Site Analysis for Wind Generators

Part 1: Average Wind Speed

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ou've decided that it's time to consider a wind electric system. It sure seems windy in your area, at least part of the time anyway. And you could really use the power!

But how can you tell if a wind generator will really do well at your site? How do you know if you have enough wind, and where the wind is? And if it turns out that you do have a good resource, where's the best place to put the tower?

Tools

The common response to the above questions is that you must monitor the wind speed at your site for a year or two to find out if a wind generator will work for you. For a residential-sized system, this is nonsense! PV installers don't record available sunlight forever, so why do it for wind? Actually, PV installers have a couple of tools at hand to help them site PV arrays. We can do the same for wind generators.

In order to correctly site and size a wind electric system, it is helpful to have the following information about your location:

- average annual wind speed
- prevailing wind directions
- · vegetation and buildings at the site
- surface roughness
- the type of energy storage

What we need to do is quantify your resource in general terms first. Once that is done, we can fine tune your resource for your specific site. So, let's analyze each of these tools and see how to use them.

Options

Because it is so easy to address, let's consider the type of energy storage first. If utility electricity is available to you, by all means, consider a utility tie-in system. By using the grid, you eliminate the need for a very expensive and time consuming component: the

batteries. In a grid intertie system, the utility stores your electricity in the form of a credit whenever the wind is blowing. When the wind is still, you reclaim that credited power. In this case, your primary concern is producing enough electricity over extended periods of time to offset your consumption of utility-generated power. Daily or weekly production is irrelevant.

If yours is a remote system utilizing batteries rather than the utility grid, then you can actually do with less wind than the minimum cost-effective grid intertie system. Any renewable source of energy is more cost effective than running, maintaining, and fueling a gas or diesel generator for several decades.

In the case of a utility intertie system, a ten mph average annual wind speed is usually considered the cut-off. Below ten mph, the wind generator cannot be justified on a purely economic basis compared to purchased utility power. With a stand-alone system, wind generators are certainly cost effective in the nine mph and even the eight mph average wind speed ranges. These numbers refer to wind speeds at the height of the blades, referred to as hub height. The big question is, how do you get these numbers for your site?

You What???

Determining your exact average annual wind speed is difficult, expensive, and time-consuming. But, Mick, you say, you just told us that monitoring the wind for a year or so was nonsense. What gives?

While it is necessary to have an idea of your average annual wind speed, you do not need an exact measurement. We're not prospecting for a wind farm here. Therefore, monitoring wind speed at hub height for several years is unnecessary.

So how do we get this elusive number called average wind speed. We guess. Don't laugh! It's done all of the time, and fairly accurately, I might add. What we need to do is get a ballpark idea of the average annual wind speed for your area. I'll explain how it was done at my site, and we can work backwards from there.

Conventional Wisdom

When we moved to our homestead in Wisconsin, we investigated the use of a wind generator because it always "seemed" so windy. Conventional wisdom said to check the airport and weather bureau data for our area. We found that the average annual wind speed at the Green Bay airport, 35 miles away, was barely nine mph, hardly worth considering due to the cost of electricity we were buying from the utility.

After replanting the same peas in our first garden four times (they kept blowing out of the ground), we asked the neighbors what they thought. A few could remember wind generators in the area in the '30s and '40s, but they had all disappeared when the REA strung power lines through the area after World War II. That winter, our most frequent visitors were the county snow plows. Our corner of the country was plowed three and four times a day for the school buses and milk haulers (we live in dairy country). We quickly learned that leaving the homestead for a few hours could very well mean half a day of snow shoveling to get the car back home again.

After a few years of battling the wind and its effects, we decided to monitor our average wind speed. While the Green Bay airport and National Weather Bureau could still only muster a paltry nine mph annual average, our site turned up a surprising 13 mph at 100 feet after a year's monitoring. As we suspected, we did indeed have a respectable resource. So much for conventional wisdom!

Lessons Missed

We actually had positive indications from several sources around us, but failed to see their value. The first was our intuition. While gut feelings are hardly scientific, it's pretty hard to discount the breeze that blows your laundry all over the township every time you use the clothesline.

Our second indication was the problem of continuously drifting snow. Crews work full time in our area to keep the roads open. Other areas of the country experience similar problems with dust, dirt, sand, and dried bits of vegetation constantly "sandblasting" the neighborhood.

Our third indication was the collective experience of various old timers and the locals. Living in the area, they have spent considerable time with environmental factors that newcomers like us may have discounted or never experienced.

Our fourth indication was the vegetation in the area. We'll get back to this one in a bit.

We made the same mistake most folks do when first investigating wind energy: attributing the final word on average wind speed for our site to professionally collected data at a less than ideal location.

Assumption is the Mother of all Screw-Ups

Our problem occurred when we unquestionably accepted the value given to airport and weather data, considering their location versus ours. We discovered that weather bureaus monitor wind speeds at or slightly above street level, where people live. They do not monitor wind speeds at 80 or 100 feet, where wind generators live. And as we saw in Tower Economics 101 (HP#37) jumping from street level to 80 feet

substantially increases the average wind speed and, therefore, the power available in that wind.

