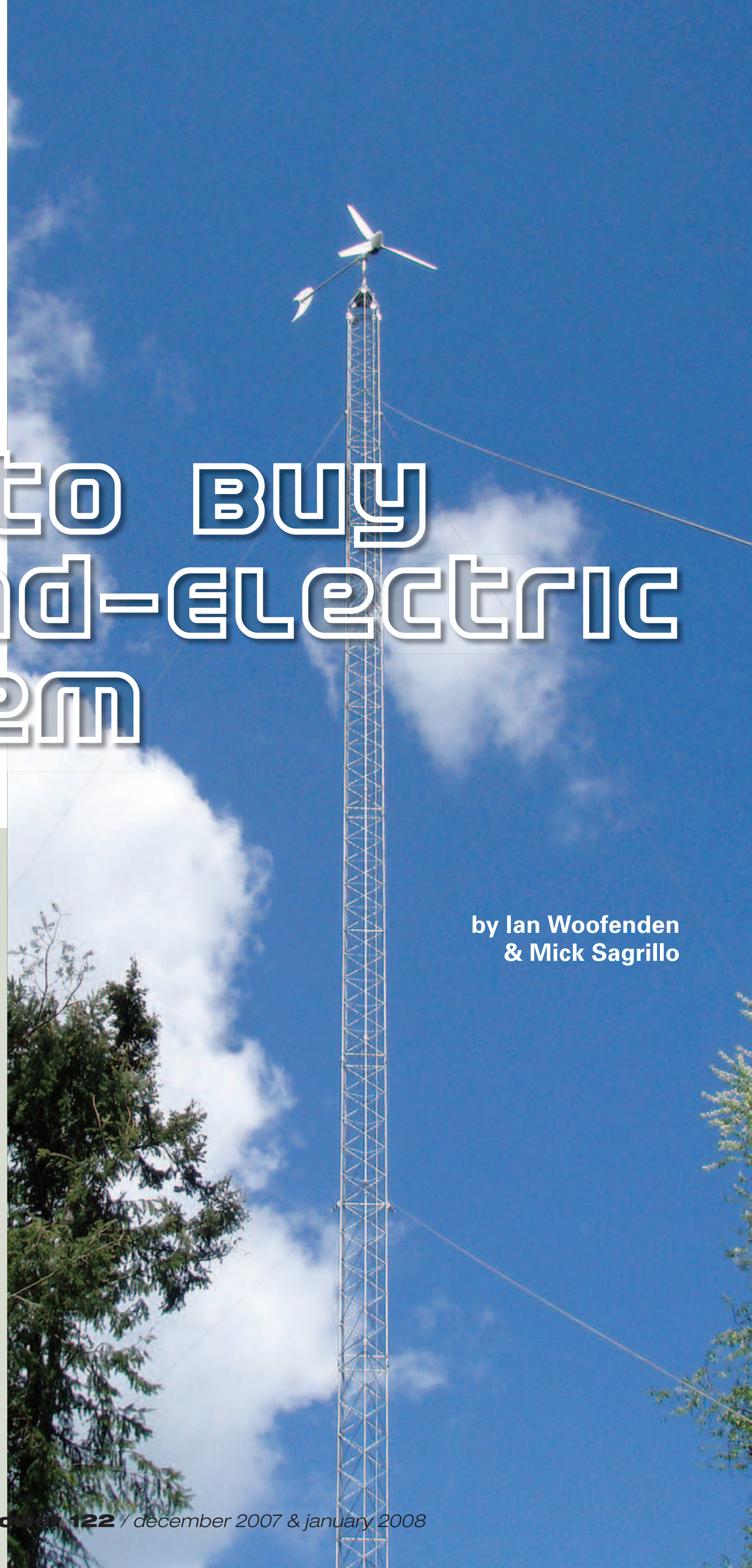
How to Buy a Wind-Electric System



by Ian Woofenden & Mick Sagrillo

You've been dreaming about it for years, and now you're ready to plunk down the cash, put concrete in the ground, and put up a tower. You understand that you need to buy a *whole* system, not just a wind turbine. And you know that there must be an orderly set of steps to follow—a process. So how do you get from Point A (life before wind generator) to Point B (happy user of wind electricity)?

