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PROSPECTS OF RENEWABLE ENERGY IN WEST AFRICA

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Abstract
The issue of electricity for industrial development of any nation cannot be overemphasized. In other words, no country can be economically and socially sound without an adequate and cheap electricity supply. The paper identifies the evil of power problems in the region, it examines the current trends and potentials of renewable energy sources (RES) in some selected nations of West Africa. It discloses the degree of current utilization of Renewable energy and the prospect of its rejuvenations in the region. It shows that hydro and solar energy are the most sought-after while efforts are being made to harness others. The conclusion stressed actions that will promote RE and its technologies in the sub-region. It is believed that by adhering to them, the bright future of RE will be attainable.

Keywords- *Biomass, Energy, Hydro, Renewable, West Africa, Wind*

1. Introduction

The development of any nation cannot be attained without adequate electricity supply (Chigozie & Oluchukwu, 2013). Machines and production facilities in industries need sufficient power supply and inadequate power supply has been an obstacle to developments in the developing world. Nigeria, the most populous in the West Africa subregion is also grappling with issues of inadequate power supply (Akinwole & Akinsanya, 2023), and in Nigeria, a whooping sum of 92 million Nigerians do not have access to electricity, an amount which translates to about 40% of the entire population lacking access to electricity (Nnodim, 2024). In the country, more scarce resources have been committed to shoring up power delivery with attendant poor results (Akinwole & Oladimeji, 2019). Apart from the resources, there have been enactments of legislation and policies put in place to enable growth in the power sector. The National Electric Power Authority (NEPA) was unbundled and renamed Power Holding Corporations of Nigeria (PHCN). Power is generated by power generation companies (GENCOS), Transmission Company of Nigeria (TCN) transmits it.

These numerous governmental interventions have not yielded the desired results. Most of the rural communities are still without a public power supply (Nnodim, 2024). Even those that are connected to the national power grid are faced with myriads of problems ranging from under-voltage to total power outages (Akinwole, 2021). Residents contribute their scarce resources to procure distribution infrastructures, such as aluminium conductors, reinforced concrete poles and transformers to enjoy the electric supply. Other anomalies being experienced by electricity consumers are overloading of power transformers and unbalanced loads which results to system's instability. Rural communities do not have a power supply while the majority of the buildings in the urban centres are not metered. The ugly situation has caused some building owners and facilities managers to seek alternative power source

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readily available in RE (Chanchangi et al., 2023).

Generally, in the West African sub-region, every house is a potential power-generating house and the generators used are fossil fuel-based, which causes air and noise pollution. Thus, life expectancy in the subregions has been reduced as a result of incessant inhalation of carbon monoxide (Oyedepo, 2012).

Another aspect of note is the skyrocketed cost of fuels, depletion of fossil fuel reserves, and accentuated carbon footprints and greenhouse gases (GHG). It was on this note that African countries keyed into actions to tackle the climate change menace (AFDB, 2022). The following section lists countries that make up the West Africa sub-region.

2. The West African Countries

The subregion of West Africa is made up of an area of 5,114162 km^2 (Nationsonline, n.d.). The countries fraternize under the umbrella of the Economic Community of West African States (ECOWAS), which was established in May 1975. It is coined Communaute Economique des Etats de l'Afrique de l'Ouest (CEDEAO) in French and Portuguese-speaking member countries. The countries are Nigeria, Sierra Leone, Liberia, Ghana, Benin, Burkina Faso, Cote d'Ivoire, Guinea, Guinea Bissau, Mali, Niger, Gambia, Senegal, Togo, and Cape Verde.

Fig. 1: Map of West African Nations (IRENA, n.d.-b).

Mauritania withdrew her membership in December, 2000 (Wikipedia, n.d.). The goal is to enhance economic cooperation thus boosting the living standards. The ECOWAS help in boosting security in the region by sending peacekeepers to any country having internal unrest. According to Worldometer, the population as of 29th November 2022 is 426,578,784 (Worldometer, n.d.). The West African region has been blessed with massive potential for renewable energy. If they are well harnessed, the issue of energy shortage will be a thing of the past (UN Chronicle, n.d.).

