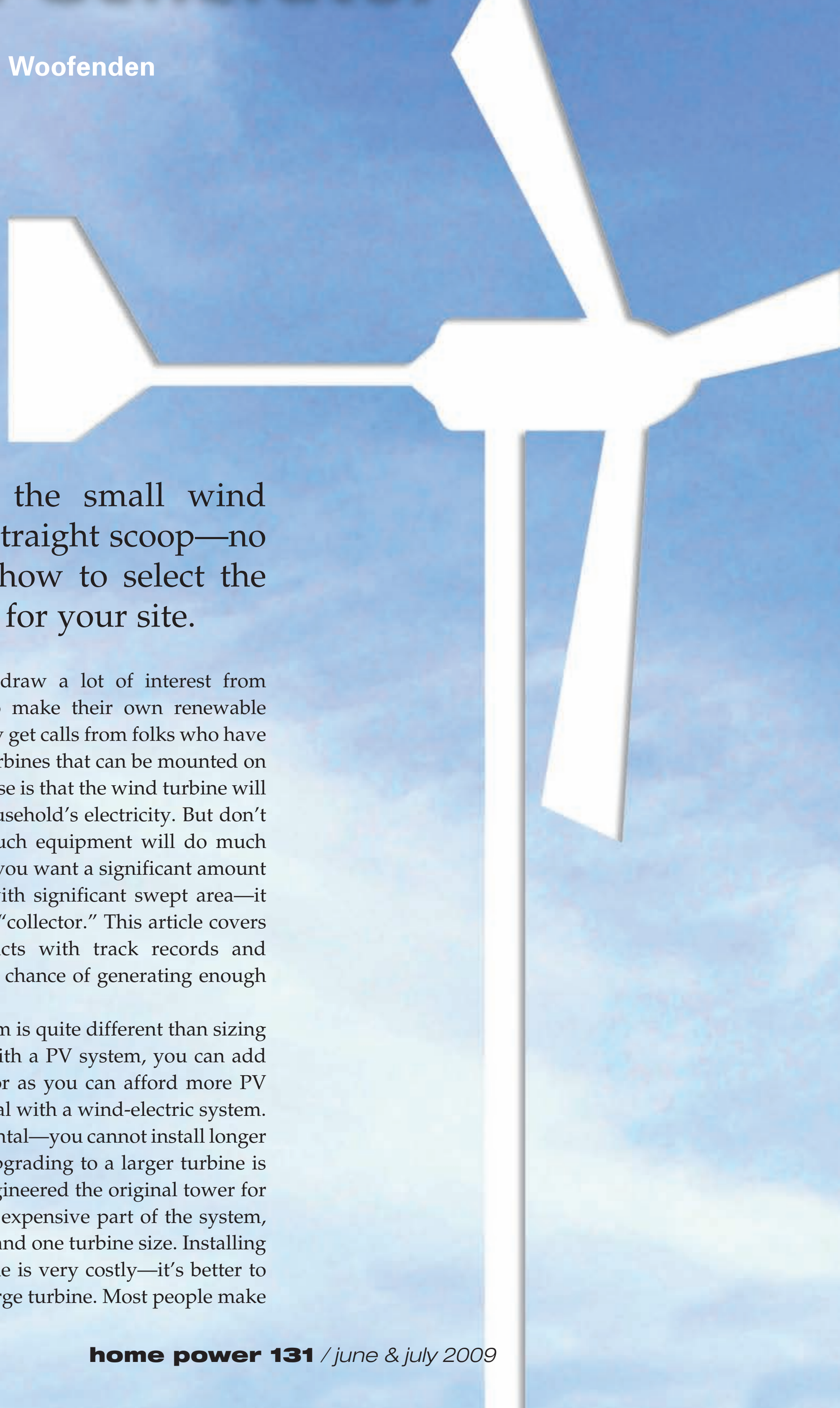
How to Buy
a Wind Generator

by Mick Sagrillo & Ian Woofenden



Two veterans in the small wind industry give the straight scoop—no sugarcoating—on how to select the right wind turbine for your site.

