NEW ENERGY OPTIONS

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RESEARCH BRIEF

OCTOBER 2021

KEY POINTS FOR DECISION-MAKING

- **Some combination of solar and wind technologies could reliably meet current electricity demand at least three-quarters of the time in almost every major country.** Even without large-scale overbuilding or long-duration storage, natural variability of solar and wind resources will not impede the "first 80%" of power sector decarbonization.

- **Natural variability of solar and wind resources determine the magnitude of back-up countries will need to acheive reliable renewables-based electricity systems.** Countries with smaller areas and at higher latitudes generally need more back-up, which could take the form of excess renewable capacity, long-duration storage, regional power-sharing, and/or firm generation.

- **There are systematic trade-offs in country characteristics and back-up options.** Our analysis shows that the reliability of solar-wind systems without energy storage increases by 7% for every factor of 10 increase in a country's area, and 10% increase in excess annual generation is equivalent to 3.9 hours of storage.

Wind turbines in west Texas

Country differences in resources determine the reliability of solar-and-wind based electricity systems —and the need for clean back-up technologies

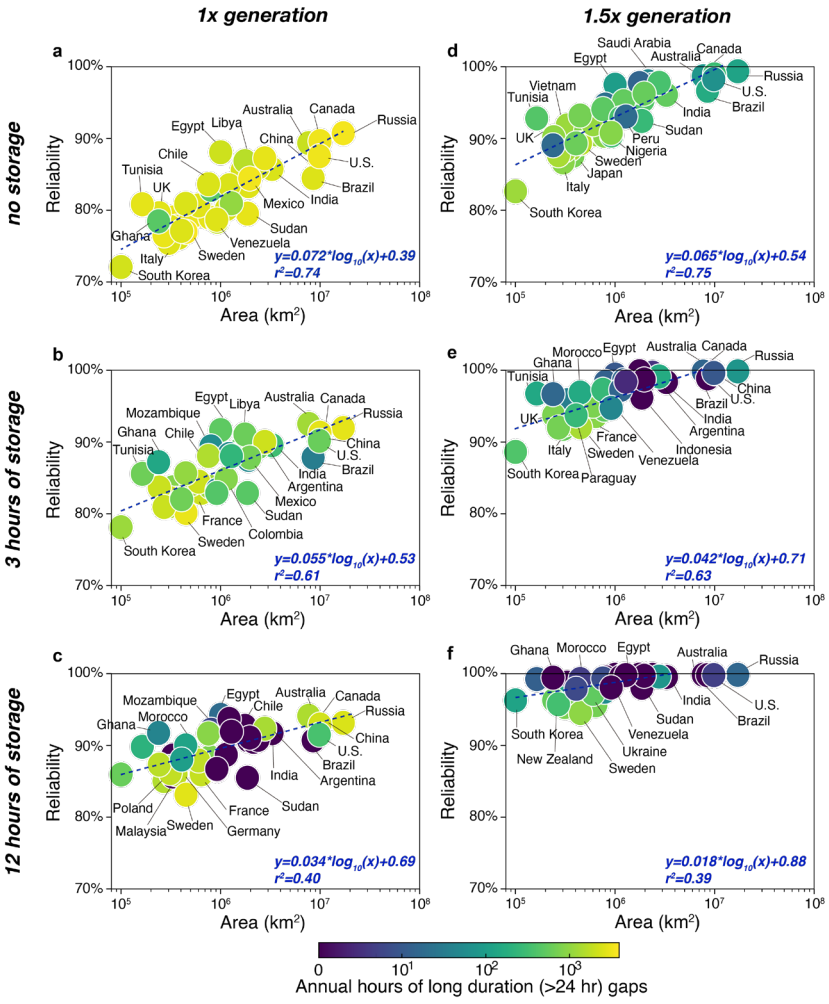
If future net-zero emissions energy systems rely heavily on solar and wind resources, spatial and temporal mismatches between resource availability and electricity demand may challenge system reliability. Using 39 years of hourly reanalysis data (1980–2018), we analyze the ability of solar and wind resources to meet electricity demand in 42 countries, varying the hypothetical scale and mix of renewable generation as well as energy storage capacity.

Assuming perfect transmission and annual generation equal to annual demand, but no energy storage, the most reliable renewable electricity systems are wind-dominated and satisfy countries' electricity demand in 72-91% of hours (incresing to 83-94% and dominantly solar when 12 hours of storage are added). This is fully consistent with other cost-optimized models which rarely exceed 80% of electricity from solar and wind regardless of how cheap those technologies are assumed to be.

Even when >90% of demand is met by solar and wind, there may be many multi-day periods with unmet demand (see fig), which periods define the need and market for back-up technologies in renewables-based electricity systems.

Summary

Our analysis helps quantify the power, energy, and utilization rates of additional energy storage, demand management, or curtailment, as well as the benefits of regional aggregation. We highlight the geophysical considerations related to these options, but economics and geopolitics will also strongly influence which strategies are ultimately adopted. However, because it is independent of costs and current policies, our analysis will continue to be informative even as technological and socio-political feasibility evolves.



The relationship between the highest reliability of electricity supply system and country area among 42 major countries. Shading of bubbles represents the annual average hours of long-duration (>24 hours) power supply gaps. Storage and generation quantities are varied in each panel: (**a**) 1x generation (i.e. annual generation equal to annual demand) without storage; (**b**) 1x generation with 3 hours of storage; (**c**) 1x generation with 12 hours of storage; (**d**) 1.5x generation without storage; (**e**) 1.5x generation with 3 hours of storage; and (**f**) 1.5x generation with 12 hours of storage.

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This brief is based on the paper "**Geophysical constraints on the reliability of solar and wind power worldwide**" published in *Nature Communications* (2021). doi: 10.1038/s41467-021-26355-z

We acknowledge support from a gift to the Carnegie Instiution for Science from Gates Ventures LLC.


Solar farm in southern California

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