Estimating energy production

Estimating energy production is complicated for two reasons:

- The best energy output calculations rely on an accurate wind resource assessment. Publicly available data is unreliable, so an assessment based on such data is at best an estimate of the wind speeds in an area. Such imprecise measurements lead to significant variability in energy calculations.
- Small wind systems lack industry standards. In 2010, the Small Wind Certification Council (SWCC) began testing turbines to newly established standards. Manufacturers volunteer to have their turbines tested, but not all turbines are tested because the process is voluntary. It also takes time to amass enough data to make useful comparisons between turbines. Manufacturers are now able to define many terms and set their own standards, which makes it difficult for homeowners to compare information from turbine to turbine.

The terms power and energy often are used interchangeably when describing output from a small wind turbine, but they have different meanings. Power typically refers to instantaneous generation, whereas energy refers to generation over time. Manufacturers often provide estimates of power output, but system owners generally place greater importance on how much they can offset their use of utility-provided electricity. Energy output is dictated mostly by the variables in the energy formula discussed in the *Understand Small Wind* guide:

- **Wind speed:** Install a turbine in an area with access to the best wind speeds and away from obstructions.
- **Swept area:** Larger rotor diameters capture more wind to generate more energy.
- **Air density:** This variable cannot be controlled, but know that there is less power generation at higher elevations than at sea level.
- **Time:** The longer a turbine operates, the more energy it will produce.

Accurate energy production estimates can be difficult to derive, but here are some suggestions that will help estimate system size and energy production without relying on manufacturer-defined terms.

Methods for determining system size

Use these steps to get a rough estimate of required turbine size to serve your electricity needs:

- Total your annual electricity use in kilowatt-hours (kWh).
- Calculate the average load by dividing annual usage by 8,760 hours per year.
- Divide the load by 0.1 and 0.2.

Table 1. Example system size calculations.

Total annual usage, in kWh	13,344
Average load (13,344 ÷ 8,760)	1.52
Average load divided by 0.2	7.6
Average load divided by 0.1	15.2

In the example in Table 1, the system size should be between seven and 15 kilowatts. Use Table 2 to complete the calculations to estimate turbine size for your application.

Table 2. Your system size calculations.

Total annual usage, in kWh	
Average load (annual usage ÷ 8,760)	
Average load divided by 0.2	
Average load divided by 0.1	
System size should be between _______ and _______ kilowatts.	

Challenges with the calculation

This simple calculation is problematic for two reasons. First, this is a rough estimate of system size that provides a general indication, but it is by no means accurate. A qualified installer will be better able to estimate system size. However, the bigger issue with this calculation is that it provides the result in rated power, which is not defined consistently in the industry. This inconsistency makes it a poor measure of comparison.

Another method

You will be better able to size and compare turbines as the SWCC tests more turbines. In the meantime, there are published sources that provide comparisons of turbines. For example, *Home Power Magazine* publishes an annual buying guide for wind turbines. Table 3 provides a sample of information from that guide that may help you understand more about system sizing. There are additional details in this guide, including survey information about each turbine, that can be useful in comparing machines.

According to Table 3, a consumer with approximately 10,000 kWh per year in electrical consumption and an estimated wind speed at the turbine's hub-height of 10 mph would be able to offset the majority of their consumption. Take note of the swept area, which is sometimes listed as rotor diameter. Swept area is one of the key determinants of energy output, so information in this guide is an indication of likely output at a given swept area. If you are considering a turbine not listed in this guide, compare its swept area with the manufacturer's estimated energy output. You may find small differences in output between systems with the same swept area. If the output projects are significantly different from actual production, inquire further about how output calculations were derived.

This method is also imperfect because it assumes you have accurately measured your wind resource. Based on the table, a change in wind speed of 1 mph will change power output by 20 to 40 percent. A qualified installer should be able to help you accurately assess wind speed and identify an appropriate system and system size for your situation.

Many homeowners question whether it is better to install a smaller system that offsets part of their consumption or a larger system that accounts for almost all of their energy needs. Here are a few considerations:

- There are economies of scale in small wind. A 10-kilowatt system is not 10 times as expensive as a one-kilowatt system. You may wish to use online calculators to identify differences in output and economic return with various system sizes.
- Most installers recommend you optimize system size for your consumption and work to offset the majority of your energy needs. Consider seasonal shifts in demand or improvements in energy efficiency as you size your system.
- It does not make financial sense in most states to purchase a system larger than your needs. In Missouri, excess energy may be purchased, but is usually purchased at wholesale or avoided cost rates — not the much higher retail electricity rate. Revenue from sales of excess energy is usually not enough to justify investment in a larger system.

Table 3. Information for comparing turbines.

Turbine	Excel-S
Manufacturer	Bergey Windpower
Specifications	
Swept area	415.0 ft^2
Warranty	10 years
SWCC certification application	Yes
Predicted annual energy output by avg. wind speed (kWh)	
8 mph	5,000
9 mph	7,100
10 mph	9,600
11 mph	12,700
12 mph	15,900
13 mph	19,500
14 mph	23,300

This information is provided for reference only and does not indicate an endorsement of Home Power Magazine *or Bergey Windpower.*

Source: Home Power Magazine *Jun-Jul 2011 edition*

Total rotor diameter is a good way to compare equipment. Do not assume total cost per foot of swept area is the best measure of value for a wind turbine. Cost per foot of swept area favors lightweight equipment, which may not be as durable as heavier equipment. Tower top weight per swept area is a better measure of viability. Greater tower top weight generally indicates a more durable turbine. Tower top weight is usually provided by the manufacturer.

