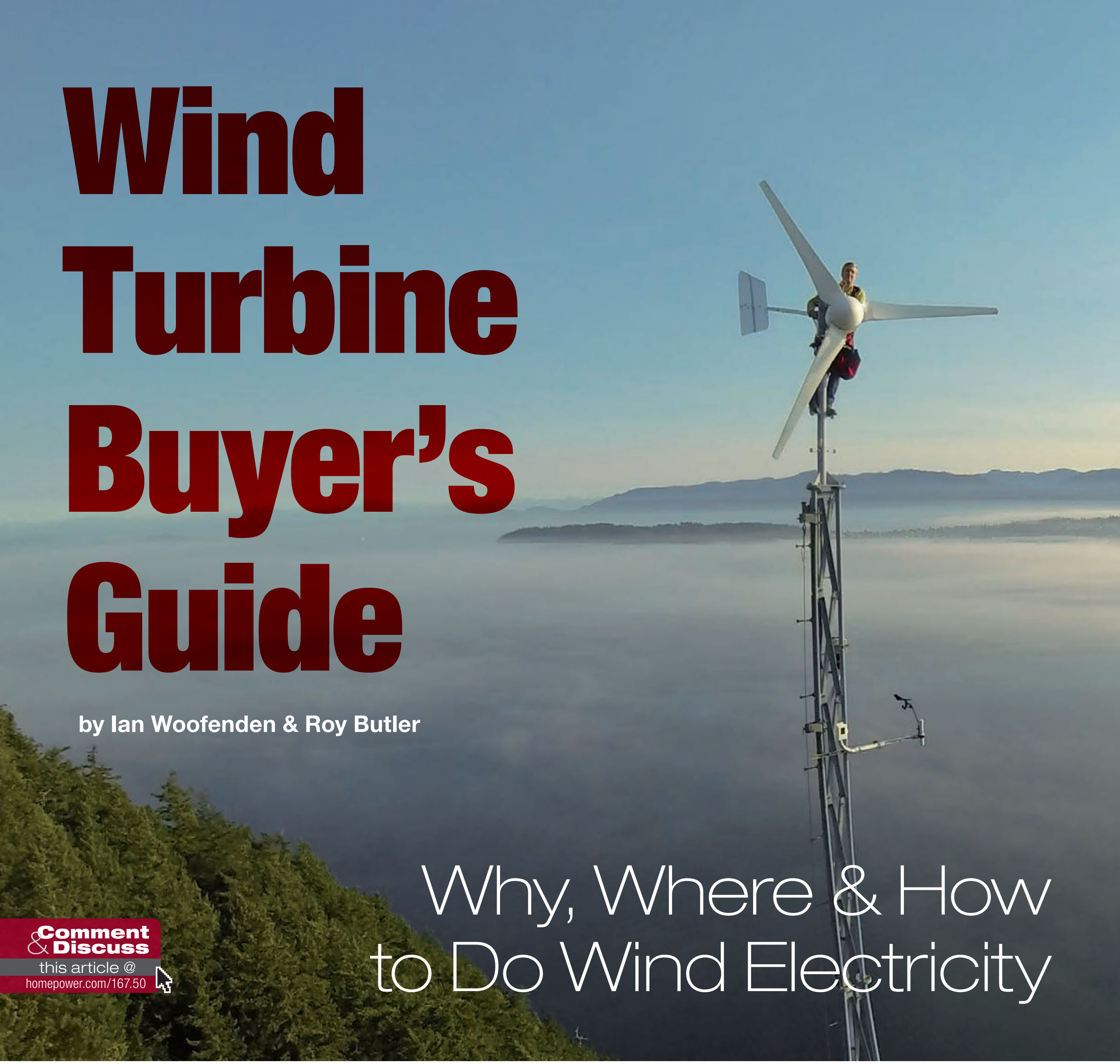
# Wind Turbine Buyer's Guide

by Ian Woofenden & Roy Butler

## Why, Where & How to Do Wind Electricity





Making electricity with the wind is not easy. As seasoned wind-energy installers with decades of experience, we—as well as thousands of others who live with home-scale wind turbines—tell a challenging tale. And the small wind industry today reflects those challenges, with long-established companies struggling and going under while the cost of reliable solar-electric modules continues to drop. If you think you want a wind-electric system, first think smart, then realistically.

