2010 WIND GENERATOR buyer's guide

by Ian Woofenden & Mick Sagrillo

Courtesy Bill Court

Looking for the perfect antidote to your static solar collectors? Want something that *moves*, letting you know that it's working? If you're ready and your site is right, you could consider a wind-electric system.

Be forewarned that when it comes to maintenance, challenges, and spectacular failures, wind-electric systems are anything but "upkeep-free" or simple. But if you make good decisions up front and stay on top of maintenance and repair, your wind-electric system should provide years of energy for your home or business.

Read on for some perspective on the three most common mistakes to avoid and the three most important decisions you need to make. Then take a look at the equipment available today, and learn more about making a wise buying decision.

How High?

The most common mistake made with small wind-energy systems is putting a turbine on too short of a tower. As with any renewable electricity system, the collector must have good access to the fuel—it needs good wind, which is somewhat different than other renewable sources. The power available in the wind increases with the cube of the wind speed. This means that there is nearly 100% more power available in 10 mph winds than in 8 mph winds.

While we might perceive some puffs and gusts at ground or rooftop level, there is little usable fuel at these heights. The rule used by experienced wind installers is to place the whole rotor at least 30 feet above any obstacle (usually trees) within 500 feet of the tower or the prevailing tree line, whichever is higher. Keep in mind that you are installing the wind turbine for decades of productivity—trees your turbine may barely clear today may be considerably taller in several years. Get it right at installation time by estimating mature tree growth and sizing the tower accordingly.

In addition to access to winds of sufficient quantity, the 30-foot rule also gets the turbine rotor above much of the turbulence created by any nearby obstructions. While turbulent winds are reduced-quantity winds, they are also reduced-*quality* winds, putting considerable stress on a wind turbine by their constant buffeting and shifting. Turbulence's continuous pounding strains all wind turbine components, adding to maintenance requirements and reducing the equipment's life.

These two wind turbines on very short towers underperform because they are below the area's tree line and very close to obstructions.

Short towers result in a quadruple whammy: Reduced wind speeds, more wear and tear from turbulence, less electricity, and compromised reliability.

How Wide?

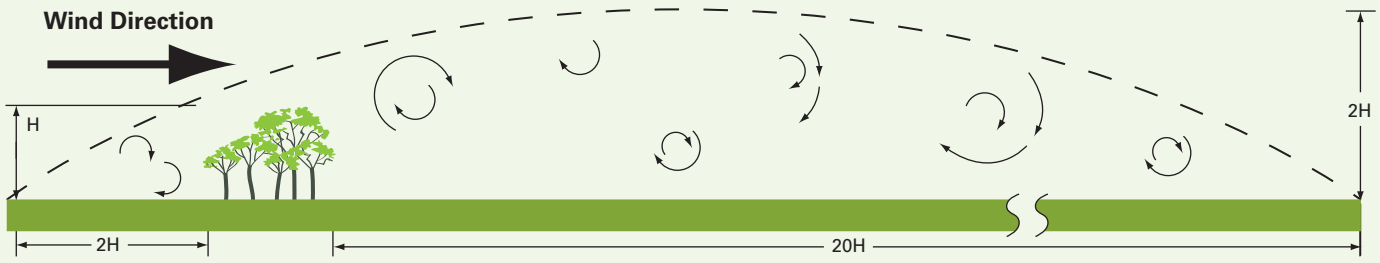
Your wind generator's "swept area" defines its ability to collect wind, which is, after all, the resource you are trying to tap. Like other renewable technologies, a small collector will collect a small amount of energy; a large collector will collect a large amount of energy. If you're trying to capture enough rainwater to supply your household, water the garden, and wash the cars, you don't try to collect it in a thimble. And in the same way, you need an adequate "wind collector" to make the amount of energy you need.

Typical small wind turbines that can contribute substantially to a home, farm, school, or business will be 12 to 70 feet in diameter. In our list, we've included a few machines that are smaller, but remember that you might not get the energy you need out of these machines.

There's no magic behind the blades of your wind generator that can make dramatically more energy from the same swept area. There's no substitute for square footage of swept area—the area of the wind that is intercepted by the rotor.

