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: 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, specifications, and power curves for a variety of wind systems.

Background

This article is an update of articles originally published in 1993 and 1995, and reflects a number of new wind generators that have come on the market. This article will review all of the commercially available wind systems that are sold in the United States by bona fide manufacturers. An explanation is in order.

In the late '70s and early '80s, the federal and state governments offered tax rebates and incentives to folks who bought renewable energy systems, including wind generators. The objective of the program was to help a fledgling RE industry get off the ground, while weaning the United States from foreign energy supplies by growing more of our own. While the intentions of the tax incentive program were good, the results for the wind industry were nearly devastating. (Similar results occurred with the other renewables, but this article will be restricted to wind electric systems.)

Scores of companies opened shop and began building wind electric equipment. Virtually all of these companies failed. Customers, however, were left with wind generators that didn't work, plus a bad taste in their mouths for RE.

The Vantage Point

Lake Michigan Wind & Sun, which I owned from 1981 through 1997, was (and still is) in the business of rebuilding and making parts for dozens of different models of wind generators that were manufactured by now defunct companies. This involved doing a lot of reverse engineering. That is, identifying system design flaws so we could correct them. By making the necessary upgrades, customers could turn a poorly designed wind generator into a usable piece of equipment.

Because of these services, I developed a unique perspective about where the wind energy marketplace was, and is now. I was in business primarily because all but a handful of wind generator manufacturers failed to build reliable equipment. As we found out about fifteen years ago, anyone can make a wind generator, but making one that will work for years is another matter entirely!

So when I say "bona fide manufacturers," I am not trying to slight anyone. I do, however, want to inform readers who the successful manufacturers are. As a former dealer for all of the U.S. manufacturers represented in this article, I have extensive experience with nearly every wind generator reviewed. While I sold all of the new wind systems available today, I do not have any allegiance to any one manufacturer. I have tried to fairly represent their products in relation to all others reviewed. They are the survivors, because they have learned how to manufacture reliable products that have withstood the test of time.

Addenda

Three more points before we start. First, this article does not include the Survivor or Soma wind generators, both of which have received press in *Home Power* at one time or another. Neither of these machines are commercially available in the United States at this time.

Second, three European manufacturers are represented by U.S. distributors, each of whom is also a factory authorized service center. Therefore, parts and repairs are available for these machines without having to wait for the next boat from the old country.

Third, a word on failures is in order. You may know someone who has, or had, one of the wind generators reviewed here that has suffered 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 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 multi-billion dollar industry which has spanned over nine decades. Yet they still don't always get it right, as evidenced by the numerous annual recalls of their products.

You should be interested in the trends, not the occasional failure. Problems with a wind generator usually occur early in the life of the system. 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. However, as stated earlier, those systems have not been included in this article.

The Envelope, Please!

The following table summarizes all of the various features that you should seriously consider when shopping for your wind system. Explanations for the column headings follow. All of the specifications have been provided by the manufacturers.

Manufacturer and Model: The various models are listed in ascending (i.e., increasing) output to help with comparisons. The abbreviations for the manufacturers or their major distributor, along with their addresses and phone numbers appear 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" models). Even though the old Jacobs has not been made for 45 years, they are still considered by many to be state-of-the-art technology. They have been remanufactured (that is, rebuilt with all new components and put back onto the streets with a warranty) by various companies for at least twenty five years. The Jacobs wind generator is the yardstick by which many judge today's wind equipment.

Rated Output refers to the maximum power output of the system before the wind generator governs. Any wind generator may peak at a higher power 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.

Rated Wind Speed is the wind speed at which the wind generator reaches its rated output. You will notice that there is no industry standard rated wind speed, although most companies rate their systems somewhere around 25 to 28 mph. With regards to rated wind speed, note that not all wind generators are created equal, even if they have comparable rated outputs. In the past, some manufacturers have abused the concept of rated output by fudging on the rated wind speed. For example, a wind generator that reaches its rated power at 50 mph is obviously not the same animal as one which generates a comparable rated output at 25 mph. How often do you see 50 mph winds?

All of this means that the lower the rated wind speed, the more power a wind generator will produce as a function of its rated output. As a consumer, therefore, you should be particularly interested in the highest rated output at the lowest rated wind speed.

Rated Rotation Speed refers to the alternator or generator rpm at which rated output occurs. Generally, the smaller the rotor, the faster the blades spin. Rpm will have an effect on the amount of noise that the wind generator produces. We'll consider noise later.

Cut-in Wind Speed is the wind speed at which the wind generator begins producing power. For all practical purposes, there is no usable power in the wind below about 6 or 7 mph, even though the blades may be spinning. This holds true unless you greatly oversize the rotor to allow it to capture power in low wind speeds. But then you open up all sorts of worm cans when trying to control generator output at higher wind speeds.

While some manufacturers claim outputs at very low wind speeds (3 to 4 mph), from my point of view a few watts does not constitute usable power. At best, this minimal output only overcomes the power losses caused by a long wire run or the voltage drop due to diodes.

Rotor Diameter: The "rotor" is defined as the entire spinning blade assembly. If the wind is the fuel, then the

