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BOOSTING THE HARVESTING OF NIGERIA'S ABUNDANT RENEWABLE ENERGY POTENTIALS AND LEGAL IMPLICATIONS

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Abstract

Renewable energy has been highlighted not only as a means of satisfying the energy needs of Nigerians but also as a tool for the country's growth, thereby improving the income of the citizens who have more energy to work with, serving as the energy source for domestic and office use, in addition to reducing the carbon footprint from the conventional fossil fuels. From data obtained *from the Photovoltaic Geographic Information System (PVGIS), the solar electricity potential at some selected cities in Southern Nigeria that ranges from 4.5 to 6.5 kWh/m^2 has been presented as a tool, which when properly harnessed, can be used to mitigate avoidable energy-related "national disasters" such as unemployment and youth-restiveness, thereby accelerating Nigeria's development. There is the urgent need to revise and effectively implement helpful laws and policies that support the addition of renewable energy sources for electricity generation. Lack of a coherent legal framework with incentives for the utilization of renewable energy is among the key factors causing poor utilization of renewable energy in Nigeria. Governmental and stakeholder collaboration is highly necessary for developing countries to robustly track renewable electricity adoption via laws aimed at boosting its adoption.*

Keywords

Renewable Energy, Solar Electricity potential, Laws, PVGIS, Nigeria

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1. Introduction

Renewable/alternative or "green" energy (solar, hydroelectric, geothermal, wind, tidal, among many other up-and-coming sources, in addition to nuclear energy) are energies produced without releasing carbon dioxide and other non-environmental friendly "pollutants" into the earth's atmosphere (Dike, Opara-Nestor, Amaechi, Dike & Chineke, 2017; Okoro & Chineke, 2021; Yusuf et al., 2022). Many countries are investing a lot more resources into the development of such alternative energy sources for reasons like financial savings and environmental protection. On the other hand, there are others, especially in developing economies that appear to be disregarding such potential entirely, of which is Nigeria, a country in Sub-Saharan Africa that has a population of about 162 million people (Ejiogu, 2013).

With solar energy as a major player in the Renewable Energy Master Plan (REMP) owing to the free and great abundance of solar radiation throughout the year in Nigeria, it is imperative that a model developed to suit both the technological and geographic location peculiarities of Nigeria is available and deployed to enable users of Photovoltaic Solar Home Systems effectively and efficiently determine the capacity demand of system needed by home users and Small and Medium Scale Enterprises (SMEs) relative to their energy (electricity) demands and financial status. Harnessing electricity from Photovoltaic Home Systems is a right option, but effectively determining the energy demands and best option to deploy per location, remains the challenge being faced and hence have left most new entrants mulling their loss on investments (Okoro & Chineke, 2021). Thus to have a good return on investment (ROI) in the long-term, reducing importation costs, a Solar Energy Capacity Demand Tool (SECDeT) would be needful from the onset of full acceptance by Nigeria and for Nigeria, important in integrating renewable energy into community energy systems (Psomopoulos, 2013; Lyden, Pepper & Tuohy, 2018).

We present in this paper the free and "seemingly idle" huge potentials of solar electricity at some selected cities in Nigeria with a strong case made for targeted renewable energy technology adoption while orchestrating the need for consideration of legal aspects in using this "green energy", not just in Nigeria but across other parts of the world's developing economies. In Nigeria, there is no practical legal support for renewable electricity disconnected from the regulation of the conventional energy sources. We are making a case for targeted introduction of legal aspects of renewable energy use in Nigeria *in the* legal and policy issues relating to the land use, development/implementation, siting and finance issues encountered by developers of renewable energy projects, commercialization of renewable energy sources and consumer rights.

