Photovoltaics: Panacea to Africa sustainable development.

Abstract.

African countries are falling behind in attaining the sustainable development goals.They are in dire need of electricity, which had been declared the essential tool to achieve most goals, to meet their population's utilizable energy requirement. With renewables being globally adopted energy options to save the changing climate and preserve the environment and biodiversity, photovoltaic (PV) is advocated to remedy the energy deficiency for sustainable development. All over Africa indicates viability in PV energy owing to the incident global solar radiation (Gh). Nigeria being a case study shows awareness of PV energy, which has manifested in the attitude towards its penetration and the expected benefits. With the anticipated threat of climate change on PV performances, the projected incident Gh across Nigeria has shown two epochs which are yet viable for PV energy by the year 2100. Foreseeable challenges in the PV penetration and investments have been presented as wrongdoings and whistleblowing is advocated as the policy that will ensure the PV penetration for sustainable development.

Keywords:PV penetration, global solar radiation, sustainable development, projections, whistleblowing.

1. Introduction.

The UN Sustainable Development Goals (SDG) are imperative to ameliorating global challenges but the execution as expected by the respective countries will have varying levels of attention and exertion to the different goals and targets based on their capacity, capability, resources and responsibility. The SDG has energy at the core of attaining sufficiency in most of the set goals. The amount of usable energy readily available in any society has been strongly linked to the growth, development and socioeconomic well-being of the citizens. The SDG envisages extensive affordable, reliable, sustainable and modern energy by mid 21st century (SDG, 2016). It is intended that global access to electricity would be achieved without jeopardizing the Paris Agreement (SEforALL, 2017). African countries are most challenged in attaining these set goals as there are varieties of issues and challenges facing the continent.

To reposition the continent with a strategic framework to actualise the set goals, the African Union developed the Agenda 2063. This Agenda has been based on the seven aspirations with the attainable goals and priority areas, respectively (Vicker, 2017). Yet most of the priority areas can be highly achieved if there is adequate energy available to the population. There have been concerted efforts by various regional government organisations in Africa towards their sustainable development with all of them indicating the significance of availability energy. One such organization, the ECOWAS in the aspirations to attain the SDG and Agenda 2063 through the ECOWAS Vision 2050, adopted five developmental themes. The themes have been anchored on the baseline scenario driven by five pillars that yet revolve around available utilizable energy for sustainable development (ECOWAS, 2022).

Renewable energy has shown to be a feasible alternative in actualising the energy requirements in Africa without compromising on the environment. It has shown to be superior to other energy options considering the carbon footprints from fossil fuels and the susceptibility of hydro-powered electricity owing to climate change. The earth's surface gets 1.4 × 105 TW of solar power, although 3.6 × 104 TW is utilizable, which is transformed into electricity by concentrating solar thermal or photovoltaic (PV) technologies (Hosenuzzaman et al., 2015). Recently, renewable energy utilization for diverse purposes within Africa has improved considerably amid the rapid population growth, energy demand and enhanced industrial activities. More energy is consumed nowadays resulting in socio-economic challenges, environmental pollution, and climate change (Chineke&Okoro, 2010). Although the cost of renewable energy electricity especially from solar PV installations has steeply declined and will continue to decline (Walwyn& Brent, 2015), It is expected that the optimal utilization of PV should contribute significantly to the national GDP of African States (Nwokocha et al., 2018).

This study presents PV energy to be the panacea for attaining Africa's energy demands, for sustainable development. The objectives are to present (i) the acceptability and feasibility of PV energy in the African energy mix, (ii) the tendency and projection to the viability of PV energy by the end of the 21st century, and (iii) actions to guarantee optimal PV usage and enterprise. Section 2 of this paper presents Africa's PV outlook, Section 3 describes the PV awareness, attitude and benefits: Nigeria case study, Section 4 shows the PV projections while Section 5 presents mitigating actions in PV enterprise. Section 6 is the conclusion.

