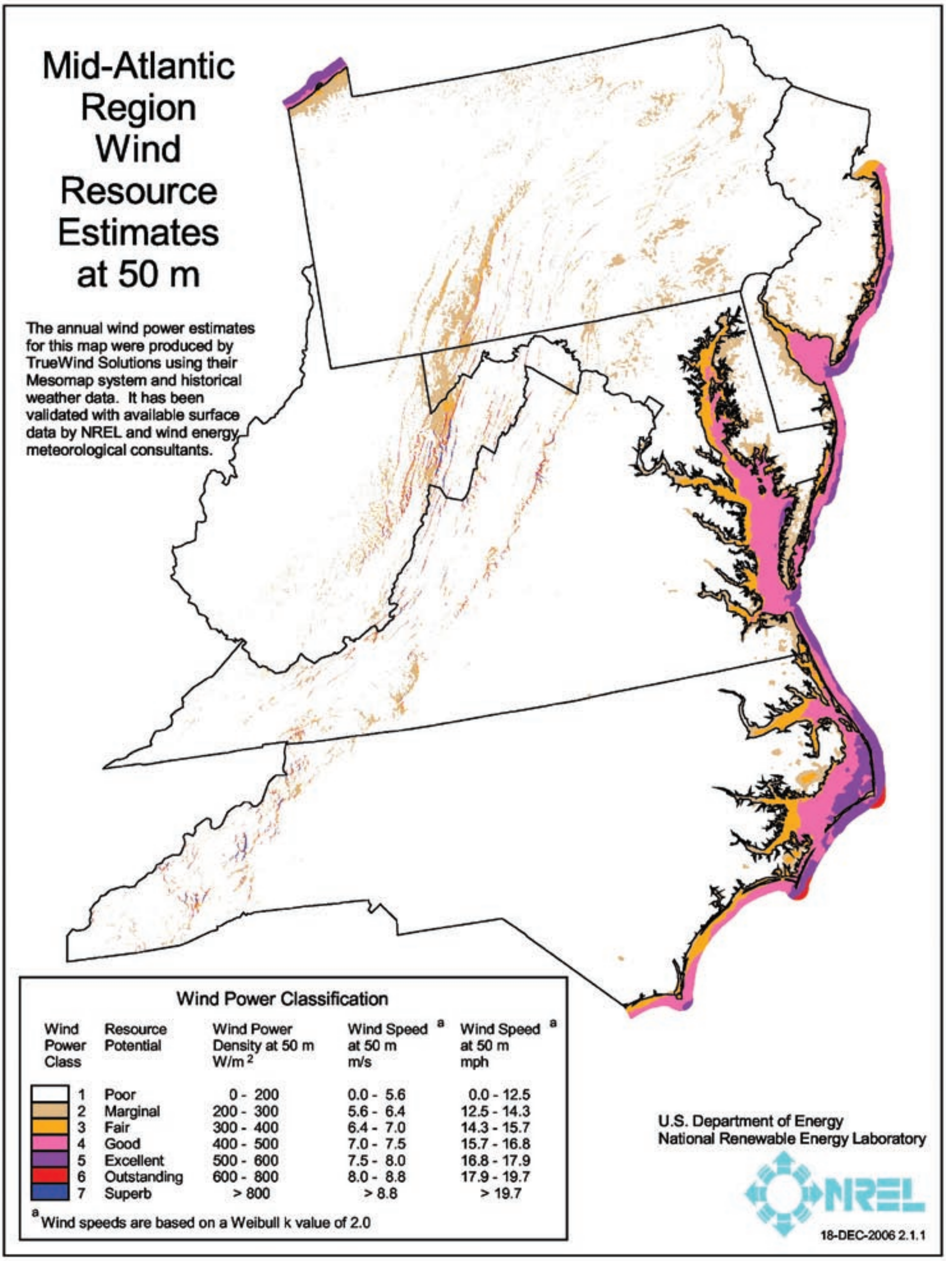
Small Wind Electric Systems

A Virginia Consumer's Guide

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable



Cover photo: A Bergey XL.1 wind turbine at James Madison University
Photo credit — Mark Lotts, JMU

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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 sources 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 generally 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 provide you with the basic information about small wind electric systems to help you decide if wind energy will work for you.

Why Should I Choose Wind?

Wind energy systems represent one of the most cost-effective, cleanest, home-based renewable energy technologies available today. A grid-connected small wind system can provide 50% to 90% of the electricity load of a residential or light commercial building. With battery

Mark Lotts, JMU

Southwest Windpower Whisper H40.

Contents

storage, a stand-alone system can power 100% of the electrical needs of a building in a remote location not served by the grid.

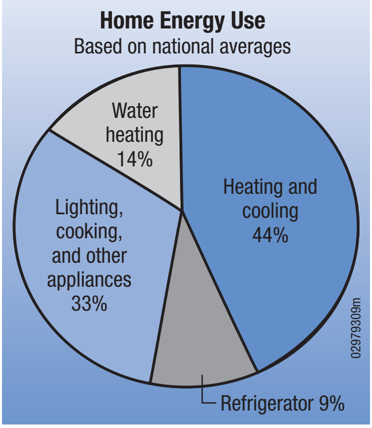
How Do Wind Turbines Work?

Wind is created by the unequal heating of the Earth's surface by the sun. Wind turbines convert the kinetic energy in wind into mechanical power that runs a generator to produce clean electricity. Today's turbines are versatile modular sources of electricity. Their blades are aerodynamically designed to capture the maximum energy from the wind. The wind turns the blades, which spin a shaft connected to a generator that makes electricity.

First, How Can I Make My Home More Energy Efficient?

Before choosing a wind system for your home, you should consider reducing your energy consumption by making your home or business more energy efficient. Reducing your energy consumption will significantly lower your utility bills and will reduce the size of the home-based renewable energy system you need. To achieve maximum energy efficiency, you should take a whole-building approach. View your home as an energy system with interrelated parts, all of which work synergistically to contribute to the efficiency of the system. From the insulation in your home's walls to the light bulbs in its fixtures, there are many ways you can make your home more efficient.

- Reduce your heating and cooling needs by up to 30% by investing just a few hundred dollars in proper insulation and weatherization products.
- Save money and increase comfort by properly maintaining and upgrading your heating, ventilation, and air-conditioning systems.



The largest portion of a utility bill for a typical house is for heating and cooling.

- Install double-paned, gas-filled windows with low-emissivity (low-e) coatings to reduce heat loss in cold climates and spectrally selective coatings to reduce heat gain in warm climates.
- Replace your lights in high-use areas with fluorescents. Replacing 25% of your lights can save about 50% of your lighting energy bill.
- When shopping for appliances, look for the Energy Star® label. Energy Star® appliances have been identified by the U.S. Environmental Protection Agency and U.S. Department of Energy as being the most energy-efficient products in their classes.
- For more information on how to make your home energy efficient, see Energy Savers in the For More Information section.

