HOME POWER

THE HANDS-ON JOURNAL OF HOME-MADE POWER

ISSUE #90

August / September 2002

$6.95 U.S.

$10.95 CAN.

Display until October 1

Choosing a Wind Generator





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Mobile Solar-Electric

Choosing a Home-Sized Wind Generator

Mick Sagrillo

You're about to make the big decision: should a wind generator be in your future? You've analyzed your resources, both environmental and monetary, and weighed the pros and cons of having a wind generator. The only question left is: which system should you choose?

I can't answer that question for you. However, I can give you the tools to help you make that big decision. Those tools are the detailed information and specifications for a variety of wind-electric systems, along with some personal observations based on 22 years of working with home-sized wind-electric systems. An appendix with additional discussion and technical commentary can be downloaded from *Home Power's* Web site.

Apples and Oranges (A&O) was originally published in 1993 and updated in 1995 and 1998. Meanwhile, a lot has happened in the small wind turbine industry. One company went out of business, two more entered the field, and one manufacturer bought out a competitor. A number of wind generator models went out of production, and some new models were introduced. While it's been a tumultuous four years since A&O was last published, perhaps the shakeout in the marketplace has at last ended, and things have settled down for the U.S., small wind turbine consumer.

Background

This article will review most of the wind generators that are sold and supported in the United States. One European manufacturer and one African manufacturer are represented by U.S. distributors. A number of new turbines are on the drawing boards, but they are not included here. In addition, at least six non-U.S. manufacturers are considering exporting their wares to the U.S., but have not yet done so.

Several wind turbines currently available on the Internet are not covered by this article. The reason for their exclusion is the outlandish claims made like, "Get a kilowatt for only $250." When compared to other commercially available wind generators, this sounds too good to be true. As the old adage leads us to conclude, it probably is.

As another example, I ordered and paid for a new turbine back on November 1, 2001 from a manufacturer trying to enter the business. As of June 2002, that turbine has not been delivered, and the manufacturer is impossible to get ahold of by phone or e-mail. While their turbine is a promising design, some companies just aren't ready for prime time yet. So, if it's not covered in this article, you'll have to draw your own conclusions.

This article diverges from past articles in covering only "home-sized" wind generators. In the past, A&O has included a large number of microturbines, those wind generators whose primary niche is sailboats, RVs, remote telecommunication sites, and other specialty markets.

While microturbines certainly provide valuable electricity to many remote applications, the intended user of this version of A&O is the homeowner who wants to install a wind-electric system on an adequate tower for either on-grid or off-grid production of substantial amounts of electricity for a home.

A word on failures is in order. You may know someone who has owned one of the wind generators reviewed here, and has experienced a failure of some sort, maybe even a catastrophic failure. Don't prejudge all wind generators based on a few isolated instances. Sure, there have been failures, even with the best of wind-electric systems. Paul Gipe, author of *Wind Power for Home & Business,* reminds us to look only as far as the automotive industry for a comparison. The auto industry is a multibillion dollar industry, spanning more than ten decades. Yet they still don't always get it right, as evidenced by the numerous annual recalls of their products.

What you should be interested in is trends—not the occasional failure. Problems with a wind generator usually occur early in the system's life. All wind generator manufacturers have experienced some failures, as have all other RE equipment manufacturers. Numerous reports of problems with a particular manufacturer should raise a red flag in your mind.

In addition, Joe Schwartz of *Home Power* magazine suggests checking out the customer service reputations of the manufacturers or distributors before buying. Your best bet is to discuss the wind generator you plan to purchase with as many owners as you can, not just your dealer or the manufacturer. Remember that manufacturers and dealers have something to sell. A pleased or disgruntled user doesn't.

The comparison table summarizes all of the various features that you should seriously consider when shopping for your wind-electric system. This article explains how to interpret the information in each row of the table. All of the information in the table (except where noted) has been provided by the manufacturers.

Manufacturer & Model

Contact information for manufacturers and major U.S. distributors listed in the table appears at the end of the article. All of the wind generators presented are new equipment, with the exception of the remanufactured Jacobs Wind Electric generators (short case and long case Jakes). The Jacobs 31-20 is a new machine, based on another Jacobs design.

Even though the old Jacobs has not been made for 50 years, they are still considered by many to be top-of-the-line technology. As such, they have been remanufactured (that is, completely rebuilt with many new components and put back onto the streets with a warranty) by various companies for at least the last 28 years. The Jacobs wind generator is the yardstick by which many judge today's wind equipment.

Swept Area & Rotor Diameter

To help with comparisons, the various wind generator models are listed in ascending order of swept area and rotor diameter. This is a radical departure from the way most manufacturers rate their various turbine models, as well as from previous versions of A&O. You'll see why when you read my comments on cost.

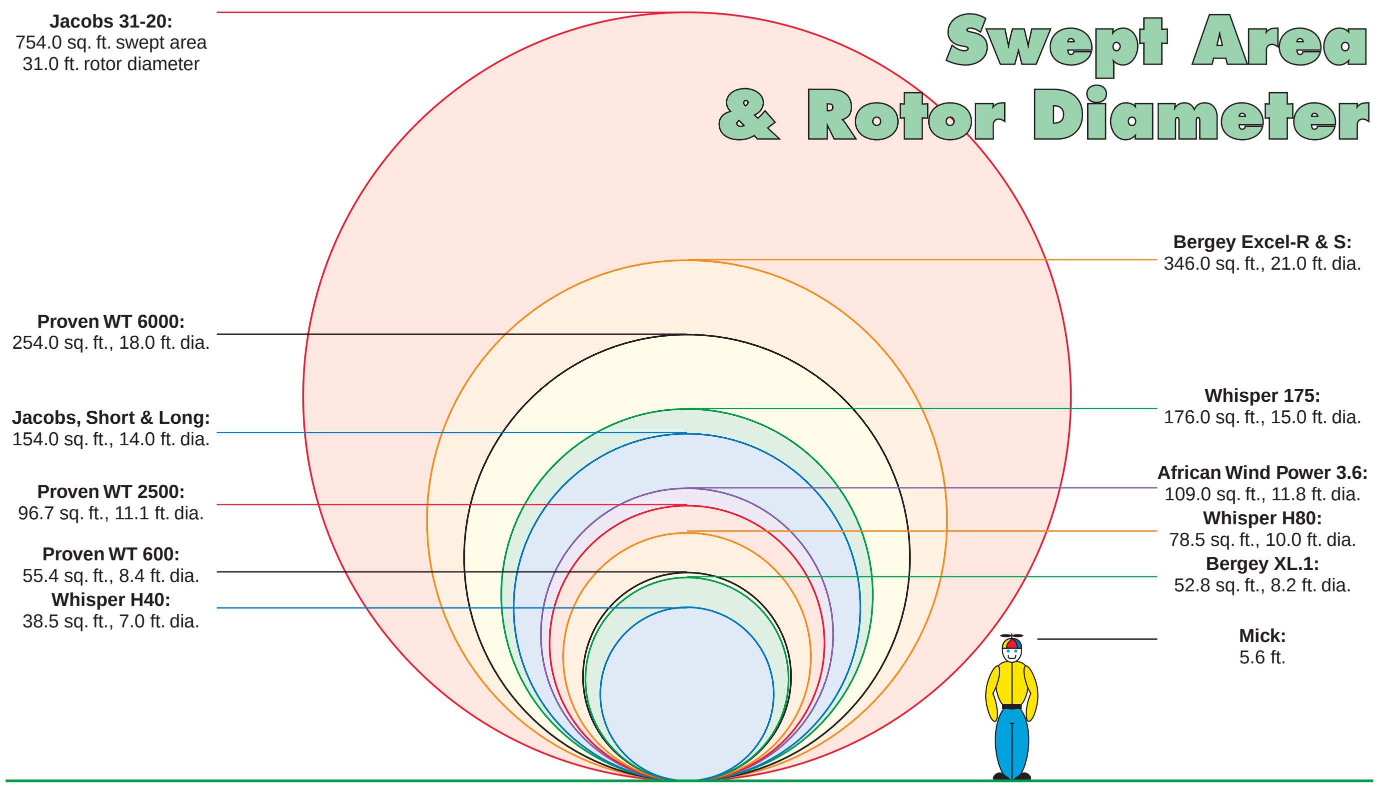
The "rotor" is defined as the entire spinning blade assembly, including the hub to which the blades are attached. The rotor is essentially the collector of the wind generator—gathering fuel in the form of wind, and converting it into electricity by driving the generator.