Done well, residential-scale wind energy can provide clean kilowatt-hours in a very satisfying way. But because of the characteristics of the wind, wind systems have several strikes against them:

- Tall towers are required for meaningful production
- Reliability and robustness are hard to come by
- Compared to solar electricity, the cost per kWh can be high
- Qualified local installation and maintenance help is difficult to find
- Hype, misinformation, and outright scams are too common

This article will help you sift through the rhetoric and numbers, and make a wise decision about whether or not to tap local wind energy. If you decide that wind is right for your site, we want to help you understand how to make it work for the long term.


Roy Butler

**For best performance, wind turbines need to be installed atop tall towers, which gives them access to less-turbulent winds.**

Ian Woofenden

**Towers need to be tall, tall, tall.**

Mike Schmidt

## Why Wind?

First, we suggest you get a handle on your motivations, needs, and situation. These will help determine whether a residential wind-electric system makes sense for you. People choose wind energy for several reasons, including:

- Environmental concerns
- Decreased cost of energy
- Desire for independence
- Fun and interest

Each of these motivations—and combinations of them—will lead to different choices. Be realistic about why you are considering wind energy and make sure the actual results satisfy your expectations and goals.

When installed correctly in the right location, a residential wind-electric system can produce cleaner energy than North America's utility grid, which is dominated by coal and other dirty energy sources. But a wind system needs to make significant energy (kilowatt-hours) for years or decades to make environmental and financial sense. Otherwise, you could end up spending a pile of money on an unproductive wind energy system—and still be shelling out dollars for that dirty coal energy you're using now.

Scrutinizing your real cost of wind energy is crucial if your primary goal is to save money. Many wind-electric

Ian Woofenden

**Wind power systems require regular maintenance, which usually means routine climbs to the tower top.**

systems are installed with unrealistic financial and durability projections, and end up generating energy that is more expensive than the local utility grid. A low cost per kWh requires a productive and long-lasting wind-electric system.

If independence is your goal, a reliable, long-lasting system is important. Otherwise, you will end up being dependent on the utility grid or worse—a fuel-fired generator.

Having a wind generator for a hobby and DIY project can be very satisfying—but requires having patience with the potential maintenance and failure in these systems. Some of our wind colleagues don't really mind when a wind turbine fails because "they get to build another one." Other people would be quite discouraged at the same situation. A large amount of patience and perseverance may be needed, depending on your budget and design decisions.

Most of these motivations require not only a firm grip on what a wind-electric system will do for you, but a clear idea of how much energy you use, and what form it is in. If your home is heated by gas or oil, you'll need to switch to electricity (we suggest minisplit heat pumps) to make an impact with your wind generator. Becoming energy literate and analyzing your home or business's energy use should be an early step in any renewable energy system design.

Whatever your motivation, do all you can to make sure your expectations of the system's costs, energy generation, longevity, and impacts are realistic. Do your homework, find local mentors and wind energy users, and make wise purchase choices so you end up satisfied—instead of disillusioned.

## Where is the Wind?

Getting an honest answer to the question, "Where do wind generators work?" could save a lot of people a lot of disappointment. The obvious answer is, "Where there is wind!" Unfortunately, many people are ignorant of or blind to the details behind this simple answer.

Wind energy is cubic—the energy in the wind increases with the cube of the wind speed. This means that a 20 mph wind has 8 times as much energy as a 10 mph wind. Even a small increase in wind speed yields a significant increase in energy potential. For example, going from 12 mph to 15 mph almost doubles the wind energy potential.

But just like trying to move water in a pipe or a rope through a pulley, friction is wind's enemy. In the case of wind, it's the drag imposed by trees, buildings, and landforms that robs the energy in the wind. The reality is that there just is not much wind energy left once it travels close to these obstructions.

