

## Abstract

Access to reliable electricity is one key to a country's economic development. However, almost 46 % of Cameroonians don't have access to electricity. The present study employs Multi-Objective Genetic Algorithm (MOGA) and Cuckoo Search (CS) optimization methods to investigate a thorough analysis of various hybrid renewable energy system (HRES) configurations, such as Photovoltaic – Wind turbine – Battery (PV-WT-BT), Photovoltaic – Wind turbine – Power-to-Hydrogen-to-Fuel Cell (PV-WT-P2H2FC), and Photovoltaic – Wind turbine – Battery – Power-to-Hydrogen-to-Fuel Cell (PV-WT-BT-P2H2FC) functioning as a mini-grid to supply electricity to a community in Garoua, Cameroon. Techno-economic and social assessments are covered in the analysis, highlighting each configuration's merits and drawbacks. Key findings emphasize the critical role of visual tools like Sankey diagrams in comprehending complex energy systems and the importance of energy storage efficiency for overall system performance. The PV-WT-BT-P2H2FC configuration, optimized with MOGA, emerges as a promising option, achieving a remarkable balance between maximizing system efficiency (system efficiency = 72.91 %) and assuring system reliability (loss of power supply probability = 0.4457 %). Nonetheless, this configuration has proven to be cost-prohibitive, primarily attributable to the efficiencies of the electrolyzers and fuel cells. Economic evaluations reveal varying costs among configurations and optimization methods with battery storage as a cost driver, making PV-WT-BT with CS optimization the most economical configuration (cost of energy = 0.0727 \$/kWh). Sensitivity analysis of cost highlighting the impact of improved electrolyzer and fuel cell efficiencies on the cost-effectiveness of PV-WT-P2H2FC and PV-WT-BT-P2H2FC configurations. The study also underlines the significance of HRES in improving social metrics like the Human Development Index (HDI) and Job Creation (JC), with hydrogen storage demonstrating substantial potential for green job development. Ultimately, this research offers actionable policy recommendations to promote sustainable energy adoption and creates opportunities for future developments in renewable energy technologies in Garoua, Cameroon.