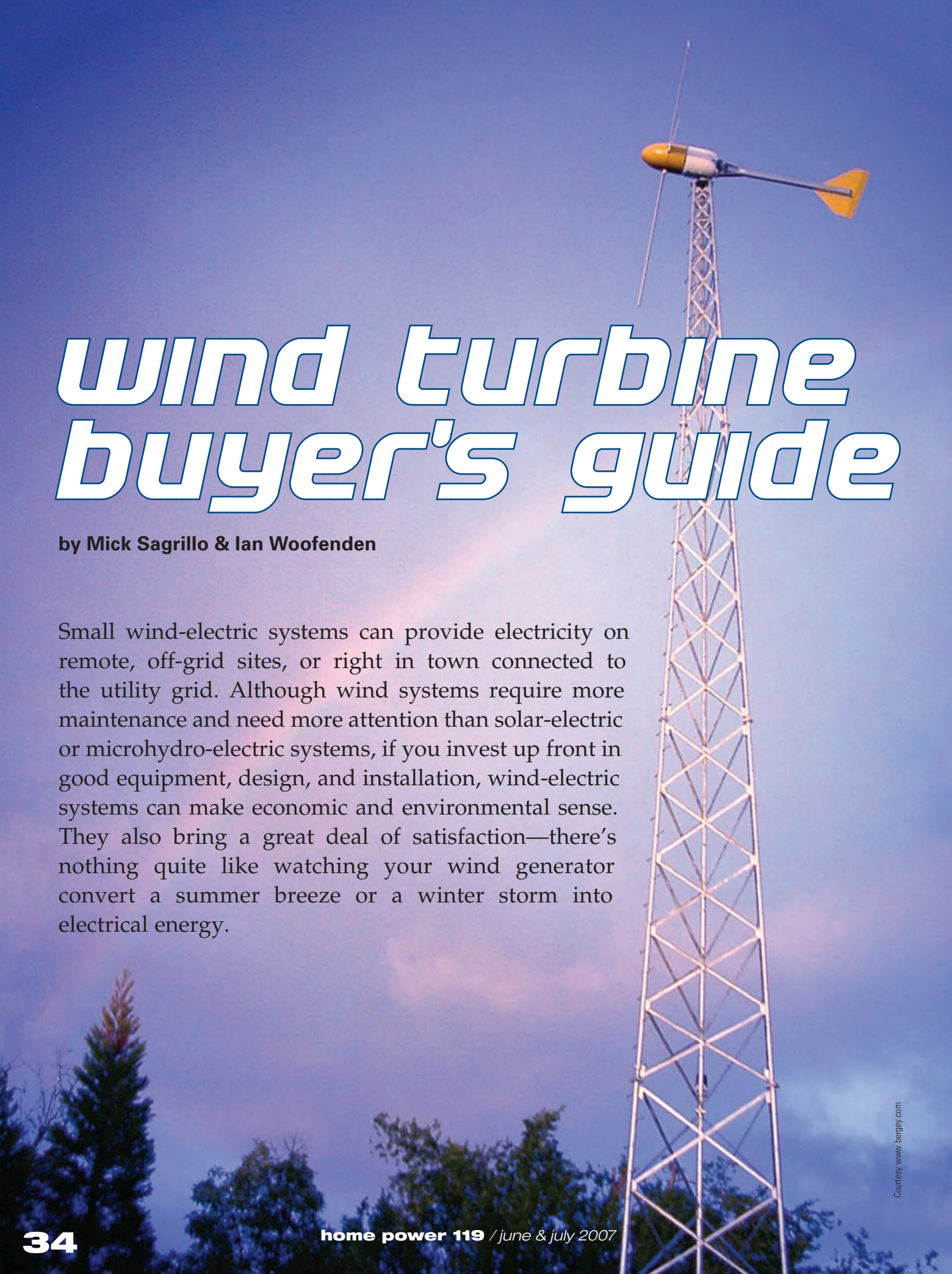
wind turbine buyer's guide

by Mick Sagrillo & Ian Woofenden

Small wind-electric systems can provide electricity on remote, off-grid sites, or right in town connected to the utility grid. Although wind systems require more maintenance and need more attention than solar-electric or microhydro-electric systems, if you invest up front in good equipment, design, and installation, wind-electric systems can make economic and environmental sense. They also bring a great deal of satisfaction—there's nothing quite like watching your wind generator convert a summer breeze or a winter storm into electrical energy.