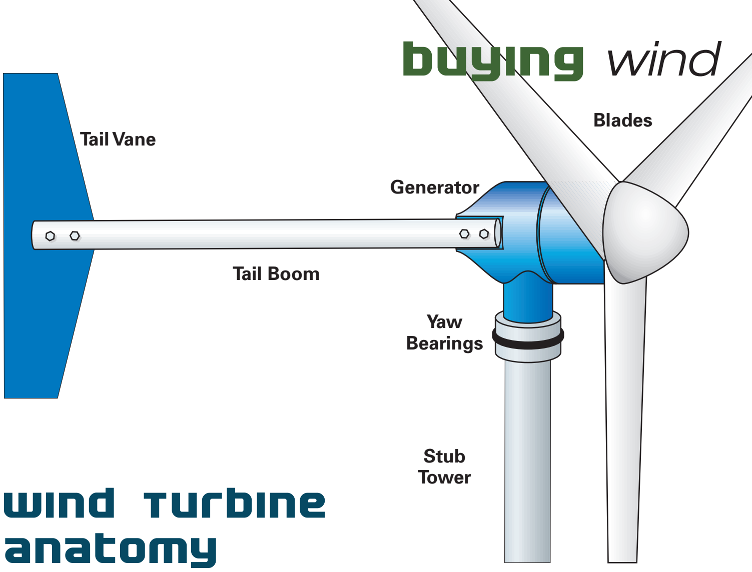
There's a lot of preparatory work to do before you get to see your wind turbine's blades spin. It includes understanding how much energy you need (or want), how to use energy efficiently, how much wind energy you have available at your site, and how to match your needs with your resource. After you've covered this ground, you can start to consider which wind turbine and what balance of system components to buy, and how to install them.

Energy Analysis First

If you want to install a wind-electric system, the first step is to determine how much electricity you use. Electrical energy is measured in kilowatt-hours (KWH), and one way or another, you need to discover how many of them you use per month. You could learn to read your utility meter and check it multiple times over the year. But it's easier to simply contact your utility, which will usually supply a summary of the past year's electrical usage.

If you're planning a new home, you'll need to estimate your electrical use. Reviewing utility bills from your current home may give you a good estimate if you're going to use a similar range of appliances. But in the end, this will only be a guess, since your actual usage may vary considerably.

The goal of the analysis is to come up with the number of KWH per year that you want your wind system to generate. Without this number, you're guessing, and may end up being unhappy with your investment in wind power. If you say you want to make "a lot" of electricity, wind energy experts will tell you that the system will cost "a lot" of money. If you say you want to make 150 KWH per month, your renewable energy installer will be able to suggest a few turbine options and give you a cost in dollars, or at least an informed estimate.



wind turbine anatomy

Efficiency Next

Once you know how many KWH you use or expect to use, you could proceed to "Go" and start shopping for wind-electric system components. But your time and money will be better spent by first focusing on energy efficiency. Typical Americans can reduce their home's energy use by 20% to 50% (or more) by using more efficient lighting and appliances, defeating phantom loads, and simply by being determined to use less.

interpreting wind turbine specifications

The Specifications table on pages 32 and 33 shows basic specs for home-scale wind turbines available and supported in North America. Understanding the specifications will help you make intelligent choices when it's time to buy your turbine.

Manufacturer/importer contact information is included in the Access section at the end of this article. In some cases, the wind turbines are either remanufactured or imported. For imports, the North American contact is listed.

Swept area of the rotor is the area in square feet of the circle "swept" by the blades. This is the "wind collector" area 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 usually are).

Rotor diameter is directly related to swept area. It would be handy to use the square footage of the rotor as an identifier for turbines. More often we use diameter, though it's hard for most people to quickly determine swept area from rotor diameter figures. Although the difference between a turbine with an 8-foot-diameter and one with a 10-foot-diameter might not seem large, it represents a 58% increase in collector size, with a proportional increase in energy output.