Think of the rotor in the same terms as we describe a solar water heater. One 4 by 8 solar hot water panel (32 square feet) will collect a certain amount of sunlight and produce a proportional amount of hot water. If you double the number of panels, you double the collector area (now 64 square feet), thereby doubling the amount of sunlight you can collect and the amount of hot water you can produce. Swept area works much the same way.

The rotor converts the movement of air passing through the two or three blades into the rotational momentum that turns the generator, thereby generating electricity. Just like a solar water heater's area, a wind generator's rotor size is a pretty good measure of how much electricity the wind generator can produce. The larger the swept area of the wind generator's rotor, the more electricity it can produce.

While manufacturers rate their products at different peak wattages, the output of a wind generator is primarily a function of its swept area. Other features will influence output, such as high-tech airfoils and more efficient generators. However, they pale when compared to the overall influence of the size of the rotor.

Mike Klemen, a seasoned wind generator user and tester in North Dakota says, "Ultimately, we must realize that energy production comes from square feet." Hugh Piggott of Scoraig Wind Electric in Scotland contends, "Swept area is easier to measure and harder to lie about than performance. What we'd like to know is KWH per month, but until we get more independent testing done, swept area is a good guide." Swept area is *the most* critical feature that will help you compare the output of one wind generator with another.



Cut-in Wind Speed

This is the wind speed at which the wind generator begins producing. For all practical purposes, wind speeds below about 6 to 7 mph (3 m/s) provide little or no usable energy, even though the blades may be spinning. From my perspective, a few watts does not result in usable energy. At best, this minimal output only overcomes the power losses caused by a long wire run or the voltage drop due to diodes.

We are beginning to see high-tech controllers that are able to “store” the small amount of energy available at low wind speeds in the alternator windings. This energy is then pulsed to the batteries in a manner similar to a pulse width modulated charge controller. The new Bergey XL.1 uses such a controller.

Rated Wind Speed

This is the wind speed at which the wind generator reaches its rated output. Note that not all wind generators are created equal, even if they have comparable rated outputs.

There is no industry standard for rated wind speed. “So what?” you ask. The listed wind generator companies rate their turbine output at anywhere from 18 to 31 mph (8–14 m/s). This may not sound like such a big deal until you understand that there is potentially 511 percent more power in a 31 mph wind than in an 18 mph wind.

To drive home the example, let’s use 16 and 32 mph instead of 18 and 31. The power in the wind available to a wind generator is defined by the equation:

$P = {}^{1}/_{2}\ d \times A \times V^3$

Where P is power, d is density of the air, A is the swept area of the rotor, and V is wind speed. Notice that wind speed is cubed. In other words, the equation really reads $P = {}^{1}/_{2}\ d \times A \times V \times V \times V$.

We can simplify the relationship by stating that $P \sim V^3$, that is, P is directly proportional to the cube of the wind speed. If we double the wind speed (V), the power (P) increases by 800 percent. So there is 800 percent more power available to the rotor at 32 mph than at 16 mph. Viewed in reverse, there is ${}^{1}/_{8}$ the power in a 16 mph wind compared to a 32 mph wind.

Let’s say we have two wind generators, both rated at 1,000 watts. Lots-o-Watts is rated at 16 mph and Mighty-Watts at 32 mph. At 32 mph, they’re both producing 1,000 watts, right? But at 16 mph, Lots-o-Watts is still producing 1,000 watts, whereas Mighty-Watts is only producing ${}^{1}/_{8}$ that amount, or a paltry 125 watts!

All of this means that the lower the rated wind speed, the more energy a wind generator will produce, given its rated output. As a consumer, therefore, you should be particularly interested in machines with low rated wind speeds.

Rated Output

This measurement is taken at an arbitrary wind speed that the manufacturer designs for. It tends to be at or just below the governing wind speed of the wind generator. Any wind generator may peak at a higher output than the rated output. The faster you spin a wind generator, the more it will produce, until it overproduces to the point that it burns out. Manufacturers rate their generators at a safe level, well below the point of self-destruction.

You are not necessarily interested in the rated output of a wind generator. A turbine with a high rated wind speed will invariably cost less than one with a lower rated wind speed, for the same rated output. How can this be? Refer back to the power equation mentioned above. A higher wind speed gives a certain wattage to the manufacturer at a smaller rotor diameter, smaller physical size of the generator, and subsequently less weight. All of this means less cost for the manufacturer, and less cost to you.

But remember, it takes a higher wind speed to achieve that rating. In a 12 mph (5 m/s) average wind speed site, you will see 18 mph (8 m/s) winds a mere 3 percent of the time. Not much, you say. But you will see 31 mph (14 m/s) winds for less than 0.2 percent of the time.

Rated output comes to us from the photovoltaic industry, where panels are tested for output at a fixed light intensity and a fixed temperature. The wind industry has no such fixed standards. So, while comparing PVs based on rated wattage makes for great cost comparisons, comparing rated outputs is a poor way to compare wind generators. You are far better off comparing swept areas, or the KWH per month of electricity the different systems will produce at different average wind speeds.

Peak Output

This figure may be the same as rated output, or it may be higher. Wind generators reach their peak output while governing, which occurs over a range of wind speeds above their rated wind speed. Although widely touted by some marketers, it has limited relevance to the buyer. To quote Hugh Piggott, “Peak or rated output specifications for small wind turbines can be red herrings unless you take the rated wind speed into account, and yet these specs are all the customers seem to want to know about.”

Wind turbines are not PVs, don’t operate in the same manner, and should not be rated in the same way. What you should be asking is what wind energy engineer Eric Eggleston asked, “What will this wind generator do at my site in my average wind speed?”