Wind-electric systems draw a lot of interest from people who want to make their own renewable energy. We frequently get calls from folks who have seen advertisements for tiny turbines that can be mounted on a rooftop. For $5,000, the promise is that the wind turbine will provide all or most of your household's electricity. But don't be fooled into thinking that such equipment will do much more than light an exit sign. 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." This article covers the serious machines—products with track records and warranties that have a realistic chance of generating enough energy for a home.

Sizing a wind-electric system is quite different than sizing a solar-electric (PV) system. With a PV system, you can add capacity as your needs grow or as you can afford more PV modules. But this is not practical with a wind-electric system. Theses systems are not incremental—you cannot install longer blades on your turbine, and upgrading to a larger turbine is not a possibility unless you engineered the original tower for it. The tower is often the most expensive part of the system, and is designed for one height and one turbine size. Installing an additional tower and turbine is very costly—it's better to have one tall tower with one large turbine. Most people make a one-time investment and size their wind system to offset a significant portion of their electric bill.

Proper tower sizing is also critical, since the wind resource worth capturing exists well above buildings and other obstructions near the ground. Winds close to the ground are often weak and turbulent, and tall towers are essential to putting wind turbines where they can do their job properly. Contrary to many advertising claims for short towers, a tall tower also makes the system more cost effective. The standard industry rule is that the lowest point of the turbine rotor should be at least 30 feet above anything within 500 feet, and taller is better. On most sites, that translates to towers between 80 and 140 feet tall. Sometimes, even taller towers are required.

The essence of selecting a wind-electric system for a viable site is: "Buy a big collector and put it on a tall tower!" You will not find better advice on effectively capturing wind energy.

Scale

"Small wind turbines" cover an extremely wide range of hardware. On the lower end of the scale, you'll find 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, and generate about 75 kWh per month with a 10 mph average wind speed. Turbines smaller than this are known as "microturbines," which may be appropriate for sailboats, cabins, or other applications that require only a small amount of electricity. These are not covered in this article.

On the upper end of the scale, "small wind turbines" include turbines with rotors up to about 70 feet in diameter (4,000 square feet of swept area). These turbines peak at about 100,000 watts (100 kW), and generate about 8,000 kWh per month with a 10 mph average wind speed. Turbines of this scale are appropriate for farms, small businesses, schools, or institutions that use a lot of electricity.

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

Courtesy www.northernpower.com

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

It's crucial that you know what your energy usage is so you can match the turbine's output to your energy needs. Don't guess: Measure your energy usage via your utility meter or other means. And then do the work to reduce your usage through energy-efficiency and conservation measures. Only then will you be ready to shop for the right-sized wind-electric system.

Reality Check

A current fad in small wind is the promotion of turbines that attach to your roof. However, these are invariably small—3 to 6 feet in diameter—and don't have enough collector area to make much electricity. In addition, many of these designs are half-baked ideas, "concept turbines," or one-off installations set up in an ideal location to attempt to optimize electrical output. Unfortunately, few small-turbine manufacturer hopefuls have any idea how much energy their turbine can generate at a given location for the prospective owner. Phrases like "a homeowner will save 20% to 80% off their electric bills" promise large generation potential with nothing to back up the inflated claims.

Many of these "urban turbines" are being installed in places that are well understood as compromised wind sites. Based on our experience, the 80-year history of small wind-electric turbine designs, and the current laws of physics and fluid dynamics, most of these systems will not work as hoped, nor ever generate meaningful amounts of electricity.

Many of these manufacturers are wildly optimistic in describing their products' performance—some bordering on outright fraud. An egregious example of this is a manufacturer claiming a turbine output of 30,000 kWh per year for a swept area comparable to the smallest of turbines we review in this article. That is an overestimate of at least 10 to 20 times the real production, based on a mathematical analysis of the rotor size and the laws of physics here on Earth that dictate the amount of energy available in the wind.

