Small Wind Electric Systems

Design :

Smaller scale turbines for residential scale use are available. Their blades are usually 1.5 to 3.5 metres (4 ft 11 in–11 ft 6 in) in diameter and produce 1-10 kW of electricity at their optimal wind speed.[1] Some units have been designed to be very lightweight in their construction, e.g. 16 kilograms (35 lb), allowing sensitivity to minor wind movements and a rapid response to wind gusts typically found in urban settings and easy mounting much like a television antenna. It is claimed, and a few are certified, as being inaudible even a few feet (about a metre) under the turbine.

The majority of small wind turbines are traditional horizontal axis wind turbines,[2] but vertical axis wind turbines are a growing type of wind turbine in the small-wind market. Makers of vertical axis wind turbines such as WePower, Urban Green Energy, Helix Wind, and Windspire Energy, have reported increasing sales over the previous years.

The generators for small wind turbines usually are three-phase alternating current generators and the trend is to use the induction type. They are options for direct current output for battery charging and power inverters to convert the power back to AC but at constant frequency for grid connectivity. Some models utilize single-phase generators.[3][4]

Some small wind turbines can be designed to work at low wind speeds,[5] but in general small wind turbines require a minimum wind speed of 4 metres per second (13 ft/s).[6]

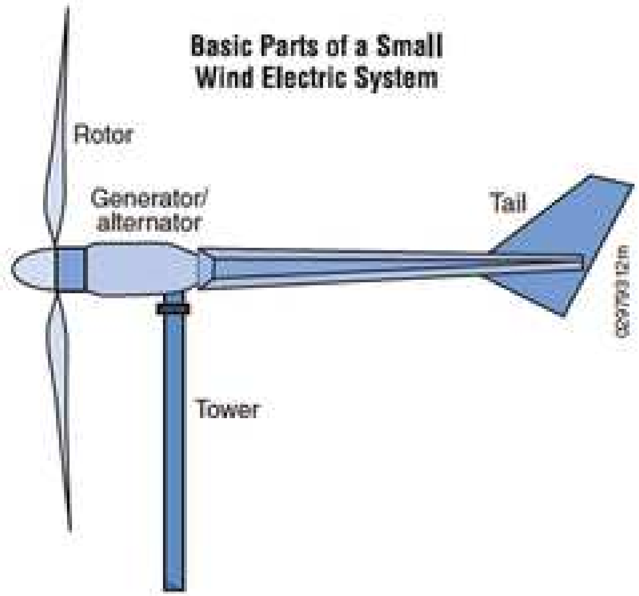
Dynamic braking regulates the speed by dumping excess energy, so that the turbine continues to produce electricity even in high winds. The dynamic braking resistor may be installed inside the building to provide heat (during high winds when more heat is lost by the building, while more heat is also produced by the braking resistor). The location makes low voltage (around 12 volt) distribution practical.

Small units often have direct drive generators, direct current output, lifetime bearings and use a vane to point into the wind. Larger, more costly turbines generally have geared power trains, alternating current output and are actively pointed into the wind. Direct drive generators are also used on some large wind turbines.

Introduction

Can I use wind energy to power my home? This question is being asked across the country as more people look for affordable and reliable sourc-es of electricity. Small wind electric systems can make a significant contribution to our nation's energy needs. Although wind turbines large enough to provide a significant portion of the electricity needed by the average U.S. home gen-erally require one acre of property or more, approximately 21 million U.S. homes are built on one-acre and larger sites, and 24% of the U.S. population lives in rural areas. A small wind electric system will work for you if: • There is enough wind where you live • Tall towers are allowed in your neighborhood or rural area • You have enough space • You can determine how much electricity you need or want to produce • It works for you economically. The purpose of this guide is to pro-vide you with the basic information about small wind electric systems to help you decide if wind energy will work for you.

In Clover Valley, Minnesota, this 3-kW Whisper H175 turbine on a 50-foot tower is connected to the utility grid to offset the farm's utility-supplied electricity



What are the Basic Parts of a Small Wind Electric System?