Maximum Design Wind Speed

Bandied about by marketing departments, this term has little bearing on the expected life of a wind generator. Wind generators are designed by engineers, on paper, to survive wind speeds of 120 mph (54 m/s) or more. Unfortunately, wind turbines are not tested for these survival speeds because, quite frankly, it’s a very difficult thing to test for, or to test repeatedly.

Much of the survival speed documentation we have is not from actually testing turbines at those speeds, but from anecdotal situations. Bergey Windpower might boast that their machine survived a hurricane in Kansas that blew Toto away from Dorothy. Great, but what have we learned?

I don’t mean to demean claims like this, but again, they are difficult to test, and everybody supposedly designs their turbines for extreme winds. In fact, Bergey Windpower has actually had very good success designing their turbines to survive such high winds. How? By making their wind generators very robust, very heavy duty.

Does that mean that any turbine will survive a 100 mph (45 m/s) storm? Maybe, maybe not. A 100 mph wind that is coming straight on is fierce, I’ll grant that. But have you ever watched a wind generator sited on a short tower near trees and buildings? The poor thing hunts around continuously, all the while buffeted by the turbulence caused by the short installation height, along with the nearby ground clutter. I have seen more wind turbines destroyed by turbulence than I have seen destroyed in survival-rated high winds.

Furthermore, a 100 mph wind packs an awesome wallop, and while wind generators and their towers can be designed to withstand those winds, there's no guarantee that they will. I live in dairy country in northeast Wisconsin. During our last 100 mph wind, cows were flying through the air! If a cow, or a 2 by 4, or a sheet of plywood hits the wind generator or tower, it will probably crumble, regardless of what wind speed the system was designed for. Flying debris is what takes out many turbines in high winds. You can’t design for flying lumber or livestock.

So what should you look for if not maximum design wind speed? I look for tower top weight, which is a pretty good indicator of reliability. My experience is that heavy duty wind generators survive, and light duty turbines do not. While all of the units listed are rated for 120+ mph (54+ m/s) winds, in-field experience indicates that many of the lighter turbines cannot handle sites with heavier winds or turbulence. Be forewarned! Weight, by the way, will be reflected in the price. You’ll only get what you pay for.




Model	**Whisper H40**	**BWC XL.1**	**WT 600**
Manufacturer	Southwest Windpower	Bergey Windpower	Proven Engineering
Swept area, square feet	38.5	52.8	55.4
Rotor diameter, feet	7.0	8.2	8.4
Cut-in wind speed, mph	7.5	5.6	6.0
Rated wind speed, mph	28.0	24.6	22.5
Rated output, watts	900	1,000	600
Peak output, watts	900	1,800	700
Maximum design wind speed, mph	120	120	145
Rpm at rated output	1,150	490	500
Blade material	Injection molded plastic	Pultruded fiberglass	Polypropylene
Tip speed ratio (TSR)	10.3	5.8	6.7
Generator type	PM 3 AC	PM 3 AC to DC	PM 3 AC
Governing system	Angle governor	Side facing	Hinged blades
Governing wind speed, mph	28.0	29.0	22.5
Shut-down mechanism	Dynamic brake	Dynamic brake	Disc brake optional
Tower top weight, pounds	47	75	154
Lateral thrust, pounds	150	200	450
Battery system voltages	12 to 48	24	12, 24, or 48
Controls included in cost	Controller & dump load	Battery controller	Battery controller
Utility intertie	With batteries	With batteries	With batteries
KWH / month @ 8 mph	30	55	42*
KWH / month @ 9 mph	45	85	66*
KWH / month @ 10 mph	65	115	83*
KWH / month @ 11 mph	80	150	113*
KWH / month @ 12 mph	105	188	124*
KWH / month @ 13 mph	125	220	146*
KWH / month @ 14 mph	155	250	167* (* Estimated by author)
Cost, US$	$1,495.00	$1,695.00	$3,338.00
Cost per sq. ft. swept area, US$	$38.83	$32.10	$60.25
Cost per pound, US$	$31.81	$22.60	$21.68
Weight per swept area, pounds	1.22	1.42	2.78
Weight per TSR, pounds	5	13	23
Years in production	3	1	5
Warranty, years	2	5	2
Routine maintenance	Annual inspection	Annual inspection	Annual inspect & grease
Notes			Downwind




Whisper H80	WT 2500	AWP 3.6	Jake, Short Case
Southwest Windpower	Proven Engineering	African Windpower	Abundant Renewable Energy
78.5	96.7	109.0	154.0
10.0	11.1	11.8	14.0
7.0	6.0	6.0	6.0
26.0	26.0	25.0	18.0
1,000	2,500	1,000	2,400
1,000	2,900	950@24 V; 1,050@48 V	2,400 @ 48 V
120	145	100 Experienced	80 Operating; 100 furled
900	300	350	225
Injection molded plastic	Polypropylene	Fiberglass	Sitka spruce
13.4	4.6	5.5	5.0
PM 3 AC	PM 3 AC	PM 3 AC	DC
Angle governor	Hinged blades	Side facing	Blade pitch governor
26.0	26.0	25.0	23.5
Dynamic brake	Disc brake	Dynamic brake	Folding tail
65	440	250	500
250	1,124	250	750
12 to 48, or 220	24, 48, 120, or 240	12, 24, 48, or 220	24 to 48
Controller & dump load	Battery controller	Battery controller	
With batteries	With batteries	With batteries	With batteries
60	167*	75	240*
90	206*	105	300*
125	292*	130	340*
160	333*	168	410*
190	417*	192	460*
215	465*	226	500*
265	542* (* Estimated by author)	246	550* (* Estimated by author)
$1,995.00	$6,900.00	$2,214.00	$8,700.00
$25.41	$71.35	$20.31	$56.49
$30.69	$15.68	$8.86	$17.40
0.83	4.55	2.29	3.25
5	96	45	100
3	9	3	20
2	2	2	2
Annual inspection	Annual inspect & grease	Annual inspect & grease	Annual inspect & grease
HVLV available	Downwind	HVLV available	Includes stub tower

