# E3A: Small Wind Energy Applications for the Home, Farm or Ranch

## Steps in the Small Wind Series



## Assess the wind resource at your site

This guide will help you understand the effects of wind speed, wind shear, wind distribution, prevailing winds, turbulence and elevation.

Take time to understand wind assessment and learn about your wind resource to help you ask the right questions when working with your installer. Your system installer should conduct a more in-depth analysis of the wind resource, as they usually have more accurate data and assessment tools. You can also purchase higher quality data using fee-for-service mapping tools.

Before buying wind data, know what data source the company uses. Some companies use free data for their maps, so you could get the same information on your own.

> Understanding how wind turbines generate power from the wind may help you to realize the importance of the wind energy resource:
>
> $\frac{1}{2}(\text{Air density}) \times (\text{Velocity})^3 \times (\text{Swept area of rotor})^2 = \text{Energy}$
>
> *Note: Wind speed is a cubic function in wind power generation. If the wind speed doubles, a wind turbine produces eight times the power. Wind power generation is sensitive to wind speed.*

## Wind speed

There are several sources for gathering information about the wind speed at your site, whether you gather the data yourself or purchase it from a third party.

### *Wind maps*

The best way to get site-specific wind information is to install an anemometer and collect data for at least one year. The anemometer should be installed at the same height as the planned wind turbine. Installing a tower and anemometer can be expensive. Most homeowners cannot afford to collect anemometer data, and the value of the data collected by an on-site anemometer is often not worth the cost for small turbines. Free data is often used to estimate wind speed, but these estimates rarely reflect actual wind speeds.

Free wind mapping data are available from:

- Department of Energy — Wind Powering America State Wind Maps: *www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp*
- National Renewable Energy Lab — PVWatts: *pvwatts.nrel.gov*

Wind maps are often created using a mix of publicly available data and wind modeling. It can be hard to know the source and quality of data used to develop a wind map. These sources indicate wind speed, but they likely have a high degree of variability.

### *Sources of local data*

Local data might be publicly available that provide information on local wind speeds, but they may not be accurate enough for your purposes. The data might be collected from rooftop anemometers at rural airports, in sheltered areas or near trees that affect wind speed. Agronomic weather stations collect data five to six feet off the ground, which is well below a typical wind generator's hub-height, and some anemometers are located in turbulent wind areas. These anemometers might work for their purposes but were probably not installed at the right hub-height or in the right area to collect wind information suitable for a wind power system. If you use local data, evaluate the site to determine whether it has good exposure to the wind, is free of turbulent air flows, and captures the wind at a hub-height similar to your potential system. In some states, anemometer loan programs for small wind are used to collect data that is often posted online and may be a good source for your project.

Free mapping tools based on existing local data are often the best information available. Data from these sources are not nearly as accurate as that from on-site data collection. Wind speed is key to accurately calculating both the energy production and economic return of a small wind turbine. Errors in wind speed estimates will yield inaccurate calculations. Most purchasers of small wind turbines have to accept some uncertainty in average annual turbine energy production projections. Here are a couple questions to consider:

- **Are you reasonably confident that your wind speed information is accurate?** If your answer is "no" or are uncertain, you may wish to buy data or ask your installer to conduct a more in-depth assessment.
- **Are you comfortable with the possibility that economic or energy output calculations might be off because of error in the wind speed estimate?** If you answered "no" or you are uncertain, consider installing an anemometer or buying data to help reduce the possibility of error. The bottom line is that wind is a variable resource, and you must accept variability in measuring wind speed. Error or uncertainty in the long-term average is different from variability. Even if an estimate for the long-term resource is precise, the wind varies from month to month and year to year. If you want more consistent energy output, you may wish to explore other technologies or invest in additional energy efficiency measures.

