Upwind wind plants can reduce flow to downwind neighbors

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New National Science Foundation and Department of Energy-funded research highlights a previously unexplored consequence of the global proliferation of wind energy facilities: a wake effect from upwind facilities that can reduce the energy production of their downwind neighbors.

In collaboration with the National Renewable Energy Laboratory (NREL), faculty at the University of Colorado Boulder (CU) and the University of Denver (DU) developed the paper, "Costs and consequences of wind turbine wake effects arising from uncoordinated wind energy development," which appears in *Nature Energy*. The study uses atmospheric modeling along with economic and legal analysis to demonstrate that wind facility wake effects—which occur when groups of turbines reduce wind speed for miles behind them—are measurable and predictable.

"This work argues for more thoughtful deployment of wind energy," said Julie Lundquist, a researcher at CU and lead author of the study. Lundquist, who works with NREL's National Wind Technology Center, is an associate professor in CU Boulder's Department of Atmospheric and Oceanic Sciences and a fellow of the CU/NREL Renewable and Sustainable Energy Institute. The paper is co-authored by K. K. DuVivier of DU's Denver Sturm College of Law, as well as Daniel Kaffine and Jessica Tomaszewski of CU.

Wind facility wakes have been observed to extend up to 25 miles. Of the

994 individual wind facilities in the United States in 2016, nearly 90 percent are within 25 miles of another wind facility, all of which could experience wake effects.

"Just as upstream water users can knowingly or unknowingly impose additional costs downstream, the same effect is in play here," said Kaffine, a professor in CU Boulder's Department of Economics. Research shows that wake effects do not undermine wind energy because they are predictable and only occur in specific atmospheric conditions.

"In addition to underscoring the value of carefully planned wind farm siting—particularly as the United States embarks on large-scale offshore wind deployment—this type of groundbreaking research exemplifies what makes NREL a leader in transforming global energy technologies and systems," said Johney Green, associate lab director for Mechanical and Thermal Engineering Sciences at NREL.

The largest wake effects occurred when winds were in a specific direction and at night as temperatures cooled. The most severe wake effects only occur less than 4 percent of the time for the wind facilities simulated in this study, indicating that wake losses can be anticipated and managed. Computer simulations allowed researchers to quantify the loss of wind generation. For the one month studied, power production dropped by 8 percent at the downwind facility when the upwind site was part of the simulation.

Tom Baerwald, program director for the National Science Foundation's Dynamics of Coupled Natural and Human Systems program, said the project explores the links among economic and legal issues and the geophysical processes in wind energy production. "These findings advance our understanding of these interactions and provide guidance for successful development of renewable energy for the future."

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