	XL.1	Whisper 200	Raum 1.3	Kestrel e300i	Proven 2.5 kW
Manufacturer/Importer	Bergey Windpower www.bergey.com	Southwest Windpower www.windenergy.com	Raum Energy www.raumenergy.com	Kestrel www.kestrelwind.co.za	Proven Energy www.provenenergy.com
Rotor diameter (feet)	8.2	9.0	9.5	10.0	11.5
Swept area (square feet)	53.0	63.5	73.0	76.0	103.0
Tower-top weight (pounds)	75	65	86	165	419
Predicted Annual Energy Output (kWh)*					
8 mph	681	794	908	950	1,864
9 mph	968	1,121	1,110	1,291	2,502
10 mph	1,301	1,483	1,539	1,652	3,215
11 mph	1,669	1,865	2,004	2,009	3,988
12 mph	2,061	2,254	2,479	2,341	4,805
13 mph	2,464	2,637	2,940	2,628	5,646
14 mph	2,866	3,005	3,365	2,863	6,492
Rpm	490	900	800	650	300
Generator type	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet
Governing system	Side Furling	Angle Furling	Tilt-Up Furling	Blade Pitching	Blade Pitching
Governing wind speed (mph)	29.0	26.0	23.0	27.0	27.0
Shut-down mechanism	Dynamic Brake	Dynamic Brake	Dynamic Brake	Dynamic Brake	Disc Brake
Battery voltages	24	24, 36, 48	24, 48	12, 24, 48	12, 24, 48
Controls included	Yes	Yes	Yes	No	Yes
Batteryless grid-tie version available	No	No	Yes	Yes	Yes
Phase configuration	Single	—	Single	Single	Single
Tower or installation included	—	—	—	—	—
Battery-based version cost	$2,790	$3,015	$3,650	$4,138	$10,500
Batteryless version cost	—	—	$3,650	$6,440	$12,650
Warranty (years)	5	5	5	2	5

*See page 44 for an explanation of data source/calculation.

Questions to Ask

So how do you compare one product to another? Begin by interviewing wind turbine manufacturers or dealers to assure yourself that what they are offering is more than a half-baked idea frosted with exaggerated and unverified promises. Here are some questions to ask:

How long has the company been in business? While you may get a straight answer, expect some exaggeration that may include how long the company has been *thinking* about offering a wind turbine, as well as designing and testing the early prototypes.

How long has this turbine been offered as a production model, available for sale to ordinary consumers—not in the prototype or beta-testing stage?

How long was the prototype tested? Who did this testing? How many beta versions were sent to the field for feedback?

How many production models have been sold to ordinary consumers? Better yet, how many production models have been sold per year over the sales life of the turbine?

How many of the turbines sold are still running? (Don't laugh—one manufacturer continues to boast about the thousands

