

PAPER 72 – Exploration of Global Renewable Energy Statistics for Electricity Generation: A Case Study of Nigeria.

Y. A. Yisah¹, S. O. Anaza^{1*}, T. Abdulraheem¹, H. Otaru¹, M. Abdulazeez¹. M. S. Salawu¹

¹Power Equipment and Electrical Machinery Development Institute, (PEEMADI) Okene, Kogi State, Nigeria
Email: sanaza@peemadi.gov.ng

Abstract:

In recent times, electricity has been the key driving factor in all aspect human life such as healthcare, transportation, entertainment and education. Providing this essential service to meet the ever growing universal energy consumption coupled with the fast exhaustion of fossil fuel reserves as well as the enormous environmental hazard associated with its consumption has necessitated substantial research consideration on clean energy sources. This study presents an exploration of global Renewable Energy (RE) statistics and its tendencies for electricity generation with particular emphasis on Nigeria. The exploration was based on the data obtained for all the various forms of RE data obtained from several RE data base. It also explores Nigeria RE potential, estimates the amount of electrical energy that can be generated from RE and the current status of their usage. Benefits and factors hampering the generation of electricity from RE sources were enumerated. The study unveils Nigeria RE potential with the annual average solar insolation ranging from 4.2kWh/m²/day in the south to 5.9kWh/m²/day in the north, wind energy ranging from 4.4 W/ m² to 35.2 W/m² (if the intensity is perpendicular to wind direction), and a hydro potential above 11,000MW.

Keywords: Electricity; Power generation; Renewable Energy;

1. Introduction

Energy is a vital constituent for growth and an influential engine of commercial and societal transformation in any nation. It is at the core of every quality life and an imperative factor for financial progress (Akorede *et al*, 2017). Electrical energy has become an essential product for a comfy life in both rural and urban areas. For this reason, its demand has been on the rise continuously universally at the rate of 3% per year. Worldwide, there is an estimation of above 1.5 billion people who lack access to electricity (Shaver, 2017). Nigeria is located in the western region of Africa (Adejumo and Suleiman, 2017) is the Africa's largest economy and home to approximately 10% of the un-electrified population of Sub-Saharan Africa (Maria *et al*, 2020, Komolafe *et al*. 2003, Lloyd 2007), with the majority of whom reside in the rural communities. (Diemuodeke *et al*, 2021). With a population of around 213 million (Nigeria population, 2021), the country barely generates meager 6000MW of electricity which by international standard is not adequate to cater for healthy living besides to support industrial development and infrastructure (Adhekpukoli, 2018: Eboibi *et al*, 2017). The energy mix of Nigeria electricity supply sector is dominated by fossil fuels with natural gas and hydro accounting for around 85% and 15% of grid-connected generation respectively (NPBR, 2015). Paradoxically, the country is endowed with huge fossil fuel reserve which according to Oyedepo *et al*, 2018 in 2017 her reserve are; Light Crude oil: 37.06 billion bbl, Natural gas: 5.284 trillion cubic meter and Coal and Lignite: 2.734 billion tones, though characterized by challenges such as depletion, high cost and greenhouse effect (Rana *et al*, 2017; Zubo *et al*, 2017).

2. Global Renewable Energy Statistics

Positive progress has been accomplished in the last decade which can be attributed to the combined effort of Engineer and scientists. Globally, several subsidies and policies have been established to assist the deployment of non-hydro RE sources and facilities, (Nadeeshani *et al*, 2015). It has yield result, the share of Net annual additions of renewable energy in power generation capacity in 2011 was less than 50% and increase to 84% in 2021 (REN, 2022).

As depicted by Table 1, Total Annual Addition of Renewable Power Capacity (TAARPC) increased by 73.2% from 2016 to 2021, In order to achieve net zero scenarios for 2030 and 2050, the Table shows projected Value. Net Zero Scenario (NZS) denotes to the method of accomplishment a Net zero carbon footprint of methane, carbon dioxide (CO₂), and other Greenhouse Gases (GHG) in the sky by eradicating all man-made GHG emissions from the air through reduction procedures (artificial

and natural sink), carbon-offsetting or by basically not radiating to reach net zero (Saheed and Hammed, 2020).

