Back to the Basics: Turbulence

Why roof-mounted and short-tower turbines won't perform well.

By **MICK SAGRILLO**

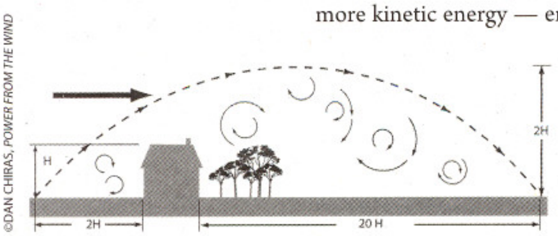
Mick Sagrillo, a small-wind consultant, owns Sagrillo Power & Light and is wind energy specialist for Focus on Energy, Wisconsin's renewable energy program. Contact him at msagrillo@wizunwired.net.

My January/February column explained speed differences in the flow of air, showing that wind near the surface of the Earth is slowed by a form of friction we call "ground drag." Ground drag reduces the speed of the moving air available to a wind turbine, regardless of the turbine technology or rotor orientation. Ground drag essentially reduces the *quantity* of the fuel we are trying to capture and convert into electricity.

Besides velocity, there is another property of a moving fluid (air is a fluid) that affects how much energy we can extract. That second property is a fluid's *quality*. The quality of the wind can be seriously compromised by something called "turbulence."

More Turbulence Means Less Energy

Let's go back to the river analogy that I used in the last column. Remember that near the riverbank, the water moved slowly due to the friction with the earth. As we moved away from the bank, toward the deep center of the river, the effect of friction diminished considerably, allowing for much faster flow of water. A faster-flowing fluid contains more kinetic energy — energy that, in the case of a water wheel or wind turbine, we can extract to generate more electricity. This is precisely why wind farm turbines are on such tall towers — they're located away from ground drag, where higher wind speeds, or more quantity of fuel, are found.



As this diagram shows, turbulence can extend well above and beyond an obstacle.

The river analogy illustrates turbulence just as well. When we toss a twig into the water near the bank, it moves slowly downstream. It also spins as it moves, caught in eddies. Toss the twig into the strong smooth current in the middle of the river and the random spinning is considerably reduced. Near the bank, we see the effect of turbulence on a moving fluid, a swirling, apparently chaotic motion. Swirling results from the water tumbling as it passes around obstacles in the river: rocks, tree stumps, branches, even the bank itself. The progress of the water downstream is compromised not only by friction with the bank, which reduces its velocity, but also by turbulent flow. The energy of turbulent water is diverted sideways, downward and even backward. It wouldn't be much use in turning a waterwheel.

The same phenomenon occurs in wind. Turbulence, like ground drag, is the bane of moving air because it reduces the amount of work the air mass can do. The amount of kinetic energy in the wind that can be extracted to generate electricity is considerably reduced by turbulence.

Snow Fences, Structures Cause Turbulence

This is not a new idea, and you don't even need to be human to use it. We know instinctively that anything attached to the ground can reduce the force or energy of the wind on its lee (or downwind) side. During a winter storm, cows and other animals hunker down behind a barn, a line of trees or a shelter, using the obstacle to block the flow of the wind. We put snow fencing up along roads and driveways to prevent the wind from drifting snow across where we want to travel. A snow fence, placed an optimal distance upwind of a road, acts as a trip line, causing the wind to tumble and reducing the work the wind can do. This intentionally induced turbulence causes the wind to drop its load of snow close to the fence and not on the road. It may not reduce blowing, but it considerably reduces drifting. Farmers often maintain fence rows, or lines of trees on the perimeter of agricultural fields. Like a snow fence, the purpose of a fence row is to break the flow of the wind, reducing the wind's power to carry away top soil.

Avoid Installing in Turbulence Bubble

There are other objects on the landscape that naturally do the same thing. These include our homes and barns and the trees we plant for shelter from the sun. They compromise the wind's forward motion, changing it from smooth laminar flow with lots of kinetic energy to turbulent flow, devoid of much of its original energy content.

This is a well understood problem when siting any wind turbine. Calculated as turbulence intensity, turbulent flow can reduce the amount of kilowatt-hours that a wind turbine can generate by 15 to 35 percent or more, depending on its severity. The more turbulence due to surface obstacles and ground clutter, the greater the turbulence intensity of the wind and the less electricity the wind turbine will generate.

The diagram printed here, from Dan Chiras' book *Power From the Wind*, shows that the bubble of turbulence around a windbreak extends well above and beyond the obstacle. A rule of thumb is that kinetic energy is compromised within a region roughly twice the height upwind and above the house or trees, and 20 times the height downwind (in the diagram, H equals the house height).

Installing a wind turbine within this turbulence bubble will result in a compromised wind resource, reduced energy generation, greater wear and tear on the wind turbine and, therefore, reduced life for the turbine. Installing beyond the turbulence bubble makes the difference between a smart installation and an ill-advised one. **ST**