3. Renewable Energy

Renewable energy is that type of energy that are naturally replenished. Examples are Solar, Wind, Hydro, Biomass and Geothermal (Akinwole & Akinsanya, 2023). The following sections provide basic information about the first three; that is solar, wind and hydro.

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4. Solar Power

Solar power is the type of energy that is obtained from the sun. As the photons from the sun strikes the photovoltaic cells, electrons are released. Thus, solar energy is converted into electrical energy. The sun's power received in any area over the earth's surface depends on the following:

i. The geographical location of the area
ii. The earth's rotation.
iii. The distance between the Earth and the sun
iv. Earth axis inclination angle

Sun emits 3.846×10^{26}W of energy per annum with annual solar flux on the earth's surface ranging from 800 to 2450 kWh/m^2 (World scientific, 2018).

$$Peak\ sun\ hour = \frac{GHI}{1000} \quad (1)$$

$$GHI = DNI \times Cos\,\vartheta + DNI\ (W/m^2) \quad (2)$$

Where GHI is the global horizontal irradiation

DNI is the diffuse horizontal irradiation measured by a pyranometer.

ϑ = angle of tilt.

Installed power P_{inst} of a power plant is defined as the maximum power that is delivered by it at P_{sun} (AM1.5) during the first year after installation (World scientific, 2018).

$$P_{inst.}(W_p) = A \times \eta \times P_{sun}\ (AM1.5) \quad (3)$$

The electric energy produced by a solar PV power plant is

$$W_{el} = A \times \eta \times (P_{sun}) \times t \quad (4)$$

Where A is the area covered by the PV panels

η is the solar energy conversion efficiency

P_{sun} is the average power of the sun on earth

T is the period of operation (World scientific, 2018).

5. Wind Power

Wind power entails the conversion of kinetic energy available in the wind into electrical energy. The system comprises a wind turbine system incorporating a rotor blade. The rotation of the rotary device is coupled to the generator. The maximum power output in watts per square metre of swept area that can be generated from a wind turbine in a site depends on the wind speed V, (Ozim et al., 2021), thus,

$$P_w = \frac{1}{2}\rho V^3 \quad (5)$$

ρ = density of the air. Wind power varies linearly with the air density sweeping the blade. The air density is a function of pressure and temperature under the gas law (Patel & Beik, 2021). Their effects produce the equation below, and, it is valid for site elevation above sea level of up to 6000m.

$$\rho = \rho_o - (1.194 \times 10^{-4} H_m) \quad (6)$$

ρ_o is 1.225 kg/m^2, that is, the value at the reference which corresponds to 1 atm. and 15.6^{o}C. The elevation of an area also affects the wind speed, if V_1 is the speed at the height of Z_1, V_2 is the speed at the height of Z_2 and α is the wind share exponent (Okedu et al., 2024).

$$V_2 = V_1 \times \left(\frac{Z_2}{Z_1}\right)^{\alpha} \quad (7)$$

6. Hydro Power

The potential energy of the water body due to its depth is converted to kinetic energy. The water location's hydrology and hydraulics will determine the amount of power to be derived from it (Odiji et al., 2021).

Hydropower output $P_{max} = Q \times H_{net} \times g \times \eta_{max}$ (8)

Where H = water head in metres

Q = volumetric flow rate in m^3/s

g = acceleration due to gravity.

η_{max} = maximum turbine efficiency.

Volumetric flow rate Q is a function of the cross-sectional area of the river in m^2 and the mean velocity in meters per second (m/s).

That is, $Q = A \times V_{mean}\ {}^{m^3}/_{S}$ (9)

7. Renewable Energy Policy in West Africa

As far back as mid-2013, the month of July to be precise, the heads of governments of

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West African nations came together to adopt RE policy for the region, the intervention was cleverly coined Economic Renewable Energy Policy (ERER). The aim is to enhance RE contribution to the energy mix in their various milieu to 35 per cent by the year 2020 and a further boost to 48 per cent by the year 2030 thus translating to about 10 per cent and 19 per cent respectively (IRENA, n.d.-b). The Economic Community of West Africa (ECOWAS), the organization that brings together West African countries for economic and other related concerns, formulated ECOWAS Energy Efficiency Policy (EEEP) which aims at garnering 2 GW as gains obtainable from improvements in energy efficiency (IRENA, n.d.-b).