Model	Aero2Gen	Windstream	Aero4Gen-F	FM 910	WG 913
Manufacturer	LVM	WPS	LVM	ME	ME
Rated Output	50 watts	120 watts	140 watts	90 watts	90 watts
Rated Wind Speed	46 mph	32 mph	46 mph	22 mph	22 mph
Rated Rotation Speed	1200 rpm	1900 rpm	600 rpm	600 rpm	600 rpm
Cut-in Wind Speed	5 to 6 mph	7.5 mph	5 to 6 mph	6 mph	6 mph
Rotor Diameter	1.9 feet	3.25 feet	2.8 feet	3 feet	3 feet
Number of Blades	5	2	6	6	6
Blade Material	Glass reinforced thermoplastic	Epoxy coated basswood	Glass reinforced nylon	Glass reinforced nylon	Glass reinforced nylon
Airfoil	True	True	True	True	True
Lateral Thrust	30 pounds	30 pounds	25 pounds	90 pounds	90 pounds
Governor System	Thermal switch	Tilt-up	Side-facing	Side-facing	None
Governing Wind Speed	None	33 mph	46 mph	37 mph	None
Shut-down Mechanism	None	None	None	None	None
Tower Top Weight	11 pounds	18 pounds	24 pounds	36 pounds	23 pounds
Marine Option Available?	Standard	Standard	No	No	Yes
Generator Type	PM alternator	PM DC generator	PM 3 phase alternator	PM alternator	PM alternator
Cost	$393	$497	$788	$999	$780
Dollars per Rated Watt	$19.65	$4.14	$5.63	$11.10	$8.67
Battery Systems (voltages)	12 or 24	12	12–36	12 or 24	12 or 24
Utility Intertie Available?	No	No	No	No	No
Resistance Heating?	No	No	No	No	No
Water Pumping?	No	Yes	No	Yes	Yes
Est. Mo. Energy @ 10mph (CF)	4 kWh (3%)	11kWh (13%)	10 kWh (10%)	15 kWh (14%)	15 kWh (14%)
Est. Mo. Energy @ 12mph (CF)	5kWh (4%)	17 kWh (20%)	15 kWh (15%)	22 kWh (20%)	22 kWh (20%)
Warranty	3 years	2 years	3 years	1 year	1 year
Years in production (business)	30 years	24 years	30 years	20 years	20 years
Routine Maintenance	Annual inspection	Annual inspection	Annual inspection	Visual inspection	Visual inspection
Controls	Optional	Optional voltage regulator	Optional	Purchased separately	Purchased separately
Notes	Non-governing model				Non-governing model







Aero4Gen	Aero6Gen-F	Aero8Gen-F	AIR	Aero6Gen	Mariner H500	Windseeker 502
LVM	LVM	LVM	SWWP	LVM	WPT	SWWP
280 watts	280 watts	280 watts	300 watts	420 watts	500 watts	500 watts
70 mph	46 mph	29 mph	28 mph	52 mph	28 mph	30 mph
950 rpm	600 rpm	600 rpm	2000 rpm	750 rpm	1700 rpm	2000 rpm
5 to 6 mph	5 to 6 mph	5 to 6 mph	6 mph	5 to 6 mph	7.5 mph	5 mph
2.8 feet	4 feet	5 feet	3.75 feet	4 feet	5 feet	5 feet
6	6	3	3	6	3	2
Glass reinforced nylon	Glass reinforced nylon	Laminated wood	Carbon reinforced thermoplastic	Glass reinforced nylon	Injection molded polycarbonate	Basswood
True	True	True	True	True	True	True
100 pounds	50 pounds	75 pounds	150 pounds	120 pounds	70 pounds	100 pounds
None	Side-facing	Side-facing	Aeroelastic Twist	Self-limiting windings	Tilt-up	Tilt-up
None	46 mph	29 mph	48 mph	None	28 mph	35 mph
None	None	None	Dynamic brake	None	Dynamic brake	none
19 pounds	35 pounds	40 pounds	13 pounds	28 pounds	29 pounds	20 pounds
Standard	No	No	Yes	Standard	Standard	Yes
PM 3 phase alternator	PM 3 phase alternator	PM 3 phase alternator	PM alternator	PM 3 phase alternator	PM 3 phase alternator	PM alternator
$612	$1,086	$1,437	$550	$864	$1,390	$875
$2.18	$3.88	$5.13	$1.83	$2.06	$2.78	$1.75
12–36	12–48	12–48	12 or 24 or 48	12–48	12–48	12 or 24 or 48
No	No	No	No	No	No	No
No	No	No	No	No	No	No
No	No	No	No	No	No	DC
10 kWh (5 %)	20 kWh (10%)	30 kWh (15%)	35 kWh (16%)	20 kWh (7%)	36 kWh (10%)	60 kWh (17%)
15 kWh (8%)	30 kWh (15%)	41 kWh (20%)	43 kWh (20%)	30 kWh (10%)	60 kWh (17%)	90 kWh (25%)
3 years	3 years	3 years	3 years	3 years	2 years	2 years
30 years	30 years	30 years	13 years	30 years	9 (20) years	13 years
Annual inspection	Annual inspection	Annual inspection	None recommended	Annual inspection	Annual inspection	None recommended
Optional	Optional	Optional	Built-In regulator	Optional	Included	Built-in regulator
Non-governing model				Non-governing model		

Model	Windseeker 503	Whisper 600	WT 600	Wind Baron 750	BWC 850
Manufacturer	SWWP	WPT	PE	WSW	BWC
Rated Output	500 watts	600 watts	600 watts	750 watts	850 watts
Rated Wind Speed	30 mph	25 mph	22 mph	30 mph	28 mph
Rated Rotation Speed	2000 rpm	1050 rpm	500 rpm	1100 rpm	520 rpm
Cut-in Wind Speed	5 mph	7 mph	5 to 6 mph	5 to 7 mph	8 mph
Rotor Diameter	5 feet	7 feet	8.4 feet	6.17 feet	8 feet
Number of Blades	3	2	3	3	3
Blade Material	Basswood	Injection molded polycarbonate	Fiberglass epoxy	Basswood	Pultruded fiberglass
Airfoil	True	True	True	True	Single-surface
Lateral Thrust	100 pounds	150 pounds	450 pounds	150 pounds	240 pounds
Governor System	Tilt-up	Angle	Hinged Blades	Tilt-up	Side-facing
Governing Wind Speed	35 mph	28 mph	22 mph	35 mph	35 mph
Shut-down Mechanism	none	Dynamic brake	None	Dynamic brake	None
Tower Top Weight	23 pounds	40 pounds	165 pounds	38 pounds	86 pounds
Marine Option Available?	Yes	Yes	No	Standard	Yes
Generator Type	PM alternator	PM 3 phase alternator	PM 3 phase alternator	PM 3 phase alternator	PM 3 phase alternator
Cost	$1,075	$1,190	$3,565	$1,995	$2,195-$2,375
Dollars per Rated Watt	$2.15	$1.98	$5.94	$2.66	$2.58-$2.79
Battery Systems (voltages)	12 or 24 or 48	12–240	12 or 24 or 48	12–48	12 or 24 or 48
Utility Intertie Available?	No	No	Optional	Optional	No
Resistance Heating?	No	No	Yes	Yes	No
Water Pumping?	DC	No	DC	DC	No
Est. Mo. Energy @ 10mph (CF)	60 kWh (17%)	63 kWh (16%)	62 kWh (14%)	70 kWh (13%)	80 kWh (13%)
Est. Mo. Energy @ 12mph (CF)	90 kWh (25%)	102 kWh (25%)	124 kWh (28%)	108 kWh (20%)	122 kWh (20%)
Warranty	2 years	2 years	2 years	1 year	2 years
Years in production (business)	13 years	9 (20) years	6 (16) years	7 (20) years	19 years
Routine Maintenance	None recommended	Visual inspection	Annual inspection	Visual inspection	Visual inspection
Controls	Built-in regulator	Included	Controls not included	Included	Included
Notes			Downwind		