2. Africa PV outlook.

Africa has 20% of the global population but contributes below 3% of CO_2 emissions related to global energy, the least in the world (IEA, 2023). The continent's (excluding South Africa) net energy generating capacity is 28 GigaWatts (WEF, 2016). Electricity from renewables is anticipated to drive Africa's energy needs. This is as 43% of the population, mostly in the sub-Saharan do not presently have access to electric energy. Of this deprived population, 80% are in rural areas and the most experiencing the negative effects of climate change that has exacerbated mass migration and the region's instability (IEA, 2023). Even those with access to electricity, they yet have about 15% of darkness a year (WEF, 2016).

However, there are enormous energy resources within the continent although the potential remains untapped. Unfortunately, there is only 1% of installed solar PV capacity in Africa that accommodates 60% of the world's top solar resources. Dike et al. (2012) showed the regional differences in the obtainable global solar radiation (Gh) over Africa and the PV potential noting the amount of energy that is lost or unutilized if the PV modules are not installed at optima inclination angles. Figure 1 shows the PV power potential (kWh/kWp) for sub-Saharan Africa indicating the daily and yearly totals, respectively. The minimum and maximum levels of Gh incidents at the various regions are superior potential for solar energy investments. The diminishing cost of PV combined with the enhanced conversion efficiency indicates it will be the least cost option for future electricity supply, projected to account for 35% by 2040 (Green, 2016). An advantage for Africa is that the PV module duration may be elongated over the purported 25 years, therefore, improving the Levelized Cost of Energy (Breyer&Gerlach, 2012).

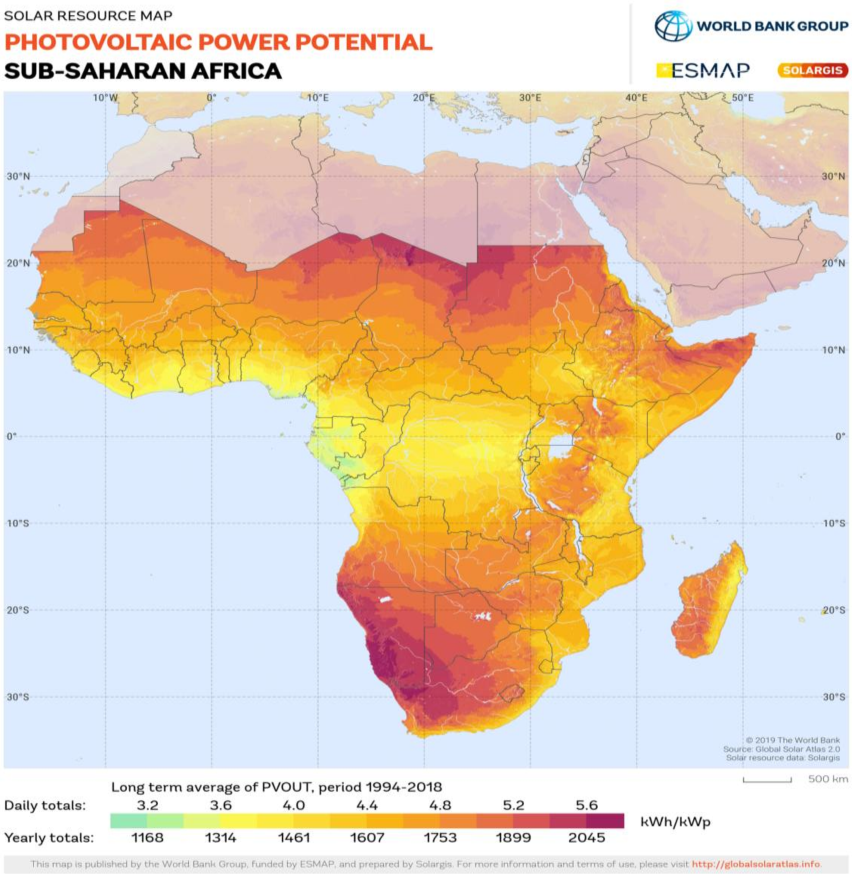

Figure 1.Photovoltaic power potential for sub-Saharan Africa indicating the daily and yearly totals, respectively (World Bank, 2023).