Wind Turbulence

Turbulence slows and degrades the wind resource, both upwind and downwind of obstructions. Note the height (H) and distance of turbulence behind an obstruction—an unsuitable area for a wind turbine.



Bergey Windpower's XL.1 is the smallest turbine listed in this guide, with a rotor diameter of 8.2 feet.

Courtesy www.bergey.com

Courtesy www.northernpower.com

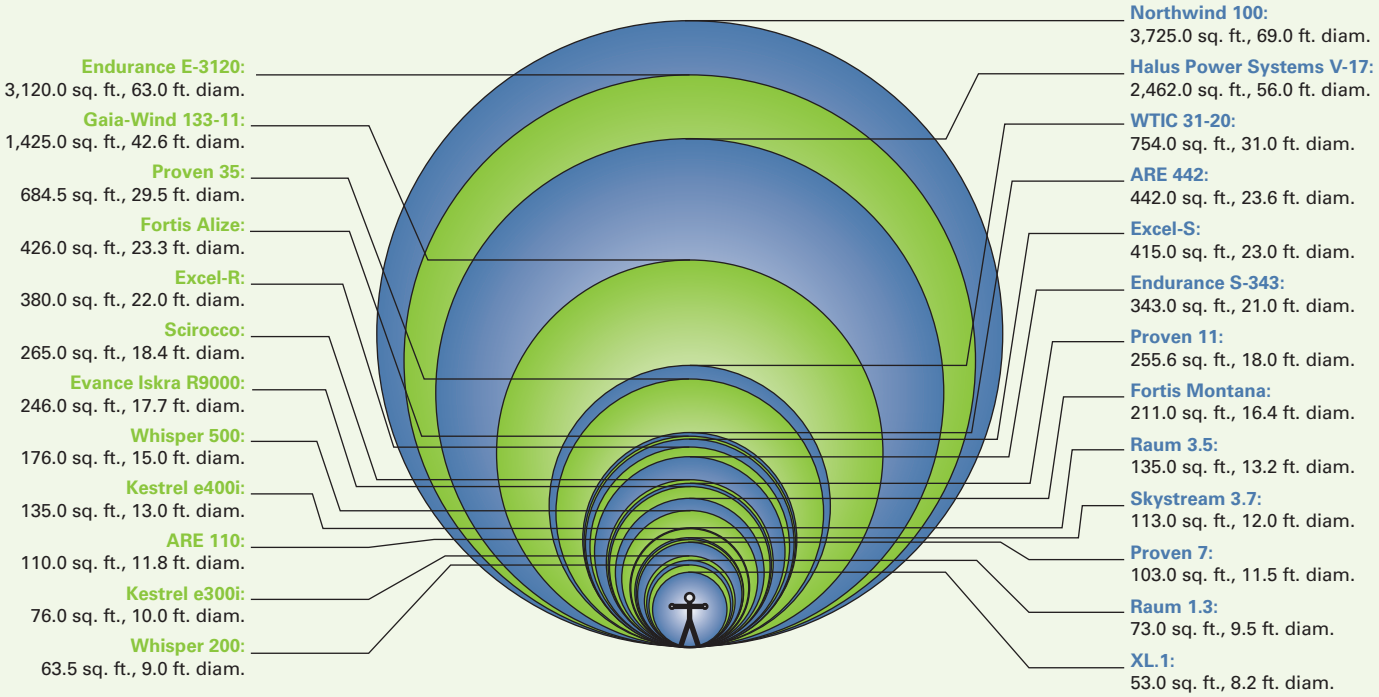
The Northern Power Northwind 100 turbine is the largest turbine included in this guide, with a 69-foot-diameter rotor.

How Robust?

You want your wind turbine up high *and* to have resilience to stay in the game for the long haul. Too many whizbang wind generators advertise their unique features, but only years of enduring tough conditions on tower tops will reveal a machine's durability and reliability.

You'll want the manufacturer you purchase from to have some depth, too—a long history in the business of designing, manufacturing, and supporting wind-electric systems. In our nearly 60-plus combined years of connection with the small wind industry, we've rarely seen a "new breakthrough" product actually deliver on its promises. Call us skeptics, but we'll wait until a company has depth in the marketplace—machines running for three to five years—before we even start to get interested.