TABLE 8: Annual Additions of Renewable Power Capacity, by Technology and Total, 2016-2021, and to Achieve Net Zero Scenarios for 2030 and 2050 (GW) (REN, 2022)

	2016	2017	2018	2019	2020	2021	2030	2050
Total annual renewable power capacity additions	155.5	163.1	180.9	183.4	194.4	269.3	730.0	824.9
Hydropower	21.9	18.0	20.2	15.8	19.4	26.7	47.7	35.4
Wind power	54.9	53.5	50.7	60.8	95.3	93.6	236.4	253.1
Solar PV	77.0	103.0	104.0	111.0	145.0	175.0	421.9	459.6
Bio-power, geothermal, ocean power, CSP	9.3	6.4	8.5	6.8	9.6	11.8	24.0	76.9

To achieve NZS by 2030, the TAARPC is projected to increase by 171.1% from 2011 to 2030 and also projected to increase by 13%, from 2030 to 2050 to achieve NZS by 2050. Achieving NZS by 2030 will be difficult considering 73.2% increase in TAARPC over a span of five years (2016-2021) compared to projected increase of 171.1% over a span of 9 years (2021-2030). But if the increments of 74.9GW in TAARPC between 2020 to 2021 (A year) can be sustained annually, then the NZS 2030 can be achieved. It requires diligence and commitment of the entire stakeholder in RE business.

2.1. Solar PV

In terms of installed cumulative solar power, the top five countries as of 2022 are China, USA, Japan, Germany and India with installed capacity of 393,032MW, 113,015MW, 78,833MW, 66,554MW and 63,146MW respectively (IRENA, 2023). The installed solar power capacity in Germany alone (a country located in a temperate region), is more than 10times the highest peak total electricity generated from all sources in Nigeria, being 6000MW (Eboibi *et al*, 2017).

As depicted by Table 1, annual addition of solar PV has the highest increase rate of 127.3 % (from 77.0GW to 175GW) from 2016 to 2021. In order to achieve NZS for 2030 annual solar PV capacity is projected to increase by 246.9GW from year 2021 to 2030(9 years span). This will be tough to achieve unless the annual additions of solar PV Capacity increase from 2020 to 2021 (30GW) can be sustained. Annual increase of 30GW can easily be continued if tropical regions that have higher solar radiation (Bekele and Palm, 2010) can be encouraged to invest into solar PV project. Similarly to achieve NZS by 2050, the annual additions of solar PV Capacity is projected to increase by 8.9% from year 2030 to 2050.

2.2. Wind Power

As shown by Table 1, annual addition of wind power capacity increases from 54.9GW to 93.6GW (70.5% increase) from year 2016 to 2021. In order to achieve NZS by 2030, the annual addition of wind power capacity is projected to increase by 152.6% from 2021 to 2030 (9 years span). The task will be challenging unless the annual additions of wind power capacity increase from 2019 to 2020 (34.5GW) can be sustained. The annual additions of wind power Capacity is also projected to increase by 7.1% from year 2030 to 2050. In terms of installed cumulative solar power, the top five countries as of 2022 are China, USA, Germany India and Spain with installed capacity of 365,964MW, 140,862MW, 66,315MW, 41,930MW and 29,308MW respectively(IRENA, 2023).

2.3. Hydro power

Amongst the most clean sources of RE is Hydro power (Ravi and Tanweer, 2016). As shown in Table 1, annual addition of hydropower Capacity increases by 21.9% from 2016 to 2021, In order to achieve NZS by 2030, annual addition of hydro power capacity is anticipated to increase by 78.7%. Like other RE sources, it will be challenging to achieve, it is also projected to decrease by 25.8% within 2030 to 2050 to achieve NZS by year 2050. China, Brazil, Canada, US and Russia are the top five largest hydroelectric producers respectively It a major source of power generation in Brazil and Canada which constitute 64.7 and 59.0 percent respectively of their domestic electricity generation (IEA, 2020)..

2.4 Other Renewables

Generating electricity and thermal energy from biomass has the potential to help meet national goals for renewable energy (US department of Energy, 2010). As depicted by Table 1, annual addition

of other RE sources Capacity increases by 24.7 % from 2016 to 2021. It estimated that in order to achieve NZS by 2030 it should increase by 103.3% which will also be challenging unless the annual rise between 2020 and 2021 can be maintained over the nine years (2021-2030). An increase of 220.4% between year 2030 to 2050 is also required to achieve NZS by 2050. Geothermal can be categorize as RE source because the water is restocked by rainfall, thus the heat can be constantly created inside the earth (Ludovít *et al*, 2010). In geothermal, US, Indonesia, Philippines, Turkey and New zealand are takes the leads with capacity of 2.57GW, 2.13GW, 1.93GW, 1.61GW and 0.98GW respectively. A country in Africa, Kenya was ranked 7 with geothermal electricity capacity of 0.82GW (The US information Administration, 2020).

