Back to the Basics: Quantity + Quality = More Electricity

More tower, more power!

By MICK SAGRILLO

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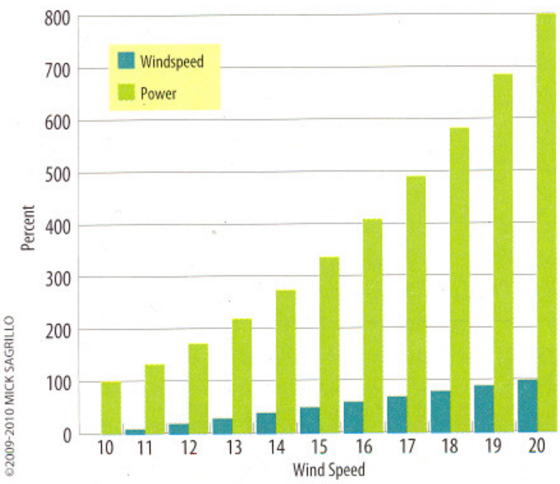
My past two columns have analyzed the two "enemies" of a wind turbine: ground drag and turbulence. As those columns pointed out, ground drag affects the quantity of the wind, while turbulence affects the wind's quality. In this column we'll take a look at just how important these variables are.

First, though, let's briefly review the concepts of wind quantity and quality.

Drag, Turbulence Are Detrimental

Wind, like water, is a fluid and follows the rules of fluid dynamics. A river flows fastest in the middle, where it's the greatest distance away from the bank and riverbed. Increased separation reduces friction with the rocks and earth of the riverbed, resulting in greater velocity of the fluid.

This is precisely what we want for our wind turbine: greater fluid velocity. Ground drag, the friction between the moving wind and the fixed Earth, is reduced considerably with tower height. Reduce ground drag with distance above the Earth and you increase wind speed, or the quantity of the wind. This is why wind farm turbines are placed on such tall towers.



Wind turbines with tall towers can take advantage of higher wind speeds, which results in exponential increases in power generation.

The second component of the wind, quality, refers to the turbulence caused by ground clutter. Trees and buildings cause the wind to tumble and swirl, which reduces the energy available for conversion to electricity. In addition, turbulence causes increased wear and tear on the wind turbine. Wind farm developers strive to site their projects well away from farm buildings, fence rows and woodlots to minimize the amount of turbulence from such obstacles.

Wind Speed Is Crucial

The phenomenal influence of these two crucial variables becomes evident in one simple equation:

$$P=1/2dAV^3$$

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 swept area, the only real variable is V, wind speed. Therefore, we can rewrite the equation as $P{\sim}V^3$.

This is stunning. It means that doubling the wind speed does not result in a doubling of power available to the turbine (a 100 percent increase), but an *800 percent* increase. This is illustrated in the graph to the left, in which the orange bars each represent a 10 percent increase in wind speed and the blue bars represent power available in the wind.

The upshot of this is that very small increases in wind will result in considerable increases in the power available in the wind. For example, wind velocity increasing from a paltry 8 miles per hour to only 10 miles per hour, a 25 percent increase in wind speed, results in a whopping 100 percent increase in power generation capacity. Again, this is why wind farm turbines are mounted atop such tall towers: to maximize the fuel available to the turbines.

Lesson: Taller = Better

A wind turbine close to the treetops or to the roofline suffers from both ground drag and turbulence. In light of this, a shorter tower than the site requires is no bargain because the turbine is not producing much electricity and its life expectancy is decreased.

Nevertheless, people often 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 or 2 kilowatts does not justify the expense of a tall tower, which might cost four or five times as much as the turbine. Worse yet, others look to completely forgo a tower and mount the wind turbine on the roof of a house. This reasoning completely ignores the physics of fluid dynamics, which dictate the tall tower in the first place, based on ground drag and turbulence.

To illustrate: If a given tower height has a 10 mph wind speed, and shortening the tower results in a 20 percent decreased wind speed to 8 mph, we've saved money on the tower, but we've also reduced the quantity of fuel available to the wind turbine by 50 percent and increased its turbulence.

A taller tower *invariably* results in the wind turbine generating more electricity.

To quote Steve Wilke at Bergey Windpower, "More tower, more power."

Next time we'll look at the rules of thumb for sizing towers. **ST**