Comparative Assessment of Wind Energy Yield Estimation Using Regional and Global Wind Atlases

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Abstract

Accurate wind resource assessment is a fundamental requirement for wind farm planning, turbine selection, and reliable estimation of long-term energy production. Mesoscale wind atlas frameworks, particularly the New European Wind Atlas (NEWA) and the Global Wind Atlas (GWA), are increasingly used to derive site-specific wind climatology and support preliminary feasibility studies. However, their predictive performance is strongly influenced by terrain complexity, surface roughness, and atmospheric flow conditions.

In this study, a systematic and comparative assessment of wind resource characterization and annual energy yield estimation is conducted using NEWA and GWA across four representative environments: forested terrain, mountainous terrain, offshore marine conditions, and normal inland terrain. Height-dependent wind statistics were extracted from both atlases and processed using Rayleigh and Weibull parameterization, Hellmann power-law extrapolation, and probabilistic turbine power curve integration to estimate hub-height wind conditions and annual energy yields. The resulting predictions were validated against reference datasets from the Bavarian Energy Atlas and official offshore production data, and relative errors were quantified to evaluate model reliability. In parallel, a bibliometric analysis of peer-reviewed literature published between 2002 and 2026 was performed to examine research trends, thematic evolution, and methodological developments related to wind atlas applications and wind energy yield assessment, providing a broader scientific context for the study.

The results indicate that both atlases perform well under homogeneous inland and offshore conditions, while prediction errors increase in forested and mountainous regions due to unresolved microscale flow effects and enhanced surface roughness. The findings highlight the terrain-dependent strengths and limitations of NEWA and GWA and emphasize the need for hybrid correction approaches and site-specific calibration to improve prediction accuracy. Overall, the study provides a validated methodological framework for the application of wind atlas data in technical and pre-investment wind energy assessments.

Keywords

Wind resource assessment, energy yield estimation, New European Wind Atlas, Global Wind Atlas, Weibull distribution, Rayleigh distribution, wind shear extrapolation, mesoscale modeling, wind power density, capacity factor, terrain effects, offshore wind, onshore wind.