The climate of West Africa has undoubtedly favoured the Renewable Energy technologies (RETs) in the subregion (Whitecase, 2021). Numerous rivers can be explored for Hydro Power Projects (HEPs), solar energy from the sun is vast and wind and biomass are available for exploitation. There is no doubt that these vast renewable energy sources, if well harnessed can bridge the energy gap of the populace. The awareness of clean energies by various agencies in the region is sine qua non to an improved electrical energy needed to power homes, health centres, schools, and Small and Medium Scale Industries (SMIs) in suburban and rural areas. RE is naturally replenished and can be positively harnessed in rural areas without a power grid. Such energy is clean, and void of noise pollution and poisonous gases emanating from the combustion of fossil fuels (EERE, n.d.). Figure 2. Shows charts representing electricity generation from RE sources in West Africa between 2012 and 2019. In 2015, it was 154.215 GWh and ramped up to 187.86 GWh in 2019 (AEP, n.d.) due to various commitments and interventions from governments and other stakeholders.

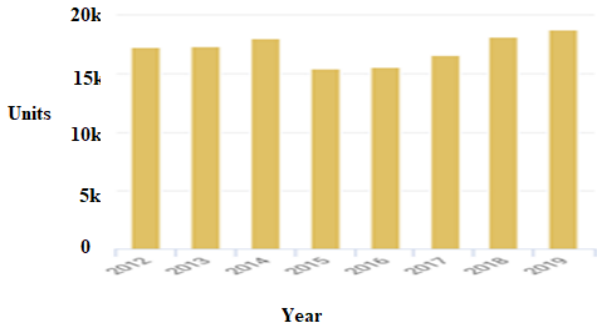

Fig 2: Electricity Generated from Renewable Sources (AEP, n.d.).

The next sections consider five countries in West Africa in relation to their current status and positive activities towards the development of RE in their various countries.

8. Renewable Energy in Nigeria

Nigeria has a high level of solar irradiation throughout the year hence solar energy systems and devices are the most promising renewable sources. She receives solar irradiation of about 7kWh/m^2 translating to 25.2 MJ/m^2 per day. If the latter is juxtaposed with fossil fuel production, the value amounts to around 258.6 million barrels of oil equivalent per annum (Okedu et al., 2024). Potential for wind energy generation is high in the country's northern and coastal regions, for example, a study shows that in the Northeast at the height of 10m, wind speed ranges from 3.18m/s to 7.04m/s (Aliyu et al., 2015). For hydropower, Nigeria has rivers and bodies of water that offer small and medium-scale hydropower (Okedu et al., 2024). According to (Aliyu et al., 2015), the small hydropower resources have reserves of 3500MW while large hydro accounts for 11235MW.

9. Renewable Energy in Sierra Leone

The Sierra Leone energy revolution has set targets to reach 250,000 domestic apartments with solar energy by the end of 2017 and a modern energy system for every household by 2025 (Olalekan Idris et al.,

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2020). Various actions with government and other stakeholders are on to support policies on energy and create awareness on benefits of RE (REASL, n.d.).

The Renewable Energy Association of Sierra Leone (REASL) was established in 2016. It was registered under the Sierra Leone Companies Act No. 5 of 2009. The trade association is poised towards fashioning the growth of an efficient RE

10. Renewable Energy in Liberia

The Renewable Energy for Electrification in Liberia (REEL) project was born in order to enhance electricity from Renewable Energy sources (RES). The initiative, which is currently under implementation was approved in 2019 and slated to run up to 2025. It is being funded by the African Development Fund ADF (AFDB, n.d.). It is a hydropower project (HPP). It is expected to furnish isolated and remote areas homes, schools and health facilities with reliable, sustainable and affordable electricity supply.

Generally, Solar Standalone Photovoltaic system enjoys 4kWh/m^2/day to 6kWh/m^2/day during rainy and dry seasons respectively (Renewable Liberia, n.d.).

11. Renewable Energy in Ghana

In order to harness Renewable Energy technologies (RETs), an act referred to as Ghana's Renewable Energy Act of 2011 (Act 832) was promulgated. It provides an enabling framework for the engagement of RES which is expected to attract various investments in the sectors (Aboagye et al., 2021). Ghana's RE arsenal comprises solar power, biomass, wind, and hydropower (Takase & Kipkoech, 2023).