2. Literature Review

The energy poverty in Nigeria has adversely affected the country's desire to attain sustainable development goals and improve the socio-economic status of its citizens. Notwithstanding the numerous renewable energy policy efforts in Nigeria, there is yet to be the desired renewable energy coverage and utilization across the country. The technical audit of the PV projects operation in Nigeria using the internally consistent latent variable scales reveals a dissenting perception of its appropriateness to their energy needs. The barriers/drivers of solar energy adoption in Nigeria include but are not limited to lack of public awareness, government policy, theft, and solar technology vandalism (Ohunakin, Adaramola, Oyewola & Fagbenle, 2014).

In an earlier study, Akinboro, Adejumobi & Makinde (2012) reviewed standalone PV installations for the country's residents and industries and highlighted the problems with possible solutions, indicating the issues confronting solar installation in Nigeria and recommended using solar PV in a hybrid to avoid blackouts. Similarly, in a research paper, Sambo & Bala (2012) discussed solar energy penetration in Nigeria and presented solar energy penetration status and challenges (Usman, Abbasoglu, Ersoy & Fahrioglu 2015). On the other hand, Ghosal, Sethi & Behera (2020) studied the performance of solar PV modules with the effects of operating parameters such as change of tilt angle and incorporated air and water cooling methods. Sukumar & Balakrishnan (2016) opined that energy can be harvested in various ways with each way having their technique and output. Simbolon (2015) explored the possibility of turning human sewage into renewable energy.

Due to a lack of electricity for domestic and business use in Nigeria, generators that run on the environmentally-polluting petrol and diesel are used mainly for electrical energy needs. Weißbach et al. (2013) had estimated that approximately 30% of energy is produced in this manner, a similar scenario in other parts of Africa (Chineke, 2018; Okoro & Chineke, 2021). In Nigeria, alternative/renewable energy (RE) sources like solar, hydroelectric, wind, biomass and geothermal, have a viable, positive and significant potentials/roles to play in addressing the availability of energy supply in the country that has abundant RE sources in all parts of the country but not utilized due to over-dependence on crude oil, that the government relies heavily on as the major energy and revenue source (Adamu, 2012; Aliyu, Dada & Adam 2015; Soares, Brito & Careto, 2019). The quality of human life depends on the availability of energy which no doubt is the driving force of every economy, the "oxygen" that sustains the economy of every nation (Ozuomba, Okoli & Ekpunobi, 2013). Many forms of community activities and national industrial sector are highly dependent on the availability of electrical energy (Afandi & Chandrarini, 2015).

Nigeria, before and after independence relied heavily on non-renewable energy such as coal, wood, and other fossil fuels from petroleum to drive her economy with attendant negative impacts on human health and the environment due to air pollution. Oil and gas continue to produce more than 70% of Nigeria's federal revenue, according to Sambo (2009). With an exponential increase in population,demand for energy has skyrocketed and the consequence is that the available energy is no longer enough for the populace (Chineke & Ezike, 2010; Dike et al., 2017). Considering the environmental problem emanating from non-renewable energy and the fear of being completely depleted overtime, the clarion call is for the government to develop a comprehensive Renewable Energy Master Plan (REMP) for Nigeria in order to guard against economic crises in the near future. Renewable energy is the best option for Nigeria if she must overcome the problem of energy generation. Aside from the high cost of importation, almost everything must be imported, which causes delays in maintenance and, as a result, significant downtime for machinery and equipment (Okoro & Chineke, 2021; Yusuf et al., 2022).

3. PVGIS Database as an Alternative for Measured Data

The Photovoltaic Geographic Information System (PVGIS) is a free online tool that is used to estimate the amount of solar electricity that can be produced by any photovoltaic (PV) system, at any location worldwide. Surrogate solar electricity potential and other desired parameters needed for photovoltaic applications can be downloaded if the user inputs the latitude and longitude of the location. It can be accessed via *https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#PVP*. Other details are found in (Huld, Müller & Gambardella, 2012; Szabó, Bodis, Huld & Moner-Girona, 2013). To showcase the abundant amount of solar electricity potentials in Nigeria, solar irradiation data in some selected regions were obtained from the Solar PVGIS database site above. Unfortunately, real-time measured solar electricity data paucity is still one of our “uniforms” in Nigeria even though we are in the 21st century and have a “continuum of energy” at the disposal of our political class that can be used to develop the nation. The latitude and longitude of each chosen city (Table 1) was found from the site *https://latitudelongitude.org/ng*.

