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SMALL TURBINE COLUMN:

The Wind's Power at Various Tower Heights

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The past two columns have dealt with the fluid dynamics branch of physics that governs the flow of air over the surface of the earth and all the human-made obstacles that clutter the area where we live. This month we'll look at some documented wind speed data that should help explain these physics principles.

The Midwest Renewable Energy Association (MREA) has a wind generator on a 100-foot tower next to the Renew the Earth Institute, which houses their educational facility, demonstration center, and offices. Behind the building is a grove of pine trees in the 40-to-45-foot range. The neighborhood is slightly rolling, with roughly equal areas covered by farm fields and trees.

Wind speeds have been monitored on the tower since May, 2000, when the tower and wind turbine were installed. Anemometers are mounted at 46, 66, and 86 feet on the tower. The records indicate that the annual average wind speeds at their respective heights are as follows:

46 feet = 5.4 miles per hour (mph)
66 feet = 8.2 mph
86 feet = 9.7 mph

It should be obvious that the neighborhood that MREA is in certainly does not have wind farm potential, but it is quite typical, in terms of average wind speed, of many locales across the country where folks are interested in installing wind systems.

If we plug these numbers into a wind speed calculator that will give us wind speeds at standard tower increments, we get the following average annual wind speeds for MREA's site:

60 feet = 7.3 mph
80 feet = 9.3 mph
100 feet = 10.7 mph

Remember that the power equation states that $P=1/2dAV^3$, where P is 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 any given location, we have no control over air density, and for a given wind generator with the rotor diameter it was bestowed with, the only real variable is V, wind speed. Therefore, we can rewrite the equation to say P~V, or more appropriately $P \sim V^3$.

If we only look at the V^3 units of the power equation, and plug in MREA's average wind speeds at the corresponding standard tower heights, we get the following:

At 60 feet, V^3=389 units
At 80 feet, V^3=804 units
At 100 feet, V^3=1225 units

The obvious conclusion that we draw from this data is that taller towers result higher wind generation. The reason is reduced ground drag. As you get away from the surface of the earth, ground drag (or friction) on the wind decreases, and V goes up. V^3 amplifies that increase.

But just how significant is this increase in wind speed with increasing tower height? For example, since the trees around MREA are 40 to 45 feet tall, a person could conclude that they could get by with a 60-foot tower. How do the taller towers stack up?

The math reveals that, compared to the 60-foot tower, the 80-foot tower has 206% more power in the wind available to it, and the 100-foot tower has 315% more power available to it. Comparing the 80-foot tower to the 100-foot tower reveals a 152% increase in power. These are substantial numbers.

This is in a low wind area. Locales with higher wind speeds show similar, although slightly lower, potential increases for small wind turbines. For example, a home wind turbine tower in North Dakota monitored with anemometers at 84 feet and half way down at 42 feet shows a 10.7 miles per hour (mph) average wind speed at 42 feet, increasing to 13.2 mph at 84 feet. Doing the math reveals that this represents a 188% increase in power available in the wind with the taller tower. A monitored home-wind site in northern Illinois with a 10.3 mph average wind speed at 30 feet and a 13.3 mph average at 120 feet results in a 215% increase in power an the higher anemometer. Again, these are substantial numbers!

The upshot of this is that installing a taller tower will always result in the generation of more electricity. But taller towers will always cost more money as well. The next question that should be raised is whether the increased tower height is justified economically compared to the increased electricity production. That will be the subject of the next column.