# Wind farms perform best when the sun is out

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The Shepherds Flat Wind Farm is an 845 MW wind farm in the U.S. state of Oregon. Credit: Steve Wilson / Wikipedia.

When set up in groups, wind turbines in the front rows cast a wind shadow on those behind them, lowering their performance. These effects dissipate fastest under convective conditions, say EPFL researchers in a recent publication.

Obviously, wind farms work best when it is windy. But aside from wind-speed and direction, there are other more subtle factors that influence their power output. Using a mathematical model, researchers from EPFL's Laboratory for Wind and Renewable Energy have shown the impact of vertical movements of the air on the productivity of wind farms. They found that increased turbulence caused by convective movements, common on hot, sunny days, increased the output of wind farms by shortening the lifespan of the turbulent wake downstream of the individual turbines. They published their results in the journal *Physics of Fluids* early this month.

Mahdi Abkar and Fernando Porté-Agel, the authors of the study, used a mathematical model to study the turbulence generated by a wind turbine as its rotors slice through the wind that drives them. With turbines often set up to form dense wind farms, understanding the turbulent wakes generated by upwind turbines and how long it takes for them to recover are important in predicting the overall power output of these wind farms, as turbines set up in the wind shadow of others are driven by strong wind. Today, turbines are spaced between five and seven turbine diameters apart – about 500 to 700 meters for large turbines – to maximize the amount of power that can be produced on a given area.

## Optimizing production over a 24-hour cycle

"What we were interested in was understanding the effect of thermal stability on the characteristics and dynamics of the turbulent wake behind wind-turbines," says Abkar. In other words, how do temperature-driven vertical movements in the lower atmosphere influence the turbulent wind shadow cast by a wind turbine. On sunny days, the hot ground causes the air above it to heat up and rise. This vertical motion is a characteristic of an unstable, convective atmosphere. On a typical night, by contrast, the earth's cold surface cools the air above it, leading to a stable situation.

Abkar used simulations to study the power output of a wind farm under convective and stable conditions and found a significant difference between both cases. "In the convective case, downwind turbines were about 30% less productive than those in the front lines. Under a stable atmosphere, the losses were even higher, on the order of 60%," he says. His findings are important to optimize the power output of wind farms over a 24-hour cycle, as the lower atmosphere goes its stable nocturnal state to the convective state typical of daytime.

So, why does the turbulence recover so much faster in the convective case? According to Abkar, this is mostly due to the higher levels of turbulence in the incoming wind, which enhances turbulent mixing within, thereby breaking apart the turbulent wake behind the turbines. By contrast, in the stable setting, the turbulence is allowed to linger on for much longer, as turbulent mixing remains low.

## Accounting for windfarms in weather models

Unraveling the detailed physics at play within wind farms is not only important to optimize their power output. Wind turbines alter the atmospheric dynamics by absorbing some of the wind and increasing turbulence, which can modify a number of other properties, such as atmospheric humidity and temperature. That is why meteorologists are interested in improving how they account for them in weather models. In a second paper, published in the journal of Renewable and Sustainable Energy, Akbar and Porté-Agel propose a new way to account for wind farms in large-scale atmospheric models that considers the number of turbines in the wind farm, the way that they are set up, and the wind direction.

**More information:** *Physics of Fluids*, scitation.aip.org/content/aip/ … /3/10.1063/1.4913695

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