Model	**Jake, Long Case**	**Whisper 175**	**WT 6000**
Manufacturer	Abundant Renewable Energy	Southwest Windpower	Proven Engineering
Swept area, square feet	154.0	176.0	254.0
Rotor diameter, feet	14.0	15.0	18.0
Cut-in wind speed, mph	6.0	7.0	6.0
Rated wind speed, mph	24.0	27.0	22.0
Rated output, watts	3,600	3,000	6,000
Peak output, watts	3,600 @ 48 V	3,200	6,500
Maximum design wind speed, mph	80 Operating; 100 furled	120	145
Rpm at rated output	325	500	200
Blade material	Sitka spruce	Fiberglass composite	Wood epoxy composite
Tip speed ratio (TSR)	5.0	10.0	5.8
Generator type	DC	PM 3 AC	PM 3 AC
Governing system	Blade pitch governor	Angle governor	Hinged blades
Governing wind speed, mph	27.0	27.0	26.0
Shut-down mechanism	Folding tail	Dynamic brake	Disc brake
Tower top weight, pounds	600	175	948
Lateral thrust, pounds	800	700	2,248
Battery system voltages	24 to 48, or 120	24 to 48, or 220	48, 120, or 240
Controls included in cost		Controller & dump load	Battery controller
Utility intertie	With batteries	With batteries	With batteries
KWH / month @ 8 mph	240*	170	417*
KWH / month @ 9 mph	300*	230	564*
KWH / month @ 10 mph	340*	330	667*
KWH / month @ 11 mph	440*	410	917*
KWH / month @ 12 mph	520*	540	1,083*
KWH / month @ 13 mph	610*	620	1,250*
KWH / month @ 14 mph	700* * Estimated by author	720	1,417* * Estimated by author
Cost, US$	$9,200.00	$5,455.00	$13,100.00
Cost per sq. ft. swept area, US$	$59.74	$30.99	$51.57
Cost per pound, US$	$15.33	$31.17	$13.82
Weight per swept area, pounds	3.90	0.99	3.73
Weight per TSR, pounds	120	18	163
Years in production	20	4	4
Warranty, years	2	2	2
Routine maintenance	Annual inspect & grease	Annual inspection	Annual inspect & grease
Notes	Includes stub tower	2 Blades; HVLV	Downwind

BWC Excel-R	BWC Excel-S	Jacobs 31-20
Bergey Windpower	Bergey Windpower	Wind Turbine Industries
346.0	346.0	754.0
21.0	21.0	31.0
8.0	8.0	8.0
31.0	31.0	26.0
7,500	10,000	20,000
8,500	12,000	20,000
125	125	120
310	310	175
Pultruded fiberglass	Pultruded fiberglass	Fiberglass over foam
7.5	7.5	7.5
PM 3 AC	PM 3 AC	Brushless 3 AC
Side facing	Side facing	Blade pitch governor
34.0	34.0	26.0
Crank-out tail	Crank-out tail	Disc brake
1,020	1,020	2,500
2,000	2,000	2,500
24, 48, 120, or 240	Grid-tie only	Grid-tie only
Battery controller	Utility-intertie inverter	Utility-intertie inverter
Use Excel-S instead	Inverter included	Inverter included
340	240	819
500	370	1,160
680	520	1,644
880	700	2,142
1,090	900	2,691
1,320	1,130	3,274
1,550	1,370	3,872
$19,400.00	$22,900.00	$23,500.00
$56.07	$66.18	$31.17
$19.02	$22.45	$9.40
2.95	2.95	3.32
136	136	333
19	19	20
5	5	1
Inspect every 2 years	Inspect every 2 years	Annual oil, grease, & inspect
		Gear box

Rethinking Cost Comparison

Cost per rated watt has been included in past versions of A&O, but is not included here. Why, you ask? It makes such an easy comparison, you argue.

First of all, there are just too many other expenses involved with installing a quality wind-electric system to just compare one wind generator with another by such a simplistic number as dollars per rated watt. Tower, installation, wire run, and other costs are a significant percentage of the generating system cost. To quote Mike Klemen again, "Dollars per rated watt can be a very misleading way to buy a wind turbine."

PV panels are typically sold by dollars per rated watt. That makes sense, since PV panels all are rated at an industry standard. They are tested at 1,000 watts per square meter at 25°C (77°F). Since one panel is easily comparable to another, based on a set of controlled specifications, it makes sense to compare the cost of one panel to another on a dollars per rated watt basis. However, wind generators don't share any similar specifications, nor are the outputs tested against each other at a standard wind speed.

For example, let's assume we have the two wind generators mentioned previously, Lots-o-Watts, which costs US$1,000, and Mighty-Watts, which costs US$500. Let's also assume that both wind generators are rated at 1,000 watts. Since both turbines have the same rated output, it might appear easy to just divide the cost of the two by their power output to arrive at dollars per rated watt. Right? So, on the surface, Mighty-Watts appears to be the better deal because it only costs US$0.50 per watt compared to the US$1 per watt Lots-o-Watts machine. It's only half the price, you say.

Not so fast. Remember that the Lots-o-Watts manufacturer has rated the wattage of their turbine at a wind speed of 16 mph, while Mighty-Watts rates theirs at 32 mph. What's this mean?

Remember the power equation, $P = \frac{1}{2} d \times A \times V^3$. And remember that we can really simplify the relationship by stating that $P \sim V^3$, that is, power is directly proportional to the cube of the wind speed. When we apply this to our wind generator comparison, we find some startling results.

The Lots-o-Watts 1,000 watt wind genny rated at 16 mph will reach its 1,000 watts at 16 mph. But the Mighty-Watts wind genny needs a 32 mph wind to reach its rated output. That means that the Mighty-Watts wind generator is producing only 125 watts when the Lots-o-Watts is peaking at its 1,000 watts. Now dividing dollars per rated watt doesn't look so good, does it? That's why it's not included here.

No Single Measure
So, if not dollars per rated watt, how do we compare one turbine against another? We can consider some other comparisons, like cost per swept area, cost per pound, weight per swept area, or weight per tip speed ratio, and gain some more meaningful information.

None of these measures is very good by itself. But they all contribute to the big picture. Looking for one perfect measure to compare wind generator cost may be a fool's quest. If we could have one, it would look something like "dollars per KWH per month at X wind speed for X years." But that's a different article.

have low numbers, while the low-speed, heavyweights end up with high numbers. The beasties with high numbers really stand out, don't they?

Years in Production
The length of time each wind generator model has been in production varies considerably. Note that some of these machines have been through numerous changes over their production life, while others have seen relatively few changes.

Warranty
All the manufacturers warrant their products for parts and labor (that is, in-house repairs at their facility) against defects in materials or workmanship. This means that you must return the defective part, or the entire wind generator, to the factory for evaluation and repair or replacement, at the discretion of the factory. Standard practice is that you will pay shipping both ways, just as with any other consumer good.

Warranties do not cover improper installation, neglect, use of unauthorized components, abuse, or acts of god. (This is why you have homeowners' insurance.) The manufacturer's liability is for the defective part only, and does not include incidental or consequential damages.

Routine Maintenance
What needs to be done to the wind generator to keep it in prime operating condition for a long life? Some manufacturers recommend only a visual inspection as their annual maintenance. Several suggest that after you install one of their units, all you need to do is go out to the base of the tower once a year and look up to see if it's still running. That's it for another year! I'm a little more realistic and conservative than that.

The life of a wind generator is directly related to the owner's involvement with the system and its

Rpm at Rated Output
This is the alternator or generator rpm at which rated output occurs. Generally, the smaller the rotor, the faster the blades spin. Generator rpm will have an effect on the amount of noise that the wind generator makes. High rpm wind generators also experience more stress due to centrifugal forces, which are constantly trying to tear the machine apart.

Bearing life is also affected by rpm. Bearing life is dependent on the load on the bearings, plus the speed at which those bearings spin. Light duty, high-speed wind turbines typically have a shorter bearing life than slow-speed, heavier machines—yet another benefit of heavy duty machines.

Blade Material
Within the last eight years, a number of new materials have become available for making wind generator blades.