Whisper H900	Whisper 1000	BWC 1500	Whisper H1500	Jacobs Short	WT2500	Jacobs Long
WPT	WPT	BWC	WPT	LMW&S	PE	LMW&S
900 watts	1000 watts	1500 watts	1500 watts	1500-2400 watts	2500 watts	2400-3600 watts
28 mph	25 mph	28 mph	28 mph	18 mph	26 mph	24 mph
1150 rpm	850 rpm	480 rpm	900 rpm	225 rpm	300 rpm	275 rpm
7.5 mph	7 mph	8 mph	7.5 mph	6 mph	5 to 6 mph	6 mph
7 feet	9 feet	10 feet	9 feet	14 feet	11.1 feet	14 feet
3	2	3	3	3	3	3
Injection molded polycarbonate	Fiberglass	Pultruded fiberglass	Fiberglass	Sitka spruce	Polypropylene	Sitka spruce
True	True	Single-surface	True	True	True	True
200 pounds	250 pounds	375 pounds	350 pounds	750 pounds	1124 pounds	800 pounds
Angle	Angle	Side-facing	Angle	Blade-activated	Flexible blades	Blade-activated
28 mph	27 mph	30 mph	28 mph	18 mph	27 mph	24 mph
Dynamic brake	Dynamic brake	Folding tail	Dynamic brake	Folding tail	Manual caliper brake	Folding tail
55 pounds	65 pounds	168 pounds	77 pounds	450 pounds	440 pounds	550 pounds
Yes	Standard	Yes	Yes	Yes	No	Yes
PM 3 phase alternator	PM 3 phase alternator	PM 3 phase alternator	PM 3 phase alternator	DC generator	PM 3 phase alternator	DC generator
$1,590	$1,990	$4,950-$5,395	$2,690	$6,000	$6,030	$7,000
$1.77	$1.99	$3.30-$3.60	$1.79	$2.50-$4.00	$2.41	$1.94-$2.92
12–48	12–240	12–120	24–240	24–48	24 or 48 or 120	12–200
No	Available	Available	Available	Yes	Optional	Yes
No	No	Possible	No	Yes	Yes	Yes
No	No	AC	No	DC	DC	DC
65 kWh (10%)	105 kWh (14%)	125 kWh (12%)	108 kWh (10%)	250 kWh (18%)	231 kWh (13%)	340 kWh (16%)
109 kWh (17%)	161 kWh (22%)	220 kWh (20%)	181 kWh (17%)	440 kWh (30%)	351 kWh (19%)	520 kWh (24%)
2 years	2 years	2 years	2 years	2 years	2 years	2 years
9 (20) years	9 (20) years	19 years	9 (20) years	18 years	6 (16) years	18 years
Annual inspection	Annual inspection	Visual inspection	Annual inspection	Tower top inspect & grease	Annual inspection	Tower top inspect & grease
Included	Included	Included	Included	Purchased separately	Controls not included	Purchased separately
	HV/LV option available		HV/LV option available	Remanufactured unit	Downwind	Remanufactured unit

Model	Whisper 3000	Whisper H4500	WT6000	BWC Excel	Jacobs 29-20
Manufacturer	WPT	WPT	PE	BWC	WTIC
Rated Output	3000 watts	4500 watts	6000 watts	10000 watts	20000 watts
Rated Wind Speed	25 mph	28 mph	22 mph	27 mph	25.5 mph
Rated Rotation Speed	500 rpm	550 rpm	200 rpm	350 rpm	175 rpm
Cut-in Wind Speed	7 mph	7.5 mph	5 to 6 mph	7 mph	8 mph
Rotor Diameter	14.8 feet	14.8 feet	18 feet	23 feet	29 feet
Number of Blades	2	3	3	3	3
Blade Material	Fiberglass	Fiberglass	Wood	Pultruded fiberglass	Sitka spruce
Airfoil	True	True	True	Single-surface	True
Lateral Thrust	700 pounds	1000 pounds	2248 pounds	2000 pounds	2500 pounds
Governor System	Angle	Angle	Hinged Blades	Side-facing	Blade activated & Side-facing
Governing Wind Speed	27 mph	28 mph	22 mph	33 mph	25.5 mph
Shut-down Mechanism	Dynamic brake	Dynamic brake	Manual caliper brake	Folding tail	Mechanical disc brake
Tower Top Weight	155 pounds	180 pounds	948 pounds	1020 pounds	2300 pounds
Marine Option Available?	Yes	Yes	No	Yes	Standard
Generator Type	PM 3 phase alternator	PM 3 phase alternator	PM 3 phase alternator	PM 3 phase alternator	Brushless 3 ph. alternator
Cost	$4,590-$5,890	$5,790-$7,490	$13,860	$17,950-$20,475	$18,750
Dollars per Rated Watt	$1.53-$1.96	$1.29-$1.66	$2.31	$1.80-$2.05	$0.94
Battery Systems (voltages)	24–240	24–240	48 or 120 or 240	48 or 120	120
Utility Intertie Available?	Yes	Yes	Optional	Yes	Yes
Resistance Heating?	No	No	Yes	Possible	No
Water Pumping?	No	No	DC	AC	No
Est. Mo. Energy @ 10mph (CF)	316 kWh (15%)	325 kWh (10%)	618 kWh (14%)	925 kWh (13%)	1644 kWh (11%)
Est. Mo. Energy @ 12mph (CF)	507 kWh (23%)	543 kWh (17%)	931 kWh (21%)	1425 kWh (20%)	2691 kWh (18%)
Warranty	2 years	2 years	2 years	2 years	1 year
Years in production (business)	9 (20) years	9 (20) years	6 (16) years	19 years	11 years
Routine Maintenance	Annual inspection	Annual inspection	Annual inspection	Visual inspection	Annual grease & oil change
Controls	Included	Included	Controls not included	Included	Controller included
Notes	HV/LV option available	HV/LV option available	Downwind		Gear box (not direct drive)