Table 1: *The study sites in Nigeria with latitude (Lat) in degrees North (N) and longitude (Long) in degrees East.*

Site	State	Lat (N)	Long (E)
Aba	Abia	5.11	7.37
Owerri	Imo	5.48	7.03
Warri	Delta	5.52	5.75
Umuahia	Abia	5.53	7.49
Oguta	Imo	5.71	6.81
Uturu	Abia	5.83	7.42
Ihiala	Anambra	5.85	6.86
Sapele	Delta	5.89	5.67
Nnewi	Anambra	6.02	6.91
Onitsha	Anambra	6.15	6.79
Awka	Anambra	6.21	7.07
Umunede	Delta	6.26	6.31
Abakaliki	Ebonyi	6.32	8.11
Benin city	Edo	6.34	5.63
Enugu	Enugu	6.44	7.50
Nsukka	Enugu	6.86	7.40

(***Source***: *Self Compiled*)

Over the Nigerian environment, the wet season, associated with the West African monsoon is April to September while the dry season is between October to March although the signatures of climate change are affecting this supposed established scenario (Haider, 2019; Okoro and Chineke, 2021). In Figure 1 are depicted solar electricity potentials over Oguta, Owerri, Umuahia and Aba showing a high potential that is available for harvest to reduce energy poverty. The maximum amount of solar electricity potential at Oguta was 6.32 kWh in the dry season month of March with a minimum of 4.23 kWh in the wet season of August. The situation was similar at Owerri with a maximum of 6.01 kWh in March and 4.06 kWh in August. At Umuahia, the maximum solar insolation of 6.02 kWh was recorded in the month of January and with a minimum of 4.11 kWh in August. At Aba, the maximum solar electricity potential was 5.88 kWh in January and 3.79 kWh in July.

