Is solar energy unreliable?

What The Science Says:
An increasing number of planned solar projects are set to include an energy storage component, and solar, wind, and storage together can provide the majority of the country's electricity without compromising reliability.

Climate Myth: Solar energy is unreliable
"“[S]olar plants require 100% back up all the time by fossil fuels. (Citizens for responsible solar)

Complete reliance on solar generation, without other sources of power generation, energy storage, long-distance transmission, or other grid flexibility resources[1] (Lovins 2017), would pose intermittency challenges. However, an increasing number of planned solar projects are set to include an energy storage component[2], and solar, wind, and storage together can provide the majority of the country's electricity without compromising reliability[3].

When a local service area does face diminished solar capacity, for instance during a cloudy day, wind and other renewable sources, as well as battery storage and long-distance transmission that carries power from sunnier regions can supplement energy supply, ensuring a resilient grid[4] (also Jacobson 2022). As a result, increased reliance on solar energy need not require the construction of new natural gas plants for backup[5]. The Department of Energy's 2021 “Solar Futures Study,” for example, outlines three distinct decarbonization scenarios, each of which assumes both a massive increase in renewable energy generation and decrease in natural gas[6]. Under the “business as usual” reference scenario, natural gas, oil, and steam together decrease from roughly 39% of U.S. annual electricity generation in 2020 to roughly 31% by 2035/2036 and 30% by 2049/2050; under the same scenario, solar PV increases from roughly 3.4% in 2020 to 17.6% by 2035/2036 and 27.3% by 2049/2050. Under the two non-reference decarbonization scenarios assessed in the studies, natural gas, oil, and steam shrink to roughly 4.7%-5.2% of annual electricity generation by 2035/2036 and 0% by 2049/2050; solar PV, meanwhile, increases to between 36.9% and 42.2% by 2035/2036 and to between 40.1% and 44.8% by 2049/2050. Princeton University's Net-Zero America study, which assesses pathways to achieving net-zero GHG emissions by 2050, likewise foresees significant reductions in fossil fuel consumption and generation, even when maintaining 500-1,000 GW of firm generating capacity to ensure reliability. Across the suite of assessed net-zero scenarios, the study assumes that all thermal coal production and consumption will cease by 2030, oil production will decline between 25% to 85% by 2050, and natural gas production will decline between 20% and 90% by 2050.

California has already increased solar energy generation while decreasing natural gas utilization. In 2012, solar PV and solar thermal together accounted for only 0.9% of California's in-state electricity generation, while natural gas accounted for roughly 70%[7]. By 2022, solar had increased to 19.9% of California's in-state electricity generation, while natural gas had decreased to 47.5%[8]. Significantly, even with this increase in solar reliance, California's grid reliability remains near, or above, the national average[9]. Elsewhere in the United States, energy experts have asserted that Texas's widespread adoption of solar generation helped prevent outages when electricity usage spiked during a recent summer heatwave[10]. And although the reliability of solar and wind energy was questioned following Texas' widespread power outages in the winter of 2021, Texas' grid failure was primarily caused by freezing natural gas infrastructure, rather than failures at solar and wind farms, though nuclear, coal, and wind also experienced disruptions at a smaller scale[11] (also Busby et al. 2021).

Energy storage also will play an important role in achieving decarbonization while improving energy reliability. The DOE's “Solar Futures Study” forecasts that an additional 60 GW per year of storage will be needed to achieve decarbonization[6]. Fortunately, research on storage technologies has experienced significant breakthroughs in recent years. For example, sodium-ion batteries have emerged as a possible alternative to lithium-ion batteries, with sodium a much more abundant and less expensive material[12]. Researchers are likewise developing more efficient utility-scale methods for storing solar energy[13].

Other researchers have highlighted energy efficiency and grid flexibility mechanisms that can complement and support solar and wind without the need for fossil fuel backup or even bulk, utility-scale energy storage (Lovins 2017). These include integrative design practices to significantly reduce the energy demands of buildings and other sectors; demand flexibility and demand response mechanisms to compensate customers for reduced energy use during peak hours; and distributed thermal and electrical storage[14] (also Lovins 2018).

