Model shows wind could meet many times world's total power demand by 2030

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A wind farm in South Australia

In 2030, if all energy is converted to clean energy, humans will consume about eleven-and-a-half terawatts of power every year, all sources combined. If there is to be a clean-energy economy based on renewable energy, wind power will no doubt have to help meet much of that demand.

In a new study, researchers at Stanford University's School of Engineering and the University of Delaware developed the most sophisticated weather model available to show that not only is there plenty of wind over land and near to shore to provide half the world's power, but there is enough to exceed total demand by several times if need be, even after accounting for reductions in wind speed caused by turbines.

The findings were published in the Proceedings of the National Academy of Sciences (*PNAS*) by Mark Z. Jacobson, a professor of civil and environmental engineering at Stanford and Cristina Archer, an associate professor of geography and physical ocean science and engineering at the University of Delaware.

High resolution models

In their study, Jacobson and Archer adapted the three-dimensional, atmosphere-ocean-land computer model known as GATOR-GCMOM to calculate the theoretical maximum wind power potential on the planet taking into account wind reduction by turbines. Their model assumed wind turbines could be installed anywhere and everywhere, without regard to societal, environmental, climatic, or economic considerations.

The new paper contradicts two earlier studies that said wind potential falls far short of the aggressive goal because each turbine steals too much wind energy from other turbines, and that turbines introduce harmful climate consequences that would negate some of the positive aspects of renewable wind energy.

The new model provides a more sophisticated look than previously possible by separating winds in the atmosphere into hypothetical boxes stacked atop and beside one another. Each box has its own wind speed and weather. In their model, Jacobson and Archer exposed individual turbines to winds from several boxes at once, a degree of resolution earlier global models did not match.

"Modeling the climate consequences of wind turbines is complex science," said Jacobson. "This software allows that level of detail for the first time."

With a single model, the researchers were able to calculate the exposure of each wind turbine in the model to winds that vary in space and time. Additionally, the model extracts the correct amount of energy from the wind that gets claimed by the turbines, reducing the wind speed accordingly while conserving energy. It then calculates the effect of these wind speed changes on global temperatures, moisture, clouds and climate.

Potential aplenty

Among the most promising things the researchers learned is that there is a lot of potential in the wind—hundreds of terawatts. At some point, however, the return on building new turbines plateaus, reaching a level in which no additional energy can be extracted even with the installation of more turbines.

"Each turbine reduces the amount of energy available for others," Archer said. The reduction, however, becomes significant only when large numbers of turbines are installed, many more than would ever be needed.

"And that's the point that was very important for us to find," Archer said.

The researchers have dubbed this point the saturation wind power potential. The saturation potential, they say, is more than 250 terawatts if we could place an army of 100-meter-tall wind turbines across the entire land and water of planet Earth. Alternatively, if we place them only on land (minus Antarctica) and along the coastal ocean there is still some 80 terawatts available—about seven times the total power demand of all civilization. Hypothetical turbines operating in the jet streams six miles up in the atmosphere could extract as much as an additional 380 terawatts.

"We're not saying, 'Put turbines everywhere,' but we have shown that there is no fundamental barrier to obtaining half or even several times the world's all-purpose power from wind by 2030. The potential is there, if we can build enough turbines," said Jacobson.

How many?

Knowing that the potential exists, the researchers turned their attention to how many turbines would be needed to meet half the world's power demand—about 5.75 terawatts—in a 2030 clean-energy economy. To get there, they explored various scenarios of what they call the fixed wind power potential—the maximum power that can be extracted using a specific number of wind turbines.

Archer and Jacobson showed that four million, five-megawatt turbines operating at a height of 100 meters could supply as much 7.5 terawatts of power—well more than half the world's all-purpose power demand—without significant negative affect on the climate.

"We have a long way to go. Today, we have installed a little over one percent of the wind power needed," said Jacobson.

In terms of surface area, Jacobson and Archer would site half the four million turbines over water. The remaining two million would require a little more than one-half of one percent of the Earth's land surface—about half the area of the State of Alaska. However, virtually none of this area would be used solely for wind, but could serve dual purposes as open space, farmland, ranchland, or wildlife preserve.

Rather than put all the turbines in a single location, Archer and Jacobson say it is best and most efficient to spread out wind farms in high-wind sites across the globe—the Gobi Desert, the American plains and the Sahara for example.

"The careful siting of wind farms will minimize costs and the overall impacts of a global wind infrastructure on the environment," said Jacobson. "But, as these results suggest, the saturation of wind power availability will not limit a clean-energy economy."

More information: Read also: Enough wind to power global energy demand, new research says

"Saturation wind power potential and its implications for wind energy," by Mark Z. Jacobson and Cristina L. Archer, *PNAS*, 2012.

Provided by Stanford University

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