Courtesy www.bergey.com

"Small wind," in our definition, starts with turbines with rotors (turbine blades and hub) that are about 8 feet in diameter (50 square feet of swept area). These turbines may peak at about 1,000 watts (1 kilowatt; KW), and generate about 75 kilowatt-hours (KWH) per month with a 10 mph average wind speed. Turbines smaller than this may be appropriate for sailboats, cabins, or other applications that require only a small amount of electricity. But if you want a significant amount of energy, you need a rotor with significant swept area—it is, after all, the wind turbine's "collector."

On the other end of the "small wind" scale, it's reasonable to include turbines with rotors up to 56 feet in diameter (2,500 square feet of swept area). These turbines may peak at about 90,000 watts (90 KW), and generate 3,000 to 5,000 KWH per month at a 10 mph average wind speed. Turbines of this scale are appropriate for very large homes, farms, small businesses, schools, or institutions that use a lot of electricity, or for heating applications, village power, and other major energy uses.

In between 8 feet and 56 feet are various sizes of turbines that can accommodate a variety of energy appetites. It's crucial that you have an accurate idea of what your energy usage is and the wind resource available at your site, so you can match the turbine's output to your energy needs.

Sizing a wind-electric system is quite different than sizing a solar-electric (PV) system. With a PV system, space permitting, you can add capacity either as your needs grow, or as you can afford it. With a wind-electric system, this is simply not the case. A wind turbine is not incremental. Nor do people typically add more wind turbines and towers as money becomes available. Because wind is more cost effective as you increase in system size, most people put up only one wind turbine, with the intent of offsetting a large percentage of their electric bill or, in off-grid systems, meeting most or all of their electrical energy requirements.

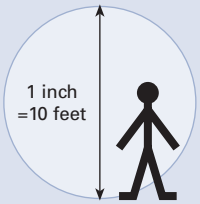
System Components

The wind generator (or "turbine") is only one component in a wind-electric system, and very often is not even the most expensive component. You need *all* of the necessary components to have a functional system. Plan ahead to buy quality components properly matched to each other and to your energy use. A complete wind-electric system includes:

- Turbine—generates electricity using the wind's energy
- Tower—supports the turbine, getting it up out of the turbulent zone created by trees and buildings, and exposes the turbine to much more "fuel"
- Wiring and conduit—carries the electricity down the tower and to power-conditioning equipment
- Controller/Electronics—controls charging of battery or input to inverter
- Batteries—used for storage in off-grid systems or grid-tied systems with battery backup
- Inverter—converts direct current (DC) electricity from batteries or rectifier to alternating current (AC) for home use or "storage" on the utility grid
- Metering—allows user to understand and manage system operation

Swept Area

The diameter of a wind turbine's rotor defines its swept area, the most important variable in the final energy generated. In the wind turbine specifications on the following pages, the blue circles represent the relative swept area of each turbine, drawn to scale.



Many Machines

The world is full of small wind generators. Chinese manufacturing numbers dwarf U.S. production, and European companies make dozens of models as well. This article covers home-scale wind generators, either manufactured or imported, that are supported in North America. The turbines profiled are readily available to buyers in the United States and Canada. And service, parts, and support are also available, either directly through the manufacturers, or through dedicated importers.

Other machines have been imported into North America in limited numbers, by individual owners or companies. Some of these may end up having long-term support from North American importers. Others may not. We suggest that you approach buying these machines with caution. If you're patient and willing to take a bit of risk, you may want to try one of these. You might end up with a real winner, or you may be stuck waiting for parts or a response from a distant manufacturer.

