Response to Miller and Keith "Climatic Impacts of Windpower" (*Joule*, 2018)

By Mark Z. Jacobson

October 2, 2018

Miller and Keith (*Joule 2*, 1-15, 2018, "Climatic Impacts of Windpower") conclude that wind turbines over the United States will themselves increase near-surface air temperatures by 0.24 ^oC.

As shown herein, these results are 100% wrong and should not be relied on to affect policy in any way.

The main reason for the error by Miller and Keith is that their model did not and cannot account for the major impact of wind turbines on temperatures, namely the impact of turbines on reducing water vapor, a greenhouse gas, globally. Such water vapor has increased over the past decades due to greater evaporation resulting from higher world temperatures and due to combustion of fossil fuels themselves. Such additional water vapor has served in a positive feedback loop to increase global temperatures beyond what carbon dioxide and other anthropogenic greenhouse gases alone have done. Wind turbines, help to reduce water vapor, reducing the impact of the additional water vapor on global warming to date.

Specifically, the main impacts of wind turbines in the atmosphere are its impacts on water vapor, as stated in Section S1.E of Reference [1], repeated here:

> "Whereas, wind turbines reduce wind speeds thus surface evaporation downwind of each wind farm, thereby warming the surface there (since evaporation is a cooling process), they reduce atmospheric water vapor thus condensation, thereby cooling the larger-scale air (since condensation is a heating process). These two factors essentially cancel each other. However, water vapor is a greenhouse gas, and the net reduction in atmospheric water vapor due to wind turbines results in a net average global surface cooling. Some previous studies have found that wind farms may warm surface temperatures in the vicinity of the wind farm, consistent with the explanation above. However, such studies do not account for large-scale impacts, particularly of reduced water vapor, so don't provide the overall impacts of wind farms on global temperature as calculated here."
>
> "Figure S2g [of Reference 1] shows a net column water vapor reduction of ~1.1% during the simulation period due to turbines and Figure S2h shows the net global cooling of ~0.03 K due to turbines. This represents ~3% of net global warming to date of ~1 K. In sum, not only do wind turbines replace polluting fossil fuel plants, but they also reduce water vapor, reducing global warming further."

The same result has been replicated with multiple additional simulations, as described on P. 15683 of Reference [2].

Miller and Keith missed entirely the main process by which wind turbines affect temperatures, which is the turbines' net reduction of the greenhouse gas, water vapor. It is impossible for their model to account for this impact, because their model is a limited-area regional model, not a global model, so any reduction of water vapor locally is not propagated either horizontally or vertically out of the domain to the large-scale atmosphere or back into the domain once the water vapor travels around the world, which takes about one week. As such, any perturbation to water vapor just "disappears" once it leaves the domain. In other words, water vapor is not conserved in their model, and it can't be conserved since their model is a limited area model.

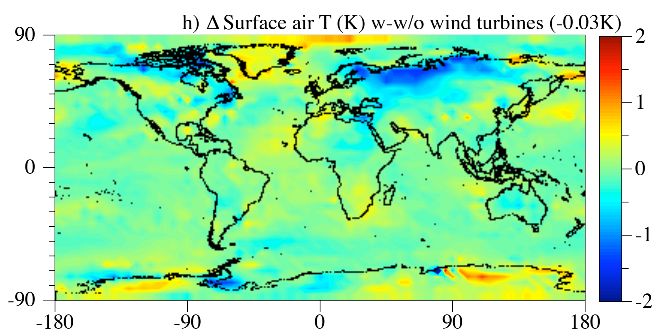
Based on the fact that Miller and Keith don't discuss radiative transfer calculations in their model, it is also not clear that they even account for the impacts of perturbations to water vapor on infrared radiative transfer in the regional portion of the domain that occur before such perturbations disappear to the larger domain.

Further, their simulations are too short (1 year) to calculate the impacts of changes in water vapor on global temperatures. Given that, during one year, reductions in water vapor due to wind turbines occur continuously but their model causes these reductions to disappear, it is impossible for their results to be correct.

Conversely, simulations that do account for the global impacts of wind turbines while accounting for water vapor changes globally and continuously as well as the radiative impacts of changes in water vapor, have been carried out and show the opposite result from Miller and Keith. These results are discussed next.

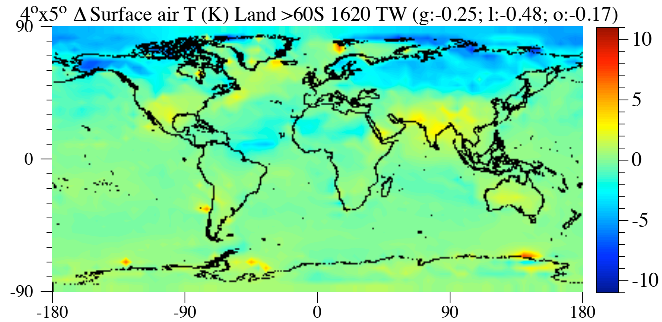
Wind Turbines May Offset Part of Global Warming

Energy extraction by 2.5 million 5-MW wind turbines needed to power 37% of world all-purpose end use energy in 2050 after all sectors have been electrified, **may reduce global temperatures by ~0.03 K, or ~3% of observed global warming.** See explanation on P. 243-244 and Section S1.E of Ref. [1], where this figure originates.

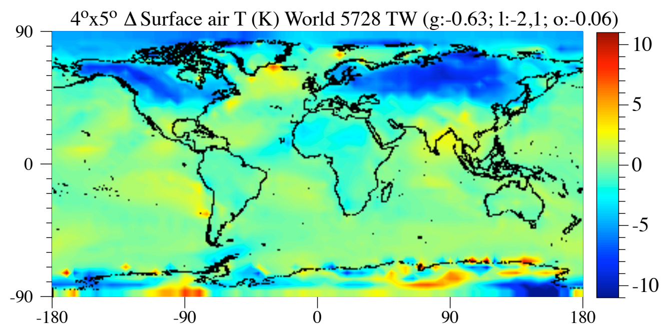


Consistently, energy extraction by 324 million 5-MW wind turbines over land (far more than will ever be needed by humans) may reduce global temperatures by

~0.25 K. See the explanation on P. 15,683 of Reference [2], where these data originate.



Consistently, energy extraction by 1.15 billion 5-MW wind turbines over land and ocean (far more than will ever be needed by humans) may reduce global temperatures by ~0.63 K. See the explanation on P. 15,683 of Reference [2], where these data originate.



References

1. Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.V, Mathiesen, Matching demand with supply at low cost among 139 countries within 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes, *Renewable Energy*, 123, 236-248, 2018, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf
2. Jacobson, M.Z., and C.L. Archer, Saturation wind power potential and its implications for wind energy, *Proc. Nat. Acad. Sci.*, *109*, 15,679-15,684, doi:10.1073/pnas.1208993109, 2012, https://web.stanford.edu/group/efmh/jacobson/Articles/I/SatWindPot2012.pdf