In summary (Table 2), it can be deducted that some countries are in the forefront to achieve NZS. China are leading in 4 RE sources such as Solar PV, wind power, Bio-power and Hydropower. US are among the top five countries in virtually all the RE sources. Germany, Brazil and India can also be seen as among the countries taking advatages of the benefits of RE sources.

TABLE 2: Top Five Countries in RE Sources

S/N	Solar PV (IRENA, 2023).	Wind Power (IRENA, 2023).	Hydro power (IEA, 2020)	Geothermal (the US information Administration, 2020)	Bio –power (REN, 2021)
1.	China	China	China	USA	China
2.	USA	USA	Brazil	Indonesia	Brazil
3.	Japan	Germany	Canada	Philippines	United State
4.	Germany	India	USA	Turkey	Germany
5.	India	Spain	Russia	New zealand	India

3. Nigeria’s RE Statistics for Electricity Generation.

Several aboriginal researchers have deliberated the possibility of Renewable Energy (RE) resources in Nigeria with a view of establishing their feasibility in the country. The country has installed capacity of 10,396MW, out of which 6,056MW is available. 82.5 % (4,996MW) of the available 6,056MW is from gas generating plants while the remaining 1,060MW is hydro (Stephen *et al*, 2022). A study conducted at the end of 2015 indicates that the segment of renewables in electric power generation (including off-grid) is around 23.7 % with 16.6% from hydropower, 3.7% from wind power while other renewables amount to 3.4% (Akorede *et al*, 2017). This necessitate the needs to access the RE potential of the country.

3.1 Solar energy potential

The information of the obtainable solar insolation at a place is crucial in choosing and planning proper solar energy systems and estimating the solar energy for that location (Okonkwo.and Nwokoye, 2014: Ilenikhena and Ezemonye, 2010). Nigeria by virtue of her location on the equator is around a high sunshine belt where solar insolation is equitably well distributed (Olayinka *et al*, 2014). A study conducted by Anaza *et al*, 2023 in as shown in Table 3.

Table 3: Solar Insolation of selected town in Nigeria (Anaza et al, 2023)

	Gombe (NE)	Katsina(NW)	Abuja (NC)	Osogbo(SW)	Owerri(SE)	Port Harcourt (SS)
January	5.6	5.5	5.4	5.0	5.1	4.9
February	6.0	5.8	5.7	5.2	5.2	4.9
March	6.4	6.4	6.1	5.3	5.0	4.6
April	6.3	6.7	6.0	5.2	5.0	4.6
May	6.1	6.4	5.6	5.1	4.8	4.3
June	5.8	6.0	5.1	4.5	4.3	3.6
July	5.3	5.8	4.6	3.9	3.9	3.4
August	5.0	5.4	4.2	3.7	3.9	3.7
September	5.5	5.9	4.8	4.1	4.1	3.6
October	5.9	5.8	5.4	4.6	4.4	4.0
November	5.8	5.5	5.8	5.1	4.8	4.4
December	5.5	5.3	5.3	4.9	4.9	4.8
Annual Avarage	5.8	5.9	5.3	4.7	4.6	4.2

From the Table 3, the annual average solar insolation ranges from 4.2kWh/m²/day to 5.9kWh/m²/day. Using an average solar irradiation 5.3kWh/m²/day for Nigeria, the average annual irradiation will be around 1934.5 kWh/m². According to Bekele and Palm, 2010, the solar irradiation in tropical regions is greater than that of more temperate latitudes. Europe has an average annual irradiation of 1000 kWh/m², while that Middle East is around 1800 kWh/m² which are lower than Nigeria (Sunday et al, 2019). Unexpectedly according to IRENA 2023, Asia and Europe are in the fore front of annual additions of solar PV Capacity. According to Ani, 2014, Ebigenibo and Oluwasanmi, 2020, the hourly energy output of the PV generator E_{pv} can be calculated according to the equation 1.

$$E_{pv} = G(t) * A * P * \eta_{pv} \text{-----(1)}$$

Where G (t) is the hourly irradiance in kWh/m², A is the surface area in m², P is the PV penetration level factor, and η_{pv} is the efficiency of PV generator.

Nigeria has a 923,768km² land area (Olayinka et al, 2014.), using an estimate of 1934.5 kWh/m² per year, an average of 178 7thousandTWh/year of solar energy is estimated to fall on the entire land area. Applying Equation (1), Using 15% conversion efficiency (solar panel conversion efficiency) and assuming 0.1% of its land is used, approximately 268.1TWh/year of electricity can be generated from solar PV, which is higher than her electricity demand estimate of 144.5 TWh/yr (Ezenanaya et al, 2014). Nigeria has an estimated population of 213.4 million (Nigeria population, 2021) as at December 2021. The W per capita is by this analogy from solar PV will be 1,256 which is higher than that of Germany (IRENA, 2023).

