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Efficient large-scale wind turbine deployment can meet global electricity generation needs

Jake Badger[a,1] and Patrick J. H. Volker[a]

Miller and Kleidon (1) study future global deployment of wind turbines. They use a general circulation model (GCM) with 2.8° resolution to simulate the electricity generation for different wind-power deployments using global constant installed capacity densities. Results from the simulations with the maximum electricity generation over land and over water form the foundation for their study: a generation over 100 times greater than the global electricity demand (2).

Correctly modeling wind resources requires a proper terrain description and that meso- and micro-scale effects are resolved (3). Power density estimates from mesoscale models with a 10-km grid spacing can be more than 50% lower than those from high-resolution models (4). However, reliable estimation of electricity generation depends on accurately modeling wind speed distributions and wake deficits, which themselves are wind speed-dependent (5). So, GCM simulations are likely to underestimate wind resources by more than 50%, also causing unreliable wake deficits.

Additionally, their approach concentrates on maximum electricity generation, ignoring the decreasing incremental gains associated with increasing installation capacity (figure 1A of ref. 1). This leads to unrealistically high installed capacity densities for large wind farms, with extremely low capacity factors. Over land the maximum electricity generation of $0.37 \, \text{MW} \, \text{km}^{-2}$ was reached for an installed capacity of $24 \, \text{MW}_i \, \text{km}^{-2}$, leading to a capacity factor of 1.5%, and over sea the capacity factor was 6.4% with a maximum electricity generation of $0.59 \, \text{MW} \, \text{km}^{-2}$.

By concentrating on wind power deployment giving maximum power production the approach ignores a range of efficient deployments. Therefore, we strongly disagree with their conclusion that "lower per-turbine generation rates are also associated with higher generation rates per unit area ($W_e \, \text{m}^{-2}$) up to the wind power limit, and likely makes wind power less economical at progressively larger deployment scales." Furthermore, the combination of their deployment approach and incorrect modeling of wind resource and electricity generation leads us to disagree with their finding that "the future expansion of wind power should not plan for installed capacities that are much above $0.3 \, \text{MW} \, \text{km}^{-2}$ over areas larger than $10,000 \, \text{km}^2$." Similarly, their claim that only 3–4% of land and 20–21% of ocean surface could produce more than $1 \, \text{MW} \, \text{km}^{-2}$ would not be valid with accurate modeling and if turbine coverage was reduced from being global.

Instead, to assess wind-energy deployment one should account for all energy scales that contribute to the local wind resources (3) and the installed power density should be wind speed distribution-dependent (5) instead of globally constant.

For example, in the US Midwest inclusive of Texas ($2,800,000 \, \text{km}^2$) six wind farms of each $114,000 \, \text{km}^2$ with an installed capacity of $2.8 \, \text{MW}_i \, \text{km}^{-2}$ would generate $0.69 \, \text{MW} \, \text{km}^{-2}$ (5). The energy production of these wind farms with a capacity factor of 25% would cover the entire US electricity consumption (2). In the North Sea, 340-km^2 wind farms with $6.4 \, \text{MW}_i \, \text{km}^{-2}$ would generate $2.52 \, \text{MW} \, \text{km}^{-2}$, with a capacity factor of 40% (5). Using around 18% of the North Sea area with these wind farms would provide enough electricity to all 28 countries of the European Union (2).

1 Miller LM, Kleidon A (2016) Wind speed reductions by large-scale wind turbine deployments lower turbine efficiencies and set low generation limits. *Proc Natl Acad Sci USA* 113:13570–13575.
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3 Landberg L, et al. (2003) Wind resource etimation – An overview. *Wind Energ* 6:261–271.
4 Triccoli A, Dubus L, Haupt SE (2014) *Weather Matters for Energy* (Springer, Berlin).
5 Volker PJH, Hahmann AN, Badger J, Jørgensen HE (2017) Prospects for generating electricity by large onshore and offshore wind farms. *Environ Res Lett* 12:034022.

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