Home-scale wind generators come and go. We do not know enough about the quality of the equipment nor the responsiveness of the manufacturers listed below to make any firm recommendations. Our non-exhaustive list of other turbines we know about in North America includes:

- Aircon—a German machine with a 23-foot-diameter rotor
- Énergie PGE—from Canada, 36-foot-diameter rotor
- Iskrawind—a UK machine with an 18-foot-diameter rotor
- Tulipo—a Dutch machine with a 16-foot-diameter rotor
- Various other machines, including Aeromax Lakota, Air-O-Power, Anhua, Exmok, E-Mark, Gryphon, Trillium, and Cyclone

Other machines are under development. It's very hard to predict what will actually come to market, and how they will perform. A few look promising to us. One is a new induction generator design from Earth Turbines, a new company founded by David Blittersdorf of NRG Systems, which has long experience in wind monitoring. Another is the Endurance, developed by an engineering team in Utah, and also using an induction design. Apply standard cautions if considering these or any other new turbine—there's nothing like a real-world track record!

Abundant Renewable Energy

Manufacturer: 503-538-8298 • www.abundantre.com

ARE 110

Rotor diameter: 11.8 feet (3.6 m)
Swept area: 110 square feet (10.2 m^2)
Rated rpm: 340
Predicted energy output at average wind speeds: 135 KWH per month at 8 mph; 262 at 10 mph; 420 at 12 mph
Application: Batteryless grid-tie or 48 VDC battery charging
Price (MSRP): $11,500 for ARE 110 wind turbine, SMA Windy Boy inverter, voltage clamp, and resistor load; $8,870 for 48 VDC turbine, charge controller, and diversion load
Warranty: 5 years

ARE 442

Rotor diameter: 23.6 feet (7.2 m)
Swept area: 442 square feet (41 m^2)
Rated rpm: 140
Predicted energy output at average wind speeds: 623 KWH per month at 8 mph; 1,171 at 10 mph; 1,831 at 12 mph
Application: Batteryless grid-tie; battery charging system under development
Price (MSRP): $36,000 for turbine, two SMA Windy Boy 6000U inverters, voltage clamp, and resistor loads
Warranty: 5 years

Bergey Windpower

Manufacturer: 405-364-4212 • www.bergey.com

Bergey XL.1

Rotor diameter: 8.2 feet (2.5 m)
Swept area: 53 square feet (4.9 m^2)
Rated rpm: 450
Predicted energy output at average wind speeds: 55 KWH per month at 8 mph; 115 at 10 mph; 188 at 12 mph
Application: 24 VDC battery charging
Price (MSRP): $2,590 without controller or inverter
Warranty: 5 years

Bergey Excel

Rotor diameter: 23 feet (7 m)
Swept area: 415 square feet (38.6 m^2)
Rated rpm: 300
Predicted energy output at average wind speeds (battery charging/batteryless grid-tie): 240/340 KWH per month at 8 mph; 520/680 at 10 mph; 900/1,090 at 12 mph
Application: Batteryless grid-tie; 48, 120, 240 VDC battery charging
Price (MSRP): $22,900 for BWC XL-R, 48 VDC; $21,900 for BWC XL-R, 120 or 240 VDC; $27,900 for BWC XL-S, 240 VAC with inverter
Warranty: 5 years


ARE 110


ARE 442


Bergey XL.1


Bergey Excel

Wind Turbine Basics

Boiled down to its simplest principles, a wind generator's rotating blades convert the wind's kinetic energy into rotational momentum in a shaft. The rotating shaft turns an alternator, which makes electricity. This electricity is transmitted through wiring down the tower to its end use.

The **blades** use engineered airfoils, matched to the alternator, that capture the wind's energy. Most modern wind generators use three blades, the best compromise between the highest efficiency possible (one blade) and the balance that comes with multiple blades. Together, the blades and the hub they are attached to are termed the "rotor," which is the "collector" of the system, intercepting winds that pass by. Most turbines on the market today are upwind machines—their blades are on the windward side of the tower. A few downwind machines are available, but neither configuration has a clear performance advantage over the other.