3. PV awareness, attitude and benefits: Nigeria case study.

Nigeria covers an area of 923,768 km^2 and has a population of over 200 million people (Olowolafe et al., 2023). There are thirty-six administrative States and a Federal Capital Territory (FCT) in the country. With over 500 ethnic groups, Nigeria has a vast diversity of cultures among its people, which have a 50% literacy rate, 66% of labour force participation rate and within the 26% multidimensional poverty index (Nwokocha et al., 2018). Nigeria has an average of 12.5 GW of installed electricity capacity, whereas, below 33% has been operational as of 2015 up till recent and only about 15% is eventually distributed to the public (Figure 2). From the southern fringe to the northern regions, the incident Gh ranges from 3.5 kWh/m^2/day to 7 kWh/m^2/day (Aliyu et al., 2015). This is categorized as radiation levels I (≥ 5.7 kWh/m^2/day), II (5.0 – 5.69 kWh/m^2/day) and III (< 5.0 kWh/m^2/day) Gh zones (Figure 3) and the values are appropriate for siting any size of PV project (Ohunakin et al., 2014). However, notwithstanding the abundant Gh across the country, there is yet to be desired in the penetration of PV and the associated impact on national development.

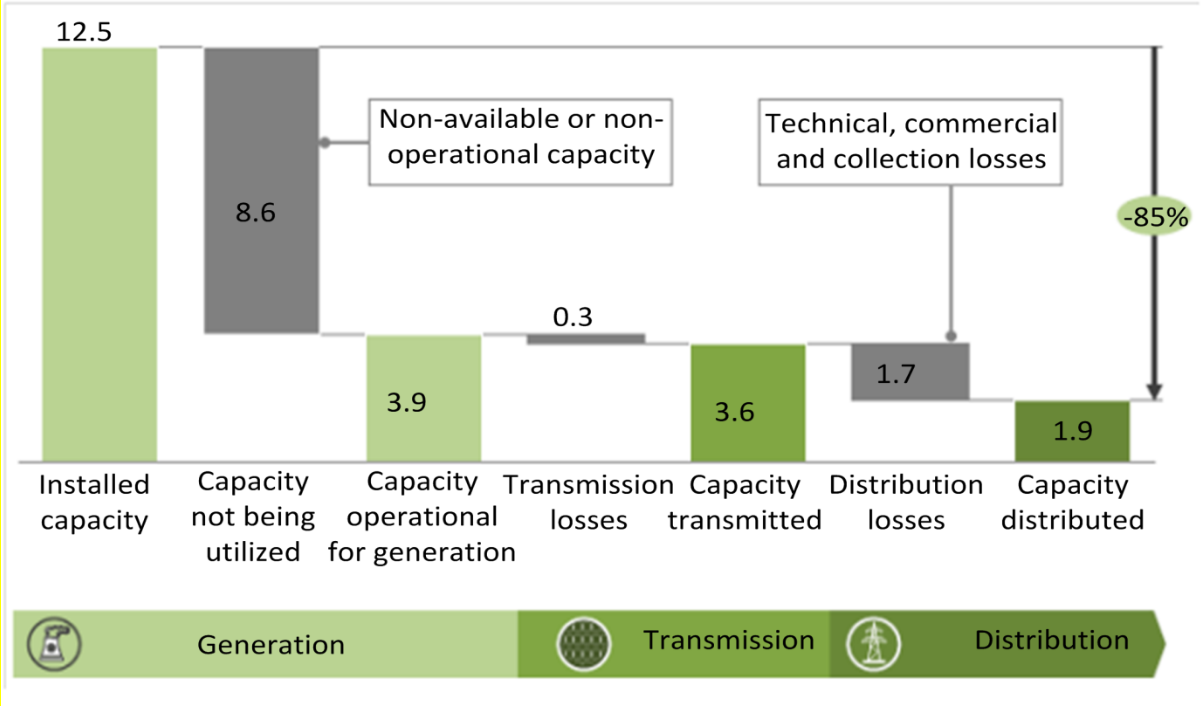

Figure 2.Nigeria average electricity energy profile in GigaWatts (GW) (ERGP, 2017).