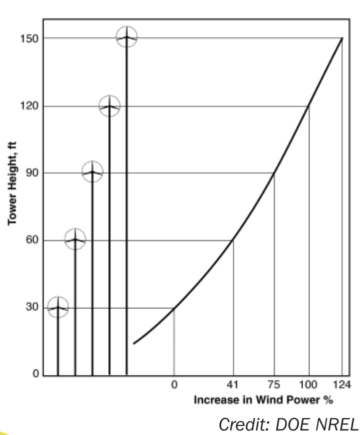
### Weibull values and online calculators

If you use an online calculator, you may need to input the k value, or Weibull. The Weibull value reflects the range of the distribution. A lower value represents a broader distribution with a wider range of wind speeds. Where it is not possible to obtain sufficient information to calculate an actual Weibell distribution, for inland locations it is typical to assume a Weibell of two, also known as a Rayleigh distribution.

### Wind shear

Wind shear is the change in wind velocity with elevation. Wind shear is affected by surface topography, wind speed and atmospheric stability. Wind shear is important to small wind because the power output of a turbine increases when wind speed increases.

Taller towers have access higher wind speeds, so a taller tower will produce more energy. You can maximize energy generation by building a tower to a height such that the bottom edge of the blade is at least 30 feet above the tallest obstacle within 500 feet.



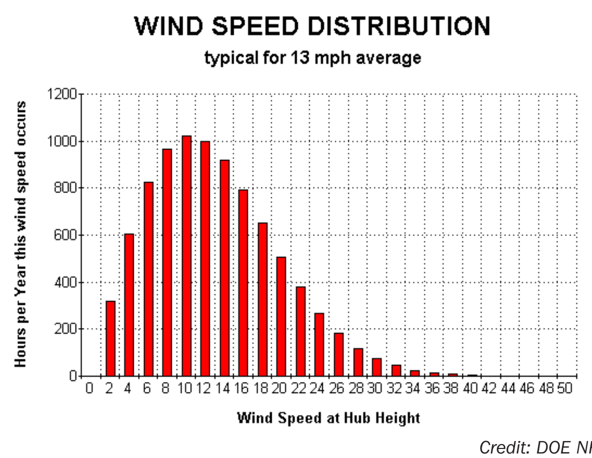

Credit: DOE NREL

### Wind distribution

Wind varies by time of day, season, height above ground and topography of the site. Wind speeds in most of the world are modeled using a statistical analysis called a Weibull distribution. A Weibull distribution describes the relationship between wind speed at a specific location and power production. Knowing the frequency of average wind speeds helps when selecting a turbine with an optimal cut-in speed, or the wind speed at which the turbine starts to generate usable power, and the speed at which the turbine is designed to curtail power production. The Weibull distribution can also be used to estimate the average annual output for a given wind turbine at your site.

### What does this mean to me?

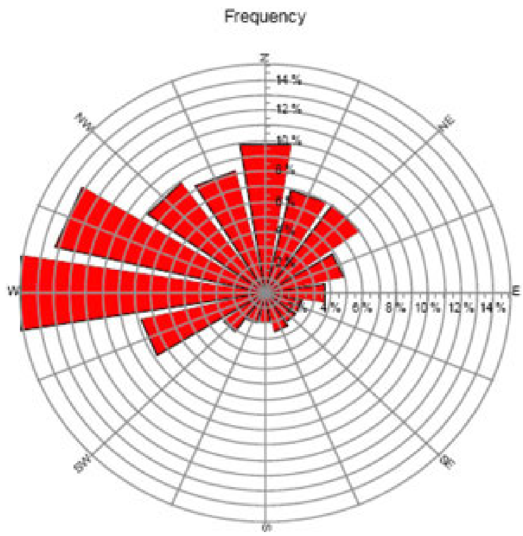
In the following diagram, you see a Weibull distribution for a site with an average wind speed of 13 miles per hour. Notice that the wind blew more often at wind speeds of 8 to 12 mph than at the average wind speed of 13 mph. Though the average wind speed is 13 mph, the more frequent wind speeds are 8 to 12 mph. In this case, if you bought a wind turbine optimized for 13 mph winds because that was the average wind speed, the turbine may perform less efficiently than a turbine optimized for 10 mph winds.