Blade Diameters & Swept Area



Wind journalist Paul Gipe wisely notes that efficiency, price, and peak power are meaningless without durability. A machine can be "engineered," "an advance in technology," and "spectacular" in the advertisements, but when it dies on the tower or falls off the tower, all "advancements" and claims are meaningless—a non-operational wind turbine is a rather expensive piece of kinetic sculpture at best.

Wind System Sizing Process

A simplified wind-electric system design process looks like this:

- Determine your energy need (kilowatt-hours; kWh) per day, week, or year) and try to reduce it via energy efficiency and conservation.
- Decide on your tower height using the 30-foot rule and estimated mature tree height—remember, a turbine on a taller tower will always generate more electricity than one on a shorter tower.
- Estimate your resource—the average wind speed at proposed machine height.
- Determine rotor diameter, based on predicted kWh at your site's average wind speed.
- Compare all of the products in the rotor diameter range you have selected. Consider a larger turbine if your needs will grow, or a small turbine if you will be downsizing your consumption.
- Choose a specific wind generator.
- If an off-grid system, choose balance-of-system (BOS) components—inverter, batteries, etc. Grid-tied systems without battery backup are usually package systems: turbine, controller, and inverter are matched and specified by the manufacturer.

It's just plain foolish to select your wind generator *before* you've done the basic groundwork of determining your energy load, tower height, and wind resource—you'd need to be very lucky to guess right. You might end up buying a wind generator that's too small, resulting in a disappointing investment. Wind isn't incremental like PV—you cannot add generating capacity to an existing system; you're stuck with what you installed. Upgrading to a larger wind generator will mean buying a stouter tower along with pouring a new foundation. It may also mean larger BOS components.

On the other hand, buying a wind generator that's too large isn't the worst problem to have, since it will result in more energy than you really need, which you'll likely find a use for. But you run the risk of spending more money than you need to, so get the data first and make wise design choices up front.

To make your decision based on cost alone is downright unwise. A cheap wind turbine that is half the price of the quality option—but only lasts two or so years—is the most expensive electricity you can buy.

Wind Turbine Specifications

The table shows basic specs for small wind turbines available and supported in North America. Understanding the specs will help you make intelligent choices when it's time to buy your turbine.

Manufacturer/importer. The wind turbines listed are either new, remanufactured (in one case), or imported. For imported models, the North American contact is listed.

Swept area is the area in square feet of the wind "swept" by the rotor. This is the size of the "wind collector," and besides your average wind speed, is the single largest factor influencing turbine output. A larger rotor will give you more energy, all other things being equal (and they generally are).

Rotor diameter is another identifier for turbines, along with swept area, but you should pay attention here. The difference between a turbine with an

(continued on page 52)