While more expensive for materials and labor, wood is still considered by some to be the tried and true material of choice for blades. Blades do a lot of flexing. That's what trees did as a side job for most of their lives, as they swayed in the ever-changing breezes. Without question, Sitka spruce is the primo material for wood blades. It has one of the highest strength-to-weight ratios of any material ever used by blade makers, as well as airplane and boat builders.

Wood blades need exceptional paint coatings to protect them, along with a durable leading edge tape to protect the blades from abrasion due to dust and insects in the air. Both paint and leading edges need maintenance. If the paint cracks or the leading edge tape tears away, resulting in wood exposed to the elements, the wood will quickly erode. Moisture entering these areas will cause an unbalanced rotor, stressing the wind generator over time. Wooden blades must be inspected annually, with repairs made as soon as damage is discovered.

Since good wood is ever more difficult to secure, as well as labor intensive to convert into quality blades, most manufacturers have moved away from wood and towards synthetic materials for their blades. A number of synthetics are currently in use.

One good replacement for wood blades is fiberglass over a foam core. The foam gives body to the blade, while the fiberglass covering laid up over the foam results in an extremely durable, smooth blade surface. The leading edge of fiberglass blades is also covered with an abrasion resistant tape to protect it from erosion. This tape needs periodic replacement.

A variation on fiberglass blades is to use a carbon fiber composite for an even tougher blade surface. Yet another variation on fiberglass is to use the material, not on the outside of the blade, but throughout the entire blade. One technique, known as pultrusion, is used by Bergey.

Pultruded fiberglass blades are made in a process that resembles making spaghetti. Spaghetti dough is squeezed through a hole in a die, and then cut to length. Pultruded blades are made by pulling fiberglass through a die along with fiberglass cloth, to make the form of the airfoil. Lengths are cut, the blade butts are fabricated and added to the blades, and, voila—you have Bergey blades.

Plastics are also being used for blades. Southwest Windpower uses injection molded plastic for the blades on their Whisper H40 and H80. Proven Engineering uses a hollow polypropylene blade, another form of plastic. One potential advantage of plastic blades is that they should be relatively inexpensive to replace when that time comes. They're also tough and impervious to water.

Blade color is not included in the table, but should be mentioned. Most blades are white, while a few are colored (blue or gray, for example) to blend in with the sky. Plastic and carbon-fiberglass blades are black. When I first encountered black blades, I thought they would look horrendous on the landscape. Interestingly, a black rotor almost disappears in the sky when spinning.

Tip Speed Ratio (TSR)
The performance of a blade's airfoil (shape) is a function of the ratio of the speed of the tip of a blade to the wind speed. A low-speed blade will have a TSR of 5 or 6 to 1, while a high-speed blade with a TSR of 10 or 11 to 1 will be a less efficient performer.

So why use a high TSR airfoil? Faster spinning blades allow a manufacturer to build a smaller generator (therefore, lighter weight) to get a certain output. However, the faster the blades spin, the more noise they make, especially when governing. A much more detailed discussion of airfoils and tip speed ratio can be found in the A&O '02 Appendix on *HP's* Web site.

"Number of blades" has not been included in this version of A&O, since all of the models listed have three blades except for one, the Whisper 175. While a number of manufacturers have offered two-bladed wind generators in the past, most no longer do. Three-bladed wind generators avoid yaw chatter, which happens when a two-bladed machine yaws. "Yaw" is a term that refers to a wind generator pivoting on its bearings around the tower top to follow the continually changing direction of the wind. See the A&O '02 Appendix on *HP's* Web site for further discussion of this issue.

So, what about the only two-bladed machine on the market, the Whisper 175? In the "Whisper 175 Redesign Status Report" dated February 14, 2002, Southwest Windpower announced that they are redesigning the blade plate for the 175. The blade plate they are considering will be made of heat treated spring steel, like the springs in a car. In theory, the spring plate will flex to absorb some of the yawing vibration to try to mitigate the yawing chatter on the two-bladed Whisper 175.

Regardless of the number of blades on the wind generator, proper blade balancing is critical for a smooth running machine. Severe chattering or a poorly balanced rotor may result in the failure of the wind generator or, in extreme cases, the tower. Look for an unbalanced rotor to show up as tail wagging.

All of the wind generators listed are upwind generators, with the exception of the Proven wind turbines. Upwind generators use a tail to orient the turbine into the wind. Downwind machines have no tails. With a downwind turbine, the wind blowing on the rotor literally pushes it away from the tower, thereby keeping the blades oriented into the wind. While some are biased towards either an upwind or downwind configuration, I think either style works just fine.

Generator Type

Three types of electrical generators are used in wind-electric systems: permanent magnet (PM) alternators, DC generators, and brushless alternators. All three do a fine job of generating electricity.

In general, PM alternators are lighter weight, less complicated, and less expensive to manufacture than either DC generators or brushless alternators. These latter two require more copper and labor to manufacture, but they match the power curve of the rotor more closely.

A more detailed analysis of the pros and cons, plus the various design parameters of the alternators and generators used in wind-electric systems, can be found in the A&O '02 Appendix on *HP's* Web site.

All of the wind generators listed are direct drive units with the exception of the Jacobs 31-20, which uses a 6 to 1 gear box in the design. Direct drive means that the blades directly drive the generator, with no gears. The advantage of gear drive machines is that they can deliver kilowatt-hours at a lower cost than direct drive machines. It's cheaper to add a gearbox than to custom design a large, slow-speed generator. The downside is that gearboxes add lots of moving parts, which translates to more wear and tear, and more maintenance.

Governing System

Governing is necessary for two reasons. The governor protects the generator itself from overproducing and burning out, and it protects the entire system from flying apart in high winds. The governing devices used on all of these wind generators fall into two general categories—those that reduce the area of the rotor facing the wind, and those that change the blade pitch.

Changing the swept area of the rotor is accomplished by tilting the rotor up and out of the wind, side facing the rotor out of the wind by moving it around the tower (Bergey and AWP), or by a combination of the two (Whisper). In all cases, the fixed-pitch rotor is offset either above or to the side of a pivot point. Wind pressure on the offset rotor causes the rotor to pivot out of the wind.

These governing mechanisms are almost a foolproof method of controlling rotor speed. However, they do come at a cost. Once the rotor governs by tilting up or side facing, it often produces very little because it is no longer oriented to the wind. One exception to this is the AWP, which maintains its power curve in the governed position.

Blade-activated governors (all of the Jacobs) work by pitching the blades out of their ideal alignment to the wind. Because these governors operate due to centrifugal forces, the greater the rotor speed, the greater the degree of pitch on the blades. Having more moving parts than either the tilt-up or side-facing mechanisms, they are more complicated governing devices. More moving parts means more parts to maintain or replace sometime in the life of the turbine. However, they offer much better power output in high winds compared to governors that reduce swept area.

Finally, the Proven turbines also govern by pitching the blades, but not only due to centrifugal forces as with the Jacobs. In addition to springs, the Proven blades have a hinge built into the blade butts. In origami fashion, the blades fold and twist in high winds, changing the ideal blade pitch, stalling the blades, and thereby reducing rotor speed. In very high winds, the blades also cone back and away from the tower, cleverly resulting in a reduced swept area.