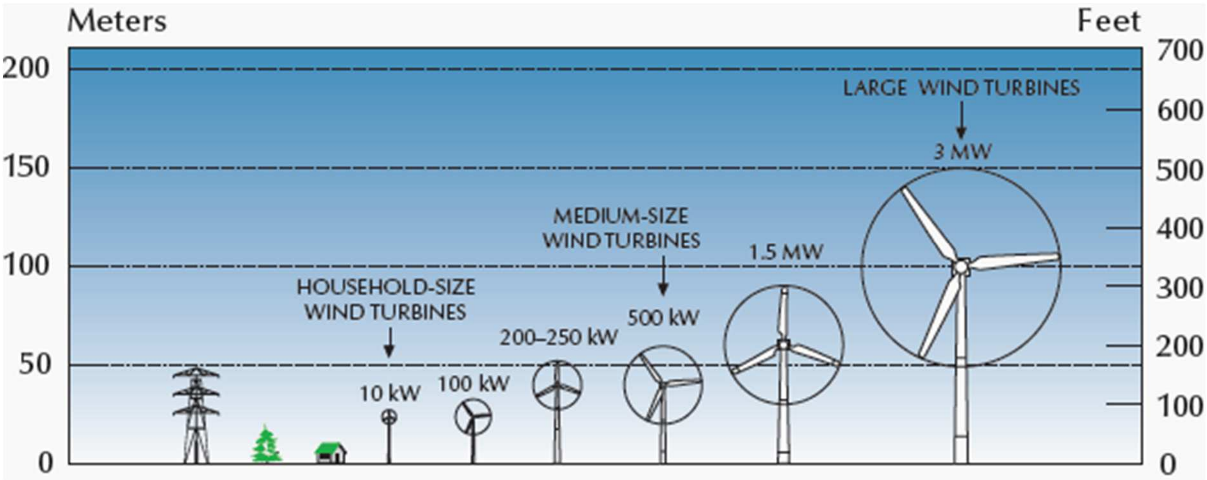
Home wind energy systems gener-ally comprise a rotor, a generator or alternator mounted on a frame, a tail (usually), a tower, wiring, and the “balance of system” components: controllers, inverters, and/or batter-ies. Through the spinning blades, the rotor captures the kinetic energy of the wind and converts it into rotary motion to drive the generator.

Wind Turbine

Most turbines manufactured today are horizontal axis upwind machines with two or three blades, which are usually made of a composite material such as fiberglass. The amount of power a turbine will produce is determined primarily by the diameter of its rotor. The diameter of the rotor defines its “swept area,” or the quantity of wind intercepted by the turbine. The turbine’s frame is the structure onto which the rotor, genera tor, and tail are attached. The tail keeps the turbine facing into the wind.

Tower

Because wind speeds increase with height, the turbine is mounted on a tower. In general, the higher the tower, the more power the wind system can produce. The tower also raises the turbine above the air turbulence that can exist close to the ground because of obstructions such as hills, buildings, and trees. A general rule of thumb is to install a wind turbine on a tower with the bot-tom of the rotor blades at least 30 feet (9 meters) above any obstacle that is within 300 feet (90 meters) of the tower. Relatively small investments in increased tower height can yield very high rates of return in power produc-tion. For instance, to raise a 10-kW



generator from a 60-foot tower height to a 100-foot tower involves a 10% increase in overall system cost, but it can produce 29% more power. There are two basic types of tow-ers: self-supporting (free standing) and guyed. Most home wind power systems use a guyed tower. Guyed towers, which are the least expensive, can consist of lattice sections, pipe, or tubing (depending on the design), and supporting guy wires. They are easier to install than self-supporting tow-ers. However, because the guy radius must be one-half to three-quarters of the tower height, guyed towers require enough space to accommodate them. Although tilt-down towers are more expensive, they offer the con-sumer an easy way to perform maintenance on smaller light-weight turbines, usually 5 kW or less.

Tilt-down towers can also be low-ered to the ground during hazard-ous weather such as hurricanes. Aluminum towers are prone to cracking and should be avoided. Most turbine manufacturers provide wind energy system packages that include towers. Mounting turbines on rooftops is not recommended. All wind turbines vibrate and transmit the vibration to the structure on which they are mounted. This can lead to noise and structural problems with the building, and the rooftop can cause excessive turbulence that can shorten the life of the turbine.