ARE110	Skystream 3.7	Kestrel e400i	Whisper 500	Proven 6 kW	Endurance	Scirocco
Abundant RE www.abundantre.com	Southwest Windpower www.windenergy.com	Kestrel www.kestrelwind.co.za	Southwest Windpower www.windenergy.com	Proven Energy www.provenenergy.com	Endurance Wind Power www.endurancewindpower.com	Eoltec www.eoltec.com
11.8	12.0	13.0	15.0	18.0	18.0	18.4
110.0	113.0	135.0	176.0	254.0	256.0	265.0
315	170	331	155	1,323	650	450
1,629	914	1,981	1,474	4,387	1,681	3,496
2,274	1,373	2,781	2,139	6,112	2,848	4,997
3,039	1,925	3,693	2,907	8,055	4,265	6,746
3,894	2,594	2,653	3,749	10,159	5,873	8,687
4,801	3,216	5,587	4,637	12,359	7,604	10,751
5,728	3,898	6,433	5,544	14,588	9,394	12,870
6,643	4,575	7,151	6,445	16,786	11,186	14,983
310	330	500	325	200	206	245
Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Induction	Permanent Magnet
Side Furling	Dynamic Brake	Blade Pitching	Angle Furling	Blade Pitching	Aerodynamic Stall Control	Blade Pitching & Stall Regulated
25.0	28.0	23.0	27.0	27.0	—	26.0
Dynamic Brake	Dynamic Brake	Dynamic Brake	Dynamic Brake	Disc Brake	Disc Brake	Dynamic Brake, Optional Blade Pitching
48	—	48	24, 36, 48	48	—	—
Yes	Yes	No	Yes	Yes	Yes	Yes
Yes	Yes	Yes	No	Yes	Yes	Yes
Single	Single	Single	—	Single	Single	Single
—	—	—	—	—	126 Ft. Tower	—
$11,800	—	$11,178	$7,810	$19,300	—	—
$12,650	$6,212	$13,328	—	$21,850	$39,995	$29,130
5	5	2	5	5	5	5

of turbines they have sold. Mick owns nine of them, all of which are broken and safely packed away in their boxes.)

How frequently has this model seen design changes or updates? What are those changes or updates? When were they incorporated? Were existing owners offered an opportunity to upgrade with the changes? At what cost? If the model has never been updated, why not?

Does the wind turbine meet the proposed American Wind Energy Association Small Wind Turbine Performance and Safety Standard?

What is the annual energy output for the turbine in average wind speeds of 8 to 14 miles per hour? How was this information developed? Has this ever been verified by an independent testing or reviewing agency from real-life installations? Or by a customer with a wind-speed data logger and kilowatt-hour meter? How and where?

Is there a performance guarantee for turbine output? (While such performance guarantees are a standard with wind farm equipment, this is a relatively new concept for

	Ventera VT10-240	Excel-R	Excel-S	ARE442	Proven 15 kW
Manufacturer/Importer	Ventera Energy www.venteraenergy.com	Bergey Windpower www.bergey.com	Bergey Windpower www.bergey.com	Abundant RE www.abundantre.com	Proven Energy www.provenenergy.com
Rotor diameter (feet)	22.0	22.5	22.5	23.6	29.5
Swept area (square feet)	380.0	397.0	397.0	442.0	683.0
Tower-top weight (pounds)	500	1,050	1,050	1,600	2,424
Predicted Annual Energy Output (kWh)					
8 mph	3,588	3,626	3,935	7,081	7,242
9 mph	5,262	5,401	5,663	9,910	11,393
10 mph	7,290	7,454	7,704	13,198	16,282
11 mph	9,661	9,712	10,043	16,819	21,700
12 mph	12,341	12,083	12,650	20,628	27,434
13 mph	15,266	14,475	15,479	24,483	33,284
14 mph	18,347	16,798	18,467	28,267	39,077
Rpm	270	310	310	150	140
Generator type	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet	Permanent Magnet
Governing system	Blade Pitching	Side Furling	Side Furling	Side Furling	Blade Pitching
Governing wind speed (mph)	29.0	35.0	35.0	25.0	25.0
Shut-down mechanism	Dynamic Brake	Crank-Out Tail	Crank-Out Tail	Dynamic Brake	Disc Brake
Battery voltages	—	24, 48, 120, 240	—	Inquire	48
Controls included	Yes	Yes	Yes	Yes	Yes
Batteryless grid-tie version available	Yes	No	Yes	Yes	Yes
Phase configuration	Single	—	Single	Single	Single
Tower or installation included	—	—	—	—	—
Battery-based version cost	—	$24,750	—	Inquire	$41,500
Batteryless version cost	$16,800	—	$29,500	$39,600	$45,700
Warranty (years)	5	5	5	5	5

small wind. Don't expect an affirmative answer on this one, but it's worth asking about.)