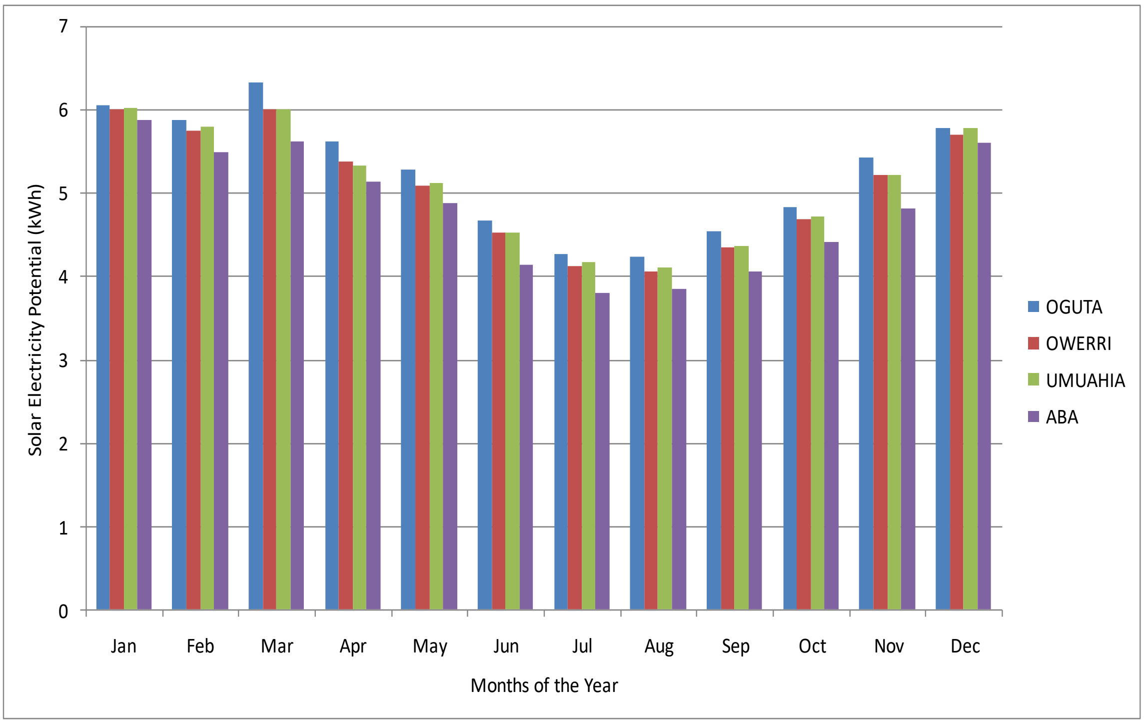

Figure 1: *Solar electricity potential (kWh) at Oguta, Owerri, Umuahia, Aba Nigerian cities*
*(**Source**:Chineke, 2018)*

In Figure 2, we see a similar scenario with high potentials of solar electricity that can be used to meet the energy poverty endemic in the region and most parts of Nigeria. But alas, people are suffering in midst of plentiful energy resources. The maximum solar electric potential for Onitsha was 6.48 kWh in March and with a minimum of 4.27 kWh in August. At Awka, the maximum solar energy potential of 6.26 kWh was in March and a minimum of 4.27 kWh in August. A similar scenario played out at Nnewi where the maximum solar electric potential was 6.27 kWh in March and a minimum of 4.24 kWh in August. The maximum solar electric potential of 6.23 kWh was recorded in March at Ihiala with a minimum of 4.13 kWh in the peak rainy (wet) season of August. The values depicted in Figures 1 and 2 are consistent with the values expected to supply solar electricity at these locations even if only 20 percent is harnessed (Chineke, 2018).

