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Analysis of Renewable Energy Resources and Estimation of Power Generation Capability in South-South Geo-Political Zone, Nigeria

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A B S T R A C T

Energy availability is a key to socioeconomic growth and industrial development of any society. It is not gain saying that Nigerians in all the six states in south-south geopolitical zone have limited access to electricity from the grid especially those living at remote and rural areas. This research was undertaken to assess the renewable energy resources domiciled in all the states in south-south geopolitical region and estimation of power generation to meet the energy demands and needs of both urban and rural population in Nigeria. Two renewable energy resources were investigated namely: solar and wind energy resources. The result obtained indicates that 18,609.27MW of electricity can be generated with the use of photovoltaic solar technology in the zone. The study also revealed that wind energy resources can generate 142,289.267MW of electricity by exploiting the 1% of available effective wind area in all the states in the zone. Therefore, this study recommended that the policymakers should entrench friendly policies to attract investors to exploit these resources to enhance power generation in Nigeria in order to improve the wellbeing of the citizens.

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INTRODUCTION

Access to adequate, reliable and stable electrical energy plays a critical role in socio-economic development, technological advancement and industrial growth of any countries in modern times. In today's world, the need for electricity has been regarded as the key fulfillment of basic individual and communal needs in the society. The need for all to have access to affordable, reliable, sustainable, and modern energy, is the 7th agenda of the 17 listed Sustainable Development Goals (SDGs) of the United Nation. Therefore, it is good to say that availability and accessibility of electricity is used as an index for assessing a country's or a society quality of life. The rising in prices of fossil fuels due to depletion of its reserve, coupled with global warming menace and greenhouse gas emission has called for the diversion from the wholly utilization of fossil fuels for power generation, which will be realized by bringing in alternative renewable means of energy sources such as; wind, solar, biomass, hydroelectric, ocean and geothermal) that are clean, sustainable and environment friendly.

According to World Bank report (2021), 85 million Nigerians don't have access to electricity from grid network, this represents about 43% percent of the country's population despite abundant amount of untapped renewable energy resources with substantial ones being solar energy, small and large hydro-energy, biomass, wind and geothermal with several potential[6][7]. If harnessed, it will increase the chances for energy self-sufficiency whilst preventing environmental degradation. For sustainable development of Nigeria, there should be assessment and policy formulation hinged on exploiting available primary renewable energy resources for electricity production in each geo-political zones, which is required for use by businesses and households in the country in both on- grid and off-grid configurations. This will alleviate the sufferings of the people caused by lack or inadequate electric power supply, and oiled the wheel of economic and industrial development in the country. This research gives an insight on analyzing renewable energy resources (solar and wind), and estimation of their electric power generation capability in South-South geo-political zone in Nigeria.

LITERATURE REVIEW

Electric Energy Situation in Nigeria

The electric energy demand outweighs the energy supplied within the country. Power Africa summit in 2017 reported that 55 percent of Nigerians lack access to electricity, while 45 percent connected to the grid suffers constantly from power failure, large portion of the country do not have enough electricity from the grid[10] [11]. Power delivered to regions that have access to electricity is insufficient and unreliable, which relates a huge supply gap [12]. Nigeria population is projected to increase progressively, which place more demand for energy availability.

Nigeria has 25 power generating plants that are connected to the grid whose installed capacity is approximately 12,500MW. However, only about 4000MW is available due to factors such as maintenance and vandalism. The gas power plants and hydroelectric dams are responsible for 80% and 20% of the

power supplied to the grid respectively[13]. Table 1,shows the name, location, installed and available capacities of the grid connected power generating plants in the country.

Table 1. Grid Connected Power Plants in Nigeria

S/No.	Name	Type	Location State	Installed Capacity (MW)	Average Operational Capacity (MW)
1.	AES	Gas	Lagos	180	0
2.	Afam IV-V	Gas	Rivers	724	2
3.	Afam VI	Gas	Rivers	685	455
4.	Alaoji NIPP	Steam	Abia	720	67
5.	ASCO	Gas	Rivers	294	0
6.	Egbin	Steam	Lagos	1,320	539
7.	Geregu	Gas	Kogi	414	131
8.	Geregu NIPP	Gas	Kogi	450	131
9.	Ibom	Gas	Akwa Ibom	190	76
10.	Ihovbor NIPP	Gas	Edo	434	182
11.	Jebba	Hydro	Kwara/Niger	720	262
12.	Kainji	Hydro	Niger	720	173
13.	Odukpani NIPP	Gas	Cross River	561	64
14.	Okpai	Gas	Delta	900	375
15.	Olorunsogo	Gas	Ogun	335	189
16.	Omotosho	Gas	Ondo	335	163
17.	Omotosho NIPP	Stream	Ondo	500	169
18.	Rivers IPP	Gas	Rivers	136	0
19.	Omoku	Gas	Rivers	110	0
20.	Olorunsogo NIPP	Gas	Ogun	760	171
21.	Sapele	Steam	Delta	504	69
22.	Sapele NIPP	Gas	Delta	450	111
23.	Shiroroo	Hydro	Niger	600	153
24.	Trans- Amadi	Gas	Rivers	150	0
25.	Transcorp Ughelli	Gas	Delta	480	374
26.	**TOTAL**			**12,522**	**3,904**