**In flat, open terrain, a shorter tower can suffice, although it still needs to be high enough to put the turbine in "clean" winds.**

Courtesy Mark & Vivian Williams

**In rugged terrain and/or trees, towers need to be significantly taller than surrounding obstacles.**

Ian Woofenden

"Friction" and turbulence from ground obstructions reduces the annual energy output (AEO; see table) of any wind turbine. The farther above these obstructions your wind turbine is, the more wind energy there is. So wind energy experts frequently recommend taller towers. This is not because they have stock in tower companies, but because they understand wind physics.

There are some devilish details. A turbine on a taller tower will always capture more wind energy, but it's more important in some situations than others. We would not recommend a tower for *any* site be shorter than 60 feet, regardless of the terrain. But getting above the obstruction is somewhat less important if that obstruction is smooth, like a wheat field, tundra, or open water. "Wind shear" (the rate of wind increase as you rise above the earth) studies show us that wind speed increases more quickly above cities and forests than above open fields and water.

So what does a good—or bad—wind site look like? One analysis involves getting a view in your mind's eye from the tower top. At that height, if you can get a very distant and broad view without obstructions, you have one crucial component of a good wind site—access to unobstructed wind. But if you're "seeing" treetops, buildings, hillsides, and such, you aren't yet at the optimum height.

So hilltops, ridges, plains, and oceanfront settings top the list of good wind sites. Forests, deep river valleys, cities and suburbs, and other complicated and uneven sites are challenged by their basic topography.

Beyond getting above the obstructions, you need a site that experiences significant wind. While we frequently hear people say things like, "It blows 20 mph constantly," this is never true—personal observations of how much wind there is are useless in most cases. What's needed is actual measurement or studied estimation based on measured sites. This information is not always easy to obtain, and many wind turbines are sited without good data. If you decide to go ahead without hard numbers, you need to realize that you're taking a calculated risk—investing based on an educated guess of your wind resource. You may find wind data from local wind-energy users, meteorological sites, and, possibly, from utility-scale wind siting services.

It's also crucial to understand the difference between instantaneous and average wind speeds. While knowing the maximum instantaneous wind speed is useful to consider the durability and longevity of a turbine, instantaneous measurements are otherwise unimportant. What we really want to know is the *average* wind speed, from which we can calculate or determine a wind generator's energy production potential. Real-world average wind speeds at residential sites range from a barely-adequate-for-off-grid 6 mph to a rare high of about 14 mph on a site that is so windy you might not enjoy living there.

Fully understanding wind physics, and the science and art of wind-system siting, will spare you wasted money and unfulfilled dreams. Don't apply magical thinking to wind-electric systems—apply (or find an expert to apply) the math of wind to the physics of your site and make a tough-minded decision about whether you have the resource to fulfill your purposes.

## Hybrid Off-Grid System Meets Winter Needs

We live on an off-grid 32-acre homestead in mid-coast Maine. Our electricity comes from a mix of solar-electric modules (990 W) and a Pika T-701 wind turbine. The PV array is mounted on a small outbuilding and feeds into a 24 V battery pack of eight Rolls-Surrette S-480 batteries through an OutBack Power MX-60 charge controller. The Pika turbine is mounted on a 107-foot NRG meteorological tower and feeds the battery bank through Pika's REcharge charge controller. Electricity is delivered to the house as 24 VDC and as AC from a Trace inverter.

We live on a hill and generally have a breeze. Before installing the wind system, the short and often cloudy days of winter meant that we had to run our generator frequently to keep the battery pack healthy. Pull-starting a generator on cold days, bringing in gasoline on a sled, and a general aversion to using gasoline-based power had us looking for renewable ways to provide energy during the winter. We approached Pika about a turbine, hoping that its off-grid system would work for us. It has worked better than we hoped, and is now our primary source of power.

Brent & Erin Bibles • Unity, Maine


Courtesy Brent & Erin Bibles

## Net-Metered Wind Energy

We've known that we wanted a wind generator since we moved to Genesee County 13 years ago. The wind resource proved good based on the site survey and our rural location lends itself to the project. Nevertheless, it took us three years of dealing with local authorities to get permission. I then worked with the local planning board to rewrite the zoning law to allow personal turbines in our community.

Our system is a Bergey 5 kW (now sold as a 6 kW) on a freestanding 100-foot tower. It has a rotor diameter of 20 feet and is connected to the grid for net metering. We purchased it through Niagara Wind & Solar, and it produces more electricity than we use.

