-hour for electricity). The economics of a home system can be substantially improved if:

(1) your state has a "net metering" law that requires your utility to credit any excess electricity you generate and feed to the utility system against any electricity you use during times when winds are low; or

(2) you have a farm, an all-electric home, or some other situation that makes your electricity consumption higher than normal, so that most or all of the wind turbine's output can be used on site.

Good wind speeds are important! The energy that the wind contains is a function of the **cube** of its speed. This means that a site with 12-mph average winds has more than 70% more energy than a site with 10-mph average winds.

Utility-scale wind systems typically generate electricity at lower cost--as low as 3-6 cents per kilowatt-hour. Most regions of the U.S. are served by "power pools" of utilities that join together to generate electricity and transmit it to where it is needed. The name "power pool" is an apt one--electricity coming from many different sources (a coal-fired power plant, a hydro plant, and others) flows into a "pool" from which it is distributed to thousands of end users. A power pool can easily absorb the electricity from a wind plant and add it to all the rest. Wind plants could be installed in many parts of our country, providing income, jobs, and electricity for homes and businesses.

Experience also shows that wind power can provide at least up to a fifth of a system's electricity, and the figure could probably be higher. Wind power currently provides more than 20% of the electricity distributed by Energia Hidroelectrica de Navarra, the regional electric utility of the industrial state of Navarra in northern Spain. In Denmark, wind supplies 20% of the nation's electricity. If wind energy in the U.S. were combined with serious efforts to increase energy efficiency, we could substantially reduce our national use of fossil fuels to generate electricity.

Today, utility-scale wind turbines worldwide total over 30,000 megawatts of generating capacity. Yet this is but a tiny fraction of wind's potential. A recent study performed by Denmark's BTM Consult for the European Wind Energy Association and Greenpeace found that by the year 2017, wind could provide 10% of world electricity supplies, meeting the needs of 500 million average European households.

One key issue for utility-scale wind plants that must be resolved in the coming years is **transmission line capacity**. Utility transmission lines are like a "pipeline" that is needed to carry wind-generated electricity from the vast and sparsely populated areas of the Great Plains, where the wind is most abundant, to large cities like Minneapolis, Milwaukee, Chicago, and Dallas where demand for electricity is high. At the moment, there are not many transmission lines that connect cities with the windiest parts of the plains.

Wind energy is a particularly appealing way to generate electricity because it is essentially pollution-free. More than half of all the electricity that is used in the U.S. is generated from burning coal, and in the process, large amounts of toxic metals, air pollutants, and greenhouse gases are emitted into the atmosphere.

Development of 10% of the wind potential in the 10 windiest U.S. states would provide more than enough energy to displace emissions from the nation's coal-fired power plants and eliminate the nation's major source of acid rain; reduce total U.S. emissions of carbon dioxide (the most important greenhouse gas) by almost a third and world emissions of CO<sub>2</sub> by 4%; and help contain the spread of asthma and other respiratory diseases aggravated or caused by air pollution in this country. If wind energy were to provide 20% of the nation's electricity--a very realistic and achievable goal with the current technology--it could displace more than a third of the emissions from coal-fired power plants, or all of the radioactive waste and water pollution from nuclear power plants.

Also, wind farms can revitalize the economy of rural communities, providing steady income through lease or royalty payments to farmers and other landowners. Although leasing arrangements can vary widely, a reasonable estimate for income to a landowner from a single utility-scale turbine is about \$2,000 a year or more, depending on the wind resource, the size of the turbine, and other factors. For a 250-acre farm, with income from wind at about \$55 an acre, the annual income from a wind lease would be \$14,000, with no more than 2-3 acres removed from production. Farmers can grow crops or raise cattle next to the towers. Wind farms may extend over a large geographical area, but their actual "footprint" covers only a very small portion of the land, making wind development an ideal way for farmers to earn additional income. In west Texas, for example, farmers are welcoming wind, as lease payments from this new clean energy source replace declining payments from oil wells that have been depleted.

Farmers are not the only ones in rural communities to find that wind power can bring in income. In Spirit Lake, Iowa, the local school is earning savings and income from the electricity generated by a turbine. In the district of Forest City, Iowa, a turbine recently erected as a school project is expected to save \$1.6 million in electricity costs over its lifetime.

Greater use of wind energy means a cleaner environment with healthier air, and more income to landowners and economically depressed counties and communities in the Great Plains. It means relying more on an energy source whose "fuel" is free and will never be exhausted or embargoed.