How does one shut down the turbine in the event of high winds, when leaving on vacation for a week or so, or to perform maintenance? Is the shutdown mechanism reliable at any wind speed? What are the guidelines for shutting down the turbine in high winds?

What maximum wind speed is the turbine designed for? What about the tower? Has this been certified by a professional engineer?

Has the turbine ever gone through a reliability test? By whom? What was the duration of that test? What were the results?

What is the sound profile for the wind turbine at various wind speeds and distances from the tower? Who performed the acoustic tests?

How long is the warranty period for the turbine? What does the warranty cover? What is excluded? Is an extended warranty available?

What rate of warranty work has this turbine required? (Do not expect an answer to this question, as the response will

WTIC 31-20 Wind Turbine Industries www.windturbine.net	**EW50** Entegrity Wind Systems www.entegritywind.com	**Vestas V-15** Energy Mainten-ance Service www.energyms.com	**Vestas V-17** Halus Power Systems www.halus.com	**Northwind 100** Northern Power www.northernpower.com
31.0	49.0	50.0	56.0	69.0
754.0	1902.0	1964.0	2462.0	3725.0
2,500	5,340	9,920	14,065	16,100
7,295	19,452	22,010	37,820	54,094
10,689	31,856	33,514	54,966	76,375
14,966	47,164	46,543	75,165	102,291
20,066	64,819	60,536	97,850	131,059
25,836	84,195	75,004	122,375	161,780
32,070	104,673	89,546	148,090	193,571
38,552	125,669	103,834	174,371	225,619
175	62	53	45 – 50	59
Brushless Alternator	Induction	Induction	Induction	Permanent Magnet
Blade Pitching & Side Facing	Stall Regulated Airfoil	Motor Yaw	Motor Yaw	Electronically Stalled & Dump Load
25.5	—	—	—	33.5
Disc Brake	Tip Brakes & Park Brake	Motor Yaw & Disc Brakes	Motor Yaw & Disc Brakes	Dynamic & Disk Brakes
—	—	—	—	—
Yes	Yes	Yes	Yes	Yes
Yes	Yes	Yes	Yes	Yes
Single	Three	Single	Three	Three
—	120 Ft. Tower & Installation	110 Ft. Tower & Installation	132 Ft. Tower & Installation	120 Ft. Tower & Installation
—	—	—	—	—
$43,225	$225,000	$180,000	$220,000	$425,000
1 (5 Available)	5	1 (5 Available)	1 (5 Available)	2 (5 Available)

How Did We Choose?

It was a tough job to decide which wind generators to include in this article. There are many models and manufacturers to choose from, but ultimately we wanted to promote machines that will serve *Home Power* readers well.

We've included turbines that meet these criteria:

- Home-, farm-, business-, and school-scale, with swept areas ranging from 50 to 4,000 square feet
- Sold and supported well in North America, with dealer network
- Have third-party verified energy data
- Have published pricing, warranty, and track records
- Authors consider the manufacturers to be long-term players in the small wind industry

—Ian Woofenden & Mick Sagrillo

likely be that this is proprietary information. Regardless, it is worth asking simply for the reaction you will get.)

