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Türkiye's Renewable Energy Outlook: GCM-Based Analysis and Future Projections Using the Extreme Gradient Boosting Algorithm

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The focus on global warming and climate change has prompted a substantial shift towards green energy technologies, which are crucial in shaping electricity generation capacity. Türkiye has actively been investing in renewable energy sources, such as wind, solar and geothermal, to reduce its dependency on imported fossil fuels and improve its energy security. In this study, we aimed to investigate the future of the electricity production in Türkiye under a changing climate using climate model projections and a machine learning algorithm. Thus, we first identified the most suitable Global Climate Models (GCMs) in simulating Türkiye's climate conditions, and then we evaluated how climate change, considering changing wind speeds, solar radiation, and temperature, will impact future electricity production in renewable energy output. We acquired historical data from 13 CMIP6 Global Climate Models, focusing on temperature, wind speed, and solar radiation parameters. Model resolution was standardized, and daily data for 120 grids in Türkiye were collected for 2010-2014. The performance of GCMs was assessed against ERA5/CRU-biased corrected datasets using metrics such as Kling-Gupta efficiency (KGE), modified index of agreement (md), and normalized root mean square error (nRMSE). A Multiple-criteria Decision Analysis (MCDA) method ranked the models based on performance, and Comprehensive rating metrics (MR) provided a unified score. Based on the result of MR, the top-performing models (ACCESS-CM2, INM-CM5–0, INM-CM4–8, and ACCESS-ESM-1-5) were ensembled, and then utilized to predict Türkiye's future climate using the Extreme Gradient Boosting Tree (XGBoost) algorithm. Projections were made for 2020-2064 under the SSP5-8.5 scenario. According to the results of the XGBoost forecast, solar power plant output is predicted to decrease across the country due to rising temperatures, with the largest drops in the Mediterranean (7.7-5.2%) and Eastern Black Sea (7.7-6.0%) regions. The Eastern Black Sea region, with low current solar potential, is deemed unsuitable for photovoltaic solar power plants in the future. Minimal decreases are anticipated in the Marmara (2.8-2.0%) and Southeastern Anatolia (2.8-4.4%) regions. Wind turbine electricity production is expected to increase, notably in Thrace (3.5-8.5%), northern Central Anatolia (3.5-8.5%), southern Southeastern Region (3.5-11.1%), and around Ağrı and Van provinces in Eastern Anatolia (3.5-6.0%). Conversely, the Eastern Black Sea, Uşak-Kütahya-Eskişehir-Bolu provinces in northwestern Anatolia (3.0-1.0%), and Mardin-Batman-Şırnak provinces in southeastern Anatolia (5.8-1.0%) may experience a decline in wind production potential. Overall, the study's findings align with existing literature, providing valuable insights into Turkey's future electricity production landscape under the influence of climate change and the transition to green

energy technologies.