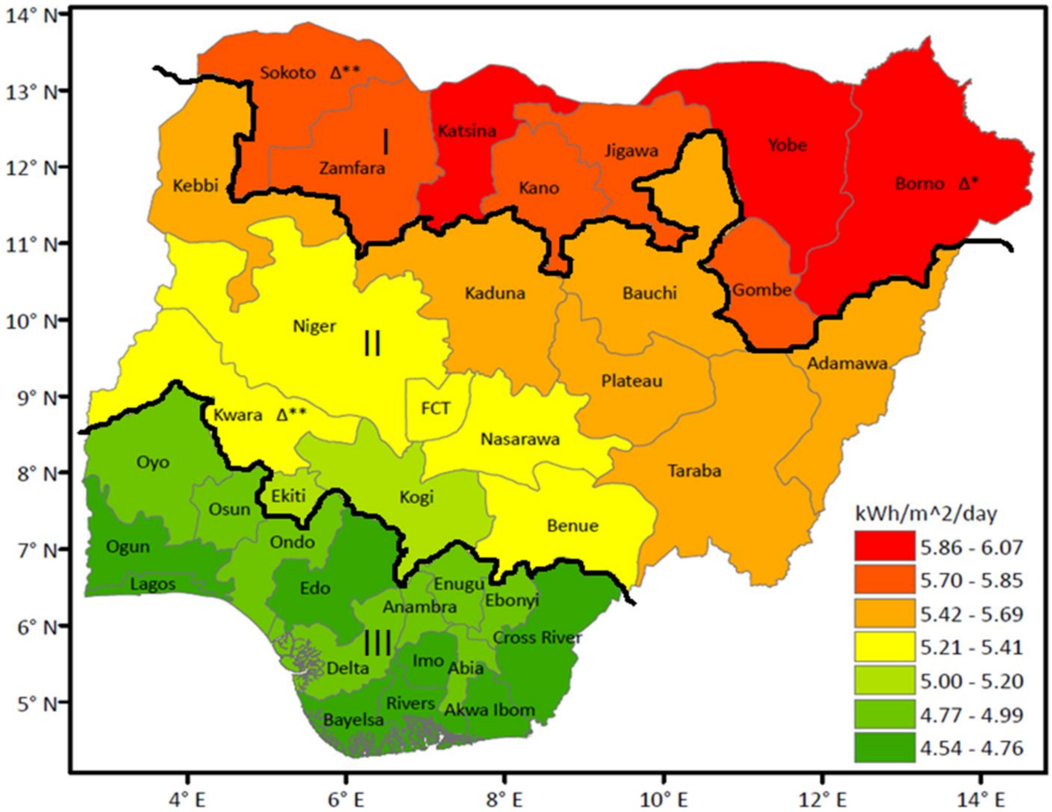

Figure 3. Nigeria indicating the climatological (1979 - 2014) annual mean of the estimated Gh (kWh/m^2/day) at each State and FCT. The Gh zones are delineated by the bold contour lines (Okoro et al. 2022).

Studies have shown that the awareness of solar PV energy across the country varies from one region to another (Nwokocha et al., 2018). This is because regional differences in awareness, information and acceptance of PV resources have shown to affect access to the technology as generalizing needs nationwide has been the source of some errors in the penetration of PV energy resources. This has resulted in the acceptance and penetration of PV energy across the country dependent on the availability and accessibility of the resources at the given locations. The study further established that the regional variation in PV awareness affects the attitudes toward utilizing PV energy resources. The idea is that less population being aware of PV energy resources prompts fewer people that use such PV devices not notwithstanding the if the devices are available or not and their quality (Nwokocha et al. 2018). The study indicated the population being conscious of the numerous expected benefits but is nevertheless handicapped since the benefits are achievable only with the penetration of the technology. The objective is that if there is the credible attitude to utilizing PV resources then it shall transcend to its sustainability and penetration into the population.

