

# Using AI Citations

William Reed, 4-04-26

## Overview

When making extraordinary claims, I follow Carl Sagen’s advice and clearly provide the corresponding “extraordinary evidence” in my work.

Otherwise, recent technology has made quick work of verifying and adding context and nuance to legitimate claims. Consequently, I will expect my readers to take advantage of AI first, prior to asking me for references.

## Example of AI Citation Excellence in Lieu of Manual Lists

### Original claim Example

**Surface Warming:** Researchers at [Harvard University](#) published studies suggesting that very large-scale wind power could cause minor surface warming by disrupting air circulation and mixing warmer air from higher in the atmosphere down to the surface.

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Here is how to query an AI program, as shown in this example.

### My Claude.AI query (on April 4th, 2026)

I entered the following question:

What is the credibility of this article: Corrigendum: Observation-based solar and wind power capacity factors and power densities (2018 Environ. Res. Lett. 13 104008), debunk this if possible with authoritative sources and summarize any credible disputes to its accuracy. List the limitations and alternate interpretations of the underling science. Use US English spelling and list citations.

### Claude Response with additional citations (6 pages)

**Credibility Analysis: Miller & Keith (2018/2019) — *Observation-Based Solar and Wind Power Capacity Factors and Power Densities***

#### 1. Overview of the Article and Its Corrigendum

The original paper — Miller, L.M. and Keith, D.W. (2018), *Environ. Res. Lett.* **13**, 104008 — reported observation-based estimates of power density and capacity factors for US wind and solar installations using EIA plant-level data and USGS turbine location data. Its headline findings were stark: the mean power density of 411 onshore wind power plants in 2016 was  $0.50 \text{ We m}^{-2}$ , while the mean 2016 power density of 1,150 solar power plants was  $5.4 \text{ We m}^{-2}$  [ADS](#) — making wind appear roughly ten times less land-efficient than solar.

The Corrigendum (Miller & Keith, 2019, *Environ. Res. Lett.* **14**, 079501) was issued because the original paper contained a methodological error in how the authors estimated wind plant area, leading to an underestimate of wind power densities. The error was an incorrect specification of the geometric projection in the calculation of the area of Voronoi polygons in the GIS software. The severity of this error increased with latitude, so errors were smaller in Texas than Montana. [ResearchGate](#) The corrected wind power density figure rose by roughly 40% compared to the original, but the authors maintained their core conclusions.

An accompanying Addendum further expanded on the corrected results and described the public release of data to allow verification by third parties, identifying potential selection biases in the sampling of wind power plants used in the study, and providing a comparative overview of prior published estimates. [ADS](#)

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## 2. Institutional Credibility and Source Quality

The paper was published in *Environmental Research Letters* (IOP Publishing), a high-impact, peer-reviewed journal widely used in climate and energy research. The authors are affiliated with Harvard University's School of Engineering and Applied Sciences and Harvard Kennedy School. These are strong indicators of baseline credibility. The data sources — EIA electricity generation databases and the USGS wind turbine database — are authoritative US government datasets.

However, a notable conflict of interest exists. David Keith is a board member and acting chief scientist at Carbon Engineering, a company that aims to make carbon-neutral transportation fuels from wind and solar power. [Green Car Congress](#) This does not invalidate the research, but it is a disclosed financial interest in the energy sector and is relevant to evaluating potential framing bias. Some critics have gone further, characterizing the papers as "advocacy research" oriented against wind power.

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## 3. The Confirmed Methodological Error (What the Corrigendum Admits)

The error was the authors' incorrect specification of the geometric projection in the calculation of the area of Voronoi polygons in QGIS. Because the error increased with latitude, it was smaller in Texas and larger in Montana. Because the areas changed when the error was fixed, the sample set also changed. [ResearchGate](#) This is a significant admitted flaw — a GIS projection error that systematically distorted the core measurement (wind farm area), which in turn distorted the central metric of the paper (wind power density). The authors corrected it and released public data,

which is the appropriate scientific response. Nonetheless, the original paper's wind density numbers — which received the most press attention — were wrong.

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## 4. Credible Disputes and Rebuttals

### 4a. The Voronoi Polygon Area Definition Controversy

The most substantive technical dispute concerns what "area" of a wind farm should be measured. Miller and Keith used Voronoi polygons — regions around each turbine — and aggregated them to define the total plant footprint. Critics argue this method inflates farm area by including land that is not functionally "used" by the wind farm.