Mark & Vivian Williams • Alabama, New York

Courtesy Mark & Vivian Williams

### Steps to Wind

If you've figured out why you want to try to capture wind energy, and you've determined that you have good wind potential at your site, what are the next steps to producing energy? Each wind system is different, depending on the site, tower choice, system configuration, installer, and owner, but this general list of steps will give you an idea of what you will need to do:

- System design
- Tower specification
- Permitting
- Soil analysis
- Excavation for tower base (all towers) and anchors (guyed towers)
- Concrete for base and anchors
- Tower assembly and installation
- Tower "tuning"—tension and plumb (guyed towers)
- Transmission and anemometry wiring
- Turbine installation
- Balance of systems and installation—electronic controls, batteries if needed, monitoring, etc.
- Commissioning and testing
- Maintenance plan
- Utility interconnection application and inspection (grid-tied systems)

Each of these items could be explained in several articles or a short book—though it's not rocket science, it's also not as simple as digging a ditch. At each step, someone needs to have a thorough understanding of the goals and challenges; the equipment that's available; and how to specify, integrate, and install it properly.

**The turbine is only part of the system mechanics and cost.**

Ian Woofenden

**The larger the turbine and tower, the more infrastructure involved.**

Courtesy Mark & Vivian Williams

Doing this yourself means you need to be a very handy person, willing to learn from the experience of others, and willing to get dirty. Otherwise, you'll need to hire contractors for the various parts of the task. Finding experienced wind help may be difficult in your area, but worth the effort, because you do not want to work with a company that is experimenting with your money, or worse.

Whether you or a contractor does the job, you'll need to get your gear from somewhere. We recommend you buy equipment from companies that have been around the block with wind energy, and those with a strong record of customer support. It's hard to put a value on the ability to make a phone call and get good information, replacement parts in a hurry, or analysis of a pressing problem.

## The Good, the Bad…

So what distinguishes good systems from bad systems? It's not easy to make broad generalizations about the various types and configurations of wind-electric systems. But it's fairly safe to say that all good installations have these attributes:

- Sited where there is sufficient wind resource
- Turbine installed well above (30+ feet) all obstructions within 500 feet, minimum
- Engineered tower installed to spec
- Properly specified components matched to each other
- Excellent and user-friendly wind and wind turbine monitoring systems installed
- Clear maintenance plan

As a result, these less technical but no less important attributes will follow:

- Happy system owners and neighbors
- Energy production within owners' and installers' expectations/predictions
- Modest noise and visual impact
- Owners understand system or have easy access to experienced support

The people who are disappointed with their wind systems tend to have short towers, low-budget and mismatched equipment from newer companies or importers, and installation by inexperienced people. Most have unrealistic expectations of the wind resource and wind systems. These installations have high failure rates and low energy production. We've seen many systems that rarely generate any energy—and a system that costs even as little as $20,000 to as much as $100,000, but only generates a handful of kWh, is making *very* expensive electricity.

## Wind Turbines Table

It was difficult to choose which wind turbines to include in this article. We start with a set of criteria, and try to apply them responsibly, but with some flexibility. Our goal is to give our readers solid information to make wise buying decisions, while being fair to manufacturers.

Included in our criteria is: sales and support in North America, warranty, certification (if applicable), price, and the company's longevity. We recommend that you only consider wind turbines with these basic qualifications. It's surprising how many people get into trouble by falling for hype about new concepts or from product promoters. Watch out for importers of gear not fully supported in North America, and companies that have more marketing than customer service.

We believe that the listed turbines offer the best opportunity to tap your wind energy. Some companies and machines are much newer than others, and are on the edge of our criteria; we encourage you to pay attention to time in business and in production when looking at the specs. The table that follows includes the following fields.

## Wind in Wyoming

J Bar 9 Ranch is small cattle ranch where we raise hay and keep pasture for 150 to 200 cattle and 30 horses. The local herds of elk, deer, and sheep also use the pastures and hay meadows for winter forage. We have solar, wind, and just finished putting in two small microhydro units. The three renewable sources supply our electricity needs for the irrigation systems and numerous buildings.