rotor is the fuel collecting part of the wind generator. The bigger the rotor diameter, the larger the collecting area (swept area), the more power the wind generator will produce (see the Blade Diameter & Swept Area illustration on page 26). While some manufacturers rate their products at different wattages or wind speeds, the output of a wind generator is primarily a function of its swept area. Rotor diameter, therefore, is a critical feature to help you compare one wind generator against another.

Number of Blades refers to the number of blades in the rotor. This is primarily a design consideration for the manufacturer. The greater the number of blades, the more torque (rotational force) the rotor can produce. A certain amount of torque is necessary to get the rotor spinning from a stopped position. However, torque is inversely related to rotor conversion efficiency. When you are trying to generate electricity competitively with the power company, efficiency is of prime concern.

The fewer the number of blades in the rotor, the more efficient the rotor becomes. One blade is the ideal, but poses some dynamic balance problems. Two blade or three blade rotors are seen most often. The question arises, why use three blades if two blades are more efficient? Time for a digression!

"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. Two-bladed rotors pose a problem as the wind generator yaws. A two-bladed rotor actually sets up a "chatter" as it yaws, which causes a strain on all of the wind generator's mechanical components.

Chattering occurs during yawing because of the continuous changing of the position of the two blades in the plane of rotation. When a two-bladed rotor has its blades in the vertical position (that is, in line with the tower) there is little resistance to the rotor yawing around the tower. However, when the blades rotate 90 degrees so that they are in the horizontal position (that is, at right angles to the tower, or parallel to the ground) they pose maximum resistance (or inertia) to any yawing motion. The result is a rhythmic starting and stopping of the yaw twice per revolution. This starting and stopping of the yaw is what is called blade chatter.

Three-bladed rotors eliminate the chattering problem because there is never enough inertia from the one blade in the horizontal position to set up a blade chatter in the first place. The horizontal blade is more than counterbalanced by the other two blades working somewhere off on their own. In contrast to two blade rotors, well-balanced three-bladed rotors operate very smoothly with no noticeable vibration or chatter.

It should be noted that several of the manufacturers offer two blade and three blade versions of the same model. Because they're more efficient, two bladed systems put out more power at any given wind speed than the three blade versions. In my opinion, the added efficiency that a two blade version has over the three blade version is not worth the resultant shorter life span of the two blade model.

World Power Technologies has come up with a unique solution to the two-blade problem on their Whisper 1000 and 3000 wind generators. The blades are mounted on a spring plate. The spring plate flexes to absorb some of the yawing vibration and helps mitigate the yawing chatter on the 2-bladed Whisper wind generators.

Regardless of the number of blades on the wind generator, proper 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.

Blade Material refers to what the blade is constructed of. Within the last five years, a number of options have become available for wind generator blades.

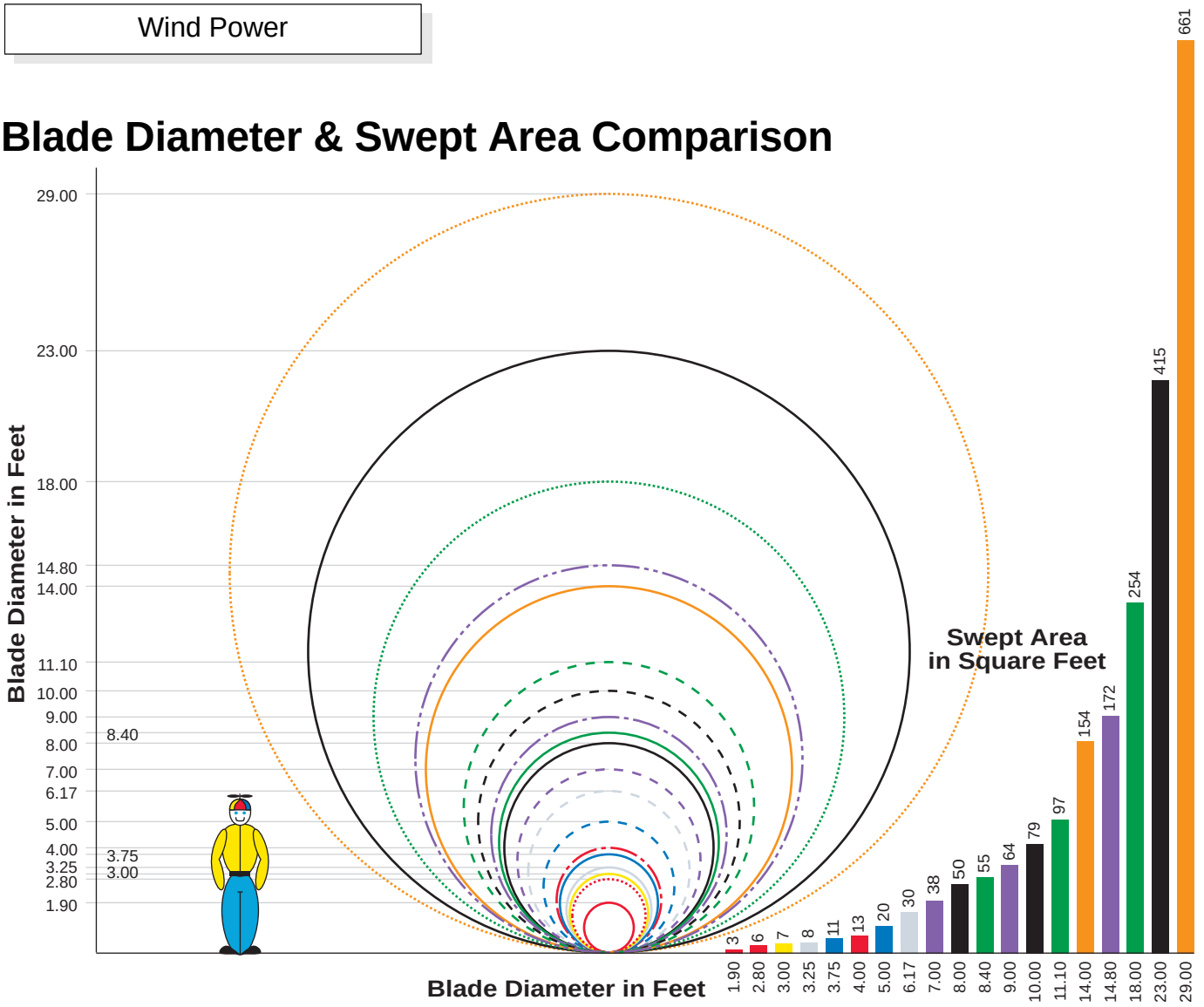
While more expensive for materials and labor, wood is still considered by many as the tried and true material of choice for blades. Blades do a lot of flexing. That's what trees did as a side job for most of their lives, as they swayed in the ever changing breezes. There is no question that sitka spruce is the primo material for wood blades. Sitka has one of the highest strength-to-weight ratios of any material ever used by blade makers, as well as airplane and boat builders.