Similarly, airport data has limited value. Because airplanes traditionally had problems taking off and landing in windy locations, airports were sited in rather sheltered locations. Virtually all airports are sheltered.

Most of the time the "professionals" really don't get it right. Without exception, all airports and weather bureaus I have visited have located their anemometers on the tops of buildings, next to trees, or in low spots on the terrain. In other words, their sampling equipment is either sheltered, or severely influenced by turbulence, or both. This helps to explain, for example, why the measured average wind speed at my site is greater than that recorded for the Green Bay airport. Taken at face value, professionally recorded wind speeds make a lousy yardstick for determining wind generator installations.

Making it Useful

Does this mean that we should discount airport or weather bureau averages? Not at all. What it does mean is that their average wind speeds are in all likelihood very low baseline numbers, really just a starting point for our consideration. Virtually all wind generator sites I have seen have higher wind speeds by at least a mile per hour or two when compared to the nearest airport or weather bureau. Many times the disparity is three or four miles per hour, as we found at our site.

Consider the location, topography, surrounding vegetation and buildings, and the monitoring height of the recording station equipment (airport or weather bureau). By comparing these to your location, you can get a feel for the potential differences between the sites. Then by using the graphs in "Tower Economics 101" (*HP*#37), you can make an educated guess as to your average annual wind speed at hub height.

You may be in for a surprise when you call or visit your nearest wind recording station asking about the physical location of the monitoring equipment. Believe it or not, a very common reply is, "We're not really sure where it is." This response doesn't do much to build confidence in their numbers!

Shear Factor

Another way of using nearby airport or weather bureau figures is to extrapolate their numbers to your location using a concept known as "shear factor". Based on their numbers and the topographical difference or similarity between your site and theirs, you can theoretically estimate your wind speed at any proposed height. I'll use our site again to explain how it's done.

Surface Friction Coefficient

from The Wind Power Book by Jack Park

Description of Terrain	α
Smooth, hard ground; lake or ocean	0.10
Short grass on untilled ground	0.14
Level country with foot-high grass, occasional tree	0.16
Tall row crops, hedges, a few trees	0.20
Many trees and occasional buildings	0.22 - 0.24
Wooded country; small towns and suburbs	0.28 - 0.30
Urban areas, with tall buildings	0.40

Table 1

How windy is it?

Table 2

Height Correction Factor, H

from The Wind Power Book by Jack Park

Height	Surface Friction Coefficient, α								
feet	0.100	0.140	0.160	0.200	0.220	0.240	0.280	0.300	0.400
10	0.895	0.857	0.839	0.802	0.785	0.768	0.735	0.719	0.644
15	0.933	0.908	0.895	0.870	0.858	0.846	0.823	0.812	0.757
20	0.960	0.945	0.937	0.922	0.914	0.907	0.892	0.885	0.850
25	0.981	0.975	0.971	0.964	0.960	0.957	0.950	0.948	0.929
30	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
35	1.016	1.022	1.025	1.031	1.034	1.037	1.044	1.047	1.063
40	1.029	1.041	1.047	1.059	1.065	1.071	1.083	1.090	1.121
45	1.041	1.058	1.067	1.084	1.098	1.102	1.120	1.129	1.176
50	1.052	1.074	1.085	1.107	1.118	1.130	1.153	1.165	1.226
55	1.062	1.089	1.102	1.128	1.142	1.156	1.184	1.199	1.274
60	1.072	1.102	1.117	1.148	1.164	1.180	1.214	1.231	1.319
65	1.080	1.114	1.132	1.167	1.185	1.203	1.241	1.261	1.362
70	1.088	1.126	1.145	1.184	1.204	1.255	1.267	1.289	1.403
75	1.096	1.137	1.158	1.201	1.223	1.245	1.292	1.316	1.442
80	1.103	1.147	1.170	1.216	1.240	1.265	1.316	1.342	1.480
85	1.110	1.157	1.181	1.231	1.257	1.283	1.338	1.366	1.516
90	1.116	1.166	1.192	1.245	1.273	1.301	1.360	1.390	1.551
95	1.122	1.175	1.203	1.259	1.288	1.318	1.380	1.413	1.585
100	1.128	1.184	1.212	1.272	1.303	1.335	1.400	1.435	1.618
105	1.133	1.192	1.222	1.284	1.317	1.350	1.420	1.456	1.650
110	1.139	1.199	1.231	1.296	1.330	1.365	1.438	1.476	1.681
115	1.144	1.207	1.240	1.308	1.343	1.380	1.456	1.496	1.711
120	1.149	1.214	1.248	1.319	1.356	1.394	1.474	1.515	1.741
125	1.154	1.221	1.257	1.330	1.368	1.408	1.491	1.534	1.769

Let's be daring and assume that the recording station knows the whereabouts of their anemometer, and that it is on the standard 30 foot tower it's supposed to be on. You visit their location and find that the anemometer is in a very well-exposed site, far from the influence of any trees or buildings. The recording station tells you that the average wind speed at the site for a 35 year period of time is 9.0 mph. What does this translate to at your site?

The first thing you do is estimate the similarity of your site to theirs and assign your site a surface friction coefficient from Table 1.

