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SMALL TURBINE COLUMN:

Tall Tower Economics

--Mick Sagrillo, Sagrillo Power & Light

The last four columns have built the case for tall wind turbine towers, based on the facts that turbulence due to ground clutter is decreased, that wind speed increases with height above the ground, and that higher wind speeds produce exponentially more power. In this column, we'll look at some options to tall towers: installing multiple turbines on shorter towers and installing a larger turbine on a shorter tower.

Last month, a real life situation was described using actual wind speed numbers recorded over several years at a site typical of many homeowners interested in installing a wind turbine. The conclusion of that column was that, at the site described, a 2.4% incremental increase in equipment and installation cost yielded a 226% increase in energy production for a 10-kW wind turbine by going from a 60-foot tower to an 80-foot tower. Installing a 100-foot tower instead of a 60-foot one resulted in a 5.5% increase in cost with a 344% increase in energy. The table from last month's column summarizes the details:

Tower height (feet)	Wind speed (mph)	kWh/year	System cost	Incremental cost from 60'	Incremental energy output from 60'	Incremental energy ÷ incremental cost = ROI*
60	7.3	2,709	$48,665	---	---	---
80	9.3	6,136	$49,841	$1176 or 2.4%	226%	226% ÷ 2.4% = 94 to 1 ROI
100	10.7	9,338	$51,346	$2681 or 5.5%	344%	344% ÷ 5.5% = 63 to 1 ROI

* = Return on investment

These are simply stunning returns on investment! But why is this? We have to back to the equation for power available in the wind, $P=1/2\ dAV^3$, explained in the four previous Small Turbine Columns. Increasing tower height means that the wind turbine will be exposed to higher winds, and V^3 exponentially amplifies the results.

However, taller towers are not the only means of increasing energy output. For example, we could put up multiple wind turbines on shorter towers to get the amount of energy we need, a suggestion often made by purveyors of wind equipment to prospective owners who are averse to heights, and therefore tall towers. Using the equipment cost table from last month's column, we found the following costs associated with the installation of the 10-kW wind turbine at various heights:

Tower Height (ft)	kWh/year	incremental energy output from 60'	System cost
60'	2,709	---	$48,665
80'	6,136	226%	$49,841
100'	9,338	344%	$51,346

For the sake of simplifying the example, let's round up the electricity production for the 60-foot tower while rounding down the outputs of the taller towers and rounding down the incremental energy for the 80- and 100-foot towers. Our new table is as follows:

Tower Height (ft)	kWh/year	incremental energy output from 60'	System cost
60'	3,000	100%	$48,665
80'	6,000	200%	$49,841
100'	9,000	300%	$51,346

Now, let's do two scenarios, the first where we need 6,000 kWh/year. The system costs would be the following:

Energy needed	Tower options	Itemized costs	Extended cost
6,000 kWh/year	1 @ 80'	$49,841	$49,841
	2 @ 60'	$48,665 x 2 =	$97,330

In the second scenario, we need 9,000 kWh/year:

Energy needed	Tower options	Itemized costs	Extended cost
9,000 kWh/year	1 @ 100'	$51, 346	$51, 346
	1@ 80' + 1@60'	$49,841 + $48,665 =	$98, 506
	3 @ 60'	$48,665 x 3 =	$145,995

Any way you rearrange this, the taller tower clearly emerges as the most cost effective option. Why? It all goes back to the power equation where power is a function of the wind speed cubed.

This model works rather dramatically for a rather large home-sized wind turbine in the 10-kW range. But what about a windier location with a reduced energy requirement, allowing for a small wind turbine?

Let's first use the Stelle, Ill., location mentioned in the December 2005 *Windletter* Small Turbine Column, where the owner monitored wind speeds at 30 feet and 120 feet, with the following results:

Tower height	Average wind speed	V^3 units	% increase
30'	10.3 mph	1093	----

120'	13.3 mph	2353	215%

The data tell us that one turbine at 120 feet will do a bit more than two turbines each on their own 30-foot tower. However, let's assume the owner is interested in several 1-kW turbines on 30-foot towers rather than the same turbine on the taller tower. We'll use complete turn-key pricing, meaning that the total cost includes the turbine, tower, batteries, inverter, electrical wiring, shipping, sales tax, and labor to install the equipment by a dealer. Note that a 30-foot tower is not available for this turbine, so we'll go to the next closest size, which is 40 feet. This will also make the two options more comparable in terms of energy output.

Tower options	Itemized costs	Extended cost
1 @ 120'	$16,168	$16,168
2 @ 40'	$13,045 x 2 =	$26,090

Again, the tall tower makes much more sense dollar-wise, even with a 1-kW wind turbine. Putting up two machines on two short towers cannot match the cost of one turbine on a taller tower. Why? V^3 !

For our final example, we'll use the North Dakota location mentioned in the December 2005 *Windletter* Small Turbine Column, where the owner monitored wind speeds at 42 feet and 84 feet, with the following results:

Tower height	Average wind speed	V^3 units	% increase
42'	10.7 mph	1225	----
84'	13.2 mph	2300	188%

For this scenario, we'll use two different manufacturers' products, both grid-tied systems. Interestingly, if we compare turbine outputs at the two heights from this site, the 1-kW turbine at 84 feet will produce about the same amount of energy as the 2.5-kW turbine on a tower half as tall.

Tower options	Itemized costs	Extended cost
1 2.5 kW turbine @ 42'	$19,518	$19,518
1 1kW turbine @ 84'	$14,279	$14,686

Again, we see that the taller tower option with a smaller wind turbine is less expensive than a larger turbine on a shorter tower to produce essentially the same amount of electricity. Why? V^3 !

So, what lessons can we learn from the past four columns, and the turbine economics scenarios laid out above?

1. Installing multiple shorter towers each with turbines instead of one taller tower to generate essentially the same amount of energy is always more expensive.

2. Installing a larger turbine on a short tower to compensate for a taller tower with a smaller wind turbine to generate essentially the same amount of energy is always more expensive.

Remember that most of the expenses for installing a wind system (turbine, shortest tower you can get by with, tower wiring, excavation, foundation, crane, electrical supplies, shipping, sales tax, and installation labor) apply to any system you install, regardless of tower height. Upgrading to a taller tower is only reflected in the incremental cost for the additional tower sections and associated hardware, plus the additional tower wiring, and maybe larger concrete footings. All of the other costs remain, regardless of the tower height. And the "magic" of V^3 will invariably skew the economics to favor the taller tower.

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