4. PV projections.

There have been indications that global Gh will vary significantly due to the changing climate and this will affect the energy output of PV system in the near future (Wild et al., 2015; Bazyomo et al., 2016; Bartók et al. 2017). Okoro et al. (2022) studied the projections of Gh derived from the temperature range across Nigeria to the end of the 21st century using the Coupled Model Intercomparison Project's 5th phase (CMIP5) and the Co-Ordinated Regional Downscaling Experiment (CORDEX) outputs, respectively. CMIP5 is a coordinated programme that provides 21st-century climate projections from Global Climate Models for climate research at horizontal resolutions of about 100 to 200 km, (Jenkins et al., 2002; Taylor et al., 2012; Vizy et al., 2013). CORDEX is the foremost global platform for the common protocol in downscaling experiments, which dynamically downscales GCMs to produce high-resolution (approximately 50 km) climate information at scales applicable for impact, adaptation and vulnerability (Giorgi&Mearns, 1999; Giorgi&Gutowski, 2015; Nikiema et al., 2017). The study validated the CMIP5 and CORDEX-Africa Gh within the baseline period by the observational Gh and the Photovoltaic Geographical Information System and the models' performances indicated consistency.

The annual Gh projections from the models in the representative concentration pathways (RCP) 4.5 and 8.5, respectively, have revealed two epochs, from 2006 to 2038 and from 2039 to 2089. Okoro et al. (2022)

indicated that there are more regions in the country with a potentially significant level of increasing or decreasing trend in the second epoch from 2039 to 2098 than in the first epoch from 2006 to 2038 from the RCP 4.5 and RCP 8.5 scenarios, respectively (Figures 4 and 5). The study noted that the percentage variations in the projections when compared to the baseline