Governing Wind Speed

The wind velocity at which the governing mechanism is fully operational occurs somewhere between the wind generator's rated power output and its maximum power output.

Wind Generator Noise

Questions often arise about how much noise a particular wind generator makes. For the most part, a well-designed wind generator is relatively quiet. By the time the wind generator is cranking enough to cause some noise, trees are rustling and buildings are rattling as well. But sometimes the wind genny rustles and rattles, too. What can you reasonably expect?

First of all, wind generators are not PVs. PVs just lie on the roof and smile at the sky all day (what a job!). Wind generators are up there hustling in the wind, making lots of motion. Motion is often accompanied by sound emissions, or what some consider noise. From my perspective, wind generators should be seen and not heard.

Two design parameters influence the amount of noise a wind generator makes. The first is tip speed ratio (TSR). Regardless of how they were designed, field observations from numerous owners say that high TSR rotors are noisy. Low TSR rotors, on the other hand, are generally quiet.

Governing also affects the amount of noise a turbine makes, especially when combined with high rotor speed. A high-speed rotor that changes its plane of rotation by side facing or tilting up can create quite a bit of noise. In contrast to side-facing and tilt-back governors, pitching the blades to govern rotor speed is very quiet.

Some permanent magnet (PM) wind turbines seem to reach a breakaway speed, a point where the rpm of the rotor really takes off. This is due to insufficient flux of the permanent magnets relative to the power available at the blades. Once the breakaway speed has been reached and rpm picks up, the rotor can get very noisy, especially when governing. Interestingly, this is not a problem with either the Proven wind turbines, or the AWP wind genny, all of which use PM alternators. The reason? They both use very low-speed alternators and low TSR blades.

So, how quiet are wind generators? The sound can be virtually imperceptible from the surrounding environmental, or ambient, noise. Two turbines fall into this category, the remanufactured Jakes and the AWP. Most people don't even know they are running without looking at them to see if the blades are spinning. Two other turbines operate close to ambient noise level. These are the Jacobs 31-20 and all of the Proven wind turbines.

The two things that all of these quieter turbines have in common is blade-pitch governors (except the AWP) and low operational rpm. While the AWP side faces, it has a very slow-speed rotor. As a result, the AWP is virtually silent when governing.

What about all the rest of the turbines? Bergey has redesigned the blades on their 10 KW Excels, in part to reduce noise. Field reports point to their success in this endeavor. Owners of other turbines listed here have mixed responses about turbine noise. Some report a given model as quiet, while others have less positive things to say about the same genny's noise.

If noise, or rather lack of noise, is as important to you as it is to me, I'd highly recommend that you experience the turbine you plan to buy in operation. Find one, and visit it when a front is approaching, or a thunderstorm is due to arrive. Listen to the turbine when it's running close to governing wind speed, and when it governs. If the noise is acceptable, buy the machine. If not, keep looking and listening.

Shut-down Mechanism

The shut-down mechanism is one of the most important considerations when buying a wind turbine. Stopping the rotor and shutting down the generator is desirable for maintenance or repairs, or whenever else you do not want the rotor to be turning, such as in a storm or when you are away for a period of time—not an unreasonable thing to want.

Shut-down mechanisms fall into two categories, mechanical and electrical. A review of shut-down mechanisms, their failure modes, and the turbines they are on is very revealing in that very few turbines have reliable shut-down mechanisms.

One mechanical shut-down method is to fold the tail so that it is parallel to the blades. All of these systems, except the Proven turbines, have tails. If the tail is parallel to the rotor, the rotor is out of the wind, and it will slow down or stop. Folding the tail involves either cranking or uncranking a cable that will furl or unfurl the tail, depending on the system. The cable winch is at the base of the tower, meaning you must go out to the tower to accomplish the shutdown, which some might consider a drag—like at 3 AM during a thunderstorm.

The Bergey Excel uses a winch and cable to crank the tail out of the wind. Unfortunately, the failure mode, (for example, if the cable breaks), is that the tail goes back into the wind. With the tail back into the wind, the rotor is back in business. By contrast, the remanufactured Jakes use a winch and cable to crank the tail into the wind. The failure mode if the cable breaks is that the tail furls, protecting the machine by taking the rotor out of the wind. Nice! In fact, this the only shut-down mechanism that is foolproof.

Wind Turbine Industries and Proven use a mechanical disc brake that slows the rotor to a stop on their wind turbines. A winch cranks a cable, which engages the brake. In high winds, it can be tough to get the Jacobs 31-20 rotor to stop with the disc brake. Unfortunately, with both the Jacobs 31-20 and Proven, the failure mode (due to a broken cable, for example) is no brake, and the rotor takes off.

The wind generators with mechanical shut-down systems are the remanufactured Jakes, the Jacobs 31-20, the Proven 2500 and 6000, and the 7.5 and 10 KW Bergey Excels. None of the other wind generators listed have mechanical shut-down mechanisms.

Dynamic braking is an electrical brake unique to permanent magnet alternators. If you short out the three phases of a permanent magnet alternator, it is supposed to overpower the ability of the rotor to spin the alternator, and the rotor will come to a stop. This can be done from the comfort of your home by flipping a switch on the control box.

Dynamic braking works in theory, but may or may not work when you most need it, during a thunderstorm with strong winds, for example. Strong winds have been known to overpower a wind generator's dynamically braked rotor. If not caught, this is potentially catastrophic, since all of the wind generator's output must be absorbed by the tower wiring and alternator windings. In fact, all of the small turbines listed with dynamic brakes have failed in 40+ mph (18 m/s) winds while being tested on my or other towers. Some wind turbine owners report dynamic brakes not holding, or not able to stop the blades in wind speeds as low as 20 mph (9 m/s).

Tower Top Weight
This covers everything that goes on top of the tower—generator, governor, rotor, tail, and yaw assembly. You'll notice that there is wide variation in tower top weights. Based on experience, I side with the school of heavy metal, those manufacturers that have proven that the longevity of equipment life is directly related to the beefiness of components.

From my 22 years of experience rebuilding wind generators, I've come to realize that heavy duty, slow-speed wind generators last longer than their lightweight, high-speed cousins. Many people opt for the lighter duty wind turbines because they are invariably cheaper. They generally buy a heavy duty machine the second time around.

Unfortunately, the trend in recent years has been to make everything as cheaply as possible. Performance and reliability of the machine, while important, were overshadowed by initial cost. Why? You, dear consumer. Weight is reflected in cost. So the goal became lightweight, high-speed wind gennys. As failures accrue in the field, some manufacturers are moving back to heavy metal. I welcome that.

Lateral Thrust at the Tower Top
This figure is important for determining tower design specifications and choices. Lateral thrust, a critical horizontal force vector, is a function of swept area of the rotor, the resistance the tower presents to the wind, and wind speed. The greater the lateral thrust, the stronger (and therefore, more expensive) the tower must be, and the larger the concrete footings and guy wires must be.

Battery System Voltages
Available voltages for the battery systems are listed. Remember that line loss is a significant consideration for low voltage systems. Wind generators are rarely sited next to the battery bank. Line loss due to wire run (including the height of the tower) pushes people to choose higher voltages.

