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Modeling Hybrid Energy Systems for Carbon Neutrality in South Africa.

This study examines the contribution of hybrid energy systems to achieving carbon neutrality in South Africa's power sector by integrating solar, wind, and hydroelectric resources. Employing the IRENA FlexTool, the study examines various hybrid system configurations to evaluate their efficiency in reducing reliance on fossil fuels while ensuring grid stability. This study investigates the complex interactions among various renewable energy sources in the context of South Africa's significant dependence on coal, a key factor in national carbon emissions. The was aimed to identify the most effective energy combinations that improve generation efficiency, reliability, and cost-effectiveness. The model used consider seasonal variability, demand fluctuations, storage capacity, and transmission limitations to assess the practical implementation of hybrid systems. A specific emphasis is placed on evaluating the practicality of integrating pumped hydro storage to address the variability of renewable energy sources and maintain a reliable power supply. The results emphasize efficient hybrid system designs that can lower emissions and enhance long-term energy security. The analysis provides practical policy suggestions for enhancing hybrid renewable initiatives, fostering investment, upgrading infrastructure, and enacting regulatory changes. This study illustrates the technical and economic feasibility of hybrid renewable systems, thereby reinforcing South Africa's net-zero commitments and offering essential insights for policymakers, planners, and stakeholders focused on developing a resilient, cost-effective, and environmentally sustainable power sector.

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