The Nation has no thorough project database of RE, no off-grid hybrid or grid connected solar projects, all existing projects are either stand-alone mini-grid or off-grid stand-alone lighting application of few kWp (Olayinka et al, 2014),

3.2 Wind energy potential.

The enthusiasm to address the country's energy and the zeal to maximize the numerous renewable energy benefits encouraged research into Nigeria's wind energy potential among which are Ajayi et al, 2011, Eboibi et al, 2017, Ajibola and Balogun 2019, Amadi 2018, Dioha et al 2016, Jasper and Bernard 2017, Joshua et al, 2015, Lawa and Isa 2013, Ogbeide et al, 2018, Yahaya et al, 2020. From their study it can be concluded that the average wind speed in Nigeria at 10m height lies between 1.9 m/s and 8 m/s depending on the location. From the wind map (Ikechukwu , 2016), it is clear that there are location such as Kastina, zamfara etc with very good wind potential having speed above 6m/s which is suitable for electricity generation. The wind potential in state like Kogi, Ekiti, Edo etc are only appropriate for water pumping.

The power generated p (t) by a wind turbine can be represented by

$$P(t) = \begin{cases} 0 & v(t) \leq V_{ci} \text{ or } v(t) \geq V_{co} \\ \frac{\rho A v(t)^3}{2} & V_{ci} < v(t) < V_r \\ p_r & V_r < v(t) < V_{co} \end{cases} \dots\dots\dots(2) \text{ (Agbetuyi et al, 2012; Eboibi et al, 2016).}$$

Where: C is coefficient of power ρ is air density (1.1 kg/m³) A is Area of wind turbine rotor. v(t) is wind speed at any time, V_{ci} is cut in wind speed, V_r is rated wind speed, V_{co} is cut out wind speed

Estimating from the above wind speed, the wind energy intensity perpendicular to the wind direction ranges between 4.4W/m² along the coastal areas to as high as 35.2W/m² to the extreme north (akinbulire et al, 2014). Currently, apart from the few stand-alone wind power plants which were installed in the 1960s in five northern states purposely for water pumping, there was no commercial wind power plants linked to the national grid. Additionally, a 5 kW wind turbine plant for electrification of a village was installed at Sayyan Gidan Gada, in Sokoto State (Uzoma et al, 2011; Sunday et al, 2019; Bamisile et al, 2017).

3.3 Hydro Energy Potential

Despite the Huge RE potential, at the moment hydropower is the only RE source used for saleable electricity generation in Nigeria (Olusola et al, 2020). The massive hydro potential source is demonstrated by her large rivers, small rivers and stream and the different river basin that were established. The country has substantial hydro potential sources spread in 13 States and in the river basin (Adebayo and peter 2014) with potential above 11,000MW (Akorede et al, 2017). The rivers were nearly evenly distributed all over the country with potential locations for hydropower scheme that can feed the rural, urban and isolated communities (Sunday et al, 2019).

The generation of electrical energy from Hydro power simply energy conversion. The turbine changes water energy into rotational energy at its shaft which the generator converted that rotational energy into electrical energy. The energy generated per year (KWH) can be calculated as:

$$E = \rho * Q * H_n * g * \eta * n \dots\dots\dots(3) \text{ (Bilal, 2013; Khizir et al, 2012)}$$

Where: Q is flow rate (m³/s), ρ is water density (1000 kg/m³), n is number of hours in year for which the specified flow occurs, H_n is net head (m), g is gravitational constant (9.8 m/s²), and η represent is efficiency which denote the extent of energy conversion. Hydropower is the on RE sources is currently been used for commercial purpose, it 15% of grid-connected electricity generation (NPBR, 2015). A study estimated the small hydropower potential of country to be 3,500 MW (Oseni, 2012)

3.4 Other renewables

Thirty geothermal potential spots were discovered in the country. It is also estimated that about 2.10 x 10⁹ GJ of biomass energy can be generated from waste and other sources yearly (Aliyu et al, 2015; Wole-Osho et al, 2014; Olusola et al, 2020). Though, there have not been commercial productions of electricity from Biomass and Geothermal.

4. Advantages and Challenges of RE

RE sources cause less environmental effect than other energy sources. The execution of RE technologies will assist to tackle the environmental concerns that developed due to greenhouse gas emissions such as oxides of nitrogen (NOx), carbon dioxide (CO₂), oxides of sulfur (SOx), and particulate matters that arise as a result to of power generation from natural gas, oil and coal. RE sources are clean energy system that has no consequence on the environment during or after generation. Variety of RE resources provides flexible sets of possibilities for their usage (Sunday 2012; Oisamoje and Oisamoje, 2013; Slootweg et al, 2001).