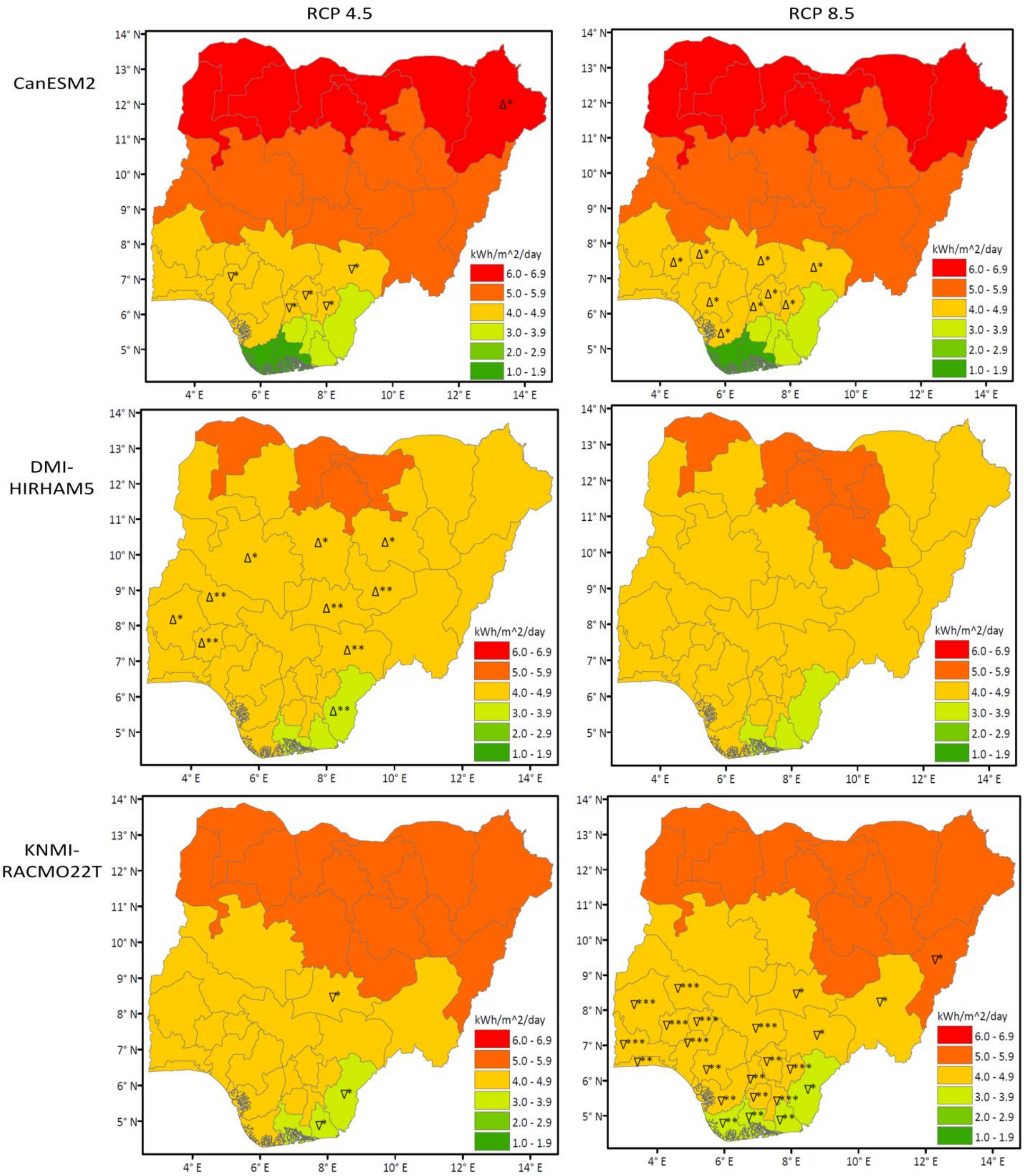

Figure 4. The models' RCP 4.5 (left) and RCP 8.5 (right) projections of annual Gh from 2006 to 2038. Only locations with a significant (* signifies $\alpha = 0.05$, ** signifies $\alpha = 0.01$ and *** signifies $\alpha = 0.001$) level of increasing (Δ) or decreasing (∇) trend from the Mann-Kendall test are indicated (Okoro et al., 2022).

