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Optimum Hybrid Configuration for Off-grid Rural Electricity Generation in the Six Geopolitical Zones of Nigeria

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Introduction

Electricity access constitutes an indispensable requirement for meaningful socio-economic growth in any nation. However, about 1.26 billion people globally (18% of global population) are without electricity access, majority of which dwell in the two developing continents of Asia and Africa where rural population is profoundly affected (WDI, 2016). In Nigeria, Africa's leading and most populous economy, over 90 million people, about 55% of the population is without access to power supply (EIA, 2015). In addition, only 30% of the rural communities is connected to the grid thus leaving larger proportion of the population without electricity access.

Given the above background, this study aims at developing optimal hybrid system harnessing the available renewable energy resources (small-scale hydropower (SHP), solar Photovoltaic (PV) and wind) for power generation, especially in remote/rural areas without access to the main grid line, thereby improving electricity access in a sustainable manner. The paper is organised thus: section one provides succinct introduction, section two gives an overview of the Nigeria's power access situation alongside review of relevant literature. The third section expounds the methodology employed for the techno-economic analysis. section four offers the results and findings of the study whereas, the conclusion is given in section five.

Methodology:

For this study, six of sites, one from each geopolitical zone, with potential for SHP identified in the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) Baseline Report (2012) are considered (see details Table 1 below).
A hypothetical remote community of 50 households, comprising of about 400 to 500 people in total is designed for each study location. A community clinic, school, hall, 5 commercial shops, 5 street lights, 2 agro-processing centres together with 3 water pumps and 2 irrigation pumps is also included. For the modelling, simulation and techno-economic analysis of all necessary inputs, Hybrid Optimization Model for Electric Renewable (HOMER) software is utilized. Four system configurations namely SHP, PV, wind, diesel generator (DG) and battery systems are considered. Additionally, a sensitivity analysis is performed for key sensitive variables of the hybrid system.
Data are sourced from United States National Aeronautics and Space Administration (NASA) database, Nigerian Meteorological Agency, River Basin Development Authority (RBDA) of Nigeria etc.

Results

Firstly, the study identifies a list of feasible hybrid system setups for electricity generation in remote locations across the six geopolitical zones of Nigeria. Secondly, the finding unravels the most economically viable option based on total net present cost (NPC), per unit cost of electricity (COE) and Renewable Fraction (RF) for all the considered zones. Thirdly, the result unleashes the significant disparity in the CO_2 emissions level of the proposed hybrid system as compared to the stand-alone DG system. Lastly, the result reveal the environmental benefit, in terms of annual GHGs cum particulate (CO_2, SO_2 and NOx) emission savings from the proposed hybrid system in all the locations.

Conclusion

Results from this research show that hybrid generation mix at off-grid locations has the potential of supplying cost-effective and environmentally friendly electricity to remote/rural communities across the six geopolitical zones of Nigeria. The study thus provides invaluable insight into developing appropriate electrification plan, implementation strategies alongside supportive mechanisms by the concerned stakeholders to curtail the lingering electricity crisis in Nigeria.

Keywords: Cost of Electricity (COE), Diesel Generator (DG), Hybrid Optimization Model for Electric Renewable (HOMER), Net Present Cost (NPC), Optimal Hybrid Mix, Renewable Fraction (RF)

Reference

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Table 1: Selected Location in each of the six Geopolitical Zones of Nigeria

Geo-Political Zone	State	Site Location	Geographic Coordinate	
			Latitude (N)	Longitude (E)
North East (NE)	Gombe	Balanga	9°55'20"	11°35'58"
North West (NW)	Kastina	Kabomo	11°32'33"	7°28'43"
North Central (NC)	Kwara	Asa Dam	8°24'50"	4°26'28"
South East (SE)	Ebonyi	Edukwu	6°43'15"	8°10'31"
South West (SW)	Ekiti	Elemi	7°54'19"	5°16'20"
South South (SS)	Delta	Ibrede	5°32'60"	6°23'60"

Source: the Study