Courtesy www.windenergy.com

Courtesy www.raumenergy.com

Courtesy www.kestrelwind.co.za

Courtesy www.provenenergy.co.uk


Cascade Wind
ARE 110
Courtesy www.cascadewindcorp.com


Southwest Windpower
Skystream 3.7
Courtesy www.windenergy.com


Kestrel
e400i
Courtesy www.kestrelwind.co.za

Wind Turbine Specifications

Manufacturer	Bergey Windpower	SW Wind Power	Raum	Kestrel	Proven Energy	Cascade Wind
Web site	www.bergey.com	www.windenergy.com	www.raumenergy.com	www.kestrelwind.co.za	www.provenenergy.co.uk	www.cascadewindcorp.com
Model	XL.1	Whisper 200	Raum 1.3	e300i	Proven 7	ARE110
Swept area (sq. ft.)	53.0	63.5	73.0	76.0	103.6	110.0
Rotor diameter (ft.)	8.2	9.0	9.5	10.0	11.5	11.8
Tower-top weight (lbs.)	75	65	86	165	420	315
Predicted annual energy output (kWh)						
8 mph	420	794	908	973	1,704	1,629
9 mph	610	1,121	1,110	1,315	2,438	2,274
10 mph	840	1,483	1,539	1,726	3,494	3,039
11 mph	1,110	1,865	2,004	2,131	4,417	3,894
12 mph	1,400	2,254	2,479	2,551	5,627	4,801
13 mph	1,710	2,637	2,940	2,966	6,614	5,728
14 mph	2,040	3,005	3,365	3,356	7,842	6,643
Rpm	490	900	800	600	300	310
Generator type	PM	PM	PM	PM	PM	PM
Governing system	Side furling	Angle furling	Tilt-up furling	Blade pitch	Blade pitch	Side furling
Governing wind speed (mph)	29	26	23	24	27	25
Shutdown mechanism	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Disc brake	Dynamic brake
Batteryless grid-tied version	Pending	No	Yes	Yes	Yes	Yes
Battery voltages	24	24, 36, 48	24, 48	12, 24, 48	24, 48	48
Controls included	Yes	Yes	Yes	No	Yes	Yes
Tower or installation included in cost	No	No	No	No	Tower (30 ft.)	No
Cost: batteryless version	—	—	$3,650	$6,440	$25,000	$12,650
Cost: battery charging version	$2,790	$3,405	$3,650	$4,138	—	$11,800
Warranty (years)	5	5	5	5	5	5


Raum Energy
Raum 3.5
Courtesy www.raumenergy.com


Southwest Windpower
Whisper 500
Courtesy www.windenergy.com


Fortis
Montana
Courtesy www.fortiswind.com

SW Wind Power	Kestrel	Raum	SW Wind Power	Fortis	Evance	Proven Energy
www.windenergy.com	www.kestrelwind.co.za	www.raumenergy.com	www.windenergy.com	www.fortiswind.com	www.evancewind.com	www.provenenergy.co.uk
Skystream 3.7	e400i	Raum 3.5	Whisper 500	Montana	Iskra R9000	Proven 11
113.0	135.0	135.0	176.0	211.0	246.0	255.6
12.0	13.0	13.2	15.0	16.4	17.7	18.0
170	331	170	155	440	660	1,323
914	2,010	2,021	1,474	3,459	3,500	2,773
1,373	2,781	3,213	2,139	4,438	5,030	3,973
1,925	3,807	4,380	2,907	5,443	6,670	5,752
2,594	5,050	5,811	3,749	6,444	9,012	7,358
3,216	5,996	7,447	4,637	7,410	10,590	9,526
3,898	7,230	8,631	5,544	8,315	12,530	11,331
4,575	8,285	10,272	6,445	9,132	14,500	13,606
330	500	350	325	400	230	200
PM	PM	PM	PM	PM	PM	PM
Dynamic brake	Blade pitch	Active brake	Angle furling	Side furling	Blade pitch	Blade pitch
28	24	35	27	25–30	134	27
Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Electric Braking	Electrodynamic Brake	Disc brake
Yes	Yes	Yes	No	Yes	Yes	Yes
—	48	24, 48	24, 36, 48	48	24 – 300	48
Yes	No	Yes	Yes	Yes	MPPT	Yes
Tower (33 ft.)	No	No	No	No	Tower (50 ft.)	Tower (30 ft.)
$9,695	$13,328	$7,000	—	$15,800	—	$38,000
—	$11,178	$7,000	$8,795	$15,800	$18,800	—
5	5	5	5	5	5	5

Courtesy www.evancewind.com

Courtesy www.provenenergy.co.uk

Courtesy www.eoltec.com

Wind Turbine Specifications (continued)