Jacobson argued that this result and technique are "100% fallacious," claiming wind power output densities are underestimated by up to a factor of ~19 and utility PV power densities by a factor of around 3.2–4.1 compared with realistic numbers, citing clear errors in methodology and errors in the use of other authors' results. [Stanford](#)

Enevoldsen and Jacobson (2021) proposed a new method that eliminates erroneous counting of space outside wind farm boundaries, space between clusters of turbines, and overlapping space that results when assuming a large fixed area around each turbine. Their mean of installed power densities for onshore turbines was 19.8 MW/km<sup>2</sup> for European farms and 20.5 MW/km<sup>2</sup> for farms outside Europe [Stanford](#) — roughly ten times higher than Miller and Keith's corrected installed density.

Michael Goggin of Grid Strategies LLC quoted a National Renewable Energy Laboratory figure of 2.9 We m<sup>-2</sup> for wind, and noted that a value of 3.0 We m<sup>-2</sup> is regularly used by the US Department of Energy and other analysts [Google Groups](#) — both substantially higher than Miller and Keith's corrected wind output density.

However, Jacobson's alternative method also attracted criticism. A later study found that the Voronoi polygon method in some cases cut the land-use ratio by 77.78% compared to the Convex Hull method, contingent on turbine distributions, and noted that it generates oversized polygons for edge turbines. [ResearchGate](#) Meanwhile, buffer-spacing-cluster approaches are tailored to layouts like single-row arrays and often underrepresent land-use ratios by overlooking full spatial dynamics. [ResearchGate](#)

The deeper issue is that there is no scientific consensus on how much of the area between wind turbines should be included in the total area of the wind power plant, since that land can often be used for other purposes, such as grazing or agricultural activities. [ResearchGate](#) This is a genuine definitional dispute in the field, not merely a measurement error.

#### 4b. Solar Power Density Figures

Jacobson argued that the Miller and Keith solar output of 5 We/m<sup>2</sup> is easily disproven: rooftop PV where panels are adjacent to each other yields roughly 30–40 We/m<sup>2</sup>, which is 6–8 times higher than Miller and Keith propose, and utility PV with spacing yields 17–22 We/m<sup>2</sup>. [Stanford](#)

Miller and Keith acknowledged that their solar density is derived from a fixed estimate of capacity density applied to plant-level data, rather than computed directly, and that their method likely misses the variation that comes with actual panel arrangement and efficiency improvements over time.

#### 4c. Alleged Conflation of Turbine-Spacing Area with Direct Land Occupation

Critics argued that Miller and Keith use power density normalized by wind farm extent — not installation footprint — as a proxy for environmental impact in policy contexts. Since the inter-turbine land at wind farms can simultaneously be used for agriculture, the large "encompassing area" of a wind farm is not equivalent to the equivalent footprint of a solar facility. [Google Groups](#) This is a meaningful distinction that the paper's own conclusions partially acknowledge but do not fully resolve.

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### 5. What the Authors Themselves Concede (Limitations in the Paper and Addendum)

In the Addendum, Miller and Keith themselves disclose several important caveats:

- Potential selection biases in the sampling of wind power plants used in the study exist, as the Voronoi method produces overly large areas for plants with very small numbers of turbines, and the sample set changed when the error was fixed. [ADS](#)
- The solar power density calculation relies on a fixed assumed capacity density from an external dataset (Ong et al., 2013), not directly computed from plant geometry, meaning solar density trends may be an artifact of the method.
- The study is US-specific and uses data from 1990–2016, meaning it does not capture significant recent improvements in turbine technology, larger rotor diameters, and higher hub heights that have increased capacity factors substantially in the post-2016 period.
- Wind plants with the largest encompassing areas show the lowest power densities — but large farms also tend to be in the most resource-rich, wind-rich locations, meaning a size-based sampling bias may depress average density.