Is Wind Energy Practical for Me?

A small wind energy system can provide you with a practical and economical source of electricity if:

- your property has a good wind resource
- your home or business is located on at least one acre of land in a rural area
- your local zoning codes or covenants allow wind turbines
- your average electricity bills are $150 per month or more
- your property is in a remote location without easy access to utility lines
- you are comfortable with long-term investments.

Zoning and Building Code Issues

Before you invest in a wind energy system, you should research potential obstacles, including relevant local laws. Particular attention should be focused on the local zoning laws and building codes.

As of fall 2004, most zoning ordinances in Virginia contained height limits of 35 feet and were silent about the siting requirements for small wind energy systems. These height limits and lack of guidance created major obstacles for local residents. However, recently several Virginia counties have adopted ordinances to clarify zoning procedures for small wind energy systems, and the Virginia Association of Zoning Officials (VAZO) is considering the adoption of a model small wind zoning ordinance for local governments. Check the Web site of the Virginia Wind Energy Collaborative (http://vwec.cisat.jmu.edu) or VAZO (http://www.vazo.org) for the status of this ordinance. With respect to building permits, most localities require that you follow the Uniform Statewide Building Code.

Most Virginia counties have Web sites that provide contact information for these offices,[1] and in some cases, the county even posts the zoning ordinance on its Web site. You also can find out about the applicable zoning laws and building codes in your county or city by calling the local planning board, county or city attorney's office, or board of supervisors.

Sometimes neighbors object to a wind turbine based on concerns about noise. These concerns can be addressed by supplying objective data. For example, the ambient noise level of most modern residential wind turbines is around 52 to 55 decibels. This means that a

[1] You can access your county Web site through the National Association of Counties Web site at www.naco.org . Click the following: (1) About Counties, (2) Find a County, (3) Select State, (4) the county name on the list of counties in that State, and (5) the county name contained on the county profile. If the county does not have a Web site, the county profile generally will contain telephone numbers for relevant county offices.

Virginia Small Wind Incentives Program

The Virginia Small Wind Incentives Program (VSWIP) was established in 2004 as a pilot project to provide landowners in the Commonwealth an opportunity to reduce the cost of a small wind system. The goal is to support a variety of diverse projects to help stimulate the market and raise awareness of the opportunities associated with small wind. During the term of the program through 2006, 12 grants were awarded (ranging from $2,500 to $10,000) to Virginia residential and commercial landowners. The longer term intention of the project is to spur confidence in wind energy among Virginians and to promote the implementation of wind energy systems, both small- and large-scale, throughout the Commonwealth. VSWIP applications were evaluated based on a landowner's known or estimated wind resource, the financial commitment of the landowner, the opportunity for the wind project to support local educational purposes, the ability of a landowner to connect to the grid, the projected visibility and accessibility of the project, and the permitting requirements corresponding to the site.

residential-size wind turbine is no noisier than your average refrigerator.

Steps toward a system

Below is a suggested list of steps to follow in pursuing the purchase and installation of a small wind electric system.

1. Assess wind resource
2. Select a turbine and vendor
3. Contact neighbors
4. Acquire permits
5. Connect to utility grid
6. Identify a maintenance plan.

What Size Wind Turbine Do I Need?

The size of the wind turbine you need depends on your application. Small turbines range in size from 20 watts to 100 kilowatts. The smaller or "micro" (20- to 500-watt) turbines are used in a variety of applications such as charging batteries for recreational vehicles and sailboats.

One- to 10-kW turbines can be used in applications such as pumping water. Wind energy has been used for centuries to pump water and grind grain. Although mechanical windmills still provide a sensible, low-cost option for pumping water in low-wind areas, farmers and ranchers are finding that wind-electric pumping is a little more versatile and they can pump twice the volume for the same initial investment. In addition, mechanical windmills must be placed directly above the well, which may not take the best advantage of available wind resources. Wind-electric pumping systems can be placed where the wind resource is the best and connected to the pump motor with an electric cable.

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James Madison University administers the Virginia State-Based Anemometer Loan Program. Measuring the wind resource onsite with an anemometer is perhaps the best way to determine which turbine is right for you.

Turbines used in residential applications can range in size from 400 watts to 100 kW (100 kW for very large loads), depending on the amount of electricity you want to generate. For residential applications, you should establish an energy budget to help define the size of turbine you will need. Because energy efficiency is usually less expensive than energy production, making your house more energy efficient first will probably be more cost effective and will reduce the size of the wind turbine you need (see How Can I Make My Home More Energy Efficient?). Wind turbine manufacturers can help you size your system based on your electricity needs and the specifics of local wind patterns.

According to the EIA, in 2002 the average annual residential energy use was 14,000 kilowatt-hours (kWh) (about 1,160 kWh per month). Depending on the average wind speed in the area, a wind turbine rated in the range of 5 to 15 kilowatts (kW) would be required to make a significant contribution to this demand. A 1.5-kW wind turbine will meet the needs of a home requiring 300 kWh per month in a location with a 14-mile-per-hour (6.26-meters-per-second) annual average wind speed. The manufacturer can provide you with the expected annual energy output of the turbine as a function of annual average wind speed. The manufacturer will also provide information on the maximum wind speed at which the turbine is designed to operate safely. Most turbines have automatic overspeed-governing systems to keep the rotor from spinning out of control in very high winds. This information, along with your local wind speed and your energy budget, will help you decide which size turbine will best meet your electricity needs.

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

Home wind energy systems generally 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 batteries. 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

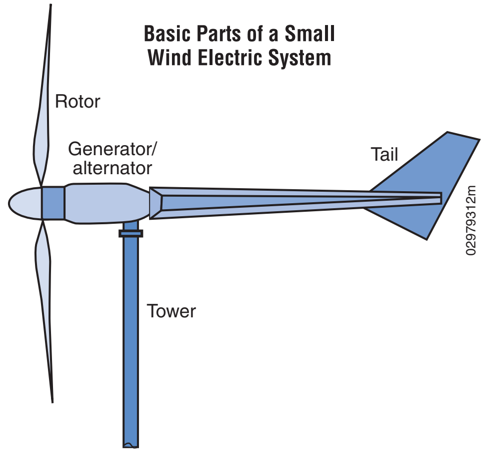
Most turbines manufactured today are horizontal axis upwind machines with two or three blades, which are usually made of a composite material such as fiberglass.

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, generator, 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 bottom 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 production. 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.

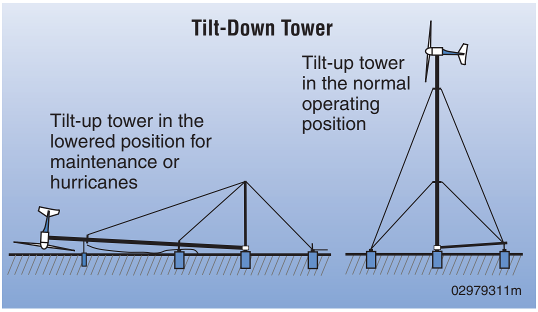
Basic Parts of a Small Wind Electric System



There are two basic types of towers: 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

Tilt-down towers provide easy maintenance for turbines.