In most small-scale designs, the rotor is connected directly to the shaft of a permanent magnet **alternator**, which creates wild, three-phase AC. Wild, three-phase electricity means that the voltage and frequency vary continuously with the wind speed. They are not "fixed" like the 60 Hz, 120 VAC electricity coming out of common household outlets. The wild output is rectified to DC to either charge batteries or feed a grid-synchronous inverter. In most designs up to 15 KW in peak capacity, the rotor is usually connected directly to the alternator, which eliminates the additional maintenance of gears. In systems 20 KW and larger, as well as some smaller wind systems (like the Endurance, Tulipo, or Aircon), a gearbox is used to increase alternator speed from a slower turning rotor.

The blades must turn to face the wind, so a **yaw** bearing is needed, allowing the wind turbine to track the winds as they shift direction. The **tail** directs the rotor into the wind. Some sort of **governing system** limits the rotor rpm as well as generator output to protect the turbine from high winds. A **shutdown mechanism** is also useful to stop the machine when necessary, as during an extreme storm, when you do not need the energy, or when you want to service the system.

Eoltec Wind Turbines

Importers:
Pine Ridge Products LLC • 406-738-4283 • www.pineridgeproducts.com

Solacity • 613-686-4618 • www.solacity.com

Eoltec 6 KW

Rotor diameter: 18.4 feet (5.6 m)
Swept area: 265 square feet (24.6 m^2)
Rated rpm: 245
Predicted energy output at average wind speeds: 294 KWH per month at 8 mph; 558 at 10 mph; 892 at 12 mph
Application: Batteryless grid-tie
Price (MSRP): $25,200 with inverter
Warranty: 5 years

Kestrel Wind Turbines

Importer: DC Power Systems • 800-967-6917 • www.dcpower-systems.com

Kestrel 800

Rotor diameter: 7 feet (2.1 m)
Swept area: 38.5 square feet (3.6 m^2)
Rated rpm: 1,000
Predicted energy output at average wind speeds: 40 KWH per month at 8 mph; 80 at 10 mph; 125 at 12 mph
Application: Batteryless grid-tie or 12, 24, 48 VDC battery charging
Price (MSRP): $1,995 without controller or inverter
Warranty: 5 years

Kestrel 1000

Rotor diameter: 10 feet (3 m)
Swept area: 79 square feet (7.3 m^2)
Rated rpm: 650
Predicted energy output at average wind speeds: 75 KWH per month at 8 mph; 130 at 10 mph; 210 at 12 mph
Application: 12, 24, 48 VDC battery charging
Price (MSRP): $2,950 without controller or inverter
Warranty: 5 years

Kestrel 3000

Rotor diameter: 12.5 feet (3.8 m)
Swept area: 120 square feet (11.2 m^2)
Rated rpm: 500
Predicted energy output at average wind speeds: 130 KWH per month at 8 mph; 230 at 10 mph; 375 at 12 mph
Application: Batteryless grid-tie or 48 VDC battery charging
Price (MSRP): $8,400 with controller and dump load, without inverter
Warranty: 5 years


Eoltec 6 KW


Kestrel 800


Kestrel 1000


Kestrel 3000

Understanding the Ratings

Wind turbine rating is a tricky affair. While solar-electric module or microhydro-electric turbine production can be predicted fairly realistically based on rated output, this number is very misleading with wind turbines. Why? Because rated output is pegged to a particular wind speed, and different manufacturers use different wind speeds to determine rated output. Also, the power available in the wind varies with the *cube* of its speed, so small increases in wind speed result in large increases in power available to the rotor. A 10 percent increase in wind speed yields a 33 percent increase in power available in the wind. Conversely, this means that a turbine rated at 1,000 watts at 28 mph might produce only 125 watts or less at half that wind speed, 14 mph.

So what's a wind turbine buyer to do? *Ignore* the peak output and the power curve. Look for the monthly or annual energy numbers for the turbine, estimated for the average wind speed you expect or measure at your site. These will be given in KWH per month (or year) in the manufacturer's specifications for each turbine. Energy is what you're after, not peak power! If, for example, you are looking for a turbine that can produce 300 KWH per month, and you know that you have a 10 mph average wind speed at the proposed turbine height, you can shop for a turbine that is predicted to generate that much energy in that average wind speed.