Assuming that their site is wide open and your site is like ours, a farm with the usual buildings and trees plus a nearby wooded area, you might choose a surface friction coefficient of 0.24. We have a 100 foot tower that we would like to use to

mount the wind generator. At 100 feet, we will easily pass the "30 feet above anything within 500 feet" rule (see Tower Economics 101). What kind of average wind speed can we expect at this height?

If we look across the 100 foot row in Table 2 to the column labeled 0.240, we find a correction factor of 1.335. Multiplying 1.335 by the recording station's figure of 9.0 mph means that we can expect an average annual wind speed of 12.0 mph at our site. While this is still below the actual measured average wind speed of 13.0 mph at our site, it's a lot closer than 9.0 mph!

The one caveat in using this technique is the assumption that the recording station's anemometer is not surrounded by trees and buildings. If it is, the shear factor technique of estimating wind speeds does not work very well.

Flagging

Another useful tool to help determine the potential of a wind site is to observe the area's vegetation. Trees, especially conifers or evergreens, are often influenced by winds. Strong winds can permanently deform the trees. This deformity in trees is known as

"flagging". Flagging is usually more pronounced for single, isolated trees with some height.

Pictured here is a pine tree in my yard with an obvious wind swept deformity. The upper part of the tree is swept back and away from the solar shower next to it. On the upwind side of the tree, the branches are noticeably stunted. On the downwind side, they're long and horizontal. The flagging was caused by persistent winds from, more or less, one direction.

Ecologists have been using flagging in trees for decades to ballpark the average wind speed for an area. (Vegetables don't lie!) Pick up any ecology book and you will find a diagram similar to the one bottom right on the page that quantifies an area's wind speed as a function of tree deformity.

Note that you can get an idea of the average wind speed by the amount of flagging. Comparing the picture to the diagrams, we could categorize my pine tree as Class III, an 11 to 13 mph average wind speed. The monitoring done at my site certainly bears this out.

If you do not have any conifers in your area, look around at the deciduous trees. They may also show evidence of flagging. Look around especially for single trees, or trees on the outskirts of a grove. Unless they have grown considerably above the common

tree line, trees in a forest will not show flagging because the collective body of trees tends to reduce the wind speed over the area.

While the presence of flagging positively indicates a wind resource, you should not conclude that the absence of flagging in your area precludes any suitable average wind speeds. Other factors that you are not aware of may be affecting the interaction of the wind with the trees.

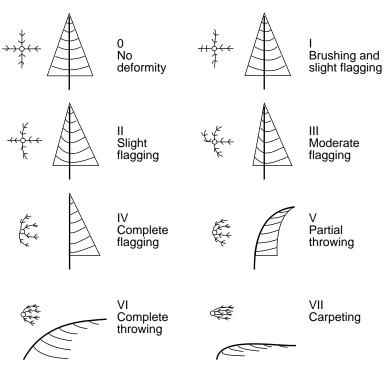
Tools Revisited

So far, the tools that we have available to us for approximating our wind resource are:

- The various experiences of your area's neighbors, especially the old timers
- Any flagging that might be observed in the surrounding areas
- Local wind generated problems (snow drifting, severe soil erosion, tumbleweeds)
- The average wind speed established by the nearest airport or weather bureau, which can be used as our baseline
- The average wind speed for your site as determined by the shear factor
- Your gut feelings based on all of the above



Above: Moderate flagging on a tree tells you how much wind is blowin' through.

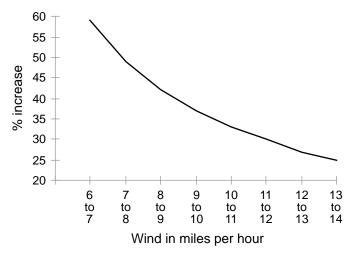


Griggs-Putnam Index of Deformity

from Wind Power for Home & Business by Paul Gipe

Index	I	II	III	IV	V	VI	VII
Wind Speed (mph)	7–9	9–11	11–13	13–16	15–18	16–21	22+

Power Increase vs. 1 mph Wind Speed Increase



Remember from "Tower Economics 101" that even small increases in wind speed can yield substantial increases in power to the wind generator because velocity is cubed in the power equation. This is especially true at lower average annual wind speeds, as depicted in the graph above.

The Bottom Line

So what is the bottom line number for an acceptable average wind speed? Because there seems to be such

a disparity between monitoring stations (airports and weather bureaus) and actual wind generator installations, we can actually fudge a little here. For a utility intertie system with a good exposure compared to the monitoring station site, an average wind speed of eight mph at the recording station or at ground level at your site is acceptable. Remember, our economic cutoff point (if you're doing this to make money) is ten mph at hub height when we're competing with cheap utility power.

For a battery charging wind system in which the monitoring station has nearly identical topographical exposure to your site, an annual average wind speed as low as seven mph at the recording station or at ground level at your site is acceptable. If the monitoring site is very sheltered compared to your site, this number could drop to about six mph. However, I wouldn't consider any site with average wind speeds less than these.

Next time we'll take a look at maximizing the usefulness of your site.

Access

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