Done properly, however, extruded fiberglass or graphite reinforced fiberglass over foam are both excellent blade materials. Several manufacturers are now using injection molded thermoplastic for their blades.

Airfoil refers to the shape of the blade. Two types of airfoils are used by wind generator manufacturers: true airfoils and what I call "single-surface" airfoils. The cross section of a true airfoil blade would look much like an airplane wing, that is, curved on one side and more or less flat on the opposite side. Single-surface airfoils have matching curves on both sides. They are easily formed by the extrusion process.

The differences between the airfoils occur in three areas: performance, noise, and manufacturing cost. True airfoils are quieter, start up in lower wind speeds, and perform better than single-surface airfoils. However, single-surface airfoils are cheaper to manufacture than the more complex true airfoils. Again, we'll deal with noise later.

Blade Diameter & Swept Area Comparison



Lateral Thrust at the Tower Top is mainly a design consideration for tower manufacturers. 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 must be.

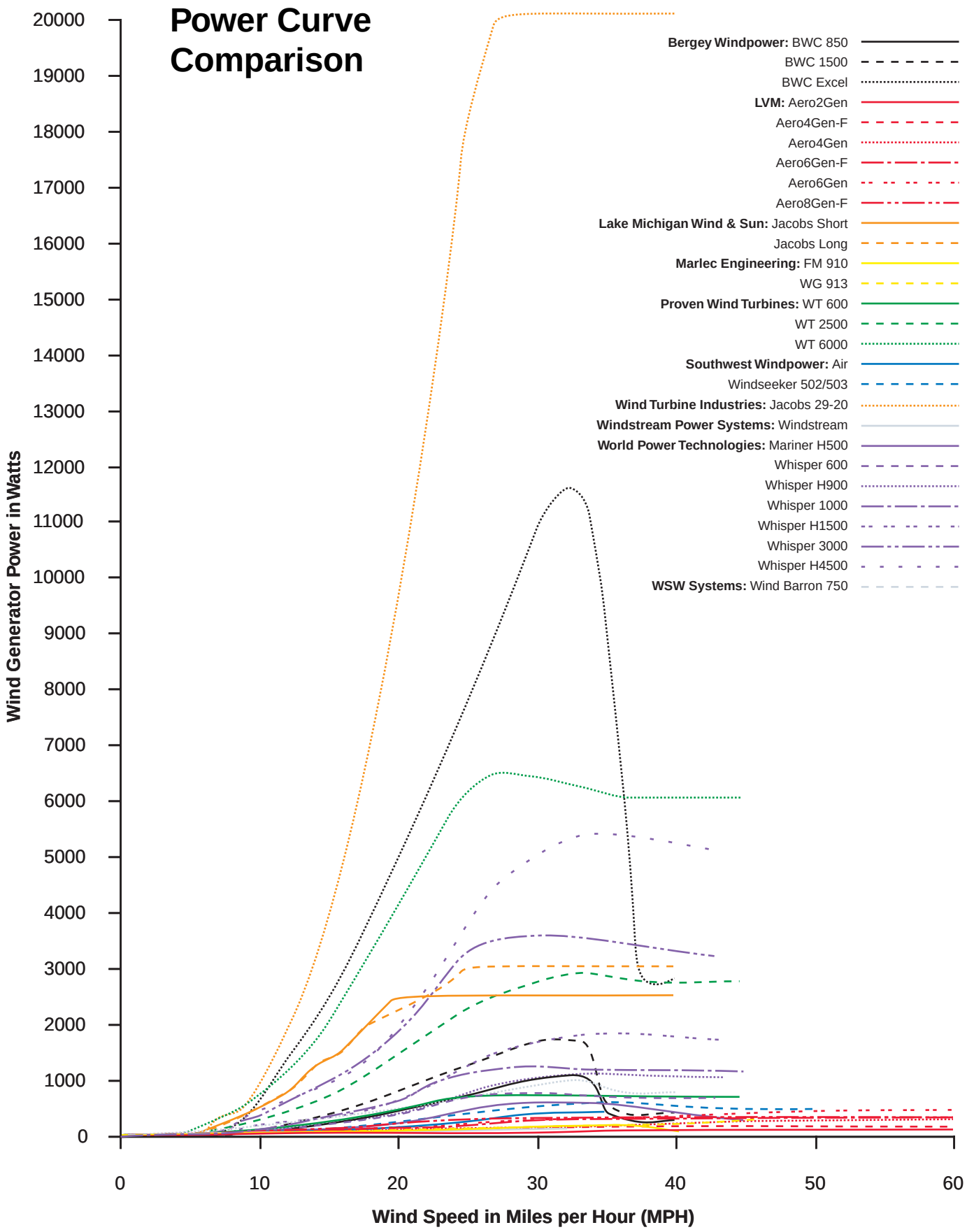
Governor System refers to the manner in which the wind generator protects itself from high winds and rotor overspeed situations. Governing is necessary for two reasons. First, the governor protects the generator itself from overproducing and burning out. Second, it protects the entire system from flying 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 (Windstream, Wind Baron and Windseeker), by side facing the rotor out of the wind by moving it around the tower (Rutland, Aerogen, and Bergey) or by a combination of the two (Whisper). In all cases, the fixed-pitched rotor is offset either above or to the side of a pivot point. Wind pressure on the 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 with a cost. Once the rotor governs by tilting up or side facing, it produces very little power because it is no longer oriented to the wind.