If you can't get energy production estimates from the manufacturer or a turbine owner, look for a different manufacturer. This is basic information that any manufacturer should supply. However, knowing a turbine's swept area may also help you calculate the annual energy output for the wind turbine. All other things being equal, "there's no replacement for displacement." Hugh Piggott gives a rough formula for calculating output based on average wind speed and swept area in his *HP102* article (see Access). Jim Green at the National Renewable Energy Lab (NREL) developed a similar formula: annual energy output (AEO) in KWH = 0.01328 x rotor diameter (ft.) squared x average wind speed (mph) cubed.

Proven Energy

Importers:
Lake Michigan Wind & Sun • 920-743-0456 • www.windandsun.com

Solar Wind Works • 877-682-4503 • www.solarwindworks.com

Proven WT 0.6

Rotor diameter: 8.4 feet (2.6 m)
Swept area: 55 square feet (5.1 m^2)
Rated rpm: 500
Predicted energy output at average wind speeds: 42 KWH per month at 8 mph; 83 at 10 mph; 124 at 12 mph
Application: Batteryless grid-tie; 12, 24, 48 VDC battery charging
Price (MSRP): $4,870 without controller or inverter
Warranty: 2 years; extended warranty available

Proven WT 2.5

Rotor diameter: 11.1 feet (3.4 m)
Swept area: 97 square feet (9 m^2)
Rated rpm: 300
Predicted energy output at average wind speeds: 167 KWH per month at 8 mph; 293 at 10 mph; 417 at 12 mph
Application: Batteryless grid-tie; 24, 48 VDC battery charging
Price (MSRP): $9,650 without controller or inverter
Warranty: 2 years; extended warranty available

Proven WT 6

Rotor diameter: 18 feet (5.5 m)
Swept area: 254 square feet (23.6 m^2)
Rated rpm: 200
Predicted energy output at average wind speeds: 417 KWH per month at 8 mph; 667 at 10 mph; 1,083 at 12 mph
Application: Batteryless grid-tie or 48 VDC battery charging
Price (MSRP): $20,500 without controller or inverter
Warranty: 2 years; extended warranty available

Proven WT 15

Rotor diameter: 29.5 feet (9 m)
Swept area: 683 square feet (63.5 m^2)
Rated rpm: 150
Predicted energy output at average wind speeds: 777 KWH per month at 8 mph; 1,451 at 10 mph; 3,080 at 12 mph
Application: Batteryless grid-tie or 48 VDC battery charging
Price (MSRP): $39,340 without controller or inverter
Warranty: 2 years; extended warranty available

Other Considerations

A turbine's revolutions per minute (rpm) at its rated wind speed can give you some idea of the relative aerodynamic sound of the machine, and also speaks to longevity. Slower-turning wind turbines tend to be quieter and last longer. High rpm machines wear out components, such as bearings, much faster. In addition, the faster blades move through the air, the greater the possibility that they will waste some of that energy as sound from the blades.

Some manufacturers make only battery-charging machines, and may offer a variety of turbine voltages. Others produce machines intended to connect to grid-synchronous inverters without batteries. One machine even includes an inverter integrated with the turbine itself. Make sure you're buying a machine that is appropriate for your intended use.

Make Your Choice

Trying to keep an inexpensive wind generator running can be an uphill battle that you'll soon tire of. But expect to pay more for a better machine—it's a tough job to design and manufacture a long-lasting, small-scale wind generator.

The bottom line: Buy a turbine that has a very good track record and a good warranty—five years is preferable but not always available in the small wind industry. A warranty is one indication of the manufacturer's confidence in their product, and their intention to stand behind it.

Real-world reports from users carry even more weight than a warranty, so search for people who own the model of turbine you're considering buying, and get the straight scoop from them about performance, durability, reliability, and maintenance issues.

