

KEY POINTS FOR DECISION MAKERS

- ▶ **Planning wind- and solar-based electricity systems with more years of weather data can increase system reliability.** More reliable systems, planned with more years of data, cost more and generally have increased asset capacities.
- ▶ **If a system is designed to operate at 100% reliability over a large number of years, the marginal cost of marginal lost load avoided becomes very high.** Therefore, it is important to consider trade-offs between system reliability and system cost when planning electricity systems.
- ▶ **If it is impractical to design a system based on a large number of years, then there are specific years that should be considered in system design.** Certain particular years can act as a “stress test” on the system. If the system functions well in these “stress test” years, it is likely to perform well in other years.



RESEARCH BRIEF

Planning highly reliable wind- and solar-based electricity systems requires more years of weather data than is now the norm

Ensuring that electricity supply reliably meets demand is more challenging for wind- and solar-based electricity systems than for fossil-fuel-based ones.

We investigated how the number of years of weather data affects reliability in out-of-sample years, when designing least-cost systems that rely on wind, solar, and energy storage.

We found that nearly 40 years of weather data are required to plan highly reliable systems that experience zero lost load over a decade. In comparison, this same degree of reliability could be attained with 15 years of weather data, when adding dispatchable generation (natural gas) to supply up to 5% of electricity demand.

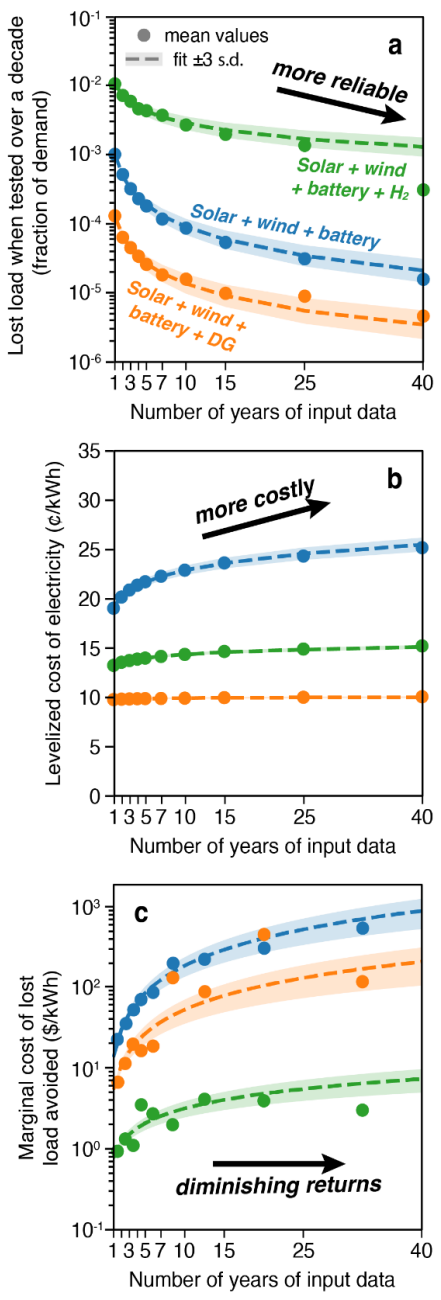
For all modeled scenarios it becomes increasingly costly to avoid lost load in out-of-sample years as the number of planning years for 100% reliable systems increases. The marginal cost of avoiding lost load increased as more years, and thus more weather variability, were considered for planning 100% reliable systems. This cost can vary by a factor of 10 for systems that rely on different technologies.

Summary

When considering the potential costs associated with unmet electricity demand, trade-offs of system costs and system reliability should be considered in the planning process.

Certain years may be particularly valuable to “stress test” systems. These years vary depending on the modeled technologies and geography. We identified 1989, 1996, and 2010, as “stress test” years for designing highly-reliable wind- and solar-based electricity systems with storage and natural gas over the contiguous U.S.





Effects of using more years of weather data to plan. Using more years of weather data during planning of solar- and wind-based systems decreases lost load (i.e. unmet demand, **a**), but also increases the cost of the least-cost electricity system (**b**) such that the marginal benefits of planning with more years of data diminishes (**c**).

CORRESPONDING AUTHORS



Tyler H. Ruggles
truggles@carnegiescience.edu

Tyler Ruggles is a senior analytics and modeling engineer at Powertech USA.



Edgar Virgüez
evirguez@carnegiescience.edu

Edgar Virgüez is a postdoctoral research scientist and deputy group leader at Carnegie Science.



Ken Caldeira
kcaldeira@carnegiescience.edu

Ken Caldeira is a senior scientist emeritus at Carnegie Science.

This brief is based on Ruggles, T. & Virgüez, E. *et al.* (2024) "Planning reliable wind- and solar-based electricity systems" published in *Advances in Applied Energy*, 15, 100185 (doi: 10.1016/j.adapen.2024.100185).

This work was supported by a gift from Gates Ventures to Carnegie Science.

FOR MORE INFORMATION

Visit our website: climateenergylab.org

