

## WIND POWER

Wind power is the conversion of wind energy into a useful form, such as electricity, using wind turbines. In 2007, worldwide wind-power capacity was 94.1 gigawatts. Wind produces about 1% of worldwide electricity use. Globally, wind power generation grew more than fivefold between 2000 and 2007.

What causes wind? The Earth is unevenly heated by the sun. The poles get less energy from the sun than the equator does, and land heats up and cools down more quickly than the seas do. The uneven heating drives a global atmospheric convection system reaching from Earth's surface to the stratosphere. Most energy stored in wind is at high altitudes where there are constant winds of over 100 mph, but enough is available near Earth's surface for wind turbines to generate a large amount of electricity.

Historically, wind energy has been used to propel sailing ships, to pump water, and to grind grain. The first windmills were built in Afghanistan in the 7th century. Horizontal-axle windmills were used extensively in Europe to grind flour beginning in the 1180s, and many Dutch windmills still exist. The multi-bladed wind turbine atop a lattice tower was once common in the rural United States, where it was used to pump water.

The modern wind turbine was developed beginning in the 1980s. Improved designs are being developed. The main use of wind power today is electrical generation. Large scale wind farms are usually connected to the electric power grid, while smaller turbines often provide electricity to isolated locations. However, utility companies increasingly buy back surplus electricity produced by small domestic turbines.

Wind energy as a power source is favored by many environmentalists as an alternative to fossil fuels. It is plentiful, renewable, widely distributed, clean, and produces lower greenhouse gas emissions, although the construction of wind farms is not universally welcomed due to their visual impact and other effects on the environment.

Because winds are *intermittent* (not constant or predictable), wind energy can vary greatly seasonally, daily, and even hourly. Because electrical generation and consumption must be in balance for a stable power supply, wind's intermittency can make it hard to use large amounts of wind power in a power system. For example, Denmark's wind power network was without power for 54 days during 2002. Experts say that periods of low wind can be dealt with by restarting existing power stations that have been held in readiness. The cost of keeping a power station idle is low, since the main cost of running a power station is the fuel. Other solutions include mixing wind power with other sources (solar, fossil fuels, hydroelectric, etc.), storing excess wind power for later use by charging batteries or using systems like pumped-storage hydroelectricity, and by establishing excess power generation capacities.

Wind energy "penetration" is the fraction of energy produced by wind compared with that from other sources. Studies show that 20% of the total electrical energy supply could come from wind with minimal difficulty. At present, few grid systems have penetration of wind energy above 5%: Denmark (about 19%), Spain and Portugal (over 9%), Germany and the Republic of Ireland (over 6%). Denmark has solved grid management problems by exporting almost half of its wind power to Norway. Denmark plans to increase the percentage of power generated by wind to over 50%.

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As of 2008, Europe leads the world in offshore wind power, due to strong wind resources and shallow water in the North Sea and the Baltic Sea, and limitations on suitable locations on land due to dense populations and existing developments. Other large wind power markets, including the U.S. and China, focus on land wind resources where construction costs are lower, but coastal population centers in many parts of the world are close to offshore wind resources, which would reduce transmission costs.

Wind power is the fastest growing energy source. In 2007, the countries with the highest total installed capacity were Germany, the United States, Spain, India, and China. In 2010, experts expect 160GW of capacity to be installed worldwide, an anticipated net growth rate of over 21% per year.

Wind turbines have been used for household electricity generation together with battery storage over many decades in remote areas. Isolated communities that otherwise rely on diesel generators may use wind turbines to reduce diesel fuel consumption. Individuals buy these systems to reduce their electricity bills, or simply to generate their own clean power. Increasingly, U.S. consumers are buying grid-connected turbines in the 1 to 10 kilowatt range to power their homes. Household generator units of more than 1 kW are now used in several countries, and in every state in the U.S.

Grid-connected wind turbines can use grid energy storage. This means purchasing energy from the grid, and selling energy to the grid when available (when the wind is blowing). Off-grid system users either adapt to intermittent power or use batteries, photovoltaic or diesel systems to supplement the wind turbine.

Wind power available in the atmosphere is much greater than current world energy use. The most comprehensive study to date found that wind power on land and near-shore had the potential to supply over five times the world's current total energy use.

In the United States, wind power receives a tax credit for each kilowatt-hour produced, and other tax benefits. Some countries also provide incentives for wind turbine construction, such as tax credits or minimum purchase prices for wind generation, with assured grid access. These prices are typically set above average electricity prices.

Wind power consumes no fuel for operation, and operation produces no air pollution, unlike fossil fuel power sources. Wind power plants consume resources in manufacturing and construction. During manufacture, steel, concrete, aluminum and other materials have to be made and transported using energy-intensive processes, generally using fossil energy sources. The initial carbon dioxide emissions "pay back" is thought to be between 3 and 13 months, according to a variety of sources.

Danger to birds is often the main complaint against wind turbines, but studies show that the number of birds killed by wind turbines is negligible compared to the number that die due to other human activities, especially the environmental impacts of using non-clean power sources. The Audubon Society supports wind energy, saying birds are over 10,000 times more likely to be killed by other human-related causes than by a wind turbine.