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Review Article

Bridging the Energy Supply Gap in Nigeria: Solar Energy Systems to the Rescue

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