From literature surveyed, several factors have been attributed to the low pace of RE as it's relates to electricity generation, They includes: lack of consciousness and technical unskillfulness, high initial investment cost, inconsistency Regulatory framework and enticements, grid unpredictability and intermittency nature of RE sources. The latter can cause undesired effects in the structure, such as increased fault current, fluctuations in the voltage profile, readjustment of the control and protection systems, inversion in the flow direction, (Benvindo et al 2015, Kaabeche et al, 2011).

5. conclusion

Attentions have been focused on RE sources for electricity generation and other usage due to its enormous benefits and the challenges and hazards attributed to the use of fossil fuel. In this paper, global RE statistics were explored and its propensities for electric power generation highlighting Nigeria RE potentials. Data were obtained from several RE database and were analyzed, references were made to the leading countries to ascertain their growth and project the possible development in the near future. Nigeria RE potential was evaluated and estimates of electrical energy that can be generated from various RE were presented in conjunction to their current status for electricity generation. The study unveils that the country can resolve its electrical energy woes if it's RE sources are properly harnessed.

References

- Adebayo C. and Peter M. (2014): "How is 100% renewable energy possible for Nigeria?", Global Energy Network Institute (GENI), www.geni.org peter@geni.org (619) 595-0139
- Adejumo A.O. and Suleiman E.A. (2017): "Application of ARMA-GARCH Models on Solar Radiation for South Southern Region of Nigeria", Proceedings of International Conference on Science and Sustainable Development (ICSSD) Center for Research, Innovation and Discovery, Covenant University, Nigeria June 20-22, 2017, Journal of Informatics and Mathematical Sciences Vol. 9, No. 2, pp. 405–416, 2017
- Adhekpukoli E. (2018): "The democratization of electricity in Nigeria," *Electr. J.*, 2018. <https://doi.org/10.1016/j.tej.2018.02.007>
- Agbetuyi, A. F., Akinbulire, T. O., Abdulkareem, A. and Awosope, C. O. A. (2012): "Wind Energy Potential in Nigeria", *International Electrical Engineering Journal (IEEJ)* Vol. 3 (2012) No. 1, pp. 595-601.
- Ajayi, O. O., Fagbenle, R. O. and Katende, J. (2011): "Wind Profile characteristics and Econometrics Analysis of Wind Power Generation of a Site in Sokoto State, Nigeria", *Energy Science and Technology*, 1(2), 54-66.
- Ajibola O. O. E., and Balogun O. J., (2019): "Stochastic Analysis of Energy Potentials of Wind in Lagos Metropolis", Proceedings of the World Congress on Engineering and Computer Science 2019 WCECS 2019, October 22-24, 2019, San Francisco, USA
- Akinbulire, T.O, Oluseyi, P.O and Babatunde, O.M (2014): 'Techno-economic and environmental evaluation of demand side management techniques for rural electrification in Ibadan, Nigeria', *Int. J Energy Environ Eng.* 5(132): 1 – 11.
- Akorede M. F., Ibrahim O., Amuda S. A., Otuoze A. O., and Olufeagba B. J. (2017). "Current Status and Outlook of Renewable Energy Development in Nigeria", *Nigerian Journal of Technology (NIJOTECH)* Vol. 36, No. 1., pp. 196 – 212, www.nijotech.com, <http://dx.doi.org/10.4314/njt.v36i1.25>.
- Ali, S., Zheng, Z., Aillerie, M., Sawicki, J. P., Péra, M. C. and Hissel, D. (2021): "A Review of DC Microgrid Energy Management Systems Dedicated to Residential Applications". *Energies* **2021**, 14, 4308. <https://doi.org/10.3390/en14144308>
- Aliyu, A.K.; Modu, B. and Tan, C.W. (2018): "A review of renewable energy development in Africa: Afocus in South Africa, Egypt and Nigeria". *Renew. Sustain. Energy Rev.* **2018**, 81, 2502–2518.
- Aliyu A. S., Dada J. O., and Adam I. K., (2015): "Current status and future prospects of renewable energy in Nigeria," *Renew. Sustain. Energy Rev.*, vol. 48, pp.336–346, 2015.
- Amadi H. N. (2018). "Wind Energy Potential Assessment of Coastal States in South-South Nigeria Based on the Weibull Distribution Model", *EJECE, European Journal of Electrical and Computer Engineering* Vol. 2, No. 7., DOI: <http://dx.doi.org/10.24018/ejece.2018.2.7.48>
- Anaza S. O. , Haruna Y. S., Amoo A. L., Sadiq A. A. and Yisah Y. A. (2023): "Potential of Renewable Energy Sources for Distributed Generations: An Overview", *International Journal of Scientific Advances*, Volume 4, Issue 1 Jan-Feb 2023 www.ijscia.com
- Ani, V. A. (2014), "Feasibility and Optimal Design of a Stand-Alone Photovoltaic Energy System for the Orphanage", Research Article, Hindawi Publishing Corporation, *Journal of Renewable Energy*, Volume 2014, Article ID 379729, 8 pages <http://dx.doi.org/10.1155/2014/379729>
- Atwa Y. M, El-Saadany E. F., Salama M. M. A., and Seethapathy R.,(2010): "Optimal Renewable Resources Mix for Distribution System Energy Loss Minimization", *IEEE Transactions on Power Systems*, VOL. 25, NO. 1, February 2010
- Bamisile O., Dagbasi M., Babatunde A. and Ayodele O. (2017): "A review of renewable energy potential in Nigeria; solar power development over the years", *Engineering and Applied Science Research*, 44 (4): 242-248 <https://www.tci-thaijo.org/index.php/easr/index>, doi:10.14456/easr.2017.37
- Bekele, G and Palm, B (2010): 'Feasibility study for a standalone solar–wind-based hybrid energy system for application in Ethiopia', *Applied Energy* 87: 487–495

