Wind resistance: Analysis suggests generating electricity from large-scale wind farms could influence climate

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Wind power has emerged as a viable renewable energy source in recent years -- one that proponents say could lessen the threat of global warming. Although the American Wind Energy Association estimates that only about 2 percent of U.S. electricity is currently generated from wind turbines, the U.S. Department of Energy has said that wind power could account for a fifth of the nation's electricity supply by 2030.

But a new MIT analysis may serve to temper enthusiasm about wind power, at least at very large scales. Ron Prinn, TEPCO Professor of Atmospheric Science, and principal research scientist Chien Wang of the Department of Earth, Atmospheric and Planetary Sciences, used a climate model to analyze the effects of millions of wind turbines that would need to be installed across vast stretches of land and ocean to generate wind power on a global scale. Such a massive deployment could indeed impact the climate, they found, though not necessarily with the desired outcome.

In a paper published online Feb. 22 in *Atmospheric Chemistry and Physics,* Wang and Prinn suggest that using wind turbines to meet 10 percent of global energy demand in 2100 could cause temperatures to rise by one degree Celsius in the regions on land where the wind farms are installed, including a smaller increase in areas beyond those regions. Their analysis indicates the opposite result for wind turbines installed in water: a drop in temperatures by one degree Celsius over those regions. The researchers also suggest that the intermittency of wind power could require significant and costly backup options, such as natural gas-fired power plants.

Prinn cautioned against interpreting the study as an argument against wind power, urging that it be used to guide future research that explores the downsides of large-scale wind power before significant resources are invested to build vast wind farms. “We’re not pessimistic about wind,” he said. “We haven’t absolutely proven this effect, and we’d rather see that people do further research.”

Daniel Kirk-Davidoff, a chief scientist for MDA Federal Inc., which develops remote sensing technologies, and adjunct professor of meteorology at the University of Maryland, has examined the climate impacts of large-scale wind farms in previous studies. To him, the most promising result of the MIT analysis is that it indicates that the large-scale installation of wind turbines doesn’t appear to slow wind flow so much that it would be impossible to generate a desirable amount of energy. “When you put the wind turbines in, they are generating the kind of power you’d hope for,” he said.

Tapping the wind resource

Previous studies have predicted that annual world energy demand will increase from 14 terawatts (trillion watts) in 2002 to 44 terawatts by 2100. In their analysis, Prinn and Wang focus on the impact of using wind turbines to generate five terawatts of electric power.

Using a climate model developed by the U.S. National Center for Atmospheric Research, the researchers simulated the aerodynamic effects of large-scale wind farms — located both on land and on the ocean — to analyze how the atmosphere, ocean and land would respond over a 60-year span.

For the land analysis, they simulated the effects of wind farms by using data about how objects similar to turbines, such as undulating hills and clumps of trees, affect surface “roughness,” or friction that can disturb wind flow. After adding this data to the model, the researchers observed that the surface air temperature over the wind farm regions increased by about one degree Celsius, which averages out to an increase of .15 degrees Celsius over the entire global surface.

According to Prinn and Wang, this temperature increase occurs because the wind turbines affect two processes that play critical roles in determining surface temperature and atmospheric circulation: vertical turbulent motion and horizontal heat transport. Turbulent motion refers to the process by which heat and moisture are transferred from the land or ocean surface to the lower atmosphere. Horizontal heat transport is the process by which steady large-scale winds transport excessive heat away from warm regions, generally in a horizontal direction, and redistribute it to cooler regions. This process is critical for large-scale heat redistribution, whereas the effects of turbulent motion are generally more localized.

In the analysis, the wind turbines on land reduced wind speed, particularly on the downwind side of the wind farms, which reduced the strength of the turbulent motion and horizontal heat transport processes that move heat away from the Earth's surface. This resulted in less heat being transported to the upper parts of the atmosphere, as well as to other regions farther away from the wind farms. The effect is similar to being at the beach on a windy summer day: If the wind weakened or disappeared, it would get warmer.

In contrast, when examining ocean-based wind farms, Prinn and Wang found that wind turbines cooled the surface by more than one degree Celsius. They said that these results are unreliable, however, because in their analysis, they modeled the effects of wind turbines by introducing surface friction in the form of large artificial waves. But they acknowledge that this is not an accurate comparison, meaning that a better way of simulating marine-based wind turbines must be developed before reliable conclusions can be made.

In addition to changes in temperatures and surface heat fluxes, they also observed changes in large-scale precipitation, particularly at the mid-latitudes in the Northern Hemisphere. Although these changes exceeded 10 percent in some areas, the global total changes were not very large, according to Prinn and Wang.

To investigate the effect of wind variability on the intermittency in wind power generation, the researchers used the climate model to estimate the monthly-mean wind power consumption and electrical generation for each continent, concluding that there are very large and geographically extensive seasonal variations, particularly over North and South

America, Africa and the Middle East. They explain that this unreliability means that an electrical generation system with greatly increased use of wind turbines would still require backup generation even if continental-scale power lines enabled electrical transmission from windy to non-windy areas.

Although Prinn and Wang believe their results for the land-based wind farms are robust, Wang called their analysis a "proof-of-concept" study that requires additional theoretical and modeling work, as well as field experiments for complete verification.

Their next step is to address how to simulate ocean-based wind farms more accurately. They plan to collaborate with aeronautical engineers to develop parameters for the climate model that will allow them to simulate turbines in coastal waters.

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