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Global environmental impacts of wind power

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Wind power and other renewable energy sources are considered vital for climate change mitigation. However, the reduced greenhouse gas emissions of renewable energy may come at the cost of enhanced use of land, water or (scarce) materials. Here, we assess the trade-offs of environmental impacts of wind power and compare these to non-renewable power sources such as coal and gas. We take into account detailed spatial variation in both technological characteristics of wind parks as well as climatology, in order to obtain localized impacts at the global scale.

We use technological characteristics of over 17,000 wind parks across the globe, including hub height, rotor diameter, location and power curve. As it is virtually impossible to determine the environmental impacts of all individual wind parks, scaling laws are used. Based on detailed life-cycle assessments of a sub-set of wind parks, these scaling laws relate environmental impacts to technological characteristics such as hub height, diameter, and whether a wind park is on- or offshore. We focus on five impact categories: greenhouse gas emissions, land use, water depletion, material use and fossil energy use. These impacts of wind power will be compared to non-renewable counterparts (oil and gas) using country-specific results of a life cycle assessment database.

In order to express the impacts per unit of produced power (kWh), we use wind speeds from the newly available global reanalysis ERA5, with hourly timesteps and a $\sim$31x31km resolution from 1979 to 2017. Using ERA5 allows us to take spatial and temporal variations in wind speed, and thus power output, into account. The wind speed is extrapolated to hub height using an exponential law and then combined with the wind park-specific power curve as well as loss factors, such as turbine efficiency, mechanical losses, wake effects, blade soiling and loss of grid connection, to obtain the lifetime power output of the wind park.

We thus create a global impact assessment comparing environmental impacts of wind power to other, fossil-fuel based, energy sources, while accounting for technological, spatial and temporal variation. Our set-up may also help plan future wind parks and will be used to assess the environmental impacts of solar (photovoltaic) power and hydropower.