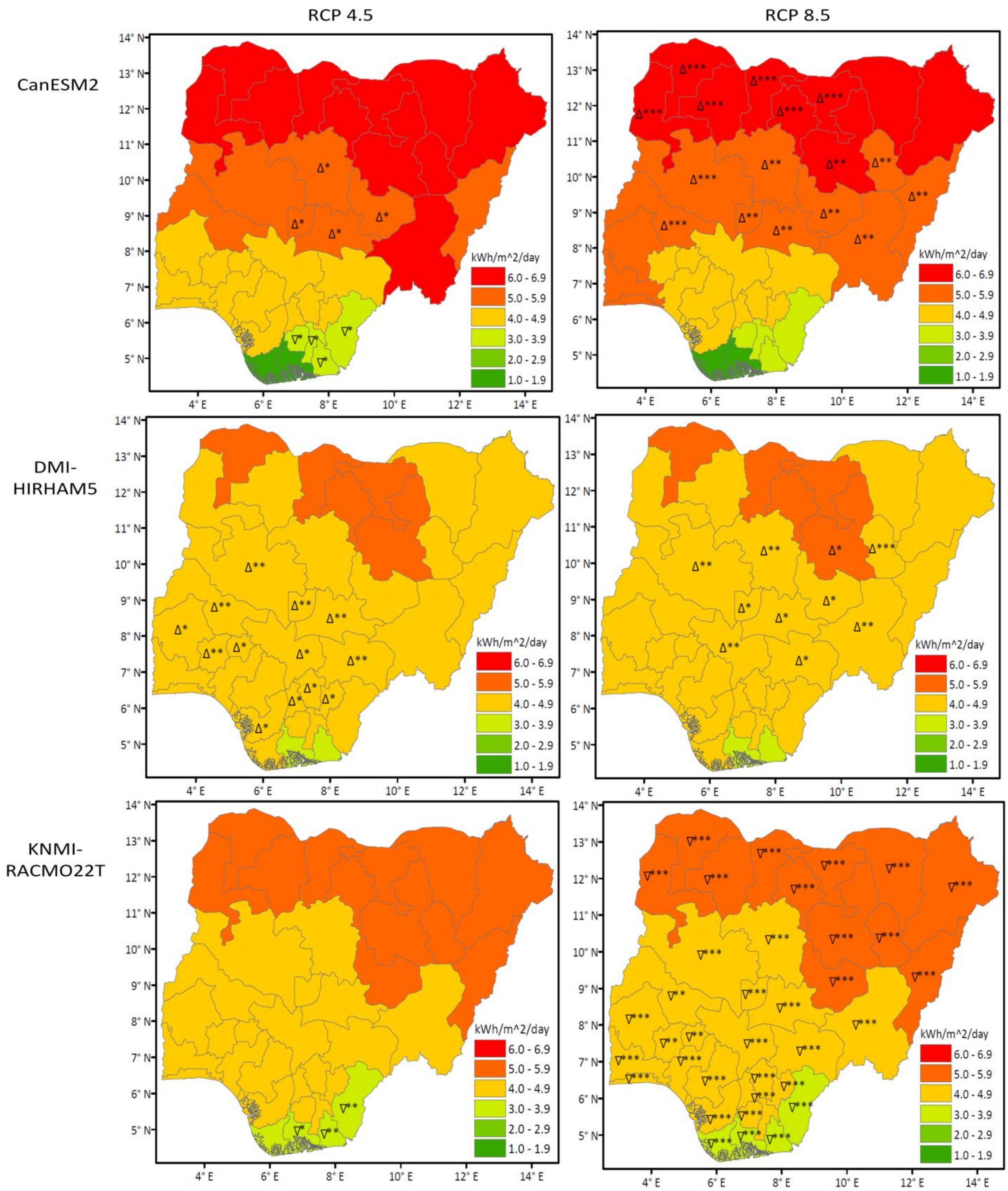

Figure 5.The models' RCP 4.5 (left) and RCP 8.5 (right) projections of annual Gh from 2039 to 2098. Only locations with a significant (* signifies $\alpha = 0.05$, ** signifies $\alpha = 0.01$ and *** signifies $\alpha = 0.001$) level of increasing (Δ) or decreasing (∇) trend from the Mann-Kendall test are indicated (Okoro et al., 2022).

period, do not pose a significant challenge in PV resource deployment in the various regions of the country. This information is imperative in planning, siting and management of PV resources across the country to meet future energy needs and this is replicable in other regions of Africa with similar climatic conditions in Nigeria.

5. Mitigating actions in PV enterprise.

There have been several policies and reforms by the Nigerian government in attaining PV energy penetration as well as for protecting business investments. Some of the recent ones are the Renewable Electricity Policy Guidelines of 2006, the 2006 National Renewable Energy Master Plan that was revised in 2012, the National Renewable Energy and Energy Efficiency Policy of 2015, The Renewable Energy Feed-in Traffic Regulations of 2015, the Rural Electrification Strategy and Implementation Plan of 2016 and the National Renewable Energy Action Plan proposed to run from 2015 to 2030 (Okoro&Chineke, 2021).The triumph in these policies and regulations has brought about the proliferation of individual and non-individual off-grid solar PV projects that are either operational or in developmental stages at different locations throughout the country (NREAP2016; Enongene et al. 2019; Khodayar et al 2019). The government then established the Nigerian Bulk Electricity Trading Plc as the sole issuer of the Power Purchase Agreement (PPA). Table 1 shows some proposed solar power plants with issued PPAs. These investments and projects yet face enormous barriers to PV penetration, which intentional or unintentional but perceived as wrongdoings.