Our main source of renewable energy is the Northern Power 100B wind turbine. The machine is a 100 kW direct-drive turbine with a 68.8-foot rotor, on a 98-foot tower. We had it factory-painted to "blend in" with the surroundings. We finished installing the turbine in October 2011. Since then, it has produced 655,735 kWh.

We chose the Northern Power 100B because our research showed it to be a very reliable and simple machine. The support and availability of parts for maintenance on the turbine was also a huge deciding factor. Northern Power has a great monitoring system that can identify problems quickly and efficiently.

Bob Curtis, J Bar 9 Ranch • Cody, Wyoming

Courtesy Bob Curtis

Wind Turbine Buyer's Guide

| Turbine | In Business (Yrs.) | In Production (Yrs.) | Warranty (Yrs.) | Rotor Swept Area (Ft.[2]) | Rotor Diameter (Ft.) | Tower-Top Weight (Lbs.) | Certification |
|---|---|---|---|---|---|---|---|
| **Bergey Excel 1** bergey.com | 38 | 15 | 5 | 53 | 8.2 | 75 | — |
| **Luminous Whisper 200** luminousrenewable.com | 8 | 6 | 2 | 64 | 9 | 66 | IEC-61400 |
| **Pika T 701** pika-energy.com | 6 | 1 | 5 | 76 | 9.8 | 93 | Power Cert. in process[2] |
| **Xzeres Skystream 3.7** xzeres.com | 5 | 2 | 5 | 117 | 12 | 170 | AWEA 9.1 |
| **Luminous Whisper 500** luminousrenewable.com | 8 | 6 | 2 | 177 | 15 | 154 | — |
| **Luminous Whisper 500+** luminousrenewable.com | 8 | 6 | 2 | 177 | 15 | 154 | — |
| **Luminous Windistar 4500** luminousrenewable.com | 2 | 2 | 2 | 177 | 15 | 249 | In process |
| **Weaver 5** weaverwindenergy.com | 5 | 1 | 5 | 210 | 16.3 | 821 | In process |
| **Bergey Excel 6** bergey.com | 38 | 3 | 5 | 325 | 20.2 | 772 | AWEA 9.1 |
| **Ventera VT-10** venterawind.com | 10 | 7.5 | 5 | 380 | 22 | 580 | In process |
| **Bergey Excel 10** bergey.com | 38 | 32 | 10 | 414 | 23 | 1,200 | AWEA 9.1 |
| **Bergey Excel R** bergey.com | 38 | 32 | 10 | 414 | 23 | 1,200 | — |
| **Xzeres 442SR** xzeres.com | 5 | 4 | 10 turbine, 5 controller | 442 | 23.6 | 1,600 | AWEA 9.1 |
| **Wind Turbine Industries Jacobs 31-20** wind-turbine.net | 29 | 30 | 5 | 755 | 31 | 2,000 | Certified Power |
| **Osiris 10** osirisenergy-usa.com | 8 | 6 | 5 | 797 | 31.8 | 1,870 | AWEA 9.1, IEC 61400-2 |
| **Eocycle 25** eocycle.com | 14 | 5 | 2, with 5 ext. | 1,347 | 41.3 | 4,960 | In process |
| **Endurance Wind Power E-3120** endurancewindpower.com | 8 | 6 | 5 | 3,120 | 63 | 8,800 | Certified Power[1, 2] |
| **Northern Power NPS-100C-24** northernpower.com | 41 | 16 (NPS100) | 2 | 4,867 | 78.74 | 15,300 | — |

[1]AWEA standards do not cover turbines this size—only up to 2,153 ft.[2] (200 m[2]). [2]The turbine power curve has been certified to industry standards by a nationally recognized testing facility.

**Manufacturer website** is your first source of information. Take the time to read through the content thoroughly, including the fine print.

**Years in business** may tell you about the reliability of the machines and the company behind them, as well as capability of keeping wind turbines and a business support structure alive.

**Years model in production** tells you how long the model has been manufactured, and may be an indication of its level of development and reliability.

**Warranty** is an important factor in choosing a machine because it protects you in the case of failure due to design and workmanship, and because it may indicate the manufacturer's confidence in the machine. Read the fine print to be clear on what is—and is not—covered. Usually it's parts, but not repair or replacement labor.