- Benvindo R. Pereira Jr., Geraldo R. Martins da Costa, Javier Contreras, and José R. Sanches Mantovani, (2015): "Optimal Distributed Generation and Reactive Power Allocation in Electrical Distribution Systems", accepted for inclusion in a future issue of IEEE Transactions on Sustainable Energy 2015
- Bilal A. N. (2013): "Design of Micro - Hydro - Electric Power Station" International Journal of Engineering and Advanced Technology (IJEAT) Volume-2, Issue-5, pp 39-47
- Diemuodeke, O.E., Mulugetta, Y., Njoku, H.I., Briggs, T.A. and Ojapah, M.M. (2021): "Solar PV Electrification in Nigeria: Current Status and Affordability Analysis",. Journal of Power and Energy Engineering, 9, 1-25. <https://doi.org/10.4236/jpee.2021.95001> [24]
- Dioha M.O., Dioha I. J. And Olugboji O. A. (2016): "An Assessment of Nigeria Wind Energy Potential Based on Technical and Financial Analyses", Journal of Sustainable Energy VOL. 7, NO. 2, June, 2016
- Ebigenibo G. S. and Oluwasanmi A. A. (2020): "The Economic Implications of Wind Energy and Solar Photovoltaic System Utilization for Electricity Generation in Nigeria". Saudi J Eng Technol, Dec, 2020; 5(12): 524-535
- Eboibi B., Eboibi O., Okubio E. and Iyasele, C (2017): "Evaluation of wind energy potential in the south-south geopolitical zone of Nigeria", J. Appl. Sci. Environ. Manage. Dec, 2017, Vol. 21 (7) 1301-1306
- Ezennaya O. S., Isaac O. E., Okolie U. O. and Ezeanyim O. I. C. (2014): "Analysis Of Nigeria's National Electricity Demand Forecast (2013-2030)," Int. J. Sci. Technol. Res., vol. 3, no. 3, pp. 333-340, 2014.
- Gungah, A.; Emodi, N.V.; Dioha, M.O. (2019) "Improving Nigeria's renewable energy policy design: A case study approach". Energy Policy **2019**, 130, 89-100.
- IEA 2020 "Key world energy statistics 2020 report". International Energy Agency. Retrieved 8th April 2023
- Ilenikhena P.A. and Ezemonye L.I.N. (2010): "Solar Energy Applications In Nigeria", WEC Montreal 2010: Paper NO. 135 Revised [6 solar e]
- IRENA 2023 "Renewable Capacity Statistics 2022" <http://www.irena.org/Statistics/Download-Data> retrieved 8th April 2023
- Jasper A. and Bernard A. (2017): "Evaluation of Wind Energy Potentials in the Nigerian Onshore and Offshore Locations", FUPRE Journal of Scientific and Industrial Research, Vol.1, (2), 2017
- Joshua O. O., Olayinka S. O. and Elizabeth T. O. (2015): "Assessments of Wind-Energy Potential in Selected Sites from Three Geopolitical Zones in Nigeria: Implications for Renewable/Sustainable Rural Electrification", Hindawi Publishing Corporation, Scientific World Journal, Volume 2015, Article ID 581679, 13 pages, <http://dx.doi.org/10.1155/2015/581679>
- Kaabeche A., Belhamel M. and Ibtouen R (2011): "Sizing optimization of grid-independent hybrid photovoltaic/wind power generation system". Energy 36 (2011) 1214-1222, www.elsevier.com/locate/energy
- Khizir M., Abu T. T. and Ashraf I. (2012) "Feasible Micro Hydro Potentiality Exploration in Hill Tracts of Bangladesh" Global Journal of Researches in Engineering Electrical and Electronics Engineering Volume 12 Issue 9 Version 1.0 pp 15-20
- Komolafe, O.A., Omoigui, M.O. & Momoh, A. (2003): "Reliability investigation of the Nigerian Electric Power Authority transmission network in a deregulated environment". Conference Proceeding: 38th Industry Applications Conference, Retrieved from http://www.researchgate.net/institution/Obafemi_Awolowo_University/department/Department_of_Electronic 25th February, 2023
- Lawa S. and Isa G. (2013), "Electricity Generation Using Wind in Katsina State, Nigeria", International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 2, February – 2013
- Lloyd, P. & Visagie, E. (2007). "The testing of gel fuels, and their comparison to alternative cooking fuels". In Domestic use of energy conference published 2007.
- Eudovit C., Vladimír K., Stanislav K., Matúš K. and Martin M. (2010): "A paper at Intensive Programme "Renewable Energy Sources"" University of West Bohemia, faculty of electrical engineering, department of electrical power and environmental engineering. <https://api.core.ac.uk/oai/oai:dspace5.zcu.cz:11025/22539>. retrieved April 16, 2023
- Maurizio D., Davide F., Marco M., and Gabriele M. (2014): "Distributed Generation Integration in the Electric Grid: Energy Storage System for Frequency Control". Hindawi Publishing Corporation, Journal of Applied Mathematics, Volume 2014, Article ID 198427, <http://dx.doi.org/10.1155/2014/198427>
- Nadeeshani J., Mohammad A. S. M., and Peter J. W., (2015): "Optimal Operation of Distributed Energy Storage Systems to Improve Distribution Network Load and Generation Hosting Capability", accepted for inclusion in a future issue IEEE Transactions on Sustainable Energy 1 DOI10.1109/TSTE.2015.2487360
- Nigeria population 2021, <https://tradingeconomics.com/nigeria/population> retrieved 16th April, 2023
- NPBR 2015, "Nigeria Power Baseline Report",. Available from: http://www.nesistats.org/uploads/3/6/3/6/3636925/20150916_nigeria_energy_power_report_final.pdf (accessed February 02, 2023).

