Wind power potential over India using the ERA5 reanalysis

It is essential to reduce the dependence on fossil fuels for India's electricity generation and relevant from the perspective of national energy security, meeting domestic energy consumption and honouring obligations under global accords to limit climate change. As a signatory of the Paris Climate Accords in 2015 and the Glasgow Climate Pact in 2021, India has set a target of 40% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 under her first Nationally Determined Contribution (NDC). An intensified focus on harnessing renewable energy is pertinent towards accomplishing this goal. To facilitate such efforts and ease the adoption of renewable energy sources, we estimated the potential for wind energy over India's sovereign territory, including maritime off-shore regions within her Exclusive Economic Zone (EEZ).

In this study, we estimated the wind energy potential at 100 m above the surface using nearly four decades of historical wind speed data (1979 - 2018) from the recently available ERA5 reanalysis. The wind speed frequency distribution, which is relevant for choosing the optimal turbine model from a techno-economic aspect, was modelled using a Weibull mixture distribution. Significant variability in wind speeds over the annual cycle, up to 50 % of the annual mean, is often observed, which can significantly affect the harvestable wind power. Further, winds within the operational range for wind turbines (3 to 25 m/s) occur over inland areas for more than 60 % of the year only over the windiest regions, in contrast to the off-shore areas (more than 70 % of the year). The generated wind power density maps indicate comparatively higher values during the monsoon season, both over mainland and off-shore regions. Wind energy potential is higher in the off-shore EEZ region (annual mean of 254 W/m2; ~2.2 × 10^{-3} GWh/m^2 per annum) than in the mainland (annual mean of 74 W/m^2; ~0.65 × 10^{-3} GWh/m^2). Gujarat state is rich in wind resources (annual mean of 150 W/m^2), followed by Puducherry, Rajasthan, Karnataka, Andhra Pradesh and Telangana states. Areas that may be amenable to renewable exploitation are identified over India by identifying sparsely vegetated areas per AWiFS-derived maps of Open Natural Ecosystems (ONEs) and MODIS Land-Use-Land-Cover. These encompass about 11.46 to 24.75 % of India's land area and feature wind power potential from 40 to 53 TW.

Our estimates indicate that 7,204 GW (18,389 GW) of power can be harnessed solely from wind over India's mainland (EEZ) regions, assuming 3% of the area is utilized for this purpose. These numbers comfortably exceed the projected annual gross electricity production of 2.4 × 10^6 GWh to 2.7 × 10^6 GWh by 2030. Our projections based on data available till 2020 indicate that electricity generation from renewables (wind) may account for about 22 % (5 to 6.7 %) of India's total electricity generation in 2030. Thus, an urgent need is to enhance the share of renewables in India's installed electricity generation capacity to meet the goals stated in the NDC.

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