Blade-activated governors (Jacobs) work by pitching the blades out of their ideal alignment to the wind. Because they operate due to centrifugal forces, the greater the rotor speed, the greater the degree of pitch. Having more moving parts than either the tilt-up or side-facing mechanisms, they are more complicated governing devices. However, they offer much better power output as you can see by comparing the power curves.

The AIR governs by what is called aeroelastic twist. At the governing wind speed, the tips of the blades twist


Power Curve Comparison
Wind Generator Power in Watts
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
Wind Speed in Miles per Hour (MPH)
Bergey Windpower: BWC 850
BWC 1500
BWC Excel
LVM: Aero2Gen
Aero4Gen-F
Aero4Gen
Aero6Gen-F
Aero6Gen
Aero8Gen-F
Lake Michigan Wind & Sun: Jacobs Short
Jacobs Long
Marlec Engineering: FM 910
WG 913
Proven Wind Turbines: WT 600
WT 2500
WT 6000
Southwest Windpower: Air
Windseeker 502/503
Wind Turbine Industries: Jacobs 29-20
Windstream Power Systems: Windstream
World Power Technologies: Mariner H500
Whisper 600
Whisper H900
Whisper 1000
Whisper H1500
Whisper 3000
Whisper H4500
WSW Systems: Wind Barron 750

and flatten so that they no longer have an ideal pitch in relation to the wind. Like the blade activated governor, this limits the rotor's speed.

Finally, the Proven turbines govern because of hinges built into the blade butts. In origami fashion, the blades fold and twist in high winds, changing the ideal blade pitch, and reducing rotor speed.

Note that some of the wind generators do not have governors. As such, they need to be more carefully watched. I would certainly not leave a wind generator without a governor unattended while I went on vacation!

Governing Wind Speed is the wind velocity at which the governing mechanism is fully operational. This occurs somewhere between the wind generators rated power output and its maximum power output.

Shut-down Mechanism refers to the manner in which the rotor can be stopped and the generator shut down. This is desirable for maintenance or repairs, or whenever else you do not want the rotor to be turning.

A common shut-down method is to fold the tail (all of these systems except the Proven turbines have tails) so that it is parallel to the blades. This takes the rotor out of the wind, and it will cease to spin. Folding the tail involves either cranking or uncranking a cable which 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.

Dynamic braking is unique to permanent magnet alternators. Dynamic braking works as follows: if you short out the three phases of a permanent magnet alternator, it will overpower the ability of the rotor to spin the alternator (i.e., stall the blades) 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.

Wind Turbine Industries and Proven utilize a mechanical brake which slows the rotor to a stop on their wind turbines. Note that some wind generators listed have no shut down mechanisms.

Tower Top Weight refers to everything that goes on top of the tower: generator, governor, rotor, tail, and turntable 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 who believe that beefiness of components is directly related to the longevity of equipment life.

Marine Option Available indicates whether the unit is suitable for use in a marine environment (within one mile of an ocean or on an island), or if this option is available for an additional price. This is one area that needs close scrutiny if it applies to your location.

Generator Type describes the electrical generator that is used in the system. Three types are used: permanent magnet alternators, DC generators, and brushless alternators. A little about the pros and cons of each is in order. But first, another digression!

Electrical generators work by moving a wire (or many wires) through a magnetic field. The movement of the wire through the magnetic field induces current to flow through the wire. It's the flowing current that we want for our batteries and grid intertie inverters.

Permanent magnet (PM) alternators use, as the name implies, permanent magnets for the magnetic field. PM alternators are lighter in weight than generators that use copper wire-wound fields. Alternators produce three-phase wild ac current. "Wild ac" means that the frequency is variable with the wind speed. As rotor speed increases, so does the frequency. Wild ac cannot be used by standard 60 cycle appliances, and must be rectified to DC before it can be used in either a battery bank or a utility tie-in synchronous inverter. DC generators simply produce DC current.

Some manufacturers claim that PM alternators are better in wind systems than DC generators, primarily because there is less maintenance involved with an alternator than with a generator. DC generators have brushes, which have to be replaced periodically, maybe every six to ten years or so. PM alternators do not have brushes. From my perspective, replacing brushes once or twice a decade can hardly be construed as a maintenance problem.

The real advantage of permanent magnets to a manufacturer is that the permanent magnets are relatively cheap compared to the cost of the copper wire needed in a wound field. Cheaper materials means that a manufacturer can be more competitive in pricing the product. PM alternators also offer two advantages to a system owner. First, you can take advantage of dynamic braking, described earlier. Second, since each leg of a three phase system carries one third of the current, you can get by with a less expensive wire run.

