Air pollution cuts solar energy potential in China

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China is rapidly expanding its solar power supply, hoping to meet 10 percent of the nation's electricity needs with solar energy by 2030. But there's a problem: severe air pollution is blocking light from the sun, significantly reducing China's output of solar energy, particularly in the

northern and eastern parts of the country.

This issue is worst in the winter, when—according to research from Princeton University—air pollution in these regions blocks about 20 percent of sunlight from reaching solar panel arrays, on average. That makes air pollution's wintertime effect on solar energy production as significant as that of clouds, which have long been considered the main impediment to solar energy production.

Published in the *Proceedings of the National Academy of Sciences*, the study shows that in the most polluted areas of northern and eastern China, aerosol pollution is reducing the potential for solar electricity generation by as much as one and a half kilowatt-hour per square meter per day, or up to 35 percent. That's enough to power a vacuum cleaner for one hour, wash 12 pounds of laundry or work on a laptop for five to 10 hours.

Burning fossil fuels increases aerosol concentrations in the atmosphere. Other researchers have recognized that these aerosols, which include sulfate, nitrate, black carbon particulates and brown organic compounds, are contributing to solar dimming over large parts of China. But no previous research had calculated just how much aerosols in the atmosphere are reducing China's solar energy generating efficiency.

"Developing countries with severe air pollution that are rapidly expanding solar power, such as China and India, often neglect the role of aerosols in their planning, but it can be an important factor to consider," said Xiaoyuan (Charles) Li, a Ph.D. candidate in Princeton's Department of Civil and Environmental Engineering and the study's lead author.

To calculate how much of the sun's radiation is reaching solar arrays on the ground, the scientists used what's called a solar photovoltaic performance model, combined with satellite data from NASA

instruments that measure irradiance from the sun and analyze aerosol components and clouds in the atmosphere. They conducted nine separate analyses, which spanned 2003 to 2014 and covered all of China, to compare the impact of aerosols compared to clouds on solar power generation with and without technology that tracks the sun as it moves across the sky.

"Particulate pollution from power plants, vehicles, biomass burning and natural events such as dust storms" can be a major impediment to solar power generation, said Daniel Kammen, the Class of 1935 Distinguished Professor of Energy and director of the Renewable and Appropriate Energy Lab at the University of California, Berkeley, who was not involved in the research. The study, he said, "uses rigorous atmospheric chemistry modeling" to quantify how pollution affects the amount of solar radiation reaching the ground, "which, ironically, also can be used to determine the clean energy benefits" of cutting carbon emissions.

Li said the study's findings should further spur countries like China and India to cut aerosol emissions so they reduce pollution and thereby increase their solar electricity generation more rapidly, in addition to the already known health benefits. There is also potential for a virtuous cycle: expanding solar energy production could reduce reliance on fossil fuels, thus cutting down on the very emissions that hamper solar power production, Li said. This would send more solar electricity into the grid—which, in turn, should further cut the need for fossil fuels.

The findings can also help determine where to build new solar arrays. Aerosol pollution in China is heavily concentrated in industrialized, urbanized regions, while remote, thinly populated areas have much cleaner air. If research can quantify how much air pollution is reducing solar power output, policymakers can weigh the costs of transmitting electricity from cleaner regions to dirtier ones against the benefits of producing more power by building arrays where more sunlight reaches

the ground.

"Reduction in solar generation due to clouds has been a primary focus in the past," said Denise L. Mauzerall, a professor of Environmental Engineering and International Affairs who serves as Li's faculty adviser and helped develop the study. "But this is the one of the first times atmospheric air pollution has been taken into account in determining solar photovoltaic cells' ability to generate electricity."

For their next project, the researchers are expanding their analyses to other regions of the world, including India, which suffers from air pollution levels as high as China's. In addition to how air pollutants in the atmosphere reduce electricity generation by absorbing sunlight, they will also examine how air pollutants may reduce power generation by dirtying the solar panels themselves.

More information: Xiaoyuan Li el al., "Reduction of solar photovoltaic resources due to air pollution in China," *PNAS* (2017). www.pnas.org/cgi/doi/10.1073/pnas.1711462114

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