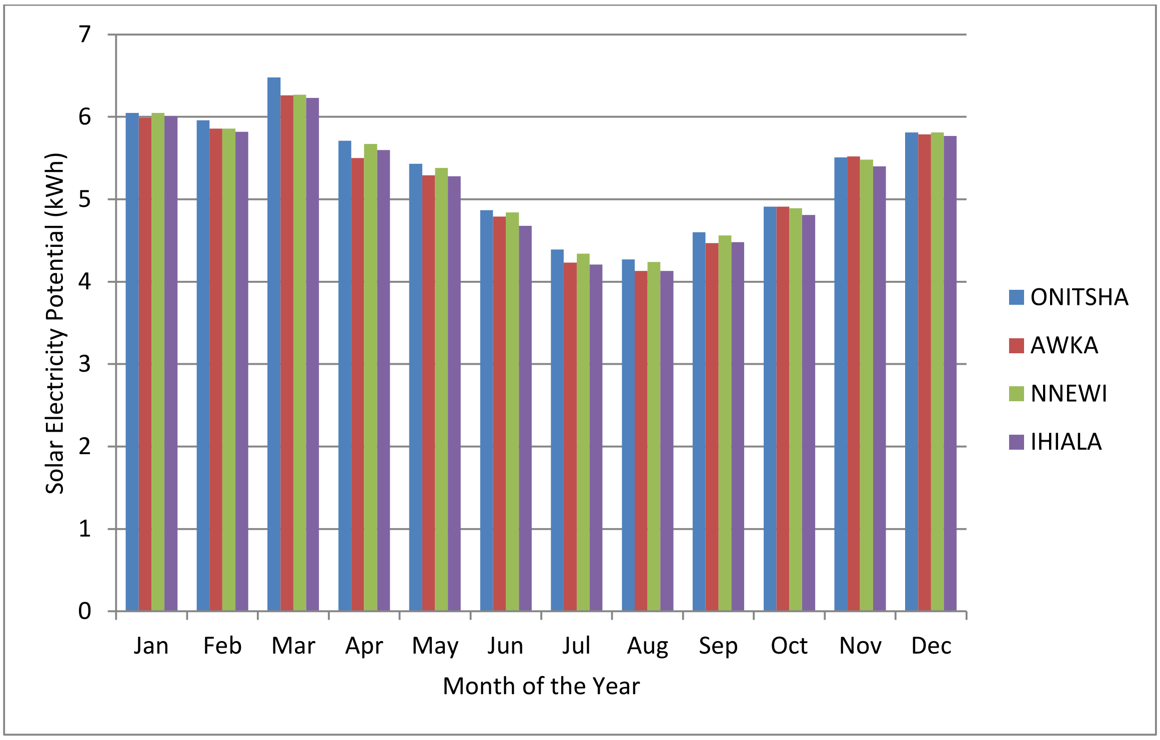

Figure 2: *Solar electricity potential (kWh) at Onitsha, Awka, Nnewi and Ihiala Nigerian cities (**Source**:Chineke, 2018)*

From the results (Figure 3), Benin, Sapele, and Warri showed the same average monthly electricity production with lower potentials during the rainy season months of July and August due to the rainy season associated with clouds that reduced the incoming solar potential. The Umunede site had a maximum amount of 5.94 kWh in March and a minimum of 4.05 kWh in August. At Benin, the month of March again had the maximum amount of solar electric potential, 6.05 kWh compared to August with 4.05 kWh. The Sapele site had a maximum amount of 6.02 kWh in March and a minimum of 3.95 kWh in July. Although Warri had its peak solar electric potential in January (5.73 kWh) and a minimum value of 3.6 kWh in July, the patterns are what is expected at such sub-tropical equatorial sites (Chineke, 2018).

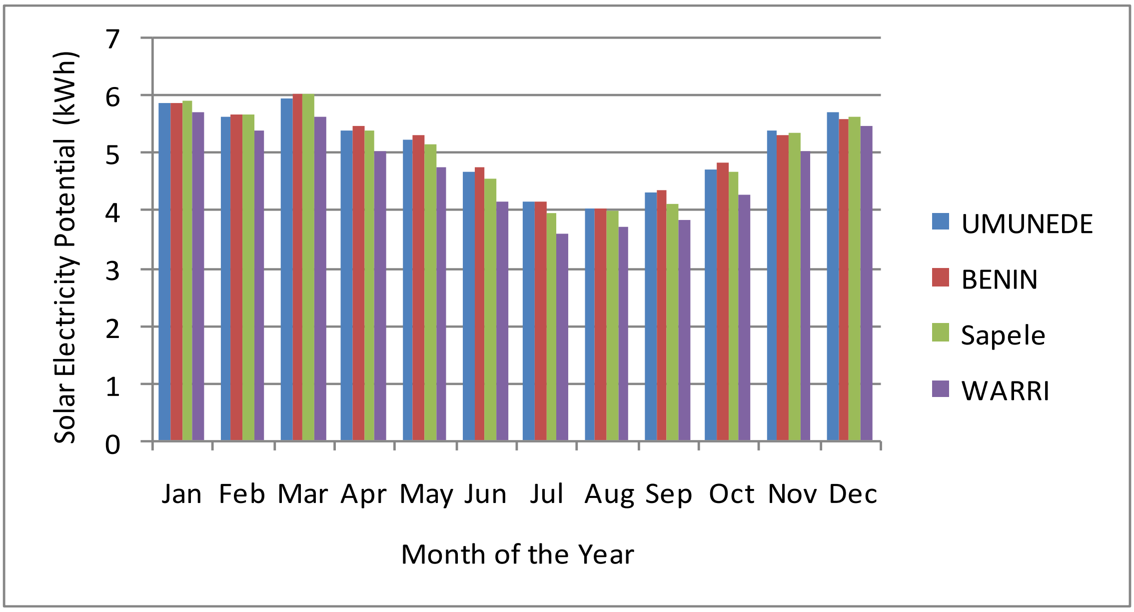

Figure 3: *Solar electricity potential (kWh) at Umunede, Benin, Sapele, Warri Nigerian cities (**Source**:Chineke, 2018)*

In Figure 4, Enugu and Nsukka are shown capricious sums of total (global) solar radiation per square meter that can be received by the components of any mounted and specified PV systems used and these can be crystalline silicon, copper indium selenide, cadmium telluride integrated or cadmium telluride mounted at optimal solar inclination (Huld et al., 2012; Szabo et al., 2013).