Tilt-Down Tower



supporting guy wires. They are easier to install than self-supporting towers. 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 consumer an easy way to perform maintenance on smaller light-weight turbines, usually 5 kW or less. Tilt-down towers can also be lowered to the ground during hazardous 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 manufacturers can provide you with a system package that includes all the parts you need for your application. For example, the parts required for a water pumping system will be much different than what you need for a residential 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 generated 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

Turbine Installed at James Madison University

The turbine in the picture to the right, a Bergey XL 1 with a 1-kW rated generating capacity, has been installed at James Madison University and is mounted on top of a 24-meter (80-ft) lattice tower coupled with a 1-kilowatt photovoltaic solar array at the base of the tower. The energy is stored in batteries and used for powering instrumentation for measurement of system performance, data acquisition, and radio relay to a database for both classroom use and publication on the VWEC Web site. Energy is also used for aviation hazard and lighting of the turbine so that it is visible from the nearby Interstate-81 at night.

Mark Lotts, JMU

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 conventional household alternating current (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 isolated from living areas and electronics 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.

What Do Wind Systems Cost?

Installation costs vary greatly depending on local zoning, permitting, and utility interconnection costs. According to the American Wind Energy Association, small wind energy systems cost from $3,000 to $5,000 for every kilowatt of generating capacity. This is much cheaper than solar electric systems, but the payback period can still be lengthy.

Wind energy becomes more cost effective as the size of the turbine's rotor increases. Although small turbines cost less in initial outlay, they are proportionally more expensive. The cost of an installed residential wind energy system that comes with an 80-foot tower, batteries, and inverter, typically ranges from $15,000 to $50,000 for a 3- to 10-kW wind turbine.

How to Finance a Small Wind Turbine

A customer-friendly net metering law makes grid-tied small wind systems more cost-effective for Virginians. If you don't have the cash to pay the full cost of your small wind system, financing the system will reduce your up-front expenses and more closely match the timing of your cash outflow to the value received for the energy your system produces, although interest and other financing costs reduce a project's overall return on investment.

Most banks offer commercial loans that could be used to finance a small wind system. However, since bank employees are generally not familiar with small wind system technology and its potential cost savings, bank financing terms and interest may not make small wind systems economically feasible.

Energy Service Companies (ESCOs) can finance small wind systems by offering paid-from-savings contracts (performance or shared savings contracts) whereby the ESCOs provide the capital to purchase customers' small wind systems and recover such investments (plus profits) from their customers' monthly energy bill savings.

If you have accumulated equity in your home or small business, refinancing your home or business is another way to come up with the cash for a small wind system. If you refinance your home to purchase a home-based small wind system, the interest may be tax deductible. You may also find it more convenient to make a single, although larger, monthly payment for your refinanced home than to make two smaller payments: one for your home and one for your small wind system.

Although wind energy systems involve a significant initial investment, 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. One of the most important factors, the electricity rate, varies greatly in Virginia (from 5 cents/kWh to 15 cents/kWh). Depending on these factors, payback periods in the Commonwealth can range from 15 years to longer than a lifetime.

Things to Consider When Purchasing a Wind Turbine

Once you determine you can install a wind energy system in compliance with local land use requirements, you can begin pricing systems and components. Comparatively shop for a wind system as you would any major purchase. Obtain and review the product literature from several manufacturers. As mentioned earlier, lists of manufacturers are available from AWEA (see For More Information), but not all small turbine manufacturers are members of AWEA. Check the VWEC Web site at http://vwec.cisat.jmu.edu for wind energy system dealers in your area.

Once you have narrowed the field, research a few companies to be sure they are recognized wind energy businesses and that parts and service will be available when you need them. You may wish to contact the Better Business Bureau to check on the company's integrity and ask for references of past customers with installations similar to the one you are considering. Ask the system owners about performance, reliability, and maintenance and repair requirements, and whether the system is meeting their expectations. Also, find out how long the warranty lasts and what it includes.

Where Can I Find Installation and Maintenance Support?

The manufacturer/dealer should be able to help you install your machine. Many people elect to install the machines themselves. Before attempting to install your wind turbine, ask yourself the following questions:

- Can I pour a proper cement foundation?
- Do I have access to a lift or a way of erecting the tower safely?
- Do I know the difference between AC and DC wiring?
- Do I know enough about electricity to safely wire my turbine?
- Do I know how to safely handle and install batteries?

If you answered no to any of the above questions, you should probably choose to have your system installed by a system integrator or installer. Contact the manufacturer for help or call your state energy office and local utility for a list of local system installers. You can also check the yellow pages for wind energy system service providers. A credible installer will provide many services such as permitting. Find out if the installer is a licensed electrician. Ask for references and check them out. You may also want to check with the Better Business Bureau.

Although small wind turbines are very sturdy machines, they do require some annual maintenance. Bolts and electrical connections should be checked and tightened if necessary. The machines should be checked for corrosion and the guy wires for proper tension. In addition, you should check for and replace any worn leading edge tape on the blades, if appropriate. After 10 years, the blades or bearings may need to be replaced, but with proper installation and maintenance, the machine should last up to 20 years or longer.

If you do not have the expertise to maintain the machine, your installer may provide a service and maintenance program.

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 (see page 11). The formula for calculating the power from a wind turbine is:

$$\text{Power} = k\, C_p\, 1/2\, \rho\, A\, V^3$$

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/ft^3

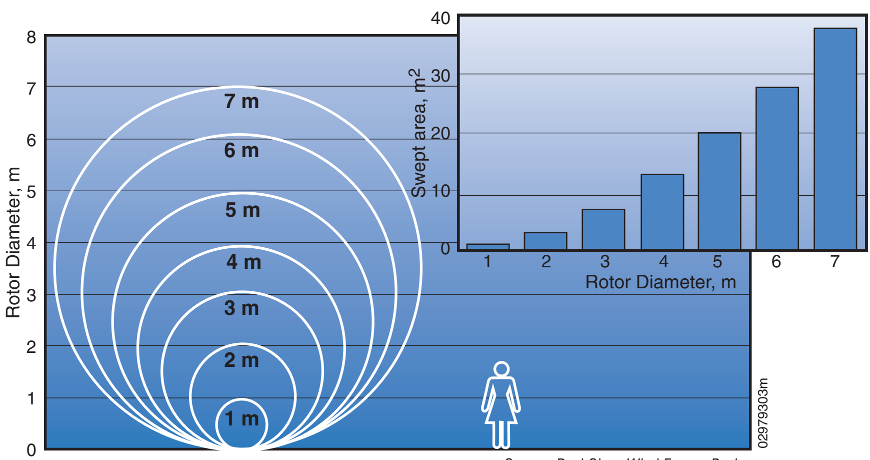
A = Rotor swept area, ft^2 or $\pi D^2/4$ (D is the rotor diameter in ft, $\pi = 3.1416$)

