Wind resistance

MIT analysis suggests generating electricity from large-scale wind farms could influence climate — and not necessarily in the desired way.

Morgan Bettex, MIT News Office

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Image: istockphoto

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

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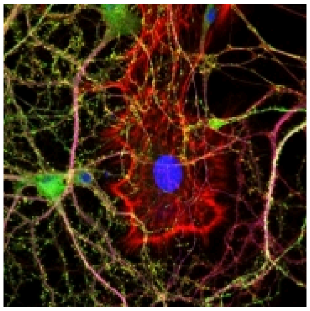
A change of mind


MIT neuroscientists have shown that the protein Arc is necessary for neurons like this one to adjust their responses to new sensory stimuli. (The blue circle is the neuron's nucleus, and the red strands are actin filaments.) Image: Jason Shepherd

One protein appears to control neurons' ability to react to new experiences, MIT scientists show.

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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.

Comments

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pa_ubach - **What is the relevance?** 2010-03-12 06:20:03

I find this article of very little relevance. The argument is very poor as other artifical constructions such as cities can indeed increase local temperatures by a much larger factor - also because of wind friction, if I may say (among other factors)- and nobody questions it.

The question that comes to my mind after reading the article is: And so what?

I am not saying that the research lacks merit, but that the focus of the article might be misguided.

spad12 2010-03-12 07:57:52

The problem is not that windmills are the only artificial construction that causes this effect, but rather that if wind is deployed on a scale to generate a significant portion of the worlds electricity these effects become very large.

To put it into perspective, in order to generate ~60% of the electricity in the US with wind you would have to cover an area twice the size of the state of Illinois with windmills. This area is immensely larger than the area of any other artificial construction.

NeilBlanchard - **Carbon offset?** 2010-03-12 06:20:09

Hello,

Did the study take a carbon offset into account? In other words, if the electricity generated from the wind turbines had to be generated by coal (or oil or gas, etc.) what would the temperature change be?

Remember, nuclear power is made by making heat, so I'll hazard a guess that it would also add heat to it's local area, too.

Sincerely, Neil

spad12 2010-03-12 07:58:13

The problem is that wind has to be backed up with natural gas. The interesting thing is that there is a maximum carbon offset by generating wind, which occurs when about 5% of your power comes from wind. After this point the carbon offset goes down with increasing wind power, eventually going negative when it starts offsetting other clean sources such as hydro and nuclear.

The amount of heat that a nuclear power plant releases into the environment is incredibly minuscule compared to the total energy deposited / radiated off into space. It really doesn't matter.

jocelynbb - **only the beginning** 2010-03-12 07:58:50

in defense of the author, obviously there are many other factors in global warming and this is only one possibility, but needs to be studied.

the difficulty presented in isolating all the different variables is precisely what keeps fueling (excuse the pun!) the argument of whether or not man made global warming exists. however, the charts on CO 2 increase since the industrial revolution are immutable.

this article introduces yet another factor to be considered as we choose which energy forms will propel us forward into the 21st century, and opens a dialogue suggesting further study, always a prudent step in the process of adopting policy and encouraging or discouraging investment.

dykesk - **inconclusive** 2010-03-15 05:20:41

The authors themselves note in the article that there are many limitations on the work at present and much more research is needed. The tone of press article above I believe overstates what the research article itself claims. It's good that research is being done on this topic, but results are FAR from conclusive - I'd worry that people just hearing about this article or reading it would get the wrong idea about what the state of science is on this topic.

sylphe - **wind farms' effect on climate** 2010-03-15 05:21:26

Let's keep in mind that this was a "proof-of-concept" study. I will be interested in the additional work and field experiments, particularly with regard to the role of ocean-based wind-farms and if it is to include modeling and verification of the changes to be expected in terms of the contribution of CO2 to global warming. This contribution may well dwarf all the other effects of wind-farms on global temperature, given that ocean-based wind-farms could cause changes in the gradient of density of CO2 closest to the surface of the ocean. Would these changes in CO2 density result in trapping more or less of the heat reflected from the oceans' surface? And could this, in turn, also contribute to other climatic changes like wind directions, amount of precipitations and even affect the direction of sea currents like El Nino?

tturner - **Wind turbines atop water towers?** 2010-03-15 05:21:52

Wind turbine pumps atop existing water towers would harvest/store intermittent energy efficiently without conversion or distribution losses. Plus in case of
disasters provide an alternative to maintain vital water supply pressures.

A google search returns a patent application for this obvious idea but finds no wide-scale deployments yet?

MacchuPicchu - **Ability to change local climate** 2010-03-18 04:45:11

What I find interesting is knowing that we could relatively control the local climate (at ground level and even if only by 1 deg), could this knowledge be used to both generate clean energy as well as have a positive effect on nearby crops that may do better in a slightly warmer climate?

Also, can the potential cooling effect of ocean based wind farms counteract the warming effect of the ground-based wind farms globally (assuming the cooling effect is demonstrable)?

If only ocean-based wind farms are massively deployed, would this then counteract global warming, one, by producing clean energy and by avoiding fossil fuel emissions and, two, by the intrinsic cooling effect created by the wind farm itself?

AMADEUS - **We must follow carefully further development...** 2010-03-22 05:26:57

Interesting work, whose further development will have to follow carefully, to act accordingly.

In any case you must balance the possible increase in the temperature of the planet due to wind, systems produced by other alternatives that are viable in the future.

That will not be many in view of the upcoming dates that we will reach the peaks current energy sources: "peak-oil" by 2015, "peak-U" in 2030, "peak-gas" in 2040.

On the other hand the article raises the need to use the element of wind variability stability combined cycle gas plants. This aspect is true today, but in the future, as we get closer to the "peak-gas" significant increases in gas prices, make economically unfeasible. The only serious alternative medium term is the energy storage. And this time the only way to mass storage at a reasonable cost is hydraulic, storing energy in reservoirs water up through the pump. And this alternative there is, in their use, off greenhouse gases.