Wind turbines lose some of the power generated, though the amount of loss varies by system. Assume total losses of 8 to 15 percent from issues such as availability, yaw, icing, electrical inverters, line losses and other factors. Energy production also varies with changes in wind speed.

According to the National Renewable Energy Laboratory, annual wind speed can vary from the average by 10 to 15 percent, and annual energy production can vary by as much as 30 percent.

Common terms

Understanding common terms may help you review information provided by manufacturers because they rarely present it in the same format. The same manufacturer may also use different assumptions for different turbines, and information differs by manufacturer. This means you have to investigate both what is said about a turbine and what assumptions are behind the data.

Annual energy output

Ideally, annual energy output calculations would determine your system size and power production. However, this is not the method preferred for several reasons:

- It is hard to know what assumptions a manufacturer uses in their calculations without industry standards.
- Calculations assume a wind resource was correctly estimated.

Most manufacturers use a range of 8 to 14 mph average wind speed in their calculations, which may be used by your installer in annual energy output calculations. The wind resource in these calculations needs to match the wind speed at your site. Some experts recommend multiplying manufacturers' annual energy output calculations by 75 percent to adjust for possible overestimates of actual energy output.

Power curves

Many manufacturers show power curves, which can be used to estimate annual energy production using the Method of Bins. The Method of Bins multiplies power production at each wind speed by the hours per year the wind blows at that wind speed, resulting in an energy "bin" for each different wind speed. Total energy output is calculated by adding the energy production in all bins.

Power curves can be hard to use and understand but it helps to know how the power curve was created. Some manufacturers use years of field data to create power curves. Others lack field data, so they generate a power curve based on computer models. Always ask for a power curve based on actual measurements. If a manufacturer does not have a measured power curve, they do not have a fully tested turbine.

Cut-in and cut-out speeds

The cut-in speed is the wind speed at which a generator begins producing power; around eight mph for most turbines. Wind speeds below seven mph provide little usable power. Turbines control power output in strong winds by reducing the rotor's exposure to the wind — such as by furling out of the wind or pitching the blades.

The cut-out speed is the wind speed at which a turbine shuts down to protect itself from strong winds. Many small wind turbines do not have actual cut-out wind speeds. Some will continue to produce power in high-wind situations. The cut-in speed of the turbine is around 9 mph, and the turbine begins limiting its power output between 25 and 30 mph. By 35 mph, the turbine protects itself from extremely strong winds and produces only limited power. Understanding your wind resource and the cut-in and cut-out speeds of a turbine is useful for selecting the best turbine for your location.

Rated wind speed

Rated wind speed is the wind speed at which a generator reaches its rated power. Because wind speed is a cubic function, doubling the wind speed results in eight times as much power. If wind speed is cut in half, power production is reduced to ⅛ of its former level.

A turbine with a lower rated wind speed is often advantageous.

Table 4. Example comparison of two turbine models.

	Scenario 1		Scenario 2	
Turbine model	A	B	A	B
Rated power	3 kW	3 kW	3 kW	3 kW
Rated wind speed	12 mph	24 mph	12 mph	24 mph
Wind speed	24 mph	24 mph	12 mph	12 mph
Power output	3 kW	3 kW	3 kW	375 watts

Other terms you might encounter

Generator size

Some manufacturers size the wind turbine by the size of the generator. For example, a turbine with a five-kilowatt generator would be a five-kilowatt wind turbine. This is not an accurate measure of energy output. "By this logic, you could slap a six-foot plank on the end of a 25-kilowatt generator and call it a 25-kilowatt wind turbine," said Paul Gipe, an industry expert on small wind. Wind energy production comes from wind speed, swept area, air density and effective blade technology. Due to variability in wind speed, air density and blade technology, a generator will not operate at its full potential all of the time and thus, is not an accurate indication of energy output.

Peak output

Peak output is a term used in marketing materials but is not helpful in many situations because the manufacturer sets the definition. Peak output can be useful in determining electrical connection, such as sizing circuit breakers. However, it is a poor method for determining energy output because it might not refer to the maximum output of the turbine.

Maximum design wind speed

This term refers to the maximum amount of wind the turbine can withstand without damage. The information is not helpful because it is hard to know if the information is correct and what standards were used to establish this figure. High winds are more likely to carry debris that could damage the turbine long before the force of the wind.

Rated output or rated power

Rated output is a power output at a certain wind speed. The problem with rated power is that it is defined by the manufacturer. The term comes from the solar panel industry, where panels are tested for output at a fixed light intensity and fixed temperature. These standards have only recently been defined for wind; they are not yet well established in the marketplace. Rated output is a poor method for calculating energy output because there is no standard definition.

The most consistent means of comparing wind turbines is the total rotor diameter, or swept area.

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