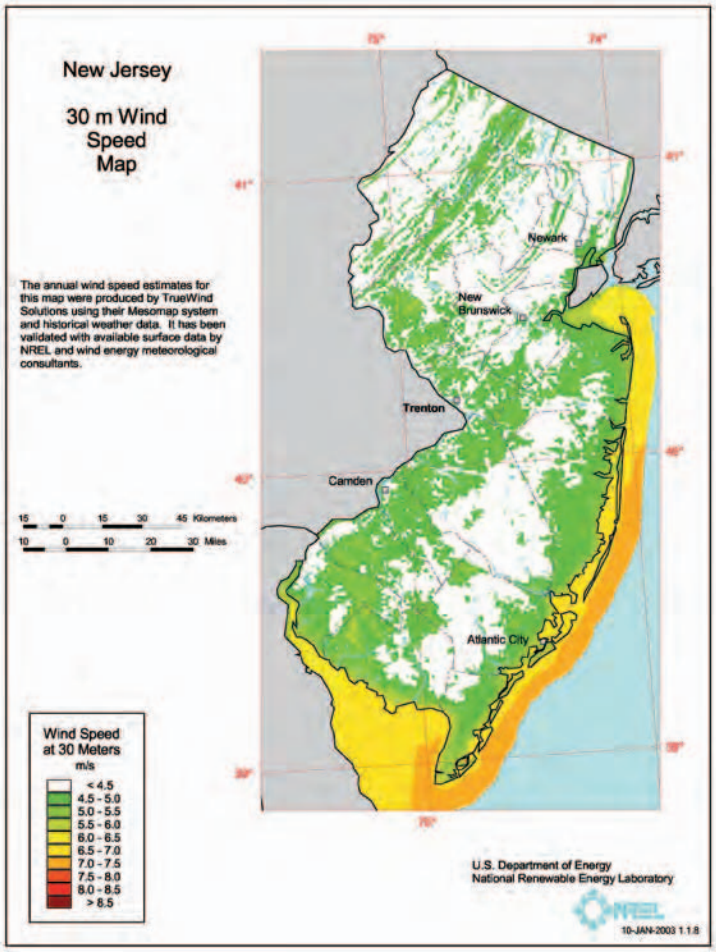
Tower-top weight is necessary to know when choosing your tower, along with swept area. A heavier turbine also may be an indication of a more rugged machine. Though weight itself doesn't necessarily translate into turbine longevity, a rugged turbine that holds up over the long haul often results from a heavier machine.

Annual energy output (AEO) at 8 through 13 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 are either from the manufacturer or derived from manufacturer's data. 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 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.

Rpm is the blade revolution speed at the turbine's rated output and relates to two factors in wind generators: durability and sound production. A slower 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 overspeed. 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. Machines that have this

wind resources map



Reducing your electrical loads will reduce the cost of your system considerably. A smaller wind generator will be needed, and that means you won't need as stout of a tower. The family of an acquaintance recently reduced their electric bill by about 50%—just by using compact fluorescent bulbs and changing their habits. The $60 per month they are saving is going into the kids' college fund—and the youngest has become a real "turn the lights off" fanatic since she saw the savings. They had been using 700 KWH per month, and they're now down to 350 KWH. At an 11 mph average annual wind speed, they just reduced their turbine needs from an Eoltec 6 KW at $25,200 to an ARE 110 at $11,500, a savings of nearly $14,000—plus the savings from the lighter tower needed for the smaller turbine. A smaller battery bank (if batteries are used) may also be in order. All the way down the line, implementing energy-efficiency measures will reduce the size and cost of your wind-electric system.

Resource Analysis

While you're doing the energy-use groundwork, start assessing your wind resource. Home wind-electric systems rarely justify a full-scale wind resource assessment with wind datalogging and analysis, but you must at least get a general idea of the amount of "fuel" you have available before you start reaching for your wallet. It's a little too common to hear of people spending thousands of dollars on a wind-electric system only to discover that reality didn't

specs continued

feature cost more (due to more moving parts and complexity) than machines that furl.

Governing wind speed is the point at which the turbine starts governing. A low governing speed shows that the turbine designer was conservative—more interested in long-term operation than squeezing out a bit more energy from infrequent high winds.

Shutdown mechanism is different from governing, and refers to a method to stop the turbine for service, 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 windings), which does not always work, especially when needed in higher winds. Mechanical brakes are usually more reliable than dynamic braking. Generally, more expensive wind turbines have more reliability and redundancy built into their shutdown mechanisms.

Batteryless grid-tie tells you whether the turbine is available in this configuration, normally the most cost-effective choice. All battery-charging turbines can be grid-tied via a battery-based inverter designed to synchronize its output with the utility grid, if you're determined to have protection from utility outages. But this approach will incur inefficiencies, losses, and additional cost.

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 today 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—whether it includes a controller, a dump load, and metering. These components can be expensive, so don't forget to add them into your calculations if they are not included.

Cost is for the turbine and any included controls, in U.S. dollars. This is only one component in the system, and usually not the most expensive one. A tower, batteries, and inverter each can easily exceed the turbine cost. Note that the EW 15, V-15, V-17, and PGE 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 peak power, since two machines with similar peak power can give very different energy outputs.

support their unscientific analysis that "it's always very windy."