Controls Included
Controller, rectifier, brake, and dump load may be standard equipment that is included with the wind generator for interfacing with a battery charging system. Or, if not listed, they may be options available at an additional cost.

Utility Intertie
Currently, only the Bergey Excel-S and Jacobs 31-20 can be directly connected to the utility grid with a synchronous inverter, which is supplied by the manufacturer. Any and all of the other turbines can also be grid tied by using a battery bank in conjunction with a utility-intertie inverter, such as the Advanced Energy's MM series, Trace SW series, and Vanner RE series inverters. Conversion efficiency with these systems varies. Seek opinions from experienced RE dealers so that your expectations are realistic.

At least three of the manufacturers are working with inverter manufacturers to develop batteryless grid-tied inverters. Watch for developments. For example, the Proven WT 2500 and WT 6000 are operating in Europe as grid-tied machines with SMA's WindyBoy inverters. While it is possible to use these inverters in the U.S., I do not know of any batteryless, utility-tied Provens operating here.

Some turbines can also be used for unusual end uses not normally thought of. Direct-coupled water pumping and resistive heating are examples of this. If you have a particular need other than battery charging or a grid-tied application, contact the manufacturers or their distributors.

KWH per Month at Wind Speeds of 8 to 14 Mph
These calculations are included so that you have some

idea of what a wind-electric system will produce at your site's average wind speed. This is how you should size your wind-electric system. You will need to do some homework before these numbers are meaningful to you.

To use this part of the table, you must know the wind speed at your site, based on locally available data. From there, you will need to extrapolate that wind speed to determine the wind speed at your proposed tower height. The procedure for determining your tower top wind speed is laid out in "Site Analysis for Wind Generators," parts 1 and 2, in *HP40* and *HP41,* available on the *Home Power* Web site.

If, for example, you are using 600 KWH per month, check the table to find the turbines that will do the job for you. If you want a wind/PV hybrid system, use your area's average winter wind speeds. For a grid-tied net metered system, the annual average wind speed will do.

For comparisons, a very efficient home or small cabin uses 75 to 200 kilowatt-hours (KWH) per month. The average home (whatever that is) in the U.S. uses 900 KWH per month. An all-electric home consumes from 1,500 to 2,500 KWH per month, as might a small business or farm. The output estimates of the various wind generators are mostly the manufacturers' numbers, not mine. Be aware that your mileage may vary, sometimes considerably. Unfortunately, KWH per month outputs are not independently tested.

Also note that the only true outputs are those listed for the utility-tied applications, the Bergey Excel-S and Jacobs 31-20. Efficiency losses due to the grid-tied inverter are built into these numbers, so the values listed are what you will see at your kilowatt-hour meter. All of the rest of the KWH per month numbers represent DC bus bar values—energy delivered to the battery bank by the wind turbine. You will still need to derate the outputs to 75 to 80 percent to reflect battery efficiency and inverter losses, just as you do with a PV system.

Cost

Note that these costs are only for the wind generator and controller or utility-tied inverter. Check under "Controls included" to determine what controllers or utility-intertie inverters are included in that price.

While this may seem obvious, it never ceases to amaze me that people don't realize that a wind-electric system's installation costs also include such miscellaneous items as shipping for the wind turbine, a tower (of all things) and its shipping charges, maybe batteries and inverter, wiring and electrical components, backhoe and crane costs for larger turbines, concrete and rebar for some towers, sales tax, and labor and travel expenses if the job is farmed out to an installer.

Actually, depending on the system you install, the wind turbine cost represents only 12 to 48 percent of the total installed cost of the wind-electric system. In PV systems, the PV panels represent the major portion of the cost of the generating part of the system. Wind generators are mounted on towers to access their fuel, the wind. While a 120 foot freestanding tower is only about half the cost of a Jacobs 31-20 wind generator, an 80 foot tilt-up tower can cost upwards of five times the price of a Whisper H40!

Cost per Square Foot of Swept Area

Remember that the rotor is effectively the collector for a wind generator. Double the collector size and you will likely double the output. It's actually not quite this simple, since we also have differences such as airfoil efficiencies, alternator efficiencies, tower height, and a myriad of other factors that impact the output of a wind generator. But still, as author Paul Gipe states, "Nothing says more about the output of a wind generator than its swept area. Nothing!"

Unfortunately, like dollars per rated watt, dollars per swept area still rewards lightweight turbines, since it doesn't say anything about the *quality* of the swept area or longevity of the machine. In my experience, quality and longevity cost more, not less.

Cost per Pound

In my bias towards heavy metal, the "beasties" look really good on a dollars per pound basis when compared to the high-speed, lightweight turbines. But perhaps this measure says more about the weight of the machine and less about the cost. Robert Preus of Abundant Renewable Energy points out, "Just throwing weight at a machine doesn't necessarily make it more robust. However, there does seem to be a close correlation."

Weight per Swept Area

This provides an indication of machine robustness, which usually translates into longevity. Notice the range in this relationship, from less than 1 pound per square foot (5 kg per m^2) to more than 4 pounds per square foot (20 kg per m^2). I consider any machine with more than a 2:1 ratio as a heavyweight. I'd categorize machines between 1:1 and 2:1 as medium weight, and anything under a 1:1 ratio as a lightweight. Substitute "heavy duty" for "heavyweight," and you will understand my bias.

Weight per Tip Speed Ratio (TSR)

For a really dramatic comparison, compare weight and rotor speed in the machines listed here. As weight increases, rotor speed and, therefore, TSR decreases. In other words, there is an inverse relationship between TSR and weight. The lightweight, high-speed machines maintenance. If you don't at least periodically inspect your wind generator, you may be picking it up off the ground someday!

What do routine maintenance and annual inspections entail? It doesn't mean that you will never have to replace parts or do some major repairs. Some blades will need repainting and new tape on the leading edge eventually. Bearings wear out and need replacing. High-speed, lightweight machines will need bearings more frequently than the beasties. Some systems, as noted, need annual greasing or oil changes.

In addition, there's what I call "common sense maintenance." Bolts might loosen and need tightening. Adjustments might be needed here or there. It is unrealistic to expect something as complex as a wind generator, operating continuously in a harsh environment, to work flawlessly with no maintenance. If that's your expectation, *don't buy a wind generator!*

Most of the catastrophic failures that I have seen over the years with various systems were due to something as seemingly inconsequential as a bolt loosening and not being attended to. The prudent wind generator owner should thoroughly inspect the complete system once a year at a minimum. Pick a nice fall day before winter hits or a warm spring day before thunderstorm season. As they say, prevention is the best cure! Preventive maintenance becomes more important to you, the owner, as your investment in the system increases.

The designs for today's wind generators have been around for a long time. For example, the side-facing governing mechanism used by Bergey and Wind Turbine Industries was patented in 1898 and originally used on waterpumpers. The tilt-up style of governing was patented in 1931. And the blade-activated governor used on the old as well as the new Jacobs was patented in 1949. (One new development: Proven's origami-like blade governing is a radically new idea in wind turbine design.)

