Researchers point the way to avoiding blackouts with clean, renewable energy

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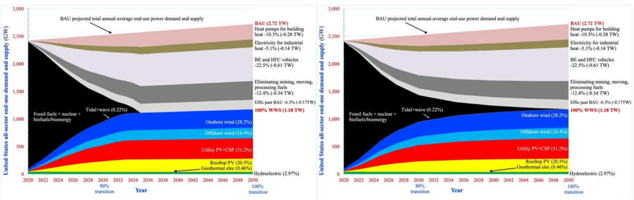

Graphs showing timeline of energy sources for meeting all U.S. energy needs with wind, water and solar (WWS) power sources. The graph on left shows mix for 80% WWS by 2030 and 100% by 2035. The graph on right shows mix for is 80% by 2030 and 100% by 2050. The 2050 end points in both cases are cases examined in the study. Credit: Jacobson, et al. / *Renewable Energy*

For some, visions of a future powered by clean, renewable energy are clouded by fears of blackouts driven by intermittent electricity supplies. Those fears are misplaced, according to a new Stanford University study that analyzes grid stability under multiple scenarios in which wind, water and solar energy resources power 100% of U.S. energy needs for all purposes. The paper, just published in *Renewable Energy*, finds that an energy system running on wind, water and solar coupled with storage avoids blackouts, lowers energy requirements and consumer costs, while creating millions of jobs, improving people's health, and reducing land requirements.

"This study is the first to examine grid stability in all U.S. grid regions and many individual states after electrifying all energy and providing the electricity with only energy that is both clean and renewable," said study lead author Mark Z. Jacobson, a professor of civil and environmental engineering at Stanford. "This means no fossil fuels, carbon capture, direct air capture, bioenergy, blue hydrogen or nuclear power"

Imagine all cars and trucks were powered with electric motors or hydrogen fuel cells, electric heat pumps replaced gas furnaces and water heaters and wind turbines and solar panels replaced coal and natural gas power plants. The study envisions those and many more transitions in place across the electricity, transportation, buildings and industrial sectors in the years 2050 and 2051. The scenario is not as far-fetched as it may seem, according to Jacobson and his coauthors. Wind, water and solar already account for almost 20% of US electricity, and 15 states and territories and more than 180 U.S. cities have enacted policies requiring a virtually all-renewable electricity sector, among other signs of a larger shift to clean, renewable energy.

Critics of such a shift have pointed to grid blackouts amid extreme weather events in California during August 2020 and Texas during February 2021 as evidence that renewable electricity can't be trusted for consistent power. Although in both instances renewable energy was not found to be more vulnerable than other sources, the fear of increased blackouts has remained substantial, according to the researchers, who aimed to evaluate the contention on a larger scale.

Expanding on a previous 2015 renewable energy roadmap study for the 50 U.S. states, the researchers looked at how to meet continuous energy demand every 30 seconds for two years. They ran simulations for six individual states—Alaska and Hawaii, which are isolated, and California, Texas, New York and Florida, large states far from each other and subject to different weather conditions—as well as all the interconnected electricity grid regions in the U.S., and the contiguous U.S. as a whole.

Their scenarios envisioned a massive scaling up of offshore wind turbines and rooftop solar panels—none of which take up new land—as well as onshore wind turbines, utility solar panels, and concentrated solar power plants. The scenarios also include some new geothermal but no new hydroelectric infrastructure. Overall, they found that new electricity generators would take up about 0.84% of U.S. land versus the approximately 1.3% of land currently occupied by the fossil fuel industry.

Under these scenarios, the researchers further found that per capita household annual energy costs were nearly 63% less than in a business as usual scenario. In some states, costs dropped as much as 79%. The investment cost to transition everything in the U.S. ranges from near $9 to $11 trillion, depending on how much interconnection of regions occurs. However, this pays for itself through energy sales and from the cost savings each year compared with not transitioning. In fact, based on energy cost savings alone, the payback time may be as short as five years.

Interconnecting larger and larger geographic regions made power supply smoother and costs lower because it upped the chances of available wind, sun and hydro power availability and reduced the need for extra wind turbines, solar panels and batteries.

A significant finding of the study was that long-duration batteries were neither needed nor helpful for keeping the grid stable. Instead, grid stability could be obtained by linking together currently available batteries with storage durations of four hours or less. Linking together short-duration batteries can provide long-term storage when they are used in succession. They can also be discharged simultaneously to meet heavy peaks in demand for short periods. In other words, short-duration batteries can be used for both big peaks in demand for short periods and lower peaks for a long period or anything in-between.

The study also finds that building and operating a completely clean, renewable grid may create about 4.7 million long-term, full-time jobs across various energy sectors, such as construction and component manufacturing, as well as indirect employment at stores, restaurants and other businesses. Cleaner air would spare about 53,200 people per year from pollution-related deaths and millions more from pollution-related illnesses in 2050, saving about $700 billion per year in health costs, the researchers found.

The researchers' simulations suggested that blackouts in California and Texas could be avoided at low cost due to a clean, renewable grid. Part of the reason is that energy requirements are reduced 60 percent in California and 57 percent in Texas by electrifying all energy sectors and providing the electricity with clean, renewable energy. A second reason is that, when the wind is not blowing, the sun is often shining during the day and vice versa, so using both helps meet demand with supply. Third, giving people financial incentives not to use electricity at certain times of day helps to shift the time of peak electricity demand. Fourth, using storage helps to fill in supply gaps when wind and solar are not available. Fifth, during cold spells, wind is stronger, on average, so increasing wind energy helps to meet winter peaks in building heat demand. Sixth, underground seasonal heat storage helps meet winter heat demand. These last two are especially helpful for Texas.

To avoid summer time blackouts in California, the study suggests more offshore wind turbines since wind speeds are fastest during summer offshore of California, especially during the late afternoon and early evening when blackouts are most likely due to drops in solar power output.

"There is so much to be gained if we can gather the willpower to undertake the transition at a pace fitting the urgency of reaching a zero carbon system," said study coauthor Anna-Katharina von Krauland, a Ph.D. student in civil and environmental engineering at Stanford. "I suspect that these ideas, which might sound radical now, will soon become obvious in hindsight."

More information: Mark Z. Jacobson et al, Zero air pollution and zero carbon from all energy at low cost and without blackouts in variable weather throughout the U.S. with 100% wind-water-solar and storage, *Renewable Energy* (2021). DOI: 10.1016/j.renene.2021.11.067

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