Note that a number of the wind turbines listed here are relatively new introductions with not very much customer run-time in North America. These turbines include the ARE, Eoltec, Kestrel, and Skystream. We recommend that you contact either your local wind turbine installer, or the manufacturers or importers and find out how many of these machines are actually operating in North

Southwest Windpower

Manufacturer: 928-779-9463 • www.windenergy.com

Whisper 100

Rotor diameter: 7 feet (2.1 m)
Swept area: 38.5 square feet (3.6 m^2)
Rated rpm: 1,200
Predicted energy output at average wind speeds: 30 KWH per month at 8 mph; 65 at 10 mph; 100 at 12 mph
Application: 12, 24, 36, 48 VDC battery charging
Price (MSRP): $2,475 with controller
Warranty: 5 years

Whisper 200

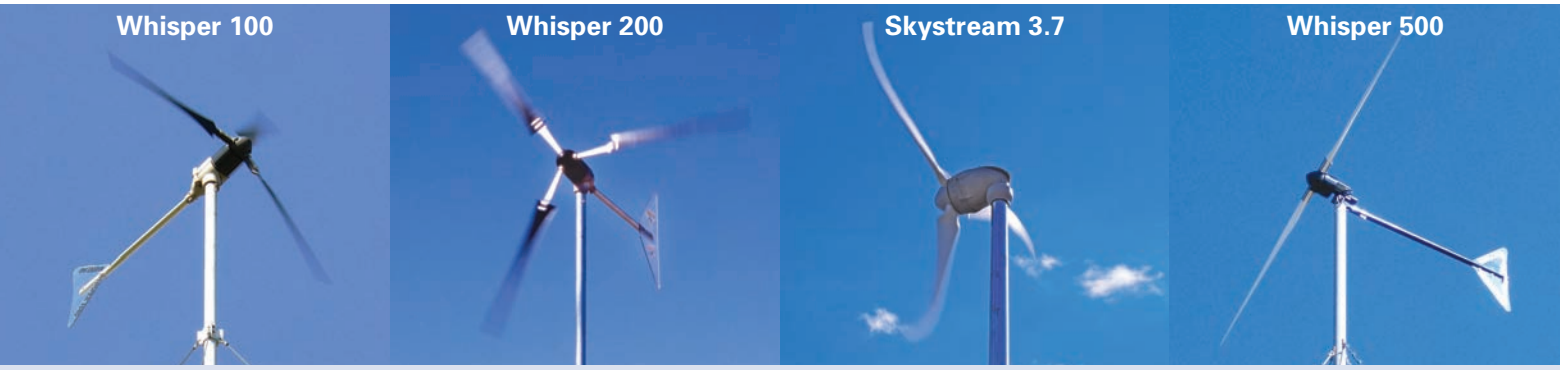
Rotor diameter: 9 feet (2.7 m)
Swept area: 63.5 square feet (5.9 m^2)
Rated rpm: 1,100
Predicted energy output at average wind speeds: 60 KWH per month at 8 mph; 125 at 10 mph; 190 at 12 mph
Application: 12, 24, 36, 48 VDC battery charging
Price (MSRP): $2,995 with controller
Warranty: 5 years

Skystream 3.7

Rotor diameter: 12 feet (3.6 m)
Swept area: 113 square feet (10.5 m^2)
Rated rpm: 325
Predicted energy output at average wind speeds: 100 KWH per month at 8 mph; 240 at 10 mph; 380 at 12 mph
Application: Batteryless grid-tie, or battery charging through battery-based inverter (not included) AC input
Price (MSRP): $5,400, including turbine-integrated batteryless inverter
Warranty: 5 years

Whisper 500

Rotor diameter: 15 feet (4.6 m)
Swept area: 176 square feet (16.4 m^2)
Rated rpm: 800
Predicted energy output at average wind speeds: 170 KWH per month at 8 mph; 330 at 10 mph; 538 at 12 mph
Application: Batteryless grid-tie; 24, 32, 48 VDC battery charging
Price (MSRP): $7,675 for battery charging with controller; $12,125 for grid tied with inverter
Warranty: 5 years



America. Then contact the owners, and inquire about their experience and satisfaction with both the machine and the manufacturer or importer.

When you look at prices, keep in mind that just buying a wind turbine will not get you any wind-generated electricity. You'll also need most or all of the components mentioned earlier. Also budget for equipment rental, like a backhoe and crane, concrete and rebar, electrical components, shipping, and sales tax. Unless you do all of the work yourself, also factor in installation labor expenses. These costs can add up significantly, so make sure that you research and understand all of the associated expenses before committing to a purchase. Many people are quite surprised to learn that the wind turbine cost can range from only 10 percent to as much as 40 percent of the entire wind system's expenses.