However, PM alternators do have one disadvantage compared to generators with a wound field. (I'm going to simplify this greatly, so all you electrical engineers out there, please don't drop your teeth!) Because the magnets in a PM alternator are permanent, the amount of magnetism they exude, or their flux density, is fixed at the magnet's maximum amount. The amount of flux density in a wire-wound field magnet, however, is proportional to the amount of current that it draws. It is also somewhat proportional to the voltage present. In other words, the higher the voltage present in a wire-wound field, the more current the field will draw, and

therefore the stronger the magnet will be. As the rotor speeds up, the flux density of the field increases.

The nice thing about this arrangement is that the magnets in a wire-wound field generator put very little magnetic drag on the spinning armature when wind is blowing slow. But there's plenty of magnetic drag available when the wind is cranking and the generator is peaking. The power curve of a DC wire-wound field generator nicely follows the power available in increasing wind speeds (the cube law). That's just the way it should be. PM alternators, on the other hand, always have maximum magnetic drag on the alternator's current generating stator. This means that performance is at its peak at really only one spot on the entire power curve. All other points on the power curve are a compromise, especially at the low wind speed end of the curve, which is the part of the curve where the wind system spends most of its life.

In order to overcome this problem, manufacturers using PM alternators have to design more torque into their blades just to get the rotor spinning in low winds. But remember, from the number of blades discussion, torque is inversely related to efficiency. So while PM alternators are simpler (no brushes) and cheaper to build than DC generators, the simplicity comes at a price. To be fair, however, it should be noted that DC generators are more expensive than PM alternators.

Brushless alternators offer the best of both worlds. The fields are wire-wound rather than permanent magnet, and there are no brushes to replace. Their power curve is similar to a DC generator. On the down side, brushless alternators are considerably more complicated, and therefore, more expensive to replace or repair than either DC generators or PM alternators.

Cost refers to the cost of the complete wind generating system. In most cases, this includes any controls needed, except where noted in Controls. Different end uses might require different types of controllers (e.g., water pumping), and some end uses don't require any.

Dollars per Rated Watt refers to the system cost divided by the rated output in watts. This figure is included so that you can make direct comparisons with the cost of, for example, PV panels or a hydro plant with their associated controls.

You must decide what the wind generator's end use will be. Different end uses will utilize different control systems, which are not interchangeable.

Battery Systems is self explanatory. The voltages available for the battery systems are listed.

Utility Intertie refers to systems connected to the utility grid.

Resistance Heating means that the wind system is used for space heating. These controls are the simplest and least expensive end use option.

Water Pumping means that a control package is available to pump water with an electric pump run off the wind generator directly. No batteries! This category designates whether an ac or DC pump is used.

Because of the wide variety of controllers available, prices and options have not been included. For example, many of the smaller wind generators can be tied to the utility with the Trace SW series inverters, but are not normally advertised for that purpose. Contact the manufacturer with specific needs and for price quotes.

Estimated Monthly Energy at sites with average wind speeds of 10 mph and 12 mph is included so that you have some idea what a wind system will produce at your site. For comparisons, a very efficient home or small cabin would use 75 to 200 kilowatt-hours (kWh) per month. The "average home in the U.S." (whatever that is) uses 700 kWh/month. An all-electric home would consume from 1200 to 2500 kWh/month, as might a small business or farm. The output estimates of the various wind generators are the manufacturers' numbers, not mine. Be aware that "your mileage may vary!"

The number in parenthesis (%) is the calculated Capacity Factor (CF) for the system based on estimated monthly output. This refers to the amount of kilowatts that the wind system produces over a given period of time compared to its potential if it were running at full output all of the time. Note that different systems boast different capacity factors. The capacity factor for a wind generator is primarily a function of the swept area of the rotor, the rated wind speed of the system, and to a lesser extent, the type of airfoil used (true or single-surfaced). In general, the lower the rated wind speed and the larger the swept area, the greater the capacity factor.

Warranty: All the manufacturers warrant their products for parts and labor (in-house repairs at their facility) against defects in materials or workmanship. This means that you must return the defective part 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). Manufacturer liability is for the defective part only, and does not include incidental or consequential damages.

Years in Production (Business) tells you how long the company has been around. Where there is a parenthesis, the first number refers to how long the current wind generator model has been in production, while the second refers to how long the company has been in business, either making another turbine or doing research and development.

Routine Maintenance refers to what needs to be done to the wind generator to keep it in prime operating condition for a long life. How long? That's hard to say. Several years ago, I took down an old Jacobs that had seen 60 years of nearly continuous duty. While the old Jacobs was certainly an over-designed and over-built wind generator from an era that valued quality workmanship; properly cared for, any one of the new systems should match half that span, given proper attention.

This doesn't mean that you will never have to replace parts or do major repairs. Blades will need repainting and some new tape on the leading edge eventually. Bearings wear out and need replacing. Some systems, as noted, need annual greasing or oil changes. 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, then don't buy a wind generator.

Some manufacturers recommend only a visual inspection as their maintenance. Bergey Windpower Company, for example, suggests that after you install one of their units, once a year you need to go out to the base of the tower and look up to see if it is still running. That's it for another year! While there is no question that Bergey builds one of the most maintenance-free wind generators available in the industry, I am a little more conservative than they are. It is well born out that the life of a wind generator is directly related to the owner's involvement with the system and its maintenance. If you don't at least periodically inspect your wind generator, you may be picking it up off the ground someday!

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

Most of the great strides in reduced maintenance have come not from new designs, but from new materials. 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 used on the Wind Baron and the Windseeker was patented in 1931. And the blade-activated governor used on the old as well as the new Jacobs was patented in 1949. However, such things as graphite-impregnated nylon used in some bushings or the aliphatic resin tapes that are used for leading edge protection were just being developed fifteen years ago. Continuous upgrading by incorporating modern materials in wind system components has helped greatly in the maintenance arena. The manufacturer who cuts corners by using cheap materials is courting trouble with customers.