Most of the great strides in reduced maintenance have come, not from new designs, but from new materials. Things like carbon reinforced fiberglass blades, aliphatic resin leading edge tapes, high-tech paints, and any number of synthetic and metal alloys have reduced wind generator maintenance considerably, while improving reliability.

Continuous upgrades by incorporating modern materials in wind-electric system components have helped greatly in the maintenance and reliability arena. The manufacturer who cuts corners by using cheap materials is courting trouble with customers. And homeowners with wind-electric systems that are never inspected and maintained have a time bomb on their hands.

So how long do these things last? That's hard to say. A decade ago, I took down an old Jacobs that had seen 60 years of nearly continuous duty. While the old Jakes were certainly overdesigned and overbuilt wind generators from an era that valued quality workmanship, there are others in that category. These are the heavyweight machines. Experience and reports from the field indicate that the heavies will last at least their 20 year design life, and then can be completely overhauled and given a new life. The lightweights? They may last half that time, or maybe only one quarter. This assumes, however, diligent maintenance.

Notes

Other than being a miscellaneous catchall, one explanation is necessary. Some of the Whisper wind-electric systems and the AWP are available with a high voltage/low voltage (HVLV) option. This means that the wind generator is wound for 240 VAC, and a step-down transformer is included near the controls to step the voltage down to the 12 to 48 VDC battery voltage. Since high voltage results in low current for a given level of power through the wire run, the HVLV option means that you can site your wind-electric system up to a mile away from the battery bank, something unheard of with low voltage DC generation.

Odds & Ends

Power curves for the wind generators, while included in the past, have not been included in this version of A&O. Unless you really appreciate the value of V^3 in the power equation, power curves tend to be meaningless to most consumers. Unfortunately, the only ones who could decipher them were the tech-weenies. If you need a power curve for any reason, check the manufacturer's Web site or product literature.

Home-sized wind generators are not manufactured on an assembly line like other consumer products. Instead, they are made in batches ranging from a handful to a few dozen at a time. As a customer, you need to be a little understanding about the lead time for the machine you order. In all likelihood, your wind generator will not be instantly available unless you happen to find a dealer who has the particular machine you want in stock, a rare occasion. Lead times can vary from three weeks to as long as eight weeks—or eight months.

A few customers (myself included) have had rather bad experiences with unusually long lead times, not only with new machine orders, but with parts and repairs as well. But the manufacturers are pretty good on the whole. They really are concerned about satisfying their customers. After all, without you, they're out of business.

My Choice?

"So, Mick, what do you recommend?" is the most frequently asked question that I get. The answer—it all depends on your situation. I can honestly say that, properly specified and installed, any one of these machines will do a fine job of producing electricity for you for many years, *in the right location.*

Notice the qualifiers. If you install a light duty machine where the winds are severe, even for part of the year, you are asking for trouble. If you install a light duty machine on a short tower where turbulence will be an issue, you are asking for trouble. If you install a machine with lots of moving parts, knowing full well that you have no intention of climbing the tower to do maintenance and repairs, you are asking for trouble. If you never do routine maintenance on your car or house, what makes you think you'll do it on your wind generator?

All of these wind generators have their own personalities and idiosyncrasies, just like the cars we drive. And, just like the cars we drive, they come in a variety of shapes and prices. Finally, just like the cars we choose, they all will get us from point A to point B.

However, not all cars, nor all wind generators, are created equal. As the saying goes, "You get what you pay for." Quality always comes at a price. To quote long-time wind energy user and *HP* editor Ian Woofenden, "Remember, what you want is value. I put high value on low maintenance, long-term performance. You do not want to buy bragging rights to the highest peak output at the lowest price. Instead you want the most energy put into your battery or the grid *for as many years as possible.* That doesn't come cheap."

What do I fly at home? An old 1946 Jake with original bearings does its magic on an 80 foot (24 m) tower, 37 feet (11 m) from our home, backfeeding to the grid. And as soon as I'm done testing some new-to-the-market turbines, the 84 foot (26 m) tilt-up tower behind the shop will see the return of the AWP 3.6. Both are heavy metal and slow speed, and I can't hear them without seeing them—my idea of what a wind generator should be. After that, my next genny will possibly be a Proven WT 6000 or Bergey Excel-S.

With the exception of a hydro plant in a raging flood, a wind generator probably lives in the most extreme environment that nature has to offer. Where I live in northeast Wisconsin, temperatures range from 100°F (38°C) in the summer to -30°F (-34°C) in the winter. Frequent howling winds bring with them dust and insects that sandblast barns over time. The turbulence associated with thunderstorms tries to wrench my turbines off their towers all summer long. We have very high humidity in the summer, and then it's desert dry in the winter.

Winds here are commonly in the 25+ mph (11+ m/s) category, but can sometimes get fierce. At least a half dozen times a year, we get 60+ mph (27+ m/s) winds. Rain, snow, sleet, and hail...you know the rest. All of nature's forces work continuously towards entropy, reducing the wind generator to its lowest elements. It's a really tough world out there!

My preference is definitely towards the "beasties," the slow-speed, heavy metal brutes that seem to be able to take most all that nature can throw at them. These include the AWP 3.6, the remanufactured Jakes, the Provens, the Bergey Excel, and the Jacobs 31-20.

The dollars per pound and weight per TSR are the categories that I look at. I've learned over the years that the cheapest turbine or least expensive dollars per rated watt may be nice for the pocketbook, upfront, but not in the long run. In my experience, inexpensive turbines do not last long. Period. If you are looking for stopgap electricity for a few years, buy cheap.

If price *is* an issue, light duty machines may be an acceptable option in moderate wind locations. According to *Home Power* tech editor Joe Schwartz, "Swept area aside, Whispers hold up OK in most of the installs I've done in moderate wind sites. The failures I see are typically maintenance related—loose bolts."

But if you're going through the effort of installing a wind generator on a quality tower and are in wind for the long haul, buy heavy duty. Heavy duty translates into reliability, pure and simple, regardless of engineered design life, designed maximum wind speed, or the highly touted dollars-per-rated-watt comparison favored by some manufacturers.

What about the rest of the turbines? Well the jury is still out on some of them, like the Bergey XL.1. I have serial number 00001. I have only had that machine for a year, and have flown it for less than that. While the XL.1 looks like a robust machine, I'd like more data points than just my own.

Others, like the Whispers, are definitely light to medium duty wind turbines. Feedback from the field indicates that they do not do well in gusty sites, sites with a lot of turbulence, or sites that experience seasonally or consistently high winds, like more than 25 mph (11 m/s). But if you really have a medium duty wind site, you may get by with a medium duty wind turbine.

Your Choice?

I've given you some tools to help you make an educated choice. Seek out other wind power users and gain from their experiences, both positive and negative. By all means, discuss owner satisfaction with your wind generator dealer. But realize that, just like the manufacturers, dealers are trying to make a living by selling a product. Does that mean they're out to deceive you? No. Just make sure that you digest the field reports, opinions, facts, and figures, and assess your needs and pocketbook, so that you choose the best wind generator for your site, system, and situation.

Access

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