V = Wind speed, mph

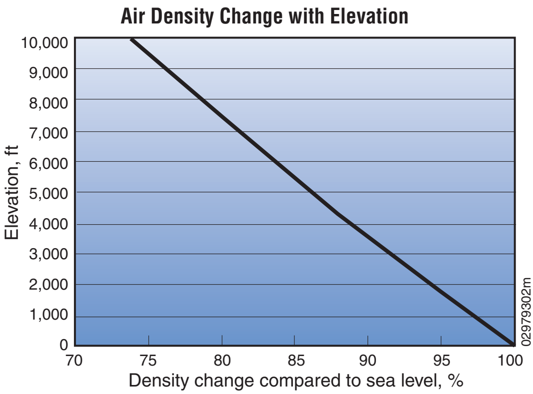
k = 0.000133 A constant to yield power in kilowatts. (Multiplying the above kilowatt answer by 1.340 converts it to horsepower. [i.e., 1 kW = 1.340 horsepower]).

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,

Relative Size of Small Wind Turbines



Source: Paul Gipe, *Wind Energy Basics*



r, changes slightly with air temperature 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 performance of a wind turbine.

While the calculation of wind power illustrates important features about wind turbines, the best measure 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 calculation 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 calculation 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 turbine, use the formula below.

$$AEO = 0.01328\ D^2\ V^3$$

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 http://www.nrel.gov/wind/docs/spread_sheet_final.xls under consumer information 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. 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 capital 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. A Virginia-specific analysis is available at http://vwec.cisat.jmu.edu/nextstep/.

Is There Enough Wind on My Site?

Does the wind blow hard and consistently enough at my site to make a small wind turbine system economically worthwhile? That is a key question and not always easily answered. The wind resource can vary significantly over an area of just a few miles because of local terrain influences on the wind flow. Yet there are steps you can take that will go a long way toward answering the above question.

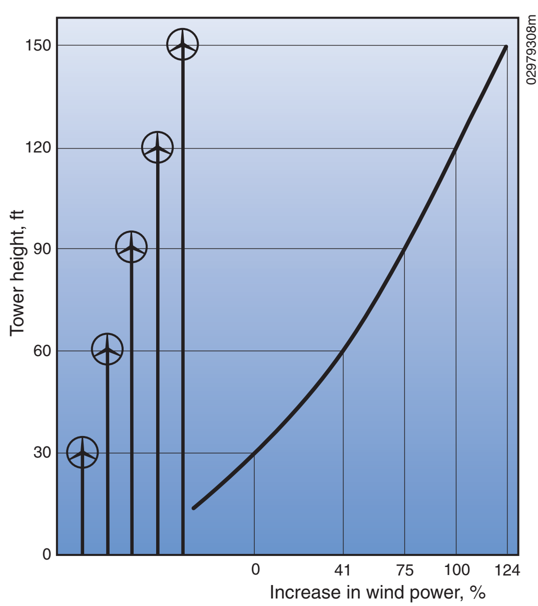
As a first step, wind resource maps like the one on pages 12 and 13 can be used to estimate the wind resource in your region.The highest average wind speeds in Virginia are located along the Atlantic Coast, Chesapeake Bay, and on ridgelines in the western part of the state. However, many areas have wind resources strong enough to power a small wind turbine economically. The wind resource estimates on this map generally apply to terrain features that are well exposed to the wind, such as plains, hilltops, and ridge crests. Local terrain features may cause the wind resource at a specific site to differ considerably from these estimates. For more detailed wind resource information, contact the Virginia Department of Mines, Minerals and Energy (DMME) for a digital copy of the Virginia wind resource map on CD (see Contacts).

Another way to indirectly quantify the wind resource is to obtain average wind speed information from a nearby airport. However, caution should be used because local terrain influences and other factors may cause the wind speed recorded at an airport to be different from your particular location. Airport wind data are generally measured at heights about 20–33 ft (6–10 m) above ground. Average wind speeds increase with height and may be 15%–25% greater at a typical wind turbine hub height of 80 ft (24 m) than those measured at airport anemometer heights. The National Climatic Data Center collects data from airports in the United States and makes wind data summaries available for purchase. Summaries of wind data from almost 1000 U.S. airports are also included in the *Wind Energy Resource Atlas of the United States* (see For More Information).

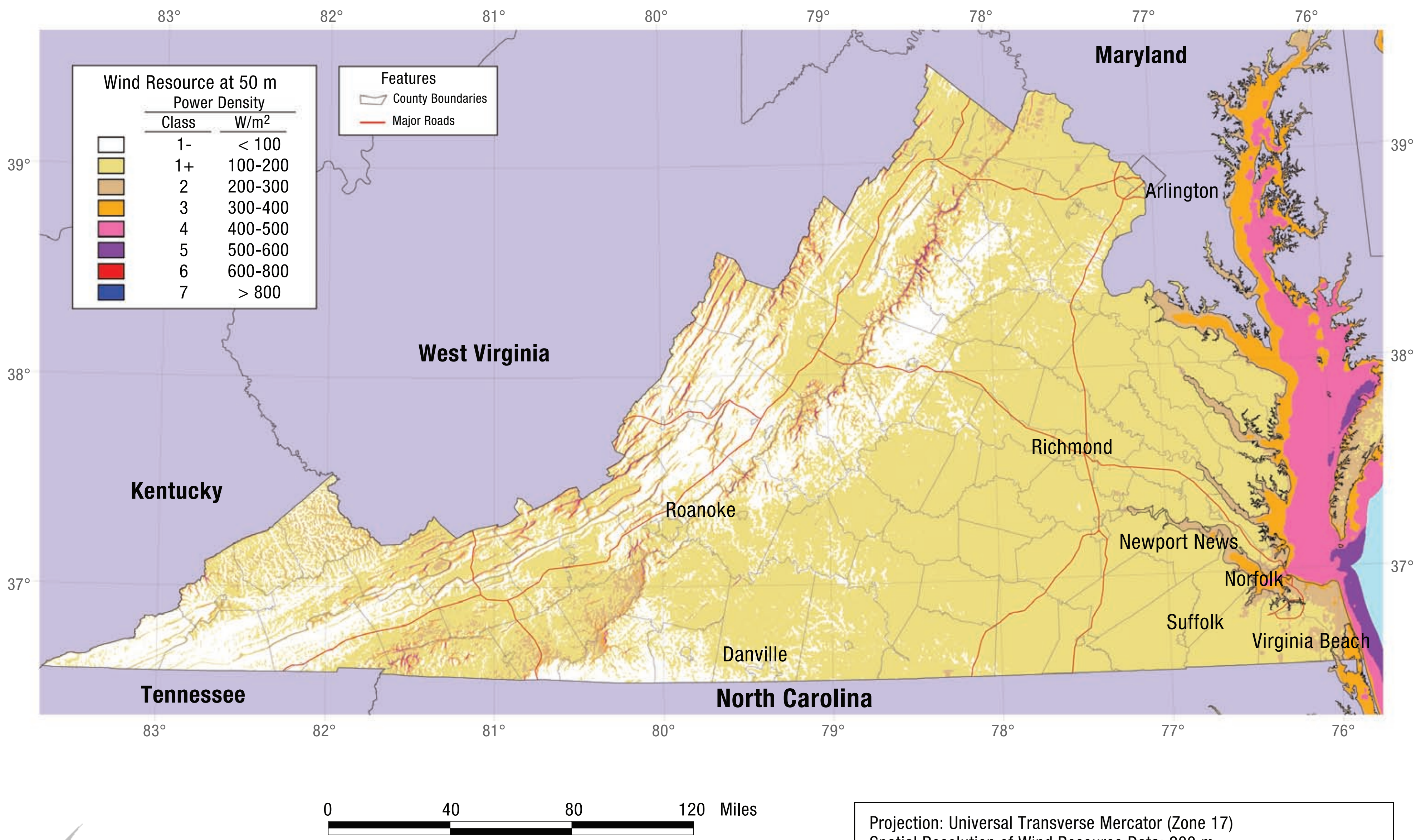
Another useful indirect measurement of the wind resource is the observation of an area's vegetation. Trees, especially conifers or evergreens, can be permanently deformed by strong winds. This deformity, known as "flagging," has been used to estimate the average wind speed for an area. For more information on the use of flagging, you may want to obtain *A Siting Handbook for Small Wind Energy Conversion Systems* (see For More Information).