**Rotor swept area** is the collection area of a wind generator—the basis of the quantity of energy it can capture. No other specification has more to do with a wind generator's production.

**Rotor diameter** is another way to indicate the swept area, but it's deceptive because area is proportional to the square of the diameter.

**Tower-top weight** may give you some indication of a machine's robustness, since heavier machines may be more durable, and also is important to know for tower specification.

| Rated Power @ 11 m/s (kW) | AEO @ 5 m/s (kWh) | Est. Annual Energy Output (AEO in kWh) for Wind Speeds 8 mph | 9 mph | 10 mph | 11 mph | 12 mph | 13 mph | 14 mph | AEO Source | RPM @ Rated Power | Governing System | Governing Wind Speed (mph) | Cost (Turbine & Controls) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 1,110 | 420 | 610 | 840 | 1,180 | 1,400 | 1,710 | 2,040 | Mfr.: Windcad | 490 | Furling | 29 | $4,595 |
| 0.99 | 2,052 | 871 | 1,231 | 1,629 | 2,048 | 2,473 | 2,890 | 3,291 | Mfr. | 1200 | Furling, dump | 31 | 3,291 |
| 1.50 | 2,420 | 700 | 1,250 | 1,800 | 2,350 | 2,900 | 3,500 | 4,100 | Mfr. | 400 | Stall | 53.7 | 6,675 |
| 2.10 | 3,420 | 989 | 1,740 | 2,576 | 3,282 | 4,115 | 4,962 | 5,814 | Mfr. | 330 | Dynamic brake | 27 | Call |
| 3.10 | 5,568 | 2,309 | 3,286 | 4,386 | 5,572 | 6,803 | 8,042 | 9,256 | Mfr. | 800 | Furling, dump | 31 | 7,296 |
| 3.15 | 5,846 | 2,424 | 3,450 | 4,605 | 5,850 | 7,143 | 8,445 | 9,718 | Mfr. | 650 | Furling, dump | 31 | 8,040 |
| 4.31 | 7,800 | 2,724 | 4,800 | 6,900 | 7,800 | 9,600 | 12,000 | 14,400 | Mfr. | 450 | Furling, dump | 31 | 9,466 |
| 3.85 | 3,857 – 4,897 | 1,647 – 2,096 | 2,312 – 3,033 | 2,945 – 4,085 | 3,496 – 5,172 | 3,944 – 6,213 | 4,290 – 7,142 | 4,546 – 7,919 | Mfr. | 260 | Active furling | 50 | 38,576 – 62,190 |
| 5.50 | 9,920 | 3,963 | 5,582 | 7,470 | 9,536 | 11,667 | 13,850 | 16,325 | Mfr.: Windcad | 400 | Furling | 31 – 45 | 21,995 |
| 9.30 | 12,772 | 5,037 | 7,218 | 8,957 | 11,625 | 13,924 | 17,599 | 20,836 | Mfr. | 280 | Blade pitching | 28 | 24,000 |
| 8.90 | 13,800 | 4,924 | 7,124 | 9,850 | 13,026 | 16,499 | 20,248 | 24,712 | Mfr.: Windcad | 400 | Furling | 31 – 45 | 31,770 |
| 7.50 | 13,800 | 4,549 | 6,723 | 9,292 | 12,114 | 15,008 | 17,922 | 21,125 | Mfr.: Windcad | 400 | Furling | 31 – 45 | 26,870 |
| 9.17 | 15,329 | 4,990 | 8,583 | 12,630 | 16,017 | 19,958 | 23,984 | 27,997 | Mfr. | 150 | Dynamic brake | 26 | Call |
| 12.00 | 16,630 | 5,100 – 7,800 | 7,450 – 11,375 | 10,420 – 15,900 | 13,900 – 21,225 | 17,742 – 2,7075 | 21,950 – 33,470 | 26,250 – 38,950 | Mfr. | 175 – 185 | Blade pitching, furling | 30 – 45 | 53,550 |
| 10.00 | 23,704 | 8,250 | 13,929 | 18,824 | 22,740 | 27,530 | 31,340 | 35,734 | Mfr. | 120 | Passive & active pitch | 20 | 27,500 |
| 23.00 | 37,229 | 11,230 | 18,992 | 25,625 | 34,160 | 44,471 | 53,775 | 64,700 | Mfr. | 90 | Stall, active yaw | 56 | 81,000 |
| 56.80 | 116,935 | 41,516 | 65,214 | 88,913 | 112,611 | 137,334 | 162,289 | 186,458 | Mfr. | 42 | Stall control, air brakes | 56 | 215,000 |
| 90.20 | 196,000 | 80,000 | 113,000 | 150,000 | 189,000 | 228,000 | 267,000 | 305,000 | Mfr. | 50 | Stall control | 56 | 365,000 |



