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What runs a zero-carbon grid in a renewable energy slump?

The Biden administration aims to drive carbon emissions out of U.S. power networks by 2035. To get there, experts must figure out how to keep on the lights when wind and solar go dark.

BY: **PETER BEHR** I 10/07/2022 07:02 AM EDT

Solar panels are seen under a storm cloud. I WichienTep/iStock

In Germany, “dunkelflaute” are the dark doldrums: the days when wind and solar power disappear from the grid.

To Paul Denholm, a senior energy analyst at the National Renewable Energy Laboratory, it’s “the last 10 percent problem” — one that hangs over the Biden administration’s goal of driving carbon emissions out of U.S. power networks by 2035.

A range of experts, including Denholm, say existing renewable technologies — including wind, solar and batteries — can fulfill 80 or even 90 percent of energy demand on the U.S. grid. But the rest is the dunkelflaute; on the days when wind and solar stops working, what reliable energy source steps in to fill the gap?

"The remainder is really hard to meet with wind, solar and storage," said Denholm, co-author of a recent NREL analysis that looked into how a carbon-free U.S. grid could operate securely in 2035.

That analysis finds that the "10 percent problem" would come down to natural gas, at least over the next dozen years. In a future where the grid's emissions steadily decline and new transmission lines are extended wherever needed — two critical policy paths not in place today — the most cost-effective backup energy would be large numbers of natural gas plants that run only occasionally.

Under that scenario, wind and solar would be the dominant sources of hour-to-hour electricity.

The NREL analysis assumes their annual deployment would quadruple, compared to today, to keep up with soaring electricity demand. By 2035, overall demand would be three times the 2020 level, fed by increasing sales of electric vehicles and the switch from gas to electric heat in buildings.

In short, said Denholm: "You're going to have to build an awful lot of stuff."

But for the handful of hours when wind and solar are down, NREL found that natural gas was the least costly option — even though that would mean keeping open many plants that rarely run. That's because such facilities have low capital and fixed operating costs.

In one principal scenario, natural gas would provide about 20 percent of total U.S. generating capacity in 2035 but supply only about 4 percent of energy demand.

"This is similar to today's power system, where peaking plants represent a large fraction of the system's capacity but provide a small fraction of total energy," the study said.

A study from the Grattan Institute comes to the same conclusion. The study — backed by the Australian government, the Victoria state government and the University of Melbourne — considered how to eliminate greenhouse gas emissions in Australia.

It found that as renewable supply grows, "the physical and economic challenge of balancing the system during rare, sustained periods of high demand, low wind, and cloudy skies becomes too big."

"Gas generation with offsets looks to be the lowest-cost 'backstop' solution until zero-emissions alternatives — such as hydrogen-fired generation or near-perfect carbon capture and storage —

are economically competitive," the study's authors wrote. "Gas is likely to play a critical, but not expanded, role."

NREL similarly concluded that other options, including advanced nuclear reactors, hydrogen storage and carbon capture, are not far enough along in infrastructure and development to determine their cost a dozen years from now. Its analysis concludes that such technology could take the place of natural gas in backing up wind and solar after 2035.

Future droughts of wind and solar

The NREL study and others like it have a large caveat: They assume future years will have similar weather to the recent past. But climate change is making extreme weather more frequent, and that could make episodes of the "dark doldrums" more threatening.

Researchers are zeroing in on closing that gap. Recently, the National Science Foundation funded a multiyear, $2 million study that will use supercomputers to look deeper into this potential threat to grid reliability, making predictions of how extreme weather could impact wind and solar power out to the midcentury.

Cornell University's Center for Advanced Computing will create a computer model to help researchers predict future extended periods of poor wind and solar output that could threaten power supplies. The results will be shared with the National Center for Atmospheric Research (NCAR).

"We need to understand how will wind speed and solar radiance change, when will there be drought of both at the same time. That is a really big concern," said Jared Lee, a project scientist at NCAR's Boulder, Colo., lab.

Researchers will run a first version of the NSF-funded model in 2024 or 2025, validating its analysis by matching its predictions for the previous decade with historical data. When complete, the model will look into the future out to 2054, adding in predictions of changes in air and sea temperatures and other weather data.

NSF aims to make the project open access, so it can easily be used by researchers on a range of equipment, from desktops to supercomputers.

The study will also examine how weather-dependent renewable energy sources will themselves be impacted by climate change between now and 2054.

Denholm said there is a lot of uncertainty about how the last 10 percent will be managed. "But it is really, really important to emphasize that we're not there yet, and we've got a long ways to go until we get to 80 or 90 percent [clean energy]," he said, adding that research will grow on new technologies and options. "We do have some time to figure it out."

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