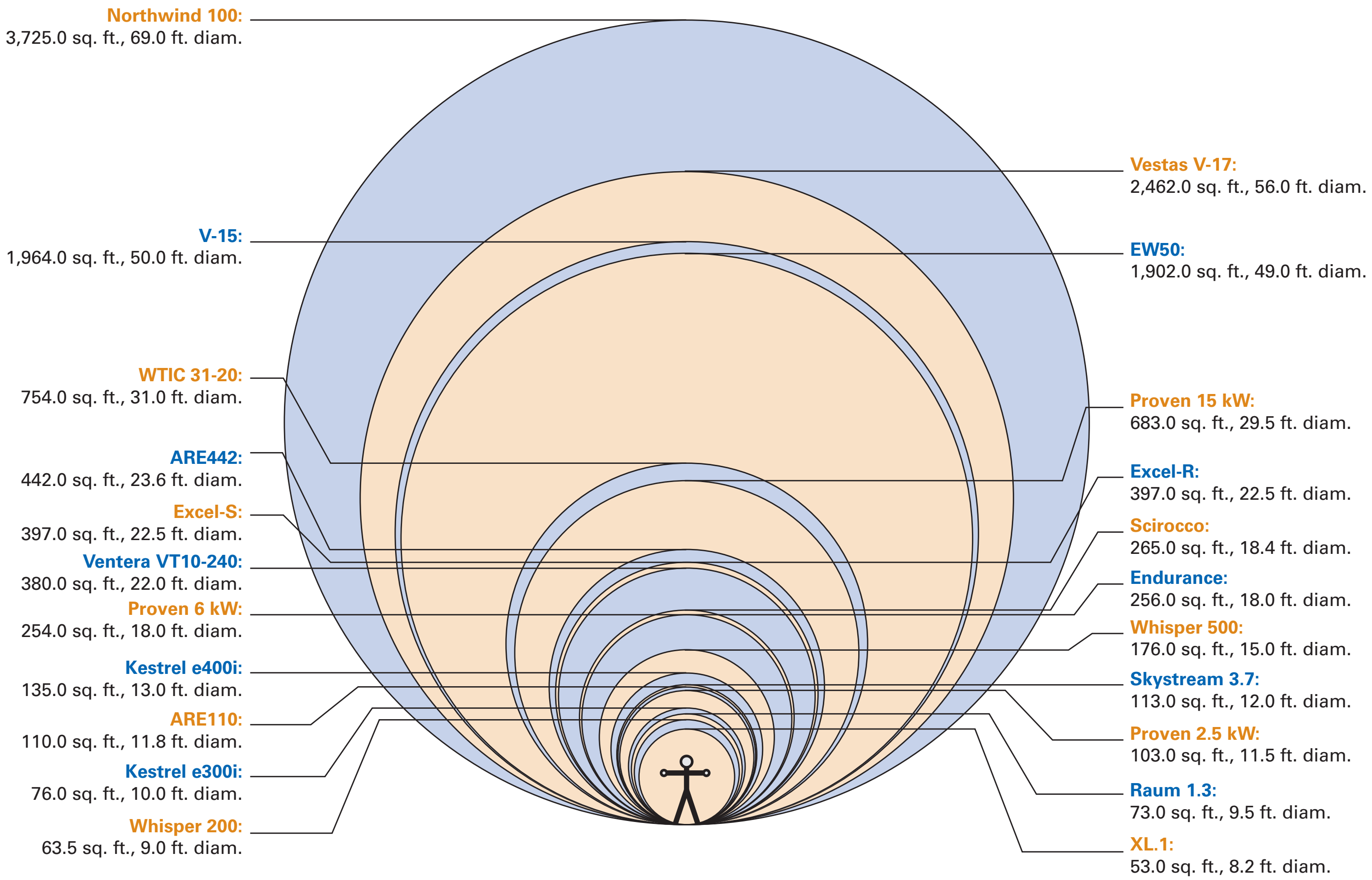
What problems in the field have been identified? How has the company dealt with them? Have any recalls or updates been issued as a result of these problems? Who does the work to remedy the problem? Who pays for this work?

Are there local any installers who can install this wind turbine? Preferably, they can recommend more than one installer so that you have some choices. In addition, an installer who also works with other manufacturers' equipment is preferable, not because you are shopping for a different turbine, but because this gives the installer the advantage of having a well-rounded "education."

Wind Turbine Specifications

The tables show basic specs for viable 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.

Blade Diameters & Swept Area



Manufacturer/importer. In some cases, the wind turbines are either remanufactured or imported. For imported models, the North American contact is listed.

Rotor diameter is a typical identifier for turbines, although using the swept area would be handier. The difference between a turbine with an 8-foot diameter and one with a 10-foot diameter might not seem large, but it represents a 58% increase in collector size, with a proportional potential increase in energy output.