**Certification** lends credibility to a machine, showing that it has gone through a standardized testing process. Some established manufacturers choose to avoid the expense and time of certification, and certification is not a direct measure of longevity in the field, which is more important than peak performance. The Small Wind Certification Council (SWCC) and Intertek are the primary North American players in the small wind certification field. They assure that the turbines are tested to U.S. and international standards, verify the accuracy of the testing data, and then issue full certification or power curve certification.

**AWEA rated power** at 11 m/s (25 mph) average wind speed is a standardized power rating that may be handy for comparison, but is not particularly useful beyond that, and can be deceptive.

**AWEA rated AEO** (annual energy output) at 5 m/s (11 mph) average wind speed is a standardized energy rating, and can be cautiously used to compare turbines—but won't relate directly to your site unless you also happen to have a 5 m/s average wind speed.

**Estimated AEO** at 8 through 14 mph is predicted energy production at the average wind speeds most common at residential sites (14 mph and above are rare). These are important specs because they relate to *your* site. This specification also demonstrates the crucial need for good average wind speed measurement or calculations for your tower top.

**AEO source** identifies the source of the AEO numbers.

## web extras

For more wind system strategies, see the following articles:

"Understanding Wind Speed" by Ian Woofenden in *HP143* • **homepower.com/143.106**

"How a Wind Turbine Works" by Ian Woofenden in *HP148* • **homepower.com/148.46**

"Wind-Electric System Maintenance" by Roy Butler & Ian Woofenden in *HP135* • **homepower.com/135.98**

**Rpm at rated power** identifies the rotational speed of the turbine and is a useful comparative number between machines of about the same rotor diameter. In general, lower rpm machines are longer-lived, with less wear and tear and lower noise levels.

**Governing system** specifies the method of controlling overspeed, a crucial design factor for all turbines. High winds pack a punch that needs to be avoided—not absorbed. Without a reliable governing system, your turbine will sooner or later break; with one, it will continue to make energy during and after high wind events.

**Governing wind speed** at which a machine is fully governed—protected from high winds and the overspeed conditions they can cause. A low governing wind speed is more likely to indicate a long-lasting machine.

**Cost** typically includes turbine and controls, but we recommend looking carefully at exactly what is included in each package—and what else you will need to make a complete system.

### Pessimistic—or Realistic?

We, the authors, both love wind power, and have lived with it, written about it, and taught it for many years. At times, we are accused of being negative about our own field. Both of us have lived with failures in our own wind systems and those of clients, friends, and neighbors. We've come to our own levels of realism about what wind energy can and can't do, and how to approach it to get the desired results.

We are definitely skeptical about manufacturer hype; light-duty machines; missing or mis-information; and untested schemes, claims, and machines. We are negative about false claims, deceptive advertising, poor support, and marketing that doesn't reflect reality. No matter how well the turbine is engineered, it cannot change the physics of the wind.

At the same time, we are exuberantly positive about machines that are well-tested in the field and have realistic ratings and good track records. We're excited about manufacturers that take care of their customers. And we're delighted to hear stories from end users that are not horrific, but tell us of energy generated and used, appreciative instead of irritated neighbors, and expected reliability and production.

Take your time approaching wind energy. It's not a quick fix, and it's definitely not for everyone. But if you have a good site, an appropriate budget, plenty of knowledge and support, and a good attitude, you can make a wind generator successfully fly over your property. It's hard to tell you in writing the level of satisfaction that can bring, but you could be the next person to have that wind generator smile.