The ideal situation is to have several years of wind data from your site, at the proposed turbine height. But small turbine buyers rarely do this, and for good reasons. Installing a tower and wind datalogging system of this sort might cost half as much as the wind-electric system, as well as delay the project. The going rate for such a monitoring project is about $15,000. More often, if any wind measurement is done, it is of shorter duration and at a lower height. Taking this data and extrapolating to turbine height, while comparing it to data from nearby monitoring sites, might give you a reasonable guesstimate of what to expect. However, this kind of analysis is more complicated than it appears, and is a good place to seek a wind expert's guidance.

The best wind resource data presently available for most states is the high-quality wind maps available on the Wind Powering America Web site (see Access). The few states without wind

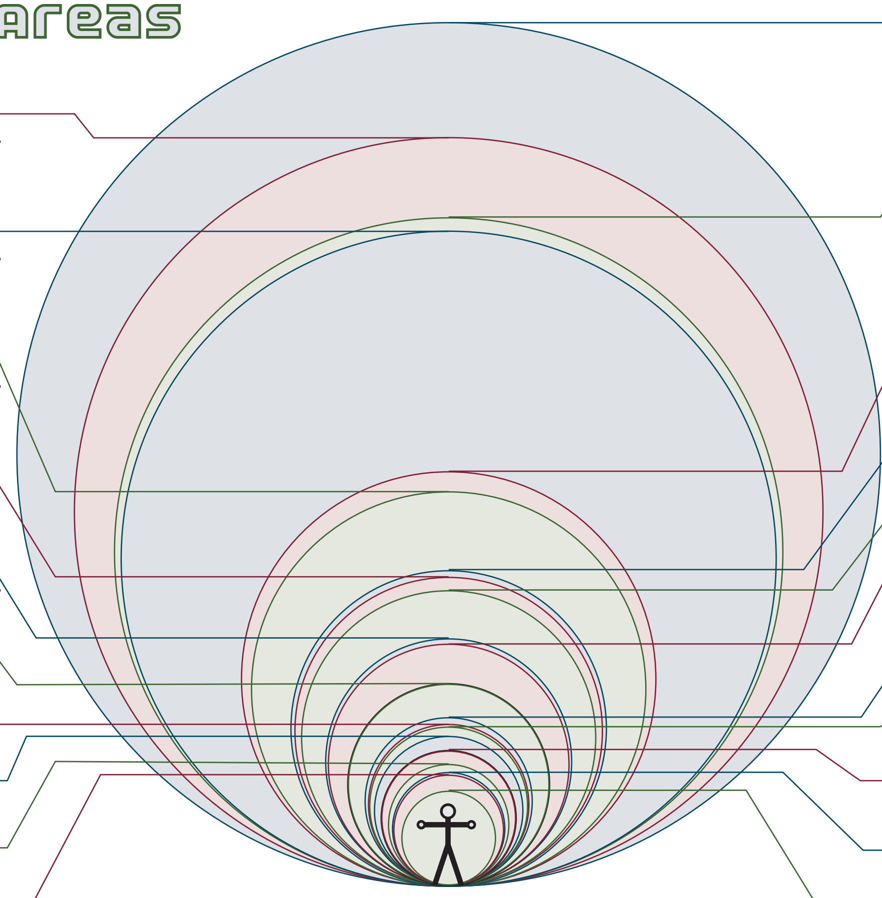
energy expectations

As noted elsewhere in this article, we are not including power (watt) ratings for the wind turbines, since this number is primarily a marketing point, and a confusing one at best. We have included annual energy (kilowatt-hour) outputs from the manufacturers for a range of wind speeds. But how accurate are these? In preparing this article, some manufacturers expressed concern about the possibility of inflated figures, and were worried that their conservative numbers wouldn't compare well.

We considered publishing only energy estimates based on the formulas (referenced in the articles in Access) developed by Jim Green at NREL and Hugh Piggott in Scotland. Though the formulas give more conservative numbers, comparing Green's with the manufacturers' numbers shows wild variation—differences ranged from 1% to 52%! We don't really know which is more accurate, and the formulas make no account for variations in efficiency of different turbines, or for performance variations at different wind speeds. Piggott states that these formulas yield numbers that may be off either way by 20% or more.