Credit: DOE NREL

### Wind rose

A wind rose can be extremely useful when choosing a site for a wind turbine. A wind rose graphs the prevailing wind direction and may show the percent of time the wind blows in a given direction or the amount of energy produced by those winds. However, free wind roses do not usually include energy information. In this drawing, prevailing winds come from the west and north. Turbines should be installed to access the strongest prevailing winds, but keep in mind the strongest wind might not be the most frequent. Wind roses from around Missouri are available at *http://agebb.missouri.edu/weather/windroses*. If data is collected from a low tower height or in an area with ground clutter, the wind rose may be inaccurate. It can, however, provide some basic information on prevailing winds in your area.




Credit: DOE NREL

### *Turbulence and obstruction*

Turbulence decreases power output from the turbine and causes stress on the equipment, so turbines should be built upwind of any obstacles to maximize energy production. Trees, buildings, grain silos and other obstacles can cause turbulence. The region of disturbed flow downwind of an obstacle is twice the obstacle's height and as much as 20 times long. For example, a 30-foot-tall house can create a region of turbulence 60 feet high and 600 feet long. This graphic depicts the turbulence created by a structure.

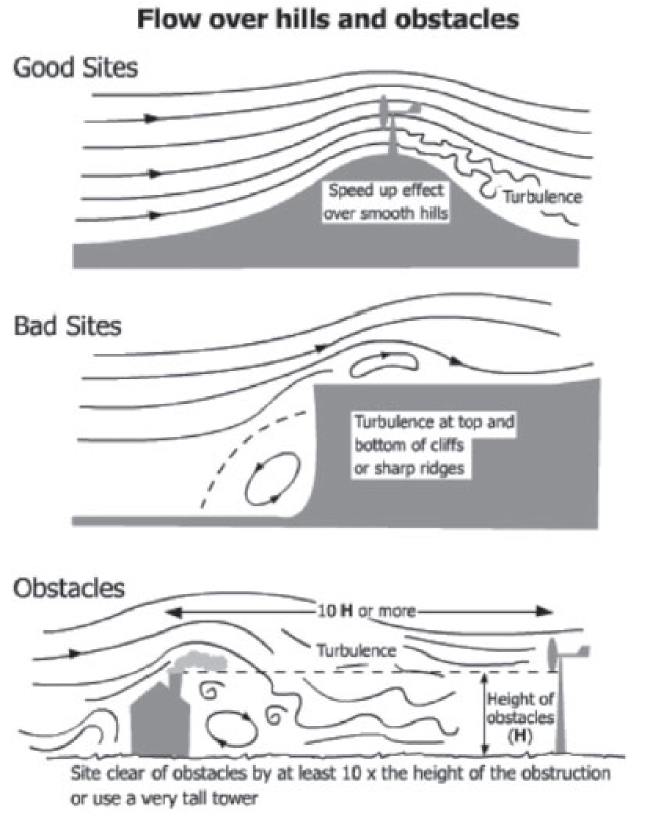
Turbulence and obstructed airflows may also be created by topography. Figure 1 illustrates characteristics of good sites and sites with high levels of turbulent airflow.

### *Sheltering*

In hilly terrain, wind follows channels, such as canyons. Placing a wind turbine on the downwind side of a hill or otherwise sheltering the turbine from the dominant wind will lower long-term energy output.

### *Air density*

Air density varies by temperature and elevation. Wind speed being equal, a wind turbine will produce more energy in the winter than in the summer due to the colder, denser air. Wind resource assessments often overlook variations in air density due to elevation. Many energy production calculators assume sea level in their calculations. Most sites in Missouri are around 1,000 feet above sea level. Air density declines at higher elevations, such that a turbine's annual energy production at 1,000 feet could be lower than a similar turbine at sea level. To adjust for elevation, estimate energy production for sea level and subtract 1.4 percent of total production for every 500 feet above sea level.




Credit: DOE NREL

Figure 1. An illustration of how turbulence affects different sites.

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