Direct monitoring by a wind resource measurement system at a site provides the clearest picture of the available resource. A good overall guide on this subject is the *Wind Resource Assessment Handbook* (see For More Information). Wind measurement systems are available for costs as low as

Wind Speeds Increase with Height



Wind Power at 50 m

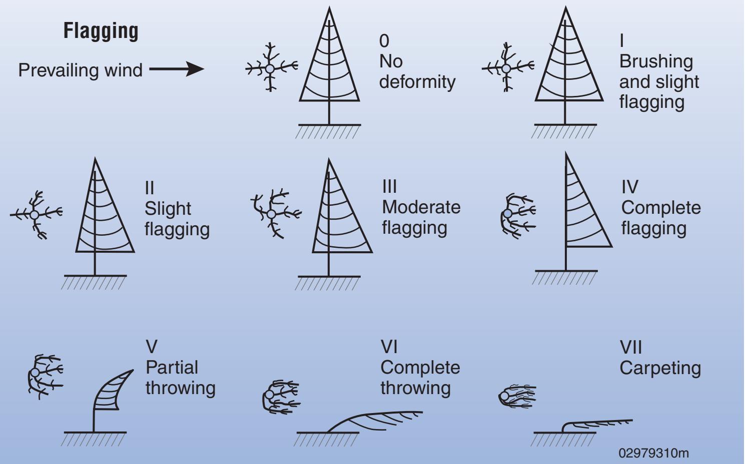


Projection: Universal Transverse Mercator (Zone 17)
Spatial Resolution of Wind Resource Data: 200 m

This map was created by TrueWind Solutions using the Mesomap system and historical weather data. It has been validated using available surface wind data by the National Renewable Energy Laboratory. Although it is believed to represent an accurate overall picture of the wind energy resource, estimates at any location should be confirmed by measurement.

TrueWind Solutions

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



Griggs-Putnam Index of Deformity

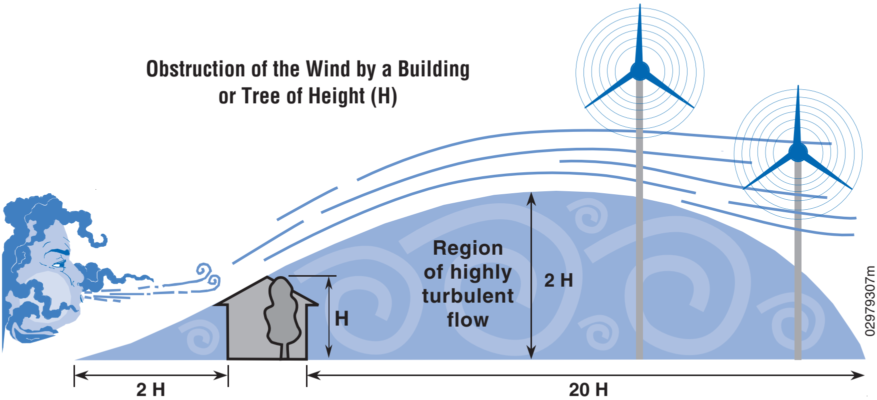
Index	I	II	III	IV	V	VI	VII
Wind mph	7-9	9-11	11-13	13-16	15-18	16-21	22+
Speed m/s	3-4	4-5	5-6	6-7	7-8	8-9	10

$600 to $1200. This expense may or may not be hard to justify depending on the exact nature of the proposed small wind turbine system. The measurement equipment must be set high enough to avoid turbulence created by trees, buildings, and other obstructions. The most useful readings are those taken at hub-height, the elevation at the top of the tower where the wind turbine is going to be installed. If there is a small wind turbine system in your area, you may be able to obtain information on the annual output of the system and also wind speed data if available.

How Do I Choose the Best Site for My Wind Turbine?

You can have varied wind resources within the same property. In addition to measuring or finding out about the annual wind speeds, you need to know about the prevailing directions of the wind at your site. If you live in complex terrain, take care in selecting the installation site. If you site your wind turbine on the top of or on the windy side of a hill, for example, you will have more access to prevailing winds than in a gully or on the leeward (sheltered) side of a hill on the same property. In addition to geologic formations, you need to consider existing obstacles such as trees, houses, and sheds, and you need to plan for future obstructions such as new buildings or trees that have not reached their full height. Your turbine needs to be sited upwind of buildings and trees, and it needs to be 30 feet above anything within 300 feet. You also need enough room to raise and lower the tower for maintenance, and if your tower is guyed, you must allow room for the guy wires.

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



The farther you place your wind turbine from obstacles such as buildings or trees, the less turbulence you will encounter.

longer the wire run, the more electricity 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 distribution system and are called grid-connected systems. A grid-connected wind turbine can reduce your consumption of utility-supplied electricity for lighting, appliances, and electric heat. If the turbine cannot deliver the amount of energy you need, the utility makes up the difference. 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 practical if the following conditions exist:

- You live in an area with average annual wind speed of at least 12 mph (5.4 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.