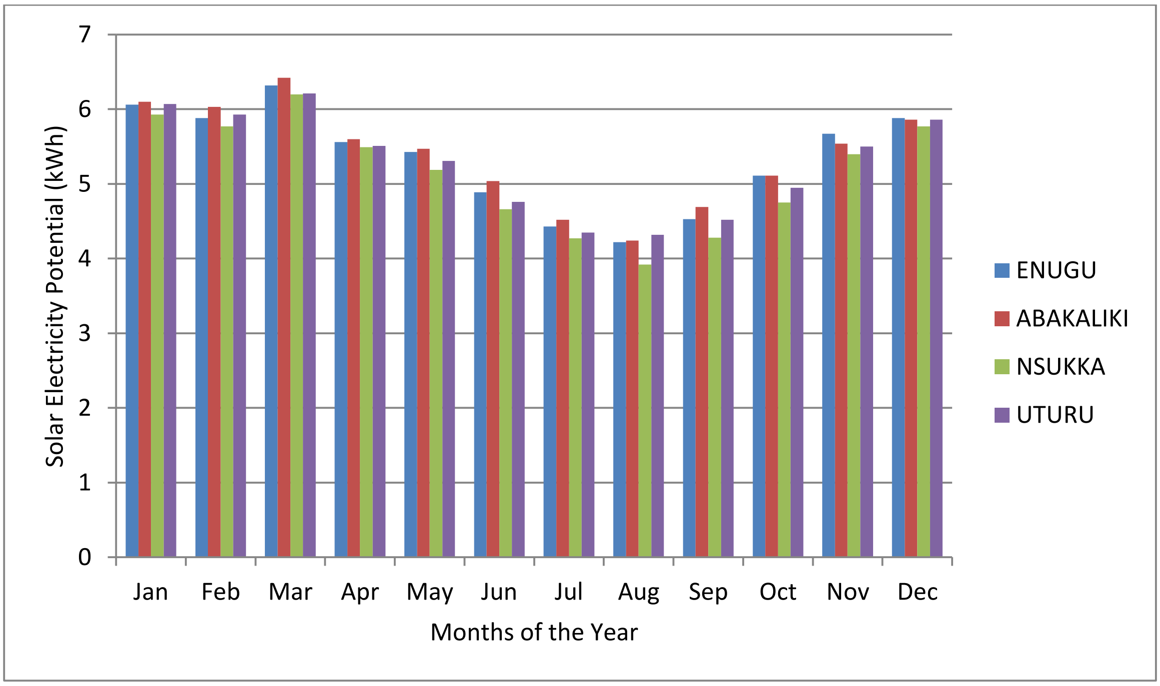

Figure 4: *Solar electricity potential (kWh) at Enugu, Abakaliki, Nsukka, Uturu Nigerian cities (**Source**: Chineke, 2018)*

At Enugu, the maximum solar electric potential data obtained from the PVGIS database was 6.32 kWh in March with a minimum of 4.22 kWh in August. The study site at Abakaliki had a maximum value of 6.42 kWh in March and a minimum of 4.24 kWh in August, similar to that at Nsukka with a maximum of 5.93 kWh in January and minimum of 3.92 solar electric potential in August, 6.21 kWh maximum at Uturu in March and minimum potential of 4.32 kWh in August (Figure 4). In order to trumpet the need to involve professionals while embarking on the installation of solar photovoltaic applications, earlier authors (Dike et al., 2017; Okoro and Chineke, 2021) had stressed that the material used for the solar cell is important in addition to the orientation used for the application. One point to be added is that even when the solar photovoltaic technology is mounted, many of them are underutilized as a result of the systems malfunctioning or performance deterioration which can be due to poor maintenance, lack of technical know-how and inadequate training, or poor technical experience of the project personnel (Ismail, Ajide & Akingbesote, 2012; Dike et al., 2017).