- Ogbeide O. O., Akpala B., Igbinomwanhia N. O. and Azi S. O. (2018): "Statistical Quality Control Analysis of Wind Energy Potential for Power Generation in Benin", *Journal of Energy Research and Reviews* 1(2): 1-14, 2018; Article no.JENRR.42701
- Oisamoje M. D. and Oisamoje E. E. (2013): "Exploring the Economic and Environmental Benefits of Solar Energy Generation in Developing Countries: The Nigerian Perspective". *Journal of Energy Technologies and Policy*, Vol.3, No.6, ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online), www.iiste.org
- Okonkwo G..N.and Nwokoye, A.O.C. (2014). "Analysis of Solar Energy Parameters in Bida, Nigeria". *European Scientific Journal* May 2014 edition vol.10, No.15, 116-131 ISSN:1857 – 7881 (Print) e - ISSN 1857- 7431
- Olayinka S.O., Muyiwa S.A, Olanrewaju. M. O, Richard O. F (2014): "Solar energy applications and development in Nigeria: Drivers and barriers". *Renewable and Sustainable Energy Reviews* 32 (2014) 294–301
- Olusola B., Qi H., Patrick A., Paul O.K. A., Serkan A. and Weihao H., (2020). "Analysis of Solar PV and Wind Power Penetration into Nigeria Electricity System", *Conference Paper* August 2020, DOI: 10.1109/ICPS48389.2020.9176822
- Oseni, M. O. (2012): "Households Access to Electricity and Energy Consumption Pattern in Nigeria," *Renewable and Sustainable Energy Reviews*, vol. 16, pp. 990-995, 2012.
- Oyedepo S. O. (2012): "Energy and sustainable development in Nigeria: the way forward". *Energy, Sustainability and Society* 2012, 2:15 <http://www.energysustainsoc.com/content/2/1/15>
- Oyedepo, S. O., Babalola, O. P., Nwanya, S. C., Kilanko, O., Leramo, R. O., Aworinde, A. K., Adekeye, T., Oyebanji. J. A., Abidakun, A. O. and Agberegha, O. L. (2018): "Towards a Sustainable Electricity Supply in Nigeria: The Role of Decentralized Renewable Energy System". *European Journal of Sustainable Development Research*, 2(2), xx. <https://doi.org/10.20897/ejosdr/xxxxx>
- Rana. H. A. Z., Geev M., Haile-Selassie R., Jamshid A., Taher N. and Prashant P.(2017) "Operation and Planning of Distribution Networks with Integration of Renewable Distributed Generators Considering Uncertainties: A Review", *Renewable and Sustainable Energy Review*, Volume 72, May 2017, Pages 1177-1198
- Ravi S. M. and Tanweer D. (2016): "Spatial Technology for Mapping Suitable Sites for Run-of-River Hydro Power Plants" *International Journal of Emerging Trends in Engineering and Development* Issue 6, Vol. 4 http://www.rspublication.com/ijeted/ijeted_index.htm
- REN21 (2021): "Renewables 2022 Global Status Report" [Online]. <http://www.ren21.net/status-of-renewables/global-status-report/>. (accessed on 16th April, 2023).
- REN21 (2022): "Renewables 2022 Global Status Report" [Online]. <http://www.ren21.net/status-of-renewables/global-status-report/>. (accessed on 25th February, 2023).