Nigeria has one of the least per capita electricity consumption in the World, with a paltry 156.73KWh per capita, it is dwarfed by other countries even in the same West Africa sub-Region [15]. Nigeria is rich in both conventional and renewable energy sources. Despite the abundance of the fossil fuels, the availability of demanded electricity in the country is uncertain and erratic,

describing it as a scenario where energy services are either insufficient or inaccessible to those who need it as suppressed demand. The use of renewable energy would be important to solve the problem of suppressed energy demand due to unavailability and inadequacies of fossil fuels [16].

Location and Demography of Nigeria

Nigeria is a country in West Africa located between latitudes 30151 and 130301N and longitudes 20591 and 150001E. Nigeria shares land borders with Republic of Benin in the West, Cameron and Chad in the east, and Niger in the North. It is bounded in the South by the Gulf of Guinea. Nigeria has an estimated population of about 200 million people with a growing rate reaching up to 4%.The land mass are of the country is 920,000km^2. Table 2, shows the projected population growth rate, the share of urban population, rural population and the number of person per household.

Review of Related Works

In the study presented by [18], they carried out an assessment of potential resources for biomass in Nigeria. Their paper presents a desk review, which investigate the potential resources for biomass energy generation within the country. They stated the technical energy potential of the biomass resources is huge as stated; that about 2.33EJ (647222.22GWh) estimation could be generated from the available resources in Nigeria. The study found that despite the available potential and existing polices, not much has been done within the implementation of large-scale Bio energy within the country.

In the proposed study by [19], they presented a paper on the assessment of renewable energy in Nigeria with emphasis on challenges and benefits. They stated that the natural sources of energy like gas, oil, coal and uranium are inadequate and expensive, which also contributes heavily to greenhouse gas emissions. They are of the opinion that there is urgent need for construction of mini and micro hydropower plant to cater for the supply of electricity to rural and remote location where water is readily available, while tapping into the abundant renewable energy resources such as hydro, solar and wind will alleviate power outage problems and which in turn will bring about job creation for the teeming youth in the country.

METHODOLOGY

Extractable Electric Power Estimation from Solar Energy

Solar energy is one of the most thriving renewable energy sources in Nigeria, owing to the simplicity and relative cheapness that come with its installation and operation. Nigeria lies within a high sunshine belt with average solar radiation of about 5.8Kwh/m2 per day [24]. In this study, all the states in South –South geo-political zone are consider to be analyzed for solar (PV) electricity generation.

Table 2: Annual Average Solar Irradiation Per Day and 1% of Landmass in States of South-South Geo- Political Zone

State	Annual Average Solar Irradiation Per Day (Kwh/m^2)	1% of Landmass ($(10^6 \times M^2)$)	Population
Edo	4.47	195.59	4,777,000
Delta	4.58	176.98	5,636,100
Bayelsa	4.21	107.73	2,587,400
Rivers	4.13	110.77	7,476,800
Ayara Ibom	4.53	70.81	4,979,400
Cross River	4.15	201.56	4,406,200

State by State Estimation of Power Generation capability in South-South Geo-Political Zone of Nigeria Through Solar Energy Resources

The estimation of electricity generation potential from solar energy in all the six states in South-South geo- political zone is determined by using equations (1) and (2) in conjunction with Table 2, showing annual average solar irradiation per day and 1% of landmass in each state in South-South zone.

Extractable Electric Power Estimation from Wind Energy

Nigeria has moderate wind potential with average wind speeds at 10metres height ranging between 2.1m/s and 8m/s with the highest values (greater than 7m/s) located in the Northern part of the country. Apart from the coastal and offshore locations, the wind speed in Southern Nigeria is relatively low [27] [28]. To estimate the amount electric power to be generated using wind energy potential in South- South geo-political of Nigeria, this project utilized secondary data which originated from Nigeria Meteorological Agency (NIMET) in conjunction with data from literature. Data used include; the mean monthly wind speed for different states of the region at the standard height of 10m and the effective wind area of each state. The air density (ρ), wind speed (V) and the area swept by wind turbine rotor are the crucial parameter used.