What's a wind turbine buyer to do? Until we have a national standard and independent standardized testing of home-scale wind turbines, you must look at the manufacturers' numbers with great skepticism. Apply the formulas to the turbines you're considering (see Access). Ask the manufacturer where their numbers come from. Search the Internet and elsewhere for end users, dealers, and others who have data. The scattered real-world data that is available often varies widely from manufacturers' numbers, a fact that should ring alarm bells in your mind. In the end, you may decide to just buy a larger turbine—being pleasantly surprised with more energy than you expected is much preferred to being disappointed with your investment.

swept areas



specifications for common wind turbines

	Kestrel 800	Whisper 100	BWC XL.1	Proven WT 0.6	Whisper 200	Kestrel 1000	Proven WT 2.5	ARE 110	Skystream 3.7	Kestrel 3000	Whisper 500
Manufacturer / importer[a]	Kestrel	SWWP	Bergey	Proven	SWWP	Kestrel	Proven	ARE	SWWP	Kestrel	SWWP
Swept area (sq. ft.)	38.5	38.5	53.0	55.0	63.5	79.0	97.0	110.0	113.0	120.0	176.0
Rotor diameter (ft.)	7.0	7.0	8.2	8.4	9.0	10.0	11.1	11.8	12.0	12.5	15.0
Tower-top weight (lbs.)	55	47	75	154	65	132	419	315	170	331	155
Annual Energy Output (KWH) at Average Wind Speed (Estimated by Manufacturer)											
8 mph	480	360	660	~504	720	900	~2,004	1,620	1,200	1,560	2,040
9 mph	780	540	1,020	~792	1,080	1,080	~2,472	2,316	2,040	2,100	2,760
10 mph	960	780	1,380	~996	1,500	1,560	~3,516	3,144	2,880	2,760	3,960
11 mph	1,320	960	1,800	~1,356	1,920	1,920	~3,996	4,068	3,720	3,900	4,920
12 mph	1,500	1,200	2,256	~1,488	2,280	2,520	~5,004	5,040	4,560	4,500	6,456
13 mph	1,920	1,500	2,640	~1,752	2,700	2,580	~5,580	6,060	5,400	5,760	7,440
Rpm at rated output	1,000	1,200	450	500	1,100	650	300	340	325	500	900–1,000
Governing system	Blade pitching	Side furling	Side furling	Blade pitching	Side furling	Blade pitching	Blade pitching	Dynamic brake, side furling	Dynamic brake	Blade pitching	Side furling
Governing wind speed (mph)	27	28	29	27	26	21	27	25	30	28	27
Shutdown mechanism	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Disc & dynamic brakes	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake
Batteryless grid-tie	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Battery voltages available	12, 24, 48	12, 24, 36, 48	24	12, 24, 48	12, 24, 36, 48	12, 24, 48	24, 48	48	No	48	24, 48
Controls included	No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes
Cost (battery-based/ batteryless)*	$1,995	$2,475	$2,590	$7,680	$2,995	$2,950	$10,140	$8,870 / $11,500	$5,400	$8,400 / Call	$7,675 / $12,125
Warranty (years)	5	5	5	2[b]	5	5	2[b]	5	5	5	5

[a] See Access for contact info. [b] Extended warranty available [c] Price includes tower & complete installation [d] Inverterless grid-tie, includes 105-ft. tower
*Cost estimates based on 10/2007 pricing

maps have *some* data available, from airports, universities, wind energy users, weather hobbyists, or government agencies. Look around to see what you can find there, but do track down where the data came from, since some data may come from monitoring equipment that is not installed high enough in the wind to produce reliable and useful information.

More subjective analytic methods can be used, though they should be used with a great deal of caution. Long-time residents can give you impressions about how windy it is and has been—apply lots of salt. Your own observations on your property can be better than nothing. And the way vegetation is deformed by the wind can be an indicator of the presence or lack of a wind resource. There's even a scale that correlates tree deformation with wind speed—the Griggs–Putnam Index.

The goal of all this analysis is to come up with your site's average annual wind speed. You want to know this number at your proposed tower height because it represents the "fuel" available to your wind generator to turn into electricity. This is most often in the 8 to 13 mph range for home-scale systems. Sites with an average below 8 mph may not have enough wind energy to justify the investment in a system, unless the site is off-grid and you're replacing engine generator fuel.

