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SMALL TURBINE COLUMN:

Considerations for Wind Generator Towers

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In order to assure good access to their fuel, wind generators are mounted high atop towers. There are two reasons for this. First, ground drag, the friction between moving air masses and the earth, decreases with increasing height above the earth's surface. Second, turbulence caused by obstacles on the earth, trees, and buildings, for example, is reduced with height above those obstacles.

The rule of thumb used in siting a home-sized wind turbine is that the entire wind turbine rotor should be at least 30 feet (10 meters) above anything within 500 feet (150 m) of the tower. Since the rotor sticks down an equal amount that it sticks above the tower height, the length of one blade is added to the tower height to give us the appropriate "hub height" for the wind generator.

Let's say that you have done a load analysis on your home, and know the annual average wind speed for your location. Manufacturers' specifications indicate that a wind generator with a 14-foot rotor will supply your electrical needs. You look around your rural property and note that the highest obstacle around is a 45-foot-high silo next to your barn. You are also surrounded by some trees, but at 30 to 40 feet, they are not quite as tall as the silo. What is the minimum height that you can get by with for your tower? Adding the 45-foot height of the silo to the 30-foot minimum rule plus the blade length of 7 feet results in a minimum hub height of 82 feet.

One thing you need to pay attention to is not the current tree height, but the height that the trees will grow to during the life of the wind system, that is, in 20 to 30 years. In my neighborhood, trees grow at a rate of about one foot per year, topping out at about 65 feet. If we take mature trees into consideration in the above example, the numbers are now a 65-foot tree height plus the 30-foot rule plus the blade length of 7 feet for a total hub height of 102 feet. Always remember the second rule of tower sizing: trees grow, but towers don't, regardless of how much it rains. This addresses the problems that turbulence poses for small wind turbines.

Note that the minimum hub height is just that – it's the minimum tower height that you can get by with and still produce electricity without the wind's power either being diminished by ground drag or compromised by turbulence. It is usually cost effective to increase tower height up to a point, depending on the size of the system and the local obstacles.

However, increasing the tower's height above the minimum still results in an increased wind system energy output. The power equation for determining the amount of energy that a wind turbine can generate states that $P=1/2dAV^3$, where P is the power available at the turbine rotor, d is the density of the air, A is the swept area of the rotor, and V is the wind speed. At a given location, we have no control over air density, so for any given wind generator with a given rotor diameter, the only real variable is V, wind speed. Therefore, we can rewrite the equation to say $P \sim V$, or more appropriately $P \sim V^3$.

For those who understand the power equation, this is stunning. While solar photovoltaics dealers cannot make the sun shine brighter at your site, and hydroelectric installers cannot make a river flow faster on your property, a good wind turbine installer can make it windier. And the V^3 portion of the power equation means that there is not a one-to-one relationship between increasing wind speed and increasing electrical generation. Doubling the wind speed does not result in a doubling of potential energy (a 100% increase), but an 800% increase, all because of V^3.

How do you increase wind speed, or V, at your site? Increase the tower height above the 30-foot rule, thereby further minimizing ground drag. Taller towers always result in the wind turbine generating more electricity. As you get away from the surface of the earth, ground drag – or the surface friction between moving air masses we call "the wind" and the surface of the earth – diminishes. As a result, wind speed – or V – goes up. V^3 considerably amplifies that increase.

Oftentimes, people rationalize a short tower height based on the cost of the turbine. I have heard it said that a small wind turbine in the size range of 1 kW or so does not justify the expense of a tall tower, which could be four or five times the cost of the turbine. This reasoning completely ignores the physics of fluid dynamics that dictates the tall tower in the first place. A wind turbine close to the tree tops suffers from lack of fuel, the wind, due to ground drag. In addition, the turbulence caused by the surface clutter at the site will cause increased maintenance on the turbine as well as shorten its life. In light of this, shorter towers than the site requires are no bargain because the turbine is not producing much electricity and its life expectancy is decreased.

The minimum acceptable tower height for a given site is always driven by the obstacles at that site. Increasing the tower's height above the minimum is driven by simple economics of incremental tower height at a certain cost versus incremental energy production.

I once told someone who lived in an area with 60-foot trees that the minimum tower he could install was 100 feet tall. He responded that a 30-foot tower should be adequate, because if he was meant to be 100 feet in the air, he would have been given 95-foot legs. If this describes your attitude because you cannot deal with tall towers, then, realistically, wind energy is not for you.

[Editors Note: The opinions expressed in this column are those of the author and may not reflect those of AWEA staff or board.]