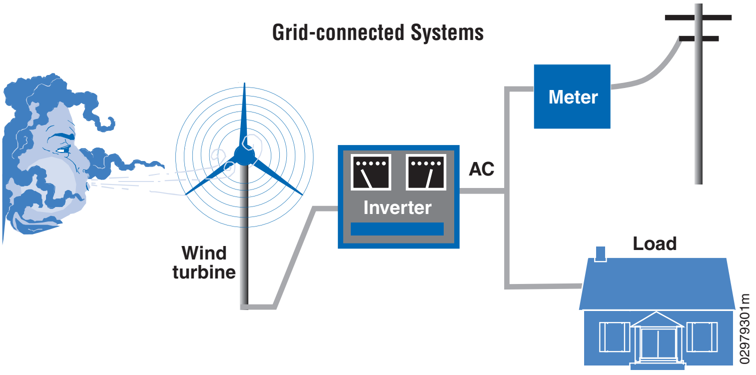
Federal regulations (specifically, the Public Utility Regulatory Policies Act of 1978, or PURPA) require utilities to connect with and purchase power from small wind energy systems.

Net Metering

The concept of net metering programs is to allow the electric meters of customers with power generators such as small wind turbines to spin backwards when their generators are producing more energy than their demand. Net metering allows customers to use their generation to offset their consumption over the entire billing period, not just instantaneously. In Virginia, this offset enables customers with generators to be credited at the retail rate for any surplus electricity they generate.

The Virginia Electric Restructuring Act of 1999 authorizes eligible customer-generators to engage in net metering, and Virginia regulators have adopted streamlined rules for such metering. Under the Restructuring Act and amendments

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



adopted in 2004, eligible customers include residential customers with small wind systems with a capacity of not more than 10 kW and non-residential customer-generators with systems with a capacity of not more than 500 kW. Eligible customer-generators include customers who own and operate a generating facility and those who contract with third-party owner/operators (20 Virginia Code 5-315-10 et. seq.).

Under the Virginia rules, net metered energy must be measured by metering equipment capable of measuring power flow in both directions. The rules are beneficial to small wind generators because they specify that the net excess generation (NEG) will be calculated on an annual basis. As a result, the NEG credit can be carried for up to 1 year. The Virginia net metering law also specifies requirements for utility notification prior to interconnection. The customer must submit a notification form set forth in the net metering regulations at least 30 days prior to the date that the customer plans to interconnect to the grid, and the utility has 30 days to determine whether all requirements have been met (20 VAC 5-315-30).

In addition, the Federal Energy Regulatory Commission is currently considering national rules for small wind generator interconnection. Updates on such rules can be obtained at http://www.ferc.gov/industries/electric/indus-act/gi.asp. The American Wind Energy Association is another good source for information on utility grid interconnection (see For More Information).

Along the ridgelines, wind speeds are highest in the winter months (November - February), while on and along the coast the wind speeds are highest during the late winter and early spring months (December - April). Both regions are subject to lower winds during the summer months than the rest of the year. For people using wind energy to displace a large load in the summer, like air-conditioning or irrigation water pumping, having an annual NEG credit allows them to produce NEG in the winter and be credited in the summer.

Safety Requirements

Whether or not your wind turbine is connected to the utility grid, the installation and operation of the wind turbine is generally required to meet local electrical codes. In Virginia, most local governments require compliance with the National Electrical Code, which is published by the National Fire Protection Association. The government's principal concern is with the safety of the facility, so these code requirements emphasize proper wiring and installation, and the use of components that have been certified for fire and electrical safety by approved testing laboratories, such as Underwriters Laboratories.

If your wind turbine is connected to the local utility grid, then your utility also may have concerns about safety and power quality that need to be addressed. The utility's principal concern is that your wind turbine automatically stops delivering electricity to its power lines during a power outage. Otherwise line workers and the public, thinking that the line is "dead," might not take necessary precautions to avoid injury. Another concern among utilities is that the power from your facility synchronize properly with the utility grid and that it match the utility's own power in terms of voltage, frequency, and power quality.

To address these utility concerns, the Virginia net metering rules have imposed certain technical conditions for interconnection (20 VAC 5-315-40). In addition, the Institute of Electrical and Electronic Engineers has adopted a consensus technical standard (IEEE-1547) for interconnection of small renewable energy generating facilities (including wind turbines).

Interconnection Requirements

Most utilities and other electricity providers require you to enter into a formal agreement with them before you interconnect your wind turbine with the utility grid. Usually these agreements are written by the utility or the electricity provider. In Virginia, if your electricity provider is a distribution company regulated by the State Corporation Commission (SCC), the terms and conditions in such agreements must be approved by the SCC.

Insurance

The Virginia net metering regulations set forth rules governing the amount of liability insurance for small wind generators as well as other customer-generators of renewable energy (20 VAC 5-315-60). The rules require that generators of small wind systems with a capacity of less than 10 kW must maintain homeowners, commercial, or other insurance coverage in the amount of at least $100,000 for liability of the insured against loss arising from the use of the small wind system. As of October 2004, the rules required liability insurance coverage of at least $300,000 for small wind systems with a capacity exceeding 10 kW. Utilities may not require customers to purchase liability insurance in excess of limits specified in the law.

However, it is possible that the SCC may change the insurance limits for larger systems to account for the fact that the capacity limit for non-commercial systems was increased from 25 kW to 500 kW in 2004. Any final

A wider view of the Bergey XL.1 installed at JMU (described on page 6), accompanied by an array of ground-mounted photovoltaic panels with a capacity of 1 kW. The wind and PV systems are coupled to a common battery bank.

Mark Lotts, JMU

changes in regulations will be posted on the SCC Web site (see Title 20 and Chapter 315, www.state.va.us/scc/commission/authority.htm).

It should be noted that in the more than 20 years since utilities have been required to allow small wind systems to interconnect with the grid, there has never been a liability claim, let alone a monetary award, relating to electrical safety.

Indemnification

An indemnity is an agreement between two parties in which one agrees to secure the other against loss or damage arising from some act or some assumed responsibility. In the context of customer-owned generating facilities, utilities often want customers to indemnify them for any potential liability arising from the operation of the customer's generating facility. Although the basic principle is sound—utilities should not be held responsible for property damage or personal injury attributable to someone else—indemnity provisions should not favor the utility but should be fair to both parties. Look for language that says, "each party shall indemnify the other . . ." rather than "the customer shall indemnify the utility . . ."

