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SMALL TURBINE COLUMN:

Back to the Basics 2: Turbulence

--Mick Sagrillo, Sagrillo Power & Light

The last Small Wind Column (www.awea.org/windletter/090818_AWEA_WL.pdf) explained the flow of water and air, both of which are fluids and therefore governed by the same laws of physics, known as "fluid dynamics." As fluids, both water and air are affected by the surfaces that they flow over or near, whether it be the bank of a river (in the case of water) or the surface of the Earth (in the case of the atmosphere). With respect to air masses that are moving, or what we call "wind," friction between the fixed planet and the moving air is termed "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.

But there is another property of fluids other than quantity and velocity that affects how much energy we can extract from them. That second property is a fluid's *quality*. The quality of the wind can be seriously compromised by something called "turbulence."

Bobbing and weaving

Let's go back to the river analogy that I used in the last column. Remember that we were sitting down by a river watching the water go by. We noticed that near the bank of the river, the water was quite sluggish due to the friction between it and the fixed river bank. As we moved away from the bank and further into the river, the effect of friction was diminished considerably, allowing for much faster flow of water. A faster flowing fluid has more kinetic energy in it—energy that, in the case of a wind turbine, we can extract to generate more electricity. The logical conclusion is that, in order to increase wind velocity, getting away from the surface of the Earth is a really good idea, just as getting away from the river bank results in faster water flow. This is precisely why wind farm turbines are on such tall towers—they're located where higher wind speeds, or more quantity of fuel, are found.

The river analogy illustrates turbulence just as well. Sitting back at the river, besides observing that the twig we tossed into the water near the bank took its sweet old time moving downstream, we also notice that it spins around a lot as it moves, tumbling down river. As we toss the twig further into the river and away from the friction caused by the bank, this random spinning is considerably reduced. What we are seeing near the bank is the effect of turbulence on a moving fluid, a swirling mess of random and chaotic motion near the bank instead of the orderly progression of water down the river. The swirling essentially results from the water tumbling as it "trips" over obstacles in the river: rocks, tree stumps and branches, even the bank itself. While this water is still moving downstream, its progress is compromised, not only by friction with the bank which reduces its velocity, but also by turbulent flow which diminishes the quality of its forward progress.

The same phenomenon occurs when it comes to air masses. Turbulence, like ground drag, is the bane of moving air because it reduces the amount of work that the air mass can do. In a river, ground drag slows the forward progress of the water while the incessant tumbling due to turbulence reduces the amount of useful work it can do. This same thing happens with air masses as they flow over the earth. Said another way, the amount of kinetic energy in the wind that can be extracted to generate electricity is considerably reduced by turbulence.

Turbulence at work

This is not a new idea or understanding. Indeed, humans as well as non-humans have put turbulence to good use for millennia. During a winter storm, for example, cows and other animals will hunker down behind a barn, a line of trees, or a shelter, using these as obstacles to block the flow of the wind. In rural locations, snow fencing is put up every fall along roads and driveways to prevent the wind from doing the work it is set on doing, which at our house is to relocate all of the snow from the surrounding farm fields right into our driveway (or so it seems). A snow fence, placed an optimal distance up wind of a road or driveway, acts as a trip line, causing the wind to tumble and reducing the work the wind can do. This intentionally induced turbulence created by the snow fence causes the wind to drop its load of snow before it has the opportunity to deposit it onto the road or driveway, considerably reducing "blowing and drifting."

Also commonly seen in rural areas are 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, lessening the wind's ability to pick up topsoil and blow it away and thereby reducing wind-blown soil erosion.

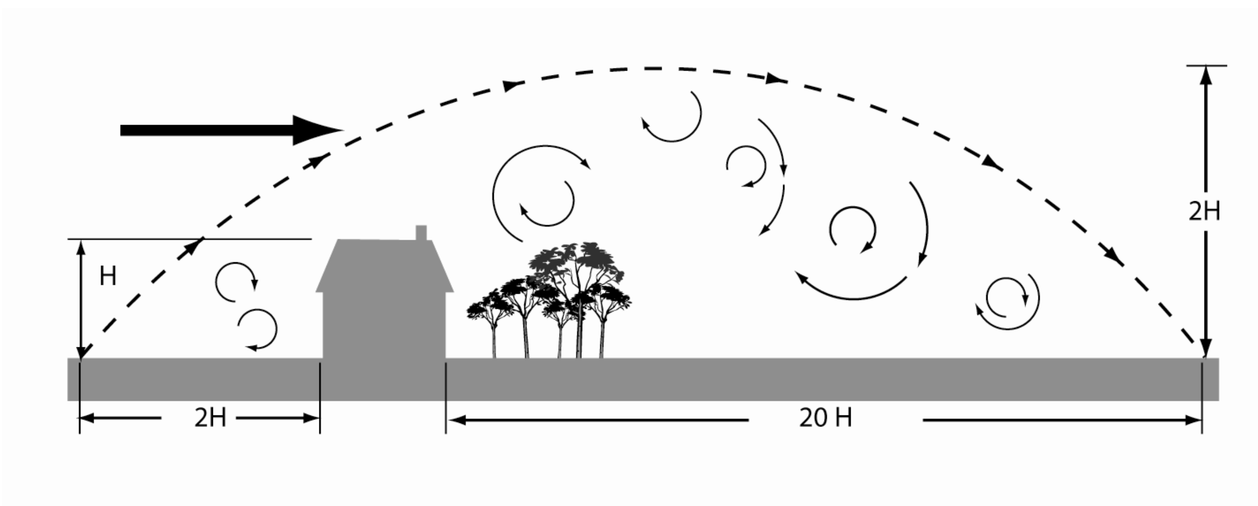
Wind shelters, snow fences, and fence rows are well understood in their design and application to create a trip line for the wind, intentionally put in the wind's path to block its flow and reduce the work that it can do. Whether to protect livestock from blustery winds, reduce "blowing and "drifting," or prevent soil erosion, the idea is to intentionally cause turbulence to disrupt the flow of the wind.

Turbulence is trouble

There are other objects on the landscape that inadvertently do the same thing. These include the buildings we dwell in and the trees we plant around those structures; in other words, they include many of the accoutrements and necessities of our lifestyle. Regardless of intent, they also 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 wind farms. Calculated as turbulence intensity, turbulent wind flow can reduce the amount of kilowatt-hours that a wind turbine can generate by 15-35% 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.

As the diagram from Dan Chiras' book *Power from the Wind* (© Dan Chiras) below shows, the bubble of turbulence around a home site extends quite a ways above and around obstacles: twice the height upwind and above the house or trees, and 20 times downwind (in the diagram, *H* equals the house's height).



So keep in mind that turbulence affects the quality of the fuel, regardless of the technology used to extract energy from it. That's because turbulence is reducing the fuel's—that is, the wind's—kinetic energy. 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 a reduced life for the turbine. Installing beyond the turbulence bubble makes the difference between a smart installation and an ill-advised one.

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Editor's note: The opinions expressed in this column are the author's and may not reflect those of AWEA's staff or board.