Ghana like other countries in West Africa has a RE development initiative otherwise referred to as Ghana's renewable energy master plan. The plan is a framework put in place to enhance the development of rich RE natural endowment in order to empower economic growth, improve citizens' social life and help to mitigate the effects of change in the climate.

Biomass resources of the country are on a large scale with the potential of using feedstock for the production of biogas thereby reducing their overdependence on the use of fuel from wood burning. In 2008 alone, it was estimated that 72 per cent of the primary energy supply in the country was from fuel wood while crude oil only caters for 22 per cent and hydro contribution was just 6 per cent (Aliyu et al., 2015). According to the work of Nelson et al, it was disclosed in their treatise that the resources entail crop and its residue, solid waste, waste from animals, algae, aquatic plants and other waste obtained from activities of food processors (Nelson et al., 2021).

12. Renewable Energy in Togo

Togo, a francophone country occupies a land area of 56,785km^2. In 2020, the solar development roadmap which comprises four phases was initiated. It was based on solar energy and photovoltaics. Its four phases are planning and preparation, visioning, roadmap development and roadmap implementation and revision (Salifou et al., 2023). The country's solar potential can generate 4.8 to 5.6 kWh/m^2 while moving from the south to the north. On hydro, the river, Mono, which is the largest in Togo with about 467 km in length runs from the northern to the southern part of the country. It was engaged for a hydropower plant at Nangbeto dam. In the same vein, wind power has wind velocity ranging from about 2.50m/s to over 9.75m/s (Energypedia, n.d.). Hydropower accounts for 50.6% of electricity generated, with a meagre 0.4% being produced from biomass and other RE sources. The contribution of RE to the energy mix as of 2017 was estimated at 6.2%. The current estimate has it that Togo generates 230MW of electricity with a future projection of 100.8GW by 2030 (Energypedia, n.d.)

Solar home systems are prevalent (SHS) with companies and projects springing

up to spread the gospel of RETs. Just in June 2021, a 50MW solar plant financed under IRENA-ADFD was inaugurated. It was commissioned to deliver clean energy to about 160,000 homes and businesses. The project which is the brainchild of the Togolese national clean energy strategy, coined Sheik Mohammed Bn Zayed Solar plant was conceived to reduce the country's overdependence on fossil fuels. The programme is poised towards increasing the share of renewable energy in electricity generation to 50% and 100% by 2025 and 2030 respectively (IRENA, n.d.-a).

I3. Conclusion

The paper has been able to enumerate the status, potential and prospects of RE in the subregion with special reference to five member states Nigeria, Liberia, Ghana, Togo and Sierra Leone. Though each country has its peculiar situation, it is believed that the pictures painted in this treatise are the conditions that are being experienced in the remaining eight member states.

To further enhance the utilization of RE in West African nations, there must be aptitudes for the countries to have the required technologies for seamless evacuation of power generated through the RE schemes for onward transmission via the existing power grids to the load centres. It is on this premise that the effort will enhance the required positive development of economies and social stability in their polities. Though the cost of installing renewable energy systems is decreasing, it is still relatively expensive to store them knowing fully that RE sources depend on the weather. It is generally known that PV devices and components are imported from other developed economies; reduced taxes and duties paid on imported photovoltaic installations' components will go in long way to boost solar power technologies penetration and applications by all and sundries.

Most of the West African nations have sizeable hydropower, but with an intensified small hydropower (SHP) project in conjunction with other world bodies, RE technologies can further be accentuated. Though there are abundant RE potentials, the aspect of utilization enhancement will be a plus to its overall development. Also, by deploying a series of well-articulated awareness campaigns and national orientations on the benefits of RE, the technology's development will ensue (Khambalkar, 2010).

Another area that can foster RE in the region is to boost the capacities of engineers and technologists by organizing manpower training sessions (UNESCO-UNEVOC, 2020). Also, there is a need for governments of nations in the subregion to shore up their political wills on strengthening research and development (R&D) on the technology. The gesture will allow local production of RE technologies' components, thereby reducing capital flights and depletions of scarce foreign reserves of the nations.

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