Customer Charges

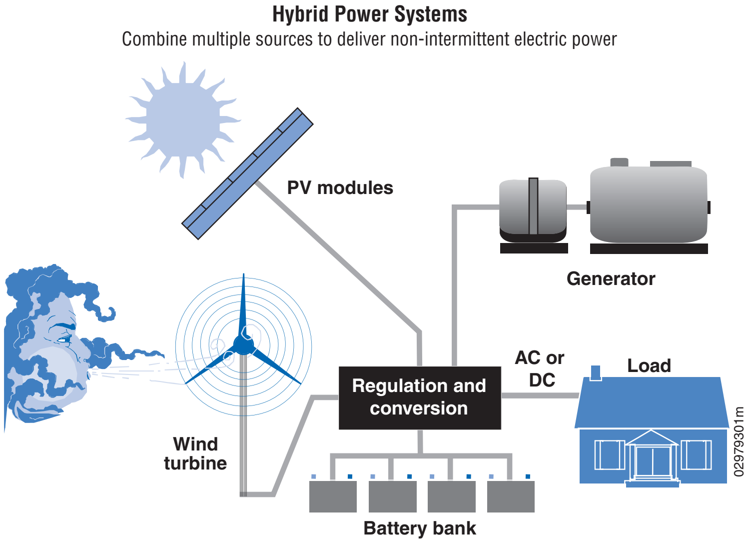
Customer charges can take a variety of forms, including interconnection charges, metering charges, and standby charges, among others. You should not hesitate to question any charges that seem inappropriate to you. Federal law (Public Utility Regulatory Policies Act of 1978, or PURPA, Section 210) prohibits utilities from assessing discriminatory charges to customers who have their own generation facilities.

In addition, the Virginia net metering law limits the ability of utilities to

Using Renewable Energy Certificates (RECs) to Increase Revenue

The market for green power is opening up new opportunities to generate wind energy and sell the credits for doing so (often called Renewable Energy Certificates or RECs) to consumers and utilities. Because many buyers are willing to pay a premium for clean power, wind RECs can command higher prices than RECs from other electricity sources. RECs represent a promise by a renewable energy generator to deliver a specific amount of renewable energy to a specified point on the electric grid, not the direct transfer of electricity from the renewable energy generator to the REC buyer. As a result, when buying or selling RECs, both consumer and independent renewable energy generator still buy their electricity from, or sell it to, their respective local electric utilities. Since a consumer can purchase, and a small wind generator can sell, wind RECs regardless of who their respective local electric utilities are, a potential exists to increase the financial return to small wind system owners. Average REC sales for wind can increase revenue between .5 and 1.5 cents per kWh of wind production.

Many national and local green power companies buy wind RECs to meet their growing demand for green power. However, in many states, including Virginia, green power cooperative groups such as Virginia Interfaith Power and Light are forming, offering the opportunity for small wind generators to sell RECs directly to the consumer. By adding the additional REC sales value to the revenue a wind turbine owner can receive through net metering with the electric utility, a small wind operator can increase the revenue of the small wind turbine by up to 20%.



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

impose excessive charges on owners of small wind generators. The regulations require that the utility charge the same amount for customers generating their own power under the net metering law as those customers that are purchasing all power from the grid (20 VAC 5-315-50).

Can I Go "Off-Grid"?

Hybrid Systems

Hybrid wind energy systems can provide reliable off-grid power for homes, farms, or even entire communities (a co-housing project, for example) that are far from the nearest 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 there is less sunlight 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 Clearinghouse—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 conventional fuels such as diesel. If the batteries 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.

An off-grid hybrid system may be practical for you if:

- You live in an area with average annual wind speed of at least 9 mph (4.0 m/s).
- A grid connection is not available or can only be made through an expensive extension. The cost of running a power line to a remote site to connect with the utility grid can be prohibitive, ranging from $15,000 to more than $50,000 per mile, depending on terrain.
- You would like to gain energy independence from the utility.
- You would like to generate clean power.

The Next Step Initiative

http://vwec.cisat.jmu.edu/nextstep

The Next Step Web site provides a tool that allows Virginia landowners to obtain a site-specific analysis of their property for consideration of wind power generation. This resource allows anyone in Virginia with Internet access to generate an assessment of the potential for wind power on their property. The resource invokes the Virginia Wind Resource Map developed by AWS Truewind, LLC (as shown in this guidebook) and considers a landowner's address to determine on-site wind characteristics. The resource also allows one to manually input wind data collected on site for analysis. One may define a broad array of economic variables to develop as site-specific an analysis as possible. The model also considers a landowner's electric load profile in order to support a comparative analysis between turbine-generated electricity and utility-supplied electricity. A comparison of the 25-year life cycle cost of electric generation with and without a turbine installation is produced in both graphical and tabular form. The most salient issues pertaining to small wind power and small wind system installations are explained within the Web site.

Glossary of Terms

Airfoil—The shape of the blade cross-section, which for most modern horizontal axis wind turbines, is designed to enhance the lift and improve turbine performance.

Ampere-hour—A unit of for the quantity of electricity obtained by integrating current flow in amperes over the time in hours for its flow; used as a measure of battery capacity.

Anemometer—A device to measure the wind speed.

Average wind speed—The mean wind speed over a specified period of time.

Blades—The aerodynamic surface that catches the wind.

Brake—Various systems used to stop the rotor from turning.

Converter—See Inverter.

Cut-in wind speed—The wind speed at which a wind turbine begins to generate electricity.

Cut-out wind speed—The wind speed at which a wind turbine ceases to generate electricity.

Density—Mass per unit of volume.

Downwind—On the opposite side from the direction from which the wind is blowing.

Furling—A passive protection for the turbine in which typically the rotor folds either up or around the tail vane.

Grid—The utility distribution system. The network that connects electricity generators to electricity users.

HAWT—Horizontal axis wind turbine.

Inverter—A device that converts direct current (DC) to alternating current (AC).

kW—Kilowatt, a measure of power for electrical current (1000 watts).

kWh—Kilowatt-hour, a measure of energy equal to the use of one kilowatt in one hour.

MW—Megawatt, a measure of power (1,000,000 watts).

Nacelle—The body of a propeller-type wind turbine, containing the gearbox, generator, blade hub, and other parts.

O&M Costs—Operation and maintenance costs.

Power Coefficient—The ratio of the power extracted by a wind turbine to the power available in the wind stream.

Power curve—A chart showing a wind turbine's power output across a range of wind speeds.

PURPA—Public Utility Regulatory Policies Act (1978), 16 U.S.C. § 2601.18 CFR §292 that refers to small generator utility connection rules.

Rated output capacity—The output power of a wind machine operating at the rated wind speed.

Rated wind speed—The lowest wind speed at which the rated output power of a wind turbine is produced.

Rotor—The rotating part of a wind turbine, including either the blades and blade assembly or the rotating portion of a generator.

Rotor diameter—The diameter of the circle swept by the rotor.

Rotor speed—The revolutions per minute of the wind turbine rotor.

SCC—State Corporate Commission, a state agency that regulates utilities.

Start-up wind speed—The wind speed at which a wind turbine rotor will begin to spin. See also cut-in wind speed.

Swept area—The area swept by the turbine rotor, $A = \pi R2$, where R is the radius of the rotor.

Tip speed ratio—The speed at the tip of the rotor blade as it moves through the air divided by the wind velocity. This is typically a design requirement for the turbine.

Turbulence—The changes in wind speed and direction, frequently caused by obstacles.

Upwind—On the same side as the direction from which the wind is blowing—windward.

VAWT—Vertical axis wind turbine.