Selecting Your Turbine

Now that you know your needs and you've determined your resource, it's time to go shopping. Any wind turbine manufacturer worth buying from can supply you with annual energy output (AEO) numbers for various average wind speeds. You simply need to choose a turbine that will produce the amount of energy you need with your wind resource. If you determine that you want to generate 2,100 KWH per year in your 11 mph average wind regime, check out the manufacturers' output predictions to see what's available.

For off-grid applications, you'll need to consider seasonal energy usage. If your windiest season matches up with your heaviest use of energy, you'll make the most of your system. But in other cases, you may need to oversize your wind turbine to cover the seasonal load variation. And with off-grid systems, you will almost certainly need a second source of energy, like solar electricity.

	Proven WT 6	Endurance	Eoltec 6 KW	VT 10-240	BWC XL-R	BWC XL-S	ARE 442	Proven WT 15[e]	WTIC 31-20	EW 15[f]	V-15[f]	V-17[f]	PGE 20/32[f]
	Proven	EWP	Eoltec	Ventera	Bergey	Bergey	ARE	Proven	WTIC	Entegrity	EMS	Halus	Energie PGE
	254.0	254.0	265.0	380.0	415.0	415.0	442.0	683.0	754.0	1,902.0	1,964.0	2,462.0	3,120.0
	18.0	18.0	18.4	22.0	23.0	23.0	23.6	29.5	31.0	49.0	50.0	56.0	63.0
	1,102	600	445	500	1,050	1,050	1,350	2,425	2,500	5,340	9,920	14,065	7,200
	~5,004	1,843	3,528	3,720	4,080	2,880	7,476	~10,980	9,828	N/A	N/A	N/A	N/A
	~6,768	3,091	4,908	5,520	6,000	4,440	10,440	~16,908	13,920	34,000	38,000	N/A	53,280
	~8,004	4,587	6,816	7,680	7,920	6,240	14,052	~22,320	19,728	50,000	43,000	62,520	64,920
	~11,004	6,268	8,544	10,200	10,560	8,400	17,640	~28,080	25,704	68,000	58,000	81,360	82,296
	~12,996	8,068	10,656	12,960	13,080	10,800	21,972	~33,360	32,292	88,000	64,000	101,640	90,000
	~15,000	9,920	12,756	16,080	15,840	13,560	25,584	~38,880	39,288	110,000	80,000	122,880	107,796
	200	206	245	280	300	300	140	150	175	62	52	45 to 50	32
	Blade pitching	Stall regulated airfoil	Blade pitching	Blade tip pitching	Side furling	Side furling	Dynamic brake, side furling	Blade pitching	Blade pitching, side furling	Stall regulated airfoil	Stall regulated airfoil	Stall regulated airfoil	Electrically stalled, blade pitch
	27	26	26	29	36	36	25	27	25.5	N/A	N/A	N/A	N/A
	Disc & dynamic brakes	Disc brake	Optional blade pitching	Dynamic brake	Crank out tail	Crank out tail	Dynamic brake	Disc, dynamic brakes	Disc brake	Tip brake, electro-dynamic brake	Motor yaw, disc brake	Motor yaw, disc brake	Disc brake
	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	48	No	No	No	48, 120, 240	No	No	48	No	No	No	No	No
	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
	$21,550	$35,000[d]	$25,200	$14,500	$22,900	$27,900	$36,000	$41,350	$33,900	$170,000[c]	$140,000[c]	$180,000[c]	$170,000[c]
	2[b]	5	5	5	5	5	5	2[b]	1[b]	5	1[b]	1[b]	2[b]

[e] Not yet available in U.S. [f] Single-phase and three-phase utility configurations may be available; energy outputs may vary with phase configuration

You'll find only a couple dozen selections in the small wind turbine market, and in any given size range, just one or a few choices. Other parameters may further limit your options, such as system voltage, batteryless versus battery-based machines, and machine durability. If you have to choose between two turbines that straddle your target energy need, buy the larger one—it's much better to end up with more energy than less.

But don't just think about the present. 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 120-foot (or so) towers not readily accessible if you don't climb, or if it's minus 30°F outside with a 30 mph wind.

Avoid these pains by buying the highest-quality system you can afford. Unlike a car, you won't be able to drive your "bargain" down to the dealer for warranty repair. You'll have to pay someone to climb your tower and fix it, or do it yourself—neither is cheap nor easy.

Balance of Systems

A wind turbine is just one part of a *system*. You'll need other components to actually make electricity. Though the wind generator is a critical component to buy well, you should give similar attention to the other parts of the system.