To this effect, Okoro and Chineke (2021) proposed whistleblowing as a means of guaranteeing the penetration of PV within the country. For instance, whistleblowing in PV operations should be in encouraging and prioritizing grid parity in per unit energy cost. In the funding gaps, it suggests financial support policies such as a third-party financing option for residential and commercial projects. In the shortage of skilled professionals, the training and retraining of technicians and artisans being issued verifiable certifications is proposed. It suggests that incorporating recent trends rather than obsolete technologies should be prioritized in PV penetration, for instance, the use of current conversion efficient generation of PV cells, the use of bifacial PV modules, incorporating Phase Change Materials in projects to enhance cell efficiency of PV modules and incorporating solar trackers in the PV installations.

For the cost and availability of components, local manufacturing is proposed for components mined locally bearing in mind the global technology trend and local environmental regulations to optimize PV operations. Off-grid technologies with scales of households to community are proposed to increase spread and area coverage, with incentives such as feed-in taxes and tax credits especially as PV project lead time is the shortest for any power generation technology. With the scarcity of land for PV projects, rooftops should be encouraged and prioritized instead of agricultural land. In the city layout of the PV locations, incorporating the aesthetic perception of PV technologies in architectural and urban planning is proposed. Incorporating smart inverters to monitor is proposed to reduce utility energy losses. Imprisonment and or fines should be penalties for compromising the quality and standards of PV materials.

Table 1. Some proposed solar power plants with issued Power Purchase Agreements (Okoro et al. 2022).

S/N	Location/ State	Capacity	Solar Project Partner
1	Adamawa	500 MW	LTI ReEnergy/ Nigus
2	Bauchi	100 MW	Nigeria Solar Capital Partners
3	Borno	100 MW	General Electric
4	Enugu	100 MW	GreenWish Partner
5	Federal Capital Territory (FCT)	100 MW	LR Aaron Power
6	Jigawa	50 MW	GreenWish Partner
7	Jigawa	80 MW	Nova Scotia/ CDIL/ Scatec Solar
8	Jigawa	50 MW	Oriental Renewable Solutions
9	Kaduna	50 MW	GreenWish Partner
10	Kaduna	50 MW	En Africa
11	Kaduna	50 MW	Quaint Abiba Power
12	Kaduna	100MW	AnjeedInnova Group
13	Kano	100MW	Dangote/ Black Rhino Group
14	Katsina	75 MW	Pan Africa Solar
15	Katsina	100 MW	Nova Solar 5 Farm
16	Kebbi	100 MW	General Electric
17	Kogi	100 MW	Middle Band Solar One
18	Nasarawa	50 MW	Afrinergia Power
19	Nasarawa	100 MW	MotirDusable
20	Nasarawa	100 MW	General Electric
21	Niger	100 MW	General Electric
22	Plateau	70 MW	CT Cosmos
23	Sokoto	100 MW	KVK Power
24	Taraba	100 MW	General Electric
Total Capacity		2425 MW	

6. Conclusion.

Africa’s energy poverty has been a bane to local industrialization towards the attainment of sustainable development. Renewable energy options for attaining energy efficiency are superior due to the reduction of global CO_2, which is a precursor to climate change. PV has been the most reliable source of renewable electric energy in recent and the technology has seen improvements in both efficiency and cost. This study has presented PV energy as a viable measure for Africa to attain energy efficiency to drive its sustainable development. The incident Gh level across the continent is viable for the siting and sizing of any PV capacity, yet much is desired in the PV penetration across the localities to meet the energy requirements. With the emphasis on Nigeria, the awareness of PV has varied across locations based on needs and this has been strongly linked to the local populations' attitude to its utilization hence its penetration and hence their reaping the associated benefits. With the indications that global Gh will vary due to climate change Nigeria has shown viable projected levels of Gh till 2100, enough to sustain PV penetration although indicating two epochs. The business environment for PV penetration is expected to be guaranteed by the governments, as has been shown in Nigeria. However, there are yet existing shortcomings which are alleged as wrongdoings and whistleblowing is prescribed as a measure to guarantee further PV penetrations. The whistleblower should be supported by policy and public participation being a crucial component to mitigate wrongdoings in PV penetration.

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Data availability.

The data can be available on request from the corresponding author.

Statements and Declarations

Competing Interests.

There is no conflicting interest.

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