Manufacturer	Eoltec	Endurance Windpower	Bergey Windpower	Bergey Windpower	Fortis
Web site	www.eoltec.com	www.endurancewindpower.com	www.bergey.com	www.bergey.com	www.fortiswind.com
Model	Scirocco	S-343	Excel-R	Excel-S	Alize
Swept area (sq. ft.)	265.0	343.0	380.0	415.0	426.0
Rotor diameter (ft.)	18.4	21.0	22.0	23.0	23.3
Tower-top weight (lbs.)	450	600	1,050	1,050	847
Predicted annual energy output (kWh)					
8 mph	3,496	5,249	3,600	5,000	11,098
9 mph	4,997	7,293	5,400	7,100	14,659
10 mph	6,746	9,498	7,500	9,600	18,456
11 mph	8,687	11,781	9,700	12,700	22,344
12 mph	10,751	14,065	12,100	15,900	26,156
13 mph	12,870	16,282	14,500	19,500	29,728
14 mph	14,983	18,375	16,800	23,300	32,925
Rpm	245	166	310	240	300
Generator type	PM	Induction	PM	PM	PM
Governing system	Blade pitch & stall regulation	Stall regulation	Side furling	Side furling	Side furling
Governing wind speed (mph)	26	—	33	32	25–30
Shutdown mechanism	Dynamic brake (opt. blade pitch)	Disc brakes	Crank out tail	Crank out tail	Electric braking
Batteryless grid-tied version	No	Yes	No	Yes	Yes
Battery voltages	—	—	24, 48, 120, 240	—	48
Controls included	Yes	Yes	Yes	Yes	Yes
Tower or installation included in cost	No	Tower (120 ft.)	No	No	No
Cost: batteryless version	$29,130	$35,000	—	$29,500	$31,100
Cost: battery charging version	—	—	$24,750	—	$31,100
Warranty (years)	5	5	10	10	5


Endurance Windpower S-343

Courtesy www.endurancewindpower.com


Bergey Windpower Excel-R

Courtesy www.bergey.com


Bergey Windpower Excel-S

Courtesy www.bergey.com

Cascade Wind	Proven Energy	WTIC	Gaia-Wind	Halus Power Systems	Endurance Windpower	Northern Power Systems
www.cascadewindcorp.com	www.provenenergy.co.uk	www.windturbine.net	www.gaia-wind.com	www.halus.com	www.endurancewindpower.com	www.northernpower.com
ARE442	Proven 35	31-20	133-11	V-17	E-3120	Northwind 100
442.0	684.5	754.0	1,425.0	2,462.0	3,120.0	3,725.0
23.6	29.5	31.0	42.6	56.0	63.0	69.0
1,600	2,424	2,500	1,984	17,000	8,800	16,100
7,081	10,759	7,295	11,535	37,820	48,145	49,099
9,910	14,826	10,689	17,004	54,966	68,890	69,742
13,198	20,400	14,966	22,962	75,165	91,758	98,996
16,819	25,057	20,066	29,127	97,850	115,746	124,508
20,628	30,895	25,836	35,263	122,375	139,955	158,135
24,483	35,448	32,070	41,167	148,090	163,647	185,793
28,267	40,863	38,552	48,676	174,371	186,254	220,558
150	150	175	56	50	41	Variable 30-60
PM	PM	Brushless alternator	Induction	Induction	Induction	PM
Side furling	Blade pitch	Blade pitch/side face	Stall-regulated airfoil	Motor yaw	Stall-regulated	Electronic stall & dump load
25	25	25.5	—	—	—	—
Dynamic brake	Disc brake	Disc brake	Disc brake	Disc brakes & active yaw	Disc brakes & pitch control	Dynamic & disc brakes
Yes	Yes	Yes	No	Yes	Yes	Yes
—	48	—	—	—	—	—
Yes	Yes	Yes	Yes	Yes	Yes	Yes
No	Tower (50 ft.)	No	Tower (60 ft.) & foundation	No	—	Tower (120 ft.)
$39,600	$79,000	$43,225	$51,652	$110,000	$250,000	$475,000+
—	—	—	—	—	—	—
5	5	1 (5 optional)	2 (5 optional)	1 (5 optional)	5	2 (3+ optional)

Courtesy www.fortiswind.com

Courtesy www.cascadewindcorp.com

Courtesy www.provenenergy.co.uk

Courtesy www.windturbine.net

8-foot diameter and one with a 10-foot diameter might not seem large, but the 25% increase in diameter represents a 56% increase in collector size, with a proportional increase in energy output.

Tower-top turbine weight may give you an idea of turbine durability. Although weight itself doesn't necessarily translate into turbine longevity, a heavier turbine often means a more durable machine.

