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Effect of biomass co-digestion on the performance and economics of a solar pv–biogas mini-grid system

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Abstract

Globally, the transition to sustainable energy is accelerating as countries seek solutions to climate change and energy poverty. Achieving this transition requires effective use of locally accessible renewable resources, especially in off-grid and rural areas. This study investigates the impact of biomass co-digestion on the design, performance, and economics of a hybrid solar PV–biogas mini-grid system for rural electrification. The study was carried out in a typical off-grid rural community in Kenya, rich in biomass from agricultural activities. Electrical load profile of the sample population and potential for harnessing solar and biomass was assessed. Data collection was carried out using direct measurements and field surveys. Using HOMER software for system modelling and optimisation, a hybrid configuration consisting of a 35 kW PV array, 20 kW biogas generator, 20 kW converter, and 39.4 kWh battery storage was found to meet local energy demand. The system achieved a Levelized Cost of Energy (LCOE) of \$0.113/kWh and a Net Present Cost (NPC) of \$171,038 making it more economically viable compared to other similar systems reported across sub-Saharan Africa. The co-digestion of cow dung, maize residues, and food waste enhanced the consistency of biogas generation, improving system reliability and reducing energy costs. These findings underscore the critical role of feedstock diversity in optimising hybrid renewable energy systems. The aspect of agricultural waste management is also achieved in a productive manner. With supportive policy frameworks and community engagement, biomass co-digestion in hybrid PV–biogas systems can offer a scalable, sustainable solution for rural electrification in developing countries such as Kenya.

Keywords: Biomass, co-digestion, hybrid energy systems., renewable energy economics, rural electrification, solar pv-biogas mini-grid