One new development: World Power Technology's new angle governor on their Whisper wind generators is a new design that was granted a patent just this year.

Controls tells you what is included in the system price or what you may need to budget for if it's not included.

Notes is a miscellaneous catch all. One explanation is necessary. Some of the Whisper wind systems are available with a high voltage/low voltage (HV/LV) option. This means 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 to transfer a given amount of power through the wire run, the HV/LV option means that you can site your wind system up to a mile away from the battery bank, something unheard of with low voltage DC generation.

Power Curves

The power curves for all of the wind systems reviewed have been put together so that you can more easily compare one system to another. The curves compare the power output of the various systems as a function of wind speed. However, be aware that this is still an "apples and oranges" comparison because there is no standard rated wind speed. However, some reasonable comparisons can be made.

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.

Noise from a wind generator can come from a number of sources, including mechanical noise, blade noise, or blade orientation. Mechanical noise would emanate from something such as a gearbox. Most of the systems reviewed are direct drive, meaning that the blade is coupled directly to the generating device. Only the 20 kW Jacobs utilizes a gearbox.

Blade noises can be caused by rpm and/or the airfoil. Rpm should be obvious. The faster something spins, the more noise it is likely to make. Being the slowest speed machines on the market, the old and new Jakes are the quietest wind machines available. The shape of the airfoil can also have an effect of the amount of noise the blades make. As a rule, true airfoils are quieter than single-surface airfoils.

The Proven wind turbines are downwind wind generators, with the blades passing through a wind wake downwind of the tower. Some wind generator blades develop a cyclic tower shadow noise running in this configuration. I have no experience with the Proven wind turbines, so I cannot attest to the presence or absence of this tower shadow noise.

Finally, rotors that side face or tilt up create some noise as the rotor changes its plane of rotation when governing.

Installation

The installation of a wind generator on a tower can be accomplished with either the use of a gin pole or a crane. A gin pole is a type of boom that is mounted on top of your tower. Using cables and rigging, either the entire wind generator or its component parts are hoisted to the top of the tower where they are installed. This is relatively easy to do with the smaller systems. However, only an experienced crew should attempt this with something as large as a 10 kW or larger system. These wind generators are probably better installed with the help of a crane.

An alternative is to install a tilt-up tower. Tilt-up towers tilt down to ground level, where the wind generator can be easily installed and serviced. Tilt-up towers are generally more expensive than guyed towers but less expensive than freestanding towers.

UL/CSA/CE Ratings

While some of the wind generators have or are acquiring a CE rating in Europe, at this time none of the systems are UL listed in the United States, or have CSA approval in Canada. As yet, these ratings have not been required.

Delivery time

A word needs to be said about the lead time required to get your wind system once you have placed an order. A wind generator is a very complex device made up of a wide variety of components and materials. All of the manufacturers represented here are small companies working with many subcontractors and suppliers. As such, they are some times at the mercy of events beyond their control.

Home-sized wind generators are not manufactured on an assembly line like many other consumer products. Instead, the “gennys” are made in batches ranging from a handful to a few dozen at a time. When you place an order, your machine becomes part of a batch. The manufacturer may already have a batch going that your order can plug into. If not, your turn comes when the next batch is started. 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 sixteen weeks.

A few customers have had rather bad experiences with unusually long lead times. Some have felt that they have been “jerked around” by the manufacturer. While I can’t say that this has never happened, I will defend the manufacturers as being pretty good guys on the whole. They really are concerned about satisfying their customers. After all, without you, the customer, 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. They all 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.

You now have all of the tools you need before you to make an educated choice. Seek out other wind power users and gain from their experiences. By all means, discuss owner satisfaction with your wind generator dealer. Make sure that you digest the facts and figures and assess your needs and pocketbook, so that you may choose well.

The Manufacturers

The manufacturers for the systems reviewed can be contacted for prices or more information, or you can

contact your favorite wind generator dealer. The abbreviations preceding the manufacturers name are those listed in the table.

BWC: Bergey Windpower Company, 2001 Priestly Ave., Norman, OK 73069 • 405-364-4212 • Fax: 405-364-2078. Manufactures the BWC 850, the 1500, and the Excel.

LMW&S: Lake Michigan Wind & Sun, 1015 County U, Sturgeon Bay, WI 54235-8353 • 920-743-0456 • Fax: 920-740-0466. Remanufactures the old Jacobs "short case" and Jacobs "long case," and is the North American distributor for the Aerogen Wind Generators.

LVM: The Aerogen line of wind generators is manufactured by LVM Ltd, in England, and distributed by Lake Michigan Wind & Sun (see above).

ME: Trillium Windmills, Inc., 1843 Marchmont Rd., R.R. #2, Orillia, Ontario, L3V 6H2, Canada • 705-326-6513 • Fax: 705-326-2778. North American distributor for the Rutland Windchargers (manufactured by Marlec Engineering Co., Ltd. of England).

PE: The Proven Wind Turbines are manufactured by Proven Wind Turbines in Scotland, and distributed in the US by WSW Systems (see below).

SWWP: Southwest Windpower, Inc., PO Box 2190, Flagstaff, AZ 86003 • 602-779-9463 • Fax: 602-779-1485. Manufactures the Windseeker 502 and 503, and the AIR.

WPS: Windstream Power Systems, One Mill Street, PO Box 1604, Burlington, VT 05402-1604 • 802-658-0075 • Fax: 802-658-1098. Manufactures the Windstream.

WPT: World Power Technologies, 19 Lake Avenue North, Duluth, MN 55802 • 218-722-1492 • Fax: 218-722-0791. Manufactures the Whisper wind generators.

WSW: WSW Systems, 2101 North Forth St., Flagstaff, AZ 86004 • 520-774-6341 • Fax: 520-774-6451. Manufactures the Wind Baron 750 and distributes the Proven Wind Turbines.

WTIC: Wind Turbine Industries, Corp., 16801 Industrial Circle SE, Prior Lake, MN 55372 • 612-447-6064 • Fax: 612-447-6050. Manufactures the Jacobs 29-20.

Access

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