Wind farm—A group of wind turbines, often owned and maintained by one company. Also known as a wind power plant.

Yaw—The movement of the tower top turbine that allows the turbine to stay into the wind.

For More Information

Books

A Siting Handbook for Small Wind Energy Conversion Systems.
H. Wegley, J. Ramsdell, M. Orgill, and R. Drake
Report No. PNL-2521 Rev.1, 1980
National Technical Information Service
5285 Port Royal Rd.
Springfield, VA 22151
Phone: (800) 553-6847
www.ntis.gov

Energy Savers Tips on Saving Energy and Money at Home — A consumer's guide for saving energy and reducing utility bills http://www1.eere.energy.gov/consumer/tips/pdfs/energy_savers.pdf

Wind Energy Basics
Paul Gipe
ISBN 1-890132-07-01
A comprehensive guide to modern small wind technology
American Wind Energy Association
Phone: (202) 383-2500
www.awea.org
or
Chelsea Green Publishing Company
www.chelseagreen.com

Wind Energy Resource Atlas of the United States
D. Elliott, et al.
American Wind Energy Association
Phone: (202) 383-2500
www.
awea.org
rredc.nrel.gov/wind/pubs/atlas

Wind Power for Home, Farm, and Business: Renewable Energy for the New Millennium
Paul Gipe
ISBN-1-931498-14-8
Completely revised and expanded edition of Wind Power for Home and Business
Chelsea Green Publishing Company
www.chelseagreen.com

Wind Power Workshop
Hugh Piggott
Provides an overview on how to design a home-built wind turbine.
The Center for Alternative Technology
Machynlleth, Powys
SY20 9AZ, UK
Phone: 06154-702400
E-mail: help@catinfo.demon.co.uk
www.foe.co.uk/CAT

Government Agencies

U.S. Department of Energy's Energy Efficiency and Renewable Energy site
www.eere.energy.gov
National Climatic Data Center
Federal Building, 151 Patton Avenue
Asheville, North Carolina, 28801-5001
Phone: (828) 271-4800
www.ncdc.noaa.gov

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
Phone: (800) 553-6847
www.ntis.gov

Non-Government Organizations

American Wind Energy Association
1101 14th St., NW
12th Floor
Washington, D.C. 20005
Phone: (202) 383-2500
www.awea.org

Solar Energy International
Short courses on renewable energy and sustainable development
Phone: (970) 963-8855
www.solarenergy.org

Periodicals

Apples and Oranges
Mick Sagrillo
A comprehensive comparison of available small wind turbines available on the Home Power Magazine Web site: www.homepower.com

Home Power Magazine
The definitive bimonthly magazine for the homemade power enthusiast.
Phone: (800)707-6586
www.homepower.com

Videos

An Introduction to Residential Wind Systems with Mick Sagrillo
A 63-minute video answering questions most often asked by homeowners as they consider purchasing and installing wind power systems
American Wind Energy Association
Phone: (202) 383-2500
www.awea.org

Web Sites

Small Wind Systems
Includes answers to frequently asked questions and information on U.S. manufacturers.
www.awea.org/smallwind.html

Database of State Incentives for Renewable Energy
www.dsireusa.org

Green Power Network Net Metering
Net metering programs are now available in more than 35 states.
www.eere.energy.gov/greenpower/markets

Small Wind "Talk" on the Web
AWEA's Home Energy Systems electronic mailing list is a forum for the discussion of small-scale energy systems that include wind. To subscribe, send a subscription request to awea-wind-home-subscribe@egroups.com

Wind Energy for Homeowners
This Web page covers items you should consider before investing in a small wind energy system and provides basic information about the systems.
www.nrel.gov/learning/ho_wind.html

Wind Resource Assessment Handbook
www.nrel.gov/docs/legosti/fy97/22223.pdf

2002 Farm Bill — Wind Energy Development Provisions

Renewable Energy Systems and Energy Efficiency Improvements

Incentive Type: Low-interest loans, loan guarantees, and grants

Eligible Technologies: Renewable energy systems (energy derived from wind, solar, biomass, geothermal, and hydrogen derived from biomass or water using a renewable energy source) and energy efficiency improvements.

Applicable Sectors: Agriculture, rural small commercial

Amount: Varies. The grant may not exceed 25% of the cost of a project, and a combined grant and loan or guarantee may not exceed 50% of the cost of a project.

Terms: 2003 – 2007

Date Enacted: 2002

Authority: Farm Bill, Title IX, Section 9006

Summary: This law allows direct financial assistance to farmers, ranchers, and rural small businesses for the purchase of wind power and other renewable energy systems and for energy efficiency improvements. This program is funded at $23,000,000 each year in 2003-2007, totaling $115 million. In determining the amount of a grant or loan, USDA shall consider the type of renewable energy system, the quantity of energy likely to be generated, the expected environmental benefits, the extent to which the system is replicable, and the amount of energy savings from energy efficiency improvements and the likely payback period.

Conservation Reserve Program

Incentive Type: CRP payments

Eligible Technologies: Wind turbines

Applicable Sectors: Agriculture

Amount: No reduction in CRP payments when a wind turbine is installed on CRP land (subject to USDA approval)

Effective Date: 2002

Authority 1: Farm Bill, Titles II and VI, Section 2101

Authority 2: Section 1232(a)(7) of the Food Security Act of 1985, 16 U.S.C. § 3831, et seq.

Summary: Wind turbine installations are now allowed on Conservation Reserve Program lands with no reduction in CRP payments. However, the wind turbine installations are subject to USDA approval, taking into account the site location, habitat, and the purpose of the CRP.

Value-Added Agricultural Product Market Development Grants

Incentive Type: Grants

Eligible Technologies: Renewable energy systems (energy derived from wind, solar, geothermal, hydrogen, and biomass—biomass is specifically defined and excludes both paper that is commonly recycled and unsegregated solid wastes).

Applicable Sectors: Agriculture

Amount: Maximum grant amount is $500,000 per project

Terms: 2002 – 2007

Authority 1: Farm Bill, Titles II and VI, section 6401

Authority 2: Section 231 of the Agricultural Risk Protection Act of 2000, 7 U.S.C. § 1621 note.

Summary: Titles II and VI, section 6401 of the Farm Bill amends Section 231 of the Agricultural Risk Protection Act of 2000, 7 U.S.C. § 1621 note to expand the definition of the term "value-added agricultural product" to include farm- and ranch-based renewable energy. The program provides for competitive grants to assist producers of value-added agricultural products, including renewable energy systems, to develop feasibility studies, business plans, and marketing strategies. Recipients also can use the grant to provide capital to establish alliances or business ventures.

The maximum grant amount is $500,000 per project. The program is funded at $40,000,000 for each year in 2002-2007, to be made available from the Commodity Credit Corporation, totaling $240 million.

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Wind Powering America

www.windpoweringamerica.gov

U.S. Department of Energy Wind Energy Program

www.eere.energy.gov/windandhydro/

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