4. Legal Aspects in Renewable Energy

Pieces of legislation in Nigeria such as the Nigerian Constitution (vests the National Assembly with powers to make laws regarding electricity production and transmission across the country), Electricity Power Sector Reform Act (EPRA) of 2005 enacted as a response to the epileptic performance of the former National Electric Power Authority (NEPA), the 1992 Environmental Impact Assessment (EIP) Act (that seeks to avert unhelpful impacts of environmental actions like power generation and extraction), make available the framework for the operation of renewable energy in Nigeria (Ladan, 2018).

In addition, the Nigerian Electricity Management Services Agency (NEMSA) Act of 2015 has the mandate to enforce/maintain standards in electric power distribution in addition to carrying out testing and technical inspection of solar photovoltaic technology materials under the benchmark stipulated by the NERC in collaboration with the Standards Organization of Nigeria (SON). Unfortunately, there seems to be negligible enforcement of the many laws relating to the environment in Nigeria whose aims are to promote the renewable and clean generation of power. In addition, ordinary citizens are discouraged from approaching the court regarding the enforcement of relevant environmental laws that may affect them or their neighborhood (Oke, 2020). The situation is not far-fetched in most developing economies of the world.

Although the renewable energies have long been seen as an expensive but viable alternative to fossil-based carbon and nuclear power electric power generation plants, green banking which is the use of private cash to fund low-carbon, climate-resilient infrastructure that began in the highly industrialized Organization for Economic Cooperation and Development (OECD) countries, gradually transitioning to renewable energy generation, is the way forward to avoid energy crisis soon and save our fragile environment (Bhattacharyya, 2012). It is noteworthy that although renewable energy projects in developed nations faced significant barriers such as excess power and established infrastructure built around the "polluting" huge thermal power plants, national grids managed by utility companies, a point worth establishing is, for a sustainable and cleaner environment, all hands must be on deck to adopt renewable energy with the proper legislations put in place to protect the consumers.

The National Renewable Energy and Efficiency Policy of (NREEP) 2015 and the Renewable Energy Action Plan are policies targeted at establishing a sustainable finance framework for energy efficiency and renewable energy in Nigeria. The policy stipulates a national generation profile for hydropower, biomass, solar power, and wind energy from 2020 to 2030. This contemplates the energy mix that will expand renewable energy development and sustenance. Government policies are not binding instruments and neither do they create serious obligations for implementation. Policies must be given legal backing to make them more effective and for accountability to be easier.

Comparatively, South Africa has similar regulations to Nigeria which were recently amended – Schedule 2 Act 5 of 2006 Electricity Regulation Act amended in 2021- to cater for smart grid, a more diversified energy mix, and increased battery storage. There is a National Energy Regulator of South Africa (NERSA) comparable to the Nigeria Electricity Regulation Commission of Nigeria. The South Africa Carbon Tax Act of 2019, (CTA) provided for carbon offsets for approved renewable energy projects as tax incentives. Nigeria has towed the same line with the provision in Section 20 (5) (f) Climate Change Act of 2021, which proposed incentives for private and public entities that achieve greenhouse gas emissions reduction. There are other laws and policies in South Africa and Nigeria regulating an aspect of Renewable Energy development which makes it imperative for regulatory energy legislation that incorporates all aspects of renewable energy directives that caters for the professionalism and quality control in renewable projects. (Nene & Nagy, 2021)

As it is, Project managers and Renewable energy professionals are not aware of the basic regulations required in the sector which makes compliance impossible. A comprehensive Renewable Energy law that sets the standards and qualifications of operators; the required permits; consents; operational utility-scale; financial incentives, tax offsets; health and safety regulations; storage capacity threshold; operation of micro-grids etc., is required as a matter of urgency.