Predicted annual energy output (AEO) at 8 through 14 mph gives you some general numbers to match to your site's average wind speed and energy needs. Note that all AEOs provided in the table were supplied by the manufacturers. Your turbine's performance at your site may be lower, sometimes significantly. To be conservatively cautious, you may want to multiply the AEOs listed by about 75%. We have no evidence that all manufacturer AEOs are overstated, although some seem to be. It would certainly be better to underpredict AEO and be pleasantly surprised with more electricity than to overpredict AEO and be disappointed.

Be conservative by choosing the next larger turbine when you're not sure of your exact energy use, if the exact size of turbine you need is not available, or if your confidence of your site's average wind speed is shaky. Also, AEOs apply to locations from sea level to 1,000 feet in elevation and must be adjusted for lower air density at higher altitudes. Your installer or turbine manufacturer can help you crunch these numbers.

Rpm is the blade revolution speed at the turbine's rated output. It relates to two characteristics of wind generators: durability and sound production. A slower rotor speed in a given class of turbines will generally mean a longer-lasting turbine—less wear and tear on the rotating parts and less centrifugal force trying to tear the rotor apart. It also usually means a quieter turbine. Note that lower rpm does not mean lower production, nor does higher rpm mean higher production. In both cases, the alternator rpm is matched to the rotor speed to get as much energy out of the wind as possible.

Generator type has to do with how the wind system is interfaced to the utility in grid-tied systems. Permanent-magnet and brushless alternators must interface with the utility through a synchronous inverter with anti-islanding protection. Induction machines do not need inverters, but have their own specialized "controllers" for utility interconnection. In either case, the inverter or controller are specifically matched to the wind turbine and sold with it.

Governing system describes the method the turbine uses to shed excess energy in high winds to protect the turbine from overspeed. Some turbines tilt or "furl" the rotor directly up or to the side, while others furl at an angle. Others use blade pitch control, turning the blades out of their optimum aerodynamic angle so that they don't capture as much energy. Induction machines typically use "stall-regulated blades," meaning they lose aerodynamic lift as the wind speed increases beyond a safe rpm. Blade pitching more reliably protects the wind generator. Due to more moving parts and greater complexity, machines that have this feature cost more than machines that furl or stall regulate.

Governing wind speed is the point at which the turbine starts governing. This is really a range of wind speeds depending on circumstances, and not usually one given wind speed for any given turbine, but convention dictates listing one wind speed. A low governing speed suggests that the turbine designer was conservative, preferring a long-lasting turbine over high peak production in the rare times of high winds. A higher governing wind speed indicates that the turbine may eke out a bit more energy in infrequent and potentially dangerous wind speeds.

Shutdown mechanism refers to the method used to stop the turbine for service, in an emergency, or when you just don't need the energy or want the turbine to run—when on vacation or before an approaching storm, for example. Many smaller turbines have no mechanical means to shut them down. Instead, they rely on dynamic braking (electrical shorting of the windings), which may or may not work in higher winds, depending on the design. Mechanical brakes are usually more reliable than dynamic braking, under which "electric braking" and

"electrodynamic brake" fall. Generally, larger and more expensive wind turbines have more reliability and redundancy built into their shutdown mechanisms and may use more than one braking method.

Batteryless grid-tied tells whether the turbine is available in this configuration—normally the most cost-effective choice. Most systems are configured to be connected to a standard 120 or 240 VAC single-phase utility service connection. A few (typically the larger turbines) are available for connection to a three-phase utility service—this is noted in the AEO row of the table.

If you're determined to have backup for utility outages, some battery-charging turbines can be grid-tied via a battery-based inverter that also synchronizes its output with the utility grid. Check with the manufacturer.

Battery voltages are listed for battery-charging turbines, so you can choose the right turbine voltage for your battery bank. Most modern, whole-house, battery-based RE systems use a 48 V battery bank with an inverter to supply the house with 120 or 240 VAC.

Controls included lists what you get when you buy an off-grid turbine—components such as a controller, a dump load, and metering. If they are not included, don't forget to add them into your cost estimates—these components can be expensive. Grid-tied wind systems are usually sold as a package, with the wind turbine, controls, and inverter.