Small-scale wind energy is not for the half-hearted, uninvolved, or uncommitted, and probably not for folks who never change the oil in their vehicles (or are willing to spend the bucks to hire someone to do the tower work). The North American landscape is littered with failed installations: Designs not fully thought-out or tested, machines bought because they were cheap, and installations that required more time and money for repairs than they ever yielded in electricity generated. Many of the failures were the result of wishful thinking and too little research. That said, there are tens of thousands of happy wind-electric system owners. These owners did their homework—purchasing, designing, and installing rugged and well-thought-out systems on adequately sized towers. In addition, they are either committed to maintaining the systems, or to hiring someone to do this regular work.

While many first-time wind turbine buyers may be looking for a bargain, second-time wind turbine buyers are seeking the most rugged machine they can afford. You can avoid a painful "learning experience" by focusing on durability, production, warranty, and track record, and *not* on price alone, or on peak output. You don't want to depend on the low bidder for something as important to you as your long-term energy investment.

Vestas

Rebuilders:
Energy Maintenance Service LLC • 605-272-5398 • www.energyms.com

Halus Power Systems • 510-780-0591 • www.halus.com

Vestas V-15

Rotor diameter: 50 feet (15 m)
Swept area: 1,964 square feet (182 m^2)
Rated rpm: 53
Predicted energy output at average wind speeds: N/A at 8 mph; 3,354 KWH per month at 10 mph; 5,371 at 12 mph
Application: Batteryless grid-tie
Price (MSRP): $140,000 installed on 110-foot tower
Warranty: 1 year; extended warranties available

Vestas V-17

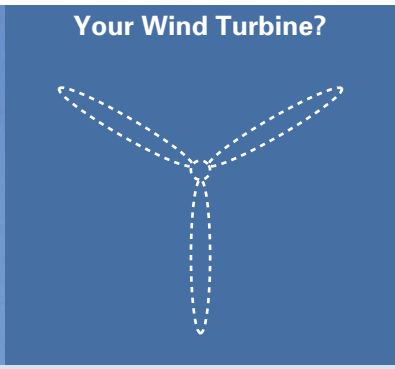
Rotor diameter: 56 feet (17 m)
Swept area: 2,462 square feet (229 m^2)
Rated rpm: 45–50
Predicted energy output at average wind speeds: N/A at 8 mph; 5,060 KWH per month at 10 mph; 8,198 at 12 mph
Application: Batteryless grid-tie
Price (MSRP): $180,000 installed on 132-foot tower
Warranty: 1 year; extended warranty available

Wind Turbine Industries

Manufacturer: 952-447-6064 • www.windturbine.net

WTIC 31-20

Rotor diameter: 31 feet (9.5 m)
Swept area: 754 square feet (70 m^2)
Rated rpm: 175
Predicted energy output at average wind speeds: 819 KWH per month at 8 mph; 1,644 at 10 mph; 2,691 at 12 mph
Application: Batteryless grid-tie
Price (MSRP): $33,900 with inverter
Warranty: 1 year; extended warranty available



In our next article, we'll discuss system design and the turbine selection process in more detail. Meanwhile, we encourage you to start with an energy analysis of your home—find out how many kilowatt-hours you need and how you can reasonably pare that number down! Next, find out what your wind resource is—guessing on this will make your whole system design a guess. And when it's time to buy, choose a rugged turbine that will produce what you expect it to, and do that for years to come.

Note: All numbers are provided by manufacturers or extrapolated from their data, since no comprehensive, independent testing data is available. Turbine performance may vary at your site.

Access

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Ian Woofenden, PO Box 1001, Anacortes, WA 98221 • ian.woofenden@homepower.com

"Anatomy of a Wind Turbine," Ian Woofenden & Hugh Piggott, *HP116*

"Wind Generator Tower Basics," Ian Woofenden, *HP105*

"Estimating Wind Energy," Hugh Piggott, *HP102*

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