Table 3: Wind speed, Capacity Factor and Effective Wind Area, Capacity Factor in each State of South- South Geopolitical Zone

States	Annual Mean Wind Speed (m/s)	Effective Wind Area of Landmass (10^6 x M^2)	1% of Effective Wind Area (10^6 x M^2)	Capacity Factor $(\frac{m}{s} - \frac{kw}{m^2})$
Edo	1.68	137.4957	1.3750	0.1834
Delta	1.70	139.1325	1.3913	0.2054
Bayelsa	1.74	142.4062	1.4241	0.3117
Rivers	1.38	112.9429	1.1294	0.2009
Akwa Ibom	1.20	98.2112	0.9821	0.2206
Cross Rivers	2.86	233.2516	2.3325	0.2600

State by State Estimation of Power Generation capability in South-South Geo-Political Zone of Nigeria Through Wind Energy Resources

The estimation of electricity generation potential from wind energy in all the six states in South-South geo- political zone is determined by using equation (6) together with Table 3, showing annual mean wind speed, effective wind area, 1% of effective area and capacity factor in each State of South- South geopolitical zone.

RESEARCH RESULT AND DISCUSSIONS

Annual Solar Power Estimates in South-South Geo- political Zones

By making use of 1% of land mass in each states of the south-south geo-political zone to place the required solar panel under one year consideration. Figure 1, shows the plot of electric power estimation from solar PV technology against respective state in south –south geopolitical zone under study.

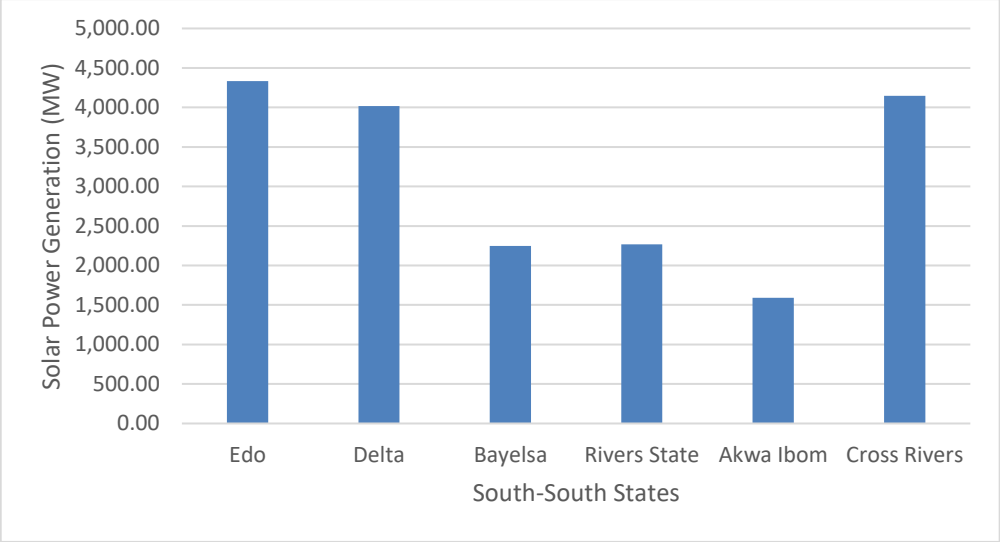

Figure 1: Solar Power Estimates in South- South Geopolitical Zone.

Figure1 indicates that generation of electricity through solar PV technology is viable in all states of south- south geopolitical zone of Nigeria. Cross Rivers state is the most viable state in the region in, with potential of generating 4,147.56MW of electric power. Akwa Ibom state has the the least solar energy potential nevertheless it has the potential of generating 1,590.5MW of electric power, which is almost half of the present 4,000MW available on the grid. The sitting of solar projects in the entire part of the south- south states will be a feasible renewable and sustainable energy project, even with mini or micro off grid systems that will serve communities to boost rural electrification.

Presentation of Annual Wind Power estimates in South- South Geopolitical Zone.

For the one year considered in this study and making use of 1% of effective wind area land mass in each state of south- south geopolitical zone of the country. Figure 2, shows the plot of wind power obtainable from wind energy technology against respective states of south- south geo-political zone.