- Saheed M and Hamed A. S. (2020): "zero Emission" *Encyclopedia of Sustainable Management*, Springer Nature Switzerland AG 2020. https://doi.org/10.1007/978-3-030-02006-4_512-1
- Shaver L. (2017): "Implementation of a DC Microgrid". Master's Degree, University of Wisconsin-Madison, USA, 2017.
- Slootweg J.G., de Haan S.W.H, Polinder H., and Kling W.L (2001): "Modeling Wind turbines in power system dynamics simulation" *Power Engineering Society Summer meeting conference Vol.1 Proceedings* (2001) Pp.22-26.
- Stephen E. E., Oluwaseun K., Eeda A. N. and Amuda-Y. G. (2022): "Renewable Energy and Green Technology Adoption: A Viable Option for Efficient Energy Supply in Nigeria". *Environ Anal Eco stud.* 000728. 10(1). 2022. DOI: 10.31031/EAES.2022.10.000728
- Sunday, O. O., Theophilus, U., Philip, O. B., Stephen C. N, Oluwaseun K., Richard, O. L., Abraham, K. A., Tunde, A., Joseph, A. O. and Olatunde, A. A. (2019): "Assessment of Decentralized Electricity Production from Hybrid Renewable Energy Sources for Sustainable Energy Development in Nigeria", *S.O. De Gruyter, Open Eng.* 2019; 9:72–89.
- The U.S. Energy Information Administration 2020 "Geothermal electricity capacity - Country rankings" the global economy https://www.theglobaleconomy.com/rankings/geothermal_electricity_capacity/ retrived 10th April, 2023
- UNEP, "Renewable Energy: Renewables on the rise.," United Nations, 2018. [Online]. Available: <https://www.unenvironment.org/explore-topics/energy/what-we-do/renewable-energy>. [Accessed: 23-02-2023].
- US department of Energy (2010): "energy efficiency and renewable energy" www.eere.energy.gov/informationcenter retrieved April 16, 2023
- Uzoma, C.C., C.E. Nnaji, C.N. Ibeto, C.G. Okpara, O.O. Nwoke, I.O. Obi and O.U. Oparaku, (2011): "Renewable energy penetration in Nigeria: A study of the South-East zone". *Continental Journal of Environmental Sciences*, 5(1): 1–5.
- Wole-Osho I., Bamisile O., Adun H., and Yusuf I (2014): "Comparison of renewable energy potential in relation to renewable energy policy in ECOWAS countries," in 13th HONET-ICT International Symposium on Smart MicroGrids for Sustainable Energy Sources.

- Yahaya, A. A., Bello, I. M., Mudassir, N., Mohammed, I. and Mukhtar, M. I. (2020): "Evaluation of Wind Potential for the Generation of Electricity in Aliero, Kebbi State", *Asian Journal of Research and Reviews in Physics* 3(1): 1-7, 2020; Article no. AJR2P.53791.
- Zubo RHA, Mokryani G, Rajamani HS, Aghaei J, Niknam T, Pillai P. (2017): "Operation and planning of distribution networks with integration of renewable distributed generators considering uncertainties: a review. *Renew*" *Sustain Energy Rev* 2017; 72: 1177–98. <http://dx.doi.org/10.1016/j.rser.2016.10.036>.