Finally, while solar energy is intermittent, multiple studies have shown that the panels themselves are highly reliable—with appreciably low degradation and failure rates, thus rarely requiring repair or replacement (Jordan et al. 2017, Jordan et al. 2020). A National Renewable Energy Laboratory (NREL) study found that the median failure rate for panels installed between 2000 to 2015 was five out of 10,000 annually, a rate of 0.05% (Jordan et al. 2017). Researchers have described the failure rate of residential PV inverters as "acceptable, even good," with an inverter typically needing to be replaced only once in the lifetime of a PV system.

Footnotes:

[1] Amory Lovins has identified eight "grid flexibility" resources that can substitute for bulk storage or fossil fuel backup: (1) efficient use, which reduces peak load; (2) flexible demand; (3) modern forecasting; (4) diversifying variable renewables; (5) integration with dispatchable alternatives and cogeneration; (6) distributed or managed thermal storage; (7) distributed electrical storage; and (8) hydrogen.

[2] Joseph Rand et al., Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2021 at 13 (Berkely Lab 2022)

[3] Eric Larson et al., Net-Zero American: Potential Pathways, Infrastructure, and Impacts: Final Report, Princeton University, 247 (Oct. 29, 2021) at 88 (noting that, "[t]o ensure reliability, all cases maintain 500-1,000 GW of firm generating capacity through all years," compared to 7,400-9,900 GW for wind and solar in net-zero scenarios for 2050).

[4] Robert Fares, Renewable Energy Intermittency Explained: Challenges, Solutions, and Opportunities, Scientific America (Mar. 11, 2015)

[5] The 2035 Report: Plummeting Solar, Wind, and Battery Costs Can Accelerate our Clean Electricity Future, U. Cal. Berkeley Goldman Sch. Pub. Pol'y, 4 (2020)

[6] U.S. Dep't. Energy Solar Energy Technologies Office, Solar Futures Study, U.S. Dep't. Energy Office of Energy Efficiency & Renewable Energy, at vi, 179 (Sep. 2021) at 215

[7] California Energy Comm'n., Electric Generation Capacity and Energy (last visited March 25, 2024).

[8] California Energy Comm'n, 2022 Total System Electric Generation, (last visited March 25, 2024).

[9] California Public Utilities Comm'n, Electric System Reliability Annual Reports (last visited March 25, 2024). In 2020, five of California's six investor-owned utilities had frequency of sustained outages below national average when including major event days; four of six had frequency of sustained outages below national average when excluding major event days; four of six had duration of outages below national average when including major event days; and four of six had duration of outages below national average when excluding major event days. "Major event days" consist of the worst 0.63% of outage events.

[10] See E&E News & Benjamin Storrow, Solar Power Bails Out Texas Grid During Major Heat Wave, Scientific American, June 26, 2023

[11] Adriana Usero & Salvador Rizzo, 'Frozen windmills' aren't to blame for Texas's power failure, Wash. Post, Feb. 18, 2021; Dionne Searcey, No, Wind Farms Aren't the Main Cause of the Texas Blackouts, N.Y. Times, Feb. 17, 2021 (updated May 3, 2021)

[12] Karyn Hede, Longer Lasting Sodium-Ion Batteries on the Horizon, Pac. Nw. Nat'l. Lab'y. (Jul. 13, 2022)

[13] Robert Armstrong et al., The Future of Energy Storage: An Interdisciplinary MIT Study, Mass. Inst. Tech. (Jun. 3, 2022)

[14] Amory B. Lovins & M. V. Ramana, Three Myths About Renewable Energy and the Grid, Debunked, Yale Env't 360, Dec. 9, 2021

[15] Emiliano Bellini, Survey shows 34.3% failure rate for residential inverters over 15 years, PV Magazine, Feb. 8, 2023 (discussing Christof Bucher et al., Life Expectancy of PV Inverters and Optimizers in Residential PV Systems, Bern University of Applied Sciences, 2022).

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