Study finds that linked wind farms can result in reliable power

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Wind farms can be built in mountainous regions, such as in Spain (above), or placed offshore like the one at Middelgrunden (other photo), near Copenhagen, Denmark.

Wind power, long considered to be as fickle as wind itself, can be groomed to become a steady, dependable source of electricity and delivered at a lower cost than at present, according to scientists at Stanford University.

The key is connecting wind farms throughout a given geographic area with transmission lines, thus combining the electric outputs of the farms into one powerful energy source. The findings are published in the November issue of the American Meteorological Society's *Journal of Applied Meteorology and Climatology*.

Wind is the world's fastest growing electric energy source, according to the study's authors, Cristina Archer and Mark Jacobson, who will present their findings Dec. 13 at the annual meeting of the American Geophysical Union in San Francisco. Their talk is titled "Supplying Reliable Electricity and Reducing Transmission Requirements by Interconnecting Wind Farms."

However, because wind is intermittent, it is not used to supply baseload electric power today. Baseload power is the amount of steady and reliable electric power that is constantly being produced, typically by power plants, regardless of electricity demand. But interconnecting wind farms with a transmission grid reduces the power swings caused by wind variability and makes a significant portion of it just as consistent a power source as a coal power plant.

"This study implies that, if interconnected wind is used on a large scale, a third or more of its energy can be used for reliable electric power, and the remaining intermittent portion can be used for transportation, allowing wind to solve energy, climate and air pollution problems simultaneously," said Archer, the study's lead author and a consulting assistant professor in Stanford's Department of Civil and Environmental Engineering and research associate in the Department of Global Ecology at the Carnegie Institution.

It's a bit like having a bunch of hamsters generating your power, each in a separate cage with a treadmill. At any given time, some hamsters will be sleeping or eating and some will be running on their treadmill. If you have only one hamster, the treadmill is either turning or it isn't, so the power's either on or off. With two hamsters, the odds are better that one will be on a treadmill at any given point in time, and your chances of running, say, your blender, go up. Get enough hamsters together, and the odds are pretty good that at least a few will always be on the treadmill, cranking out the kilowatts.

The combined output of all the hamsters will vary, depending on how many are on treadmills at any one time, but there will be a certain level of power that is always being generated, even as different hamsters hop on or off their individual treadmills. That's the reliable baseload power.

The connected wind farms would operate the same way.

"The idea is that, while wind speed could be calm at a given location, it could be gusty at others. By linking these locations together we can smooth out the differences and substantially improve the overall performance," Archer said.

As one might expect, not all locations make sense for wind farms. Only locations with strong winds are economically competitive. In their study, Archer and Jacobson, a professor of civil and environmental engineering at Stanford, evaluated 19 sites in the Midwestern United States with annual average wind speeds greater than 6.9 meters per second at a height of 80 meters above ground, the hub height of modern wind turbines. Modern turbines are 80 to 100 meters high, approximately the height of a 30-story building, and their blades are 70 meters long or more.

The researchers used hourly wind data, collected and quality-controlled by the National Weather Service, for the entire year of 2000 from the 19 sites. They found that an average of 33 percent and a maximum of 47 percent of yearly-averaged wind power from interconnected farms can be used as reliable baseload electric power. These percentages would hold true for any array of 10 or more wind farms, provided it met the minimum wind speed and turbine height criteria used in the study.

Another benefit of connecting multiple wind farms is reducing the total distance that all the power has to travel from the multiple points of origin to the destination point. Interconnecting multiple wind farms to a common point and then connecting that point to a far-away city reduces the cost of transmission.

It's the same as having lots of streams and creeks join together to form a river that flows out to sea, rather than having each creek flow all the way to the coast by carving out its own little channel.

Another type of cost saving also results when the power combines to flow in a single transmission line. Explains Archer: Suppose a power company wanted to bring power from several independent farms—each with a maximum capacity of, say, 1,500 kilowatts (kW)—from the Midwest to California. Each farm would need a short transmission line of 1,500 kW brought to a common point in the Midwest. Then a larger transmission line would be needed between the common point and California—typically with a total capacity of 1,500 kW multiplied by the number of independent farms connected.

However, with geographically dispersed farms, it is unlikely that they would simultaneously be experiencing strong enough winds to each produce their 1,500 kW maximum output at the same time. Thus, the capacity of the long-distance transmission line could be reduced significantly with only a small loss in overall delivered power.

"Due to the high cost of long-distance transmission, a 20 percent reduction in transmission capacity with little delivered-power loss would notably reduce the cost of wind energy," added Archer, who calculated the decrease in delivered power to be only about 1.6 percent.

With only one farm, a 20 percent reduction in long-distance transmission capacity would decrease delivered power by 9.8 percent—not a 20 percent reduction, because the farm is not producing its maximum possible output all the time.

Archer said that if the United States and other countries each started to organize the siting and interconnection of new wind farms based on a master plan, the power supply could be smoothed out and transmission requirements could be reduced, decreasing the cost of wind energy. This could result in the large-scale market penetration of wind energy—already the most inexpensive clean renewable electric power source—which could contribute significantly to an eventual solution to global warming, as well as reducing deaths from urban air pollution.

A wind power feasibility study of potential sites along the California coast by Mike Dvorak, a Stanford doctoral student in civil and environmental engineering who is working with Jacobson and Archer, also is being presented during an afternoon poster session at the meeting.

Source: Stanford University

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