Cost is the MSRP for the turbine and any included controls or inverter. Remember that the turbine is only one component in the system—and usually not the most expensive one. For smaller systems, a tower can easily exceed the turbine cost. Off-gridders need to include the cost of batteries and inverter. And don't forget the other installation costs: excavation for the foundation; concrete and rebar; possible crane costs; wiring and all electrical components; shipping; taxes; and labor, if the job is contracted. Note that some turbines include tower, wiring, installation materials, and labor costs.

Warranty is an indication of the manufacturer's confidence in the machine, or is set to meet the requirements for state incentive programs. Find out what is covered—usually it's equipment only, and not the costs of replacement shipping or labor, which can be significant. Several of the manufacturers that offer shorter than five-year warranties will extend the warranties for an additional cost.

Understanding Rated Output

"Wind turbine rated output" or "rated kW" is the most misunderstood specification. Unlike PV module ratings that are standardized at 1,000 watts per square meter at 25°C, small wind turbines have no such standard. As a result, one wind turbine might be rated at 10 kW in a 25 mph wind; another might carry the same rating—but at 32 mph. Because the power available in the wind increases with the cube of the wind speed, a turbine rated at 10 kW at 32 mph is analogous to only a 5 or 6 kW turbine rated at 25 mph. In addition, your turbine will see *neither* of these speeds often since the most common wind speeds for residential systems are 10 to 20 mph, with the latter seen only a very small percentage of the time. That's why using rated power as a performance measure is deceptive at best.

Our advice is to ignore the kW rating for wind turbines—unless you are a wind techie using them to categorize physical sizes of the equipment. Instead, look for documentation of the turbine's annual energy output (AEO). Since you are likely to install only one wind turbine, it makes sense to shop for a turbine that will generate the amount of electricity you need each year. The kW rating does not—and cannot—tell you this.

The American Wind Energy Association recently developed a standard for small wind turbines to meet when marketed. In addition to the most important measure—AEO—the standard will include a kW rating, but not at an arbitrary wind speed. The new standard follows the European standard, and turbine kW rating will be at 25 mph (11 m/s). Including the AEO rating will put all turbines on a level playing field once manufacturers certify their turbines to the standard.

Courtesy www.gaia-wind.com

Courtesy www.halus.com

Courtesy www.endurancewindpower.com

web extra

Learn more about wind-electric systems on our Web Extras page: **www.homepower.com/webextras**.

Reputation, Not Sales Pitch

A recent study indicated that there are at least 74 wind-turbine manufacturers in the United States offering products, plus a comparable number of non-U.S. companies that sell in the states. That same study also indicated that only 14 companies "have begun sales," meaning they actually have something to sell other than a computer simulation on their Web site, a prototype, or "vaporware." In other words, only one in five small-wind companies in the states really has a product that is available.

We have been criticized in the past for not including "this turbine" or "that company" in our coverage. We have included all of the U.S. and foreign firms that offer what we understand to be viable products from viable companies—turbines that might make good investments, and generate AEO as claimed.

Don't take our word for it—ask around. Seek out wind turbine owners, especially of the turbines you are interested in purchasing. What are the experiences of end users? A wind turbine is a major expense for most people. You are going to live with this system for the next 20 to 30 years, maybe longer. Would you pick a car off an Internet site without at least kicking the tires? Go out and kick some propellers—and see what will work for you.

Never buy a turbine solely on its up-front cost, but rather on what it will cost you over the long haul—in money, time, and aggravation. Wind-electric systems are the toughest renewable energy systems to maintain, with the highest failure rate. Why? Because wind turbines live in a brutal environment, atop 80- to 140-foot towers that are not readily accessible if you don't climb or if it's -30°F outside with a 30 mph wind howling. Avoid as much pain as possible by buying the highest-quality system you can afford.

Access

Ian Woofenden (ian.woofenden@homepower.com) lives with wind and solar energy, and appreciates reliability even more than he did when he was a young and foolish wind newbie.

Mick Sagrillo (msagrillo@wizunwired.net) is still learning about small wind—and not to stick his finger in the blades—after 30 years and hundreds of wind turbine installations.

SINCE 1987

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