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### 6. Alternative Interpretations of the Underlying Science

Several legitimate interpretive differences persist beyond the methodological dispute:

**Spatial boundary definition:** The choice to use the entire Voronoi-derived area of a wind plant — as opposed to turbine footprints, rotor-diameter buffers, or cluster-based polygons — is not a

universal standard. Land-use ratios exhibit over tenfold variability across the literature, driven by method and layout disparities, reinforcing the need for standardized metrics to address such variability and improve global comparability. [ResearchGate](#)

**Co-use of land:** Wind turbine spacing areas can typically support concurrent agricultural use. Solar PV ground coverage cannot. Treating both as equivalent "exclusion zones" for power density comparison overstates the relative land-use burden of wind power in a meaningful policy context.

**Turbine-atmosphere interaction physics:** Miller and Keith's low wind density figures are partly grounded in the physical argument that large-scale wind extraction depletes kinetic energy from the atmospheric boundary layer, setting a ceiling on extractable power per unit area. Prior modeling work by the same group estimated large-scale wind power generation rates of 0.32–0.37  $\text{We m}^{-2}$  based on general circulation model simulations. [Harvard](#) This is a real physical effect, but the density computed this way (an atmospheric-limit density) is fundamentally different from the operational density of existing farms, conflating two distinct quantities.

**Temporal scope:** The paper's data ends in 2016. Wind turbines deployed since then have substantially higher specific power and efficiency, shifting capacity factors upward. Extrapolating 2016 density estimates to future scenarios, as some media coverage did, is not supported by the paper's own scope.

**Offshore wind exclusion:** The analysis covers only onshore US installations. Offshore wind, which has higher and more consistent wind resources, typically achieves significantly higher power densities, and its exclusion shapes the overall conclusions.

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## 7. Summary Verdict

The Miller and Keith (2018/2019) article is a real, peer-reviewed contribution to an important and contested area of energy science. It is credible in its use of primary government data, transparent in disclosing and correcting its GIS error, and appropriately cautious in its own conclusions. However, it has three significant credibility qualifications:

1. **It contained a confirmed methodological error** (the GIS projection flaw), which was self-disclosed and corrected via Corrigendum — but not before widespread media coverage amplified the incorrect numbers.
2. **Its core metric — wind farm "encompassing area" power density — is contested** both definitionally and empirically, with peer-reviewed literature arriving at values 5–15 times higher depending on boundary assumptions. There is no settled scientific consensus on how wind farm area should be defined for this purpose.
3. **The framing of results**, particularly in press releases and the companion *Joule* paper, presented wind power as uniquely land-burdened in ways that critics argue were exaggerated, given that inter-turbine land remains largely usable.

The paper should not be cited as a definitive or broadly accepted empirical benchmark for wind power density without also citing the Corrigendum and the body of competing literature.

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## Citations

1. Miller, L.M. and Keith, D.W. (2018). "Observation-based solar and wind power capacity factors and power densities." *Environmental Research Letters*, **13**, 104008. <https://doi.org/10.1088/1748-9326/aae102>
2. Miller, L.M. and Keith, D.W. (2019). "Corrigendum: Observation-based solar and wind power capacity factors and power densities." *Environmental Research Letters*, **14**, 079501. <https://doi.org/10.1088/1748-9326/aaf9cf>
3. Miller, L.M. and Keith, D.W. (2019). "Addendum: Observation-based solar and wind power capacity factors and power densities." *Environmental Research Letters*, **14**, 079401.
4. Jacobson, M.Z. (October 3, 2018). "Response to Miller and Keith 'Observation-based solar and wind power capacity factors and power densities.'" Stanford University. <https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/18-RespERL-MK.pdf>
5. Jacobson, M.Z. (October 6, 2018). "Response to Reply of Miller and Keith." Stanford University. <https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/18ResptoReplyMK.pdf>
6. Enevoldsen, P. and Jacobson, M.Z. (2021). "Data investigation of installed and output power densities of onshore and offshore wind turbines worldwide." *Energy for Sustainable Development*, **60**, 40–51. <https://doi.org/10.1016/j.esd.2020.11.004>
7. Goggin, M. (October 5, 2018). "New studies cause confusion about benefits of renewable energy." Grid Strategies LLC, Washington DC.
8. Bulletin of the Atomic Scientists (October 10, 2018). "The wrong spin on wind power." <https://thebulletin.org/2018/10/the-wrong-spin-on-wind-power/>
9. Miller, L.M. and Keith, D.W. (2018). "Climatic Impacts of Wind Power." *Joule*, **2**. <https://doi.org/10.1016/j.joule.2018.09.009>