Swept area of the rotor is the area in square feet of the circle "swept" by the blades. This is the "wind collector" and, besides your site's 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 usually are).

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.

Annual energy output (AEO) for 8 to 14 mph gives general energy production to match to your site's average wind speed and your home's energy needs. Your turbine's performance on your site may vary, sometimes significantly. Be conservative by choosing the next larger turbine when you're not sure of your exact energy use or if the exact size of turbine you need is not available. 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. All AEOs in the table are derived by the authors from manufacturers' data using the following assumptions:

- 1,000 feet above sea level
- Derated 5% for inverter-based systems
- 0% derating for induction generators
- No derating for turbulence at the site. (A more accurate estimate would be to derate the AEO by 15% for turbulence at a well-exposed, elevated site; 20% for a site with fencerows and buildings, but average exposure relative to the surrounding terrain; and 25% for a more cluttered site with nearby trees, houses, and other buildings.)

AEO was calculated using the 7th Wind Output Calculator, a version of WindCAD, with performance determined based on the power curves supplied by the manufacturers for this purpose.

Rpm is the blade revolution speed at the turbine's rated output and relates to two factors in wind generators: durability and sound production. In a given class of turbines, a slower

Understanding Turbine Rating

Wind turbine ratings are the most often misunderstood specification in the small wind industry. Unlike PV ratings that are standardized at 1,000 watts per square meter at 25°C, small wind turbines currently have no such standard. As a result, one wind turbine might be rated at 10 kW in a 25 mph wind, while 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 would only be rated at 5 or 6 kW at 25 mph. That's one reason why using rated power as a performance measure is deceptive at best.

Our suggestion is to ignore the kW rating for wind turbines. Instead, look for documentation of the annual or monthly energy output. 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 consume. The kW rating does not and cannot tell you this.

The American Wind Energy Association is developing a standard for small wind turbines to meet when marketed and sold. The standard will include a kW rating at a standard 25 mph, not at an arbitrary wind speed determined by the manufacturer. Much more important will be standardized energy (kWh) estimates, which will put all turbines on a level playing field.

rotor speed will generally mean a longer-lasting turbine—less wear and tear on the rotating parts. 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 is matched to the rotor speed to get as much energy out of the wind as possible.

Governing system describes the method the turbine uses to shed excess energy in high winds to protect the turbine from overspeeding. Some turbines tilt or "furl" the rotor directly up or to the side, while others furl at an angle. Still others use blade pitch control, turning the blades out of their optimum aerodynamic angle so that they don't capture as much energy. Blade pitching more reliably protects the wind generator, but this feature costs more than machines that furl (due to more moving parts and complexity).

Governing wind speed is the point at which the turbine starts governing. A low governing speed suggests that the turbine designer was conservative—more interested in long-term reliability than inflating peak output and squeezing a bit more energy out of infrequent high winds.

Shutdown mechanism is different from governing, and refers to a method to stop the turbine for servicing, in an emergency, or when you just don't need the energy. Many small turbines have no mechanical means to shut them down. Instead, they rely on dynamic braking (electrical shorting of the permanent magnet alternator windings), which does not always work, especially when needed in higher winds. Mechanical brakes are usually more reliable than dynamic braking. Generally, larger and more expensive wind turbines have more reliability and redundancy built into their shutdown mechanisms.

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 are what you get when you buy the turbine—such as a controller, a dump load, and/or metering. These components are specific to the turbine and can be expensive, so don't forget to add them into your calculations if they are not included.

A Vestas V-15 rotor being installed on the turbine by a crew of four.

Courtesy www.seventhgenerergy.org

Batteryless grid-tie tells you whether the turbine is available in this configuration, which is normally the most efficient choice. If you're determined to have protection for utility outages, all battery-charging turbines can be grid-tied via a battery-based, grid-tied inverter. But this approach will incur inefficiencies and additional cost.