Your tower design will be determined by the weight and swept area of your wind generator, the specifics of your site, and your preferences and budget. (See the tower article referenced in Access for more information.) The best suppliers of wind generators also supply towers, knowing what is appropriate for their machines.

System electronics include charge controllers, inverters, and metering. Sometimes these are included with the turbine, and other times you have some choices—depending on whether your home is off-grid or on, battery-based or batteryless. Make sure you understand the options, as these components must be matched to the turbine and to other parts of your system.

Batteries are a big subject, and if you intend to use them in your system, you should educate yourself. Off-grid users must carefully consider how much storage they want, and whether they will use backup or other energy sources like PV.

caveat emptor

If you cruise the Internet, you may find a turbine that interests you, but is not listed in this article. This article includes only the turbines that we consider reliable at the present time, manufactured or imported, and supported by reputable companies in the small wind industry. There are turbines in development that are not quite ready for production but may become available in the future. There are attractively priced imports that may eventually be considered viable choices. And there is a lot of equipment that is just not ready for prime time yet. Stay tuned—they may make it into future updates.

On-grid users who want utility outage backup must analyze the critical loads they'll want to power. We recommend that you work with an experienced supplier who can help you make the important decisions of battery type, size, and system design and installation.

Other components in a system include wiring, disconnects, overcurrent protection, and grounding. These are issues that require electrical expertise and experience. Either hire a qualified person or take the time to get enough education to do a safe, code-compliant job.

Do It Right!

If you're a novice at electrical and mechanical installations, don't even consider taking on a wind turbine installation yourself. Because of gravity and the tower heights involved, this is serious business—fraught with potential danger to life and limb, as well as the opportunity to make poor design and installation decisions that could affect performance and safety over the life of the system. If you have any doubt about your abilities, hire a professional. Think of this system like an automobile. Most of us don't even do our own auto maintenance; much less would we would even consider designing and building a vehicle. Wind electricity is not an easy DIY project, and may never be, since it requires tall towers to get the turbine up into its "fuel."

Wind-electric systems are not easy, simple, cheap, or perfectly reliable. But if you do your homework, buy quality equipment, and get the help you need, you can end up with a long-lasting and satisfying system. Thousands of families have done just that, and they look up regularly to see their turbine spinning, making electricity from the wind!

Access

Ian Woofenden (ian.woofenden@homepower.com) has been living with wind electricity since the early 1980s, and teaches, consults, and writes about wind energy from a real-world perspective. He is a supporter of *successful* wind-electric systems, steering people away from hype and unrealistic expectations.

Mick Sagrillo consults (currently as the wind technology specialist for Wisconsin's Focus on Energy), teaches, and writes about small wind based on almost 30 years' experience installing and operating nearly all the turbines covered in this article. He reminds folks that it's not about "cheap," but about reliable renewably generated electricity.

Further Reading:

"Wind Turbine Buyer's Guide," Mick Sagrillo & Ian Woofenden, *HP118*

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

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

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

Other Resources:

Explanation of Jim Green's AEO formula can be found at www.nrel.gov/docs/fy07osti/40925.pdf on page 9

Wind Powering America • www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp • Wind resource maps

For more detailed information on the topics raised in this article, see the technical appendix, available at www.homepower.com/promisedfiles

Wind Turbine Manufacturers/Importers:

ARE, Abundant Renewable Energy • www.abundantre.com

Bergey, Bergey Windpower • www.bergey.com

EMS, Remanufactured by Energy Maintenance Systems • www.energyms.com

Endurance, Endurance Wind Power • www.endurancewindpower.com

Entegrity, Entegrity Wind Systems Inc. • www.entegritywind.com

Eoltec, Pine Ridge Products • www.pineridgeproducts.com; Solacity • www.solacity.com

EWP, Endurance Wind Power • www.endurancewindpower.com

Halus, Remanufactured by Halus Power Systems • www.halus.com

Kestrel, Imported by DC Power Systems • www.dcpower-systems.com

PGE, Énergie PGE • www.energiepge.com

Proven, Imported by Alaska RE • www.remotepowerinc.com; Lake Michigan Wind & Sun • www.windandsun.com; Solar Wind Works • www.solarwindworks.com

SWWP, Southwest Windpower • www.windenergy.com

Ventera • www.venteraenergy.cm

WTIC, Wind Turbine Industries Corp. • www.windturbine.net