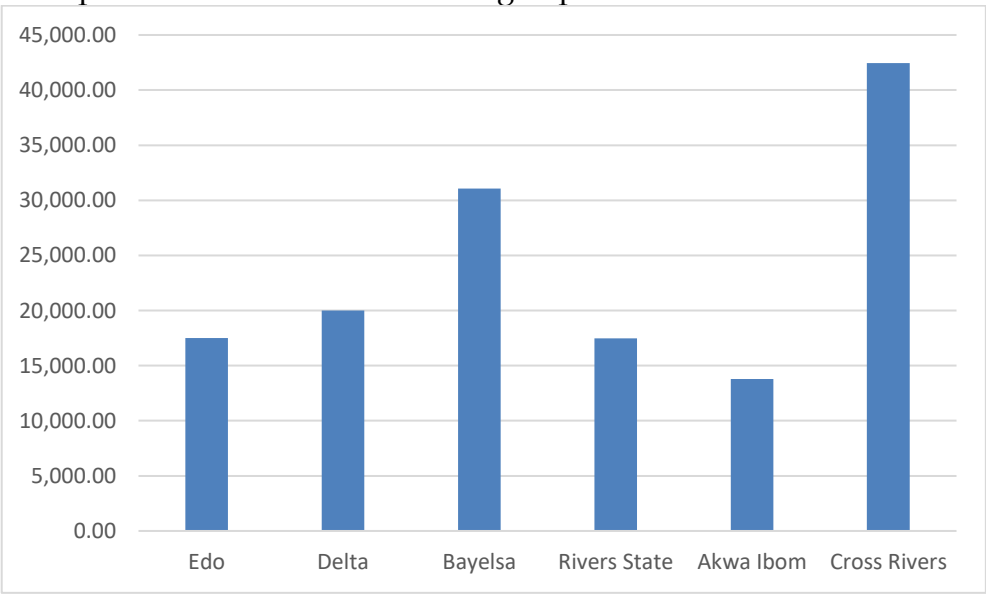

Figure 2: Wind Power Estimates in South- South Geopolitical Zone.

Cross Rivers state has the highest wind speed and effective wind area making it the most viable region for sitting of a wind power project in South-South geo-political zone. It can be seen that if 1% of the effective wind areas of the six states in south- south geopolitical zone is utilized, it can be used for the generation of 142,289.2697MW of electricity. This is more than sufficient to meet the energy demand of the region and the whole country.

CONCLUSIONS AND RECOMMENDATIONS

The energy poverty in Nigeria is one of the highest in the world. Within Nigeria, all the six geopolitical ones have poor per capital electricity consumption and access to electricity from grid especially in south-south geo-political zone despite having abundant renewable energy resources. This study carried out the analysis of renewable energy resources and estimate power generation capability in south- south geo-political zone using appropriate approach. It was found out from this study that every states of the zone has vast untapped solar and wind energy.

The states in south- south geopolitical zone in Nigeria are suitable for the generation of electricity with the deployment of solar technology. The six states together were estimated to be able to generate up to 18,609.27MW of electricity via solar technology if 1% of the landmass is utilized.

The study also revealed that all the six states in south-south geopolitical zone have the capacity to generate 142,289.269MW of electricity through wind renewable energy resources capable of meeting the energy demand of the zone and beyond it, if 1% of effective wind area in Rivers, Cross Rivers, Akwa Ibom, Bayelsa, Delta and Edo states are utilized for power generation using wind technology

ADVANCED RESEARCH

This study has established a baseline analysis of renewable energy resources and their potential power generation capacity in the South-South Geo-Political Zone of Nigeria. However, several areas remain open for further research to strengthen the findings and improve the implementation feasibility of renewable energy projects:

1. **Temporal and Seasonal Variability Analysis**

Future research should incorporate long-term data to account for seasonal variations in solar radiation, wind speed, and hydrological flows. This will enable a more accurate estimation of annual energy generation and reliability metrics.

2. **Hybrid Energy Systems Optimization**

An integrated approach combining solar, wind, biomass, and small hydropower should be modeled to determine the most cost-effective hybrid configurations for rural and urban electrification.

3. **Techno-Economic Feasibility and Policy Assessment**

Detailed cost–benefit analyses, including capital investment, operation and maintenance costs, and payback periods, should be carried out. Additionally, the impact of existing government policies and incentives on renewable energy adoption should be evaluated.

4. **Environmental and Social Impact Studies**

A comprehensive assessment of the environmental benefits and possible adverse impacts (such as land use changes, biodiversity loss, or community displacement) should be undertaken, alongside a social acceptance survey to understand local perceptions and willingness to adopt renewable energy.

5. **Grid Integration and Storage Solutions**

Future work should assess the technical requirements for integrating intermittent renewable resources into the national grid, including energy storage options, smart grid technologies, and load management strategies.

6. **Predictive Modeling Using AI and Machine Learning**

Advanced computational models can be developed to predict renewable energy generation under different climate scenarios, helping policymakers and investors plan for resilience against climate change impacts.

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