Phase configuration. For grid-tied applications, all wind turbines sized up to and including the Jacobs 31-20 are for single-phase electrical services, the standard for homes in the United States. Turbines larger than the 31-20 must all be connected to a three-phase utility service, usually available to larger electrical customers. The Vestas V-15 is available as both single-phase and three-phase.

Cost is for the turbine and any included controls. Remember that the turbine is only one component in the system—and usually not the most expensive one. A tower, batteries, and inverter each can exceed the turbine cost. Note that the EW15, EW50, V-15, V-17, and Northwind 100 turbines also include tower, wiring, all 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 incentive programs in states such as California. Find out what is covered—usually it's equipment only, and not the costs of replacement *labor*, which can be significant. Several of the manufacturers that offer shorter than five-year warranties will extend the warranties for an additional cost.

What we're not listing is rated or peak power. That data is close to meaningless and a distracting marketing ploy. One cannot accurately predict annual energy output (which is what you want to know) from rated power, since two machines with similar peak power can give very different energy outputs. (See "Understanding Turbine Rating" sidebar.)

Newcomers we're not listing. There are several promising "newcomers" to the North American wind scene that deserve a closer look as they further develop their presence or their products. These include Aerostar from Massachusetts, Gaia-Wind (Denmark), Iskra (UK), Fortis (New York), PGE (Canada), and African Wind Power (South Africa).

Selecting Your Turbine

We firmly believe that small wind is part of the energy solution. However, there are numerous companies now in business, selling everything from ideas and investment opportunities to beta systems and equipment they know full well will not or cannot work. This has been spurred on by the state public benefits programs combined with the federal investment tax credits for homeowners. Everybody wants to cash in, and this is a problem.

There are numerous turbine-purchasing opportunities available. One survey of the small wind industry stated that 35 manufacturers or importers now sell 102 different turbines in North America and 11 more plan to sell turbines within three years. One look at the accompanying table reveals far fewer viable choices. Rather than tell you what *not* to buy, we can tell you which turbines we think might make good investments.

To select your turbine, you need two critical numbers. First, you need to know what your wind resource is at "hub height"—where the wind generator will live. You're looking for the average annual wind speed. For most viable home sites, that number will be in the range of 8 to 14 miles per hour. A professional site assessor can give you a good idea of your wind resource, or you can do the research and legwork yourself if you're motivated, educated, and have the time.

The other number you need is the amount of energy you want to generate. You're looking for kWh per day, month, or year. You can find this on your utility bill or by performing a more detailed analysis of your home's loads. From this, you can calculate your annual energy consumption. We encourage you to put time and money into reducing this number instead of installing a wind generator to make energy that will be squandered by inefficient appliances.

With these two numbers, you can begin your search for the *best* wind generator options for your site and match a turbine to your needs at your tower-top average annual wind speed. Notice we didn't say "perfect"—all wind generators will need regular inspections and maintenance, and most wind generators will need repair or replacement over time. These machines have a tough job to do in a very harsh environment.

If you do your homework and choose carefully, you'll have taken the first step toward building your system. Keep in mind that a complete system involves many other components, and *all* are necessary to actually generate wind electricity. Though these systems are complex and can be expensive, designing, installing, maintaining, and living with your own wind-electric system can be entertaining, satisfying, and rewarding.

Access

Mick Sagrillo (msagrillo@wizunwired.net) has pondered wind generators in northeast Wisconsin for nearly 30 years.

Ian Woofenden (ian.woofenden@homepower.com) gets high on life and towers in northwest Washington and beyond.

Recommended Reading:

"How To Buy a Wind-Electric System," 2007 edition, Ian Woofenden & Mick Sagrillo, *HP122*

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

"Wind Electric Systems Simplified," Ian Woofenden, *HP110*

"Wind Generator Power Curves," Ian Woofenden, *HP127*

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

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