4. Conclusions

A key institutional impediment regarding the adoption of renewable energy technology in households within Nigeria was noted as the lack of national standards and adequate quality control units in the country (Olatomiwa, Mekhilef, Huda & Ohunakin, 2015; Chineke, 2018). The lack of suitable training and staff is the cause of this absence. The majority of the solar products are imported into the market from other countries, especially China. There are no established rules or regulations that regulate these products, and they lack trademark certifications and manufacturer manuals (most of the products in the market have no brand name). Solar street lighting installations, for example, have harmed renewable energy's reputation in Nigeria more than any other flaw in the nascent industry. They've been popular with state governments since roughly 2003 as a quick cure for the shortage of lights in urban and rural regions caused by failing grid electricity. However, most of the systems built employed low-cost, poorly integrated components, underestimated battery requirements, and had inadequate installation and maintenance (Ogbeidi, 2012; Dike et al., 2017; Okoro & Chineke, 2021).

As a result, enormous numbers of substandard/low-quality solar components have flooded the market; most times mounted improperly by workers with insufficient competence and professionalism (Akinbanmi, 2001; Usman et al., 2015; Abdullahi, Suresh, Renukappa & Oloke, 2017). Because the high initial costs of investing in these items have not been justified, confidence in the renewable energy technology, especially regarding to solar photovoltaic applications, has been eroded, and this act has an impact on the Renewable Energy Master Plan (REMP) in the country (Oseni, 2012; Afandi & Chandrarini, 2015). However, there is reason to be optimistic. Nigeria's energy sector is yet to develop, and with the right regulations in place, it might reduce emissions while also addressing job issues (Oyedepo, 2012). It offers a lot of promise for renewable energy sources; all that is required is a well-thought-out implementation strategy (Lowitzsch, Hoicka & Van Tudler, 2020). Finally, Nigeria must consider its role in climate change, as a high-risk country that will be impacted by desertification, droughts, flooding, and water scarcity. This country must do everything possible to mitigate future change.

It is important that with government support, as we continue with developing the renewable energy sector, we deploy a model tool mapped into the Renewable Energy Master Plan (REMP) to aid Photovoltaic System Home Users, Small and Medium-Scale Enterprises (SMSE) to make a guided decision on the choice of Photovoltaic Systems to adopt in homes, business and public places to reduce the economic burden of wastefulness that has been experienced in time past by individuals and governments collectively as a result of lack of proper calculation/estimation of system demands needed per installation (Daning et al., 2022). This we believe will play its role in the Economic Growth and Recovery Plan (EGRP) of the government. Renewable energy has proven to be less harmful, cleaner, and cost-effective. With exception of bio-energy which entails burning and the production of greenhouse gases, the majority of them pose no danger to the environment or its living components (Careto, 2019; Yusuf et al., 2022).

Embracing these renewable energy sources and incorporating legal implications (Omorogbe, 2016) will ensure less/reduced dependence on fossil fuels in addition to reduced global warming caused by constant combustion of fossil fuels. According to Chineke (2018), there will be improved food production as there will be no soil contaminants inhibiting growth and yielding of crops. Furthermore, the unavailability of toxic effluents channeled into water bodies will mean that water bodies will be fit for human and animal consumption as well as the fish therein. Other benefits include that small and medium-scale industries will spend less amount of money that is normally invested in electricity with a reduction of the cost of goods and services thereby making them very affordable for the common man (Kamil, 2012). We also expect that with the proper legal protection for all and sundry, there will be a reduction in crime rate: increase in crime rate stems largely from joblessness, poverty, and frustration. With the rise of renewable energy generation sites, people will get employed, which will certainly reduce the perpetration of crime in the society (Moussa & Cosgrove-Davies, 2019; Okoro & Chineke, 2021; Yusuf et al., 2022).

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