Balance of System

The parts that you need in addition to the turbine and the tower, or the balance of system parts, will depend on your application. Most manufac-turers can provide you with a system package that includes all the parts you need for your application. For exam-ple, the parts required for a water pumping system will be much differ-ent than what you need for a residen-tial application. The balance of system required will also depend on whether the system is grid-connected, stand-alone, or part of a hybrid system. For a residential grid-connected application, the balance of system parts may include a controller, storage batteries, a power conditioning unit (inverter), and wiring. Some wind turbine controllers, inverters, or other electrical devices may be stamped by a recognized testing agency, like Underwriters Laboratories.

Stand-Alone Systems

Stand-alone systems (systems not connected to the utility grid) require batteries to store excess power gener-ated for use when the wind is calm. They also need a charge controller to keep the batteries from overcharging. Deep-cycle batteries, such as those used for golf carts, can discharge and recharge 80% of their capacity hundreds of times, which makes them a good option for remote renewable energy systems. Automotive batteries are shallow-cycle batteries and should not be used in renewable energy systems because of their short life in deep-cycling operations.

- Small wind turbines generate direct current (DC) electricity. In very small systems, DC appliances operate directly off the batteries. If you want to use standard appliances that use con-ventional household alternating cur-rent (AC), you must install an inverter to convert DC electricity from the batteries to AC. Although the inverter slightly lowers the overall efficiency of the system, it allows the home to be wired for AC, a definite plus with lenders, electrical code officials, and future homebuyers. For safety, batteries should be iso-lated from living areas and electron-ics because they contain corrosive and explosive substances. Lead-acid batteries also require protection from temperature extremes.

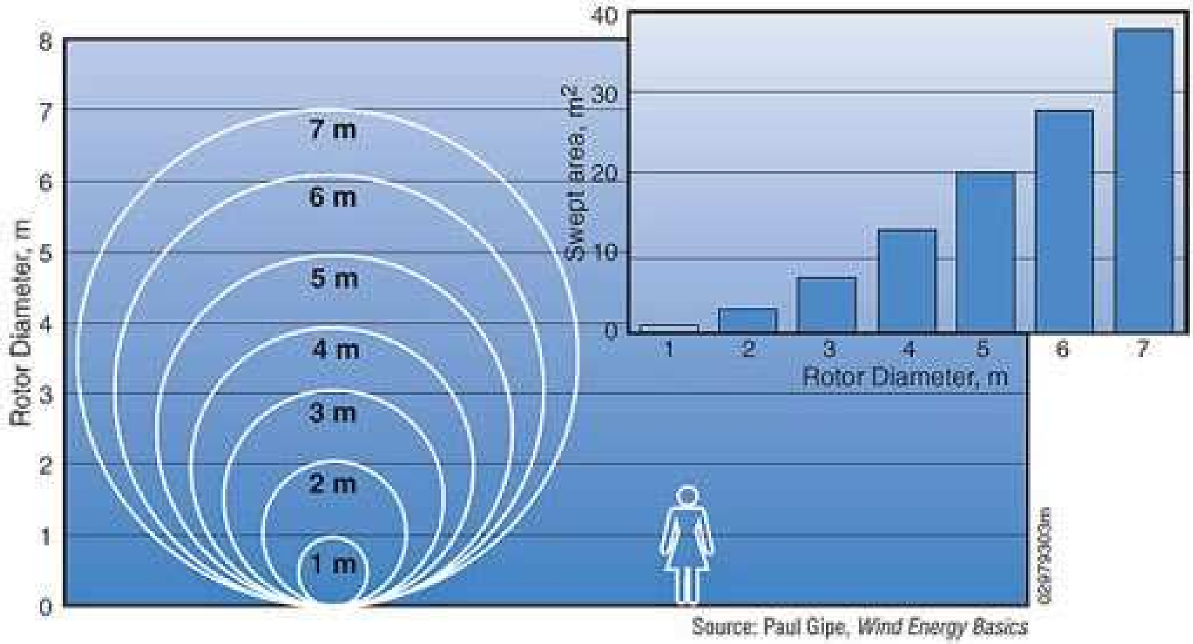
Grid-Connected Systems

In grid-connected systems, the only additional equipment required is a power conditioning unit (inverter) that makes the turbine output electrically compatible with the utility grid. Usually, batteries are not needed.

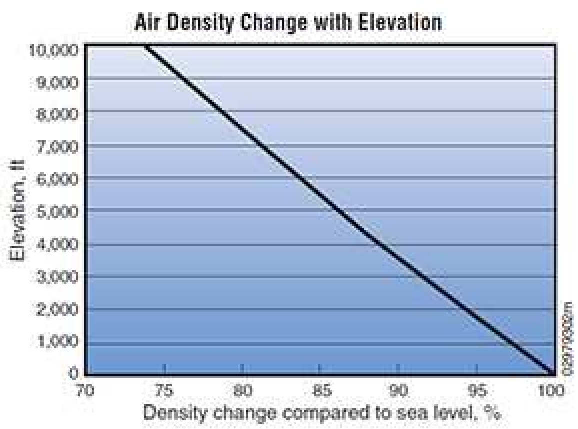
Although wind energy systems involve a significant initial invest-ment, they can be competitive with conventional energy sources when you account for a lifetime of reduced or avoided utility costs. The length of the payback period—the time before the savings resulting from your system equal the cost of the system itself—depends on the system you choose, the wind resource on your site, electricity costs in your area, and how you use your wind system. For example, if you live in California and have received the 50% buydown of your small wind system, have net metering, and an average annual wind speed of 15 miles per hour (mph) (6.7 meters per second [m/ s]), your simple payback would be approximately 6 years.

How Much Energy Will My System Generate?

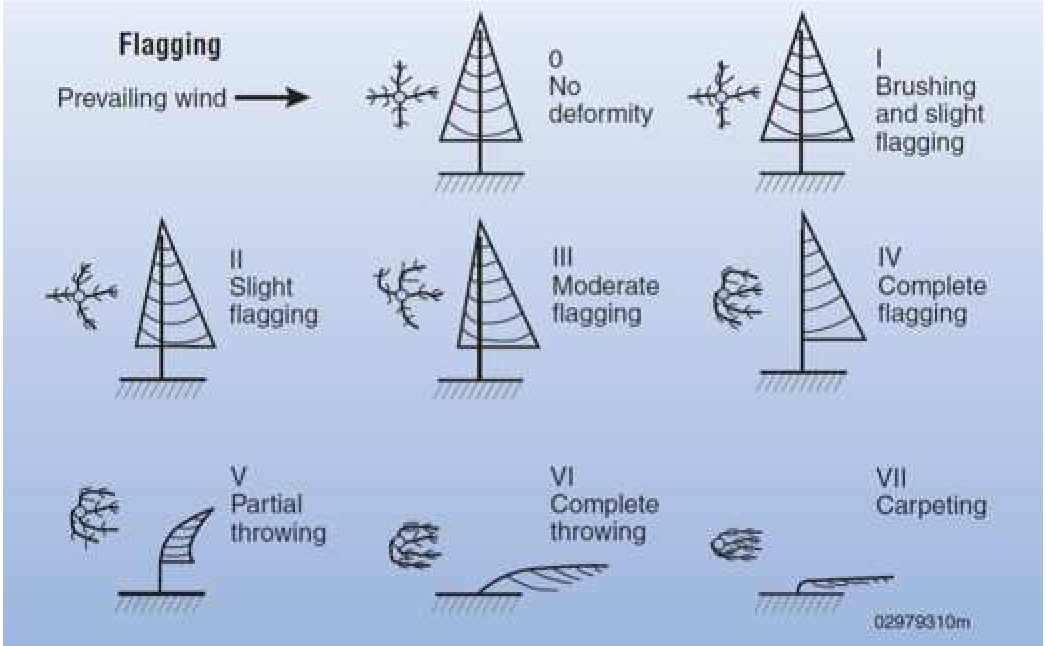
Most U.S. manufacturers rate their turbines by the amount of power they can safely produce at a particular wind speed, usually chosen between 24 mph (10.5 m/s) and 36 mph (16 m/ s). The following formula illustrates factors that are important to the performance of a wind turbine. Notice that the wind speed, V, has an exponent of 3 applied to it. This means that even a small increase in wind speed results in a large increase in power. That is why a taller tower will increase the productivity of any wind turbine by giving it access to higher wind speeds as shown in the Wind Speeds Increase with Height graph. The formula for calculating the power from a wind turbine is: Power = k Cp 1/2 ρ A V3 Where: P = Power output, kilowatts Cp = Maximum power coefficient, ranging from 0.25 to 0.45, dimension less (theoretical maximum = 0.59) ρ = Air density, lb/ft3 A = Rotor swept area, ft2 or π D2/4 (D is the rotor diameter in ft, π = 3.1416) V = Wind speed, mph k = 0.000133 A constant to yield power in kilowatts. (Multiplying the above kilowatt answer by 1.340 converts it to horse-power [i.e., 1 kW = 1.340 horsepower]). The rotor swept area, A, is important because the rotor is the part of the turbine that captures the wind energy.



So, the larger the rotor, the more energy it can capture. The air density, ρ, changes slightly with air tempera-ture and with elevation. The ratings for wind turbines are based on standard conditions of 59° F (15° C) at sea level. A density correction should be made for higher elevations as shown in the Air Density Change with Elevation graph. A correction for temperature is typically not needed for predicting the long-term perfor-mance of a wind turbine. Although the calculation of wind power illustrates important features about wind turbines, the best mea-sure of wind turbine performance is annual energy output. The difference between power and energy is that power (kilowatts [kW]) is the rate at which electricity is consumed, while energy (kilowatt-hours [kWh]) is the quantity consumed. An estimate of the annual energy output from your wind turbine, kWh/year, is the best way to determine whether a particular wind turbine and tower will produce enough electricity to meet your needs. A wind turbine manufacturer can help you estimate the energy production you can expect. They will use a cal-culation based on the particular wind turbine power curve, the average annual wind speed at your site, the height of the tower that you plan to use, and the frequency distribution of the wind–an estimate of the number of hours that the wind will blow at each speed during an average year. They should also adjust this calcula-tion for the elevation of your site. Contact a wind turbine manufacturer or dealer for assistance with this calculation. To get a preliminary estimate of the performance of a particular wind tur-bine, use the formula below. AEO = 0.01328 D2 V3 Where: AEO = Annual energy output, kWh/year D = Rotor diameter, feet V = Annual average wind speed, mph The Wind Energy Payback Period Workbook found at www.nrel.gov/ wind/docs/spread_sheet_Final.xls is a spreadsheet tool that can help you analyze the economics of a small wind electric system and decide whether wind energy will work for you. The spreadsheet can be opened using Microsoft Excel 95 software. It asks you to provide information about how you're going to finance the system, the characteristics of your site, and the properties of the system you're considering. It then provides you with a simple payback estimation in years. If it takes too long to regain your capi-tal investment—the number of years comes too close or is greater than the life of the system—wind energy will not be practical for you.



Flagging, the effect of strong winds on area vegetation can help determine are wind speeds :



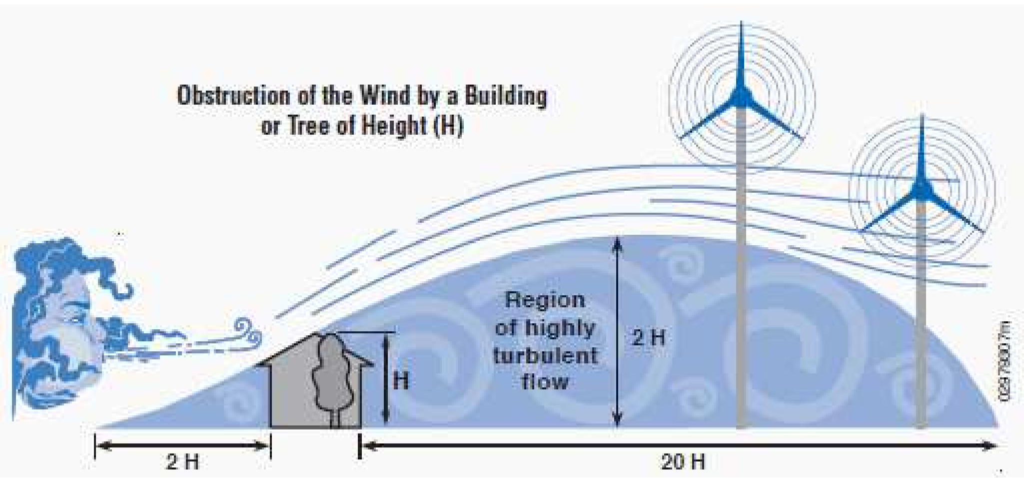
Griggs-Putnam Index of Deformity

Index	I	II	III	IV	V	VI	VII
Wind mph	7-9	9-11	11-13	13-16	15-18	16-21	22+
Speed m/s	3-4	4-5	5-6	6-7	7-8	8-9	10

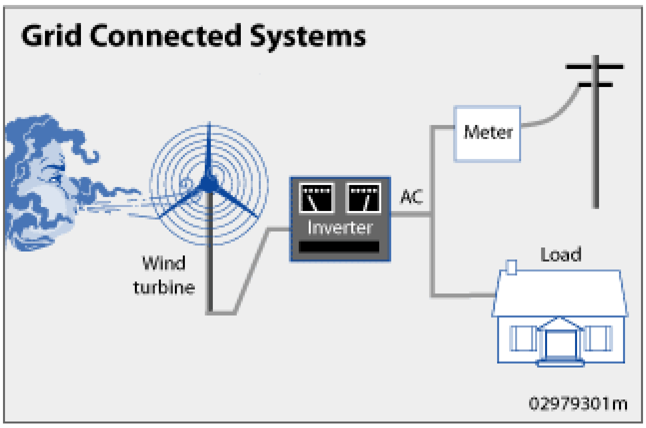
Whether the system is stand-alone or grid-connected, you will also need to take the length of the wire run between the turbine and the load (house, batteries, water pumps, etc.) into consideration. A substantial amount of electricity can be lost as a result of the wire resistance—the lon-ger the wire run, the more electric-ity is lost. Using more or larger wire will also increase your installation cost. Your wire run losses are greater when you have direct current (DC) instead of alternating current (AC). So, if you have a long wire run, it is advisable to invert DC to AC.

Can I Connect My System to the Utility Grid?

Small wind energy systems can be connected to the electricity distribu-tion system and are called grid-connected systems. A grid-connected wind turbine can reduce your con-sumption of utility-supplied electric-ity for lighting, appliances, and electric heat. If the turbine cannot deliver the amount of energy you need, the utility makes up the differ-ence. When the wind system produces more electricity than the household requires, the excess is sent or sold to the utility. Grid-connected systems can be practi-cal if the following conditions exist: • You live in an area with average annual wind speed of at least 10 mph (4.5 m/s) • Utility-supplied electricity is expensive in your area (about 10 to 15 cents per kilowatt-hour) • The utility's requirements for connecting your system to its grid are not prohibitively expensive • There are good incentives for the sale of excess electricity or for the purchase of wind turbines.



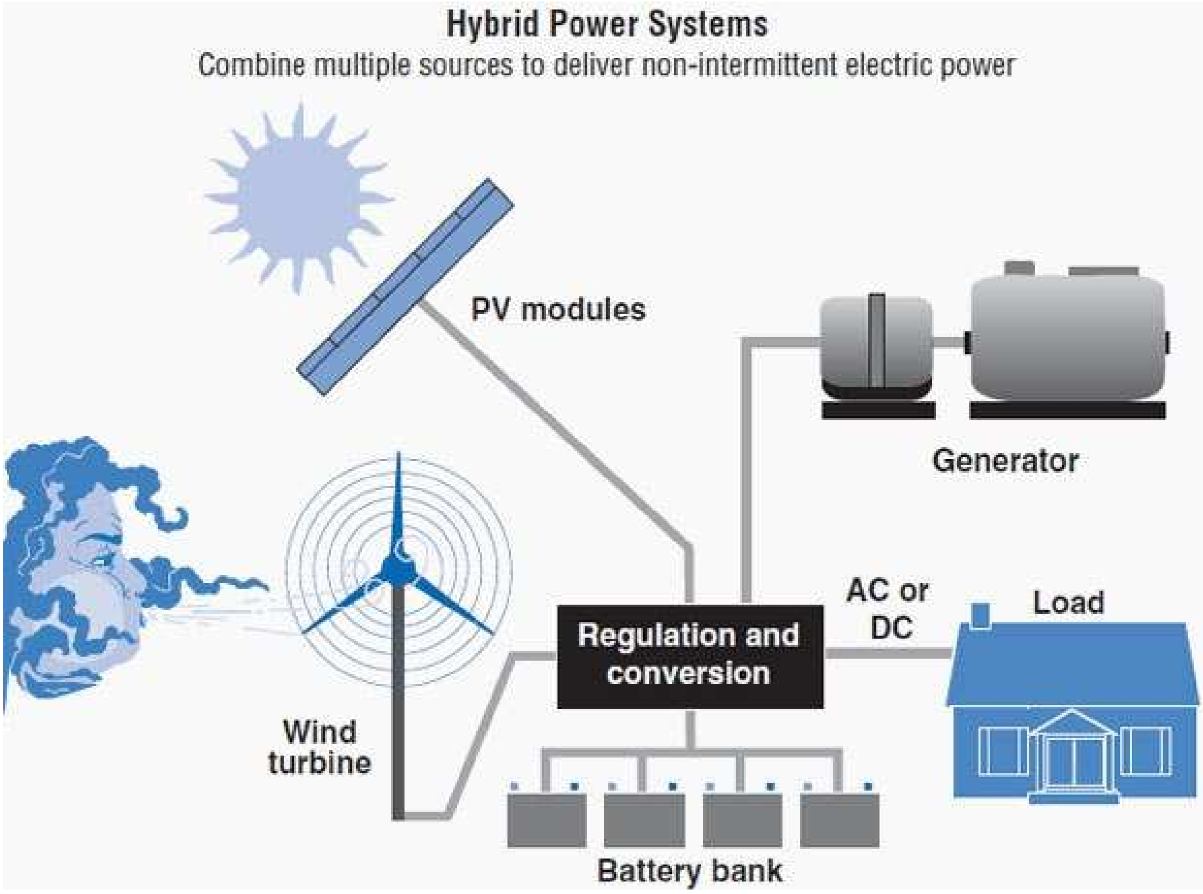
A grid-connected wind turbine can reduce your consumption of utility-supplied electricity :



Connecting to the Utility Grid: A Success Story

This 10-kW Bergey wind turbine, installed on a farm in Southwestern Kansas in 1983, pro-duces an average 1700–1800 kilowatt-hours per month, reducing the user's monthly utility bills by approximately 50%. The turbine cost about $20,000 when it was installed. Since then, the cost for operation and maintenance has been about $50 per year. The only unscheduled main-tenance activity over the years was repair to the turbine required as a result of a lightning strike. Insurance covered all but $500 of the $9000 cost of damages. The basic system parts include: Bergey XL.10 wind turbine 100-foot free-standing lattice tower Inverter

A hybrid system that combines a wind system with a solar and/or diesel generator can provide reliable off-grid power around the clock :



Hybrid Systems

Hybrid wind energy systems can provide reliable off-grid power for homes, farms, or even entire com-munities (a co-housing project, for example) that are far from the near-est utility lines. According to many renewable energy experts, a "hybrid" system that combines wind and photovoltaic (PV) technologies offers several advantages over either single system. In much of the United States, wind speeds are low in the summer when the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and PV occur at different times of the day and year, hybrid systems are more likely to produce power when you need it. (For more information on solar electric or PV systems, contact the Energy Efficiency and Renewable Energy Information Portal—see For More Information.) For the times when neither the wind turbine nor the PV modules are producing, most hybrid systems provide power through batteries and/or an engine-generator powered by conven-tional fuels such as diesel. If the bat-teries run low, the engine-generator can provide power and recharge the batteries. Adding an engine-generator makes the system more complex, but modern electronic controllers can operate these systems automatically. An engine-generator can also reduce the size of the other components needed for the system. Keep in mind that the storage capacity must be large enough to supply electrical needs during non-charging periods. Battery banks are typically sized to supply the electric load for one to three days.

Living Off-Grid: A Success Story

This home, built near Ward, Colorado (at an elevation of 9000 feet), has been off-grid since it was built in 1972. When the house was built, the nearest util-ity was over a mile away, and it would have cost between $60K–$70K (based on 1985 rates) to connect to the utility lines. The owners decided to install a hybrid electric system powered by wind, solar, and a generator for a cost of about $19,700. The parts of the system include: Bergey 1.5-kW wind turbine, 10-ft (3-m) diameter rotor, 70-ft. (21-m) tower Solarex PV panels, 480 watts 24 DC battery bank, 375 ampere-hours Trace sine wave inverter, 120 AC, 1 phase, 4 kW Onan propane-fueled generator, 6.5 kW rated (3 kW derated for altitude) Electric appliances in the home include television, stereo, two computers, toaster, blender, vacuum cleaner, and hair dryer. The largest electric loads are created by a well pump and washing machine. The generator runs about 20% of the time, par-ticularly when the washing machine is in use. Propane serves the other major loads in the home: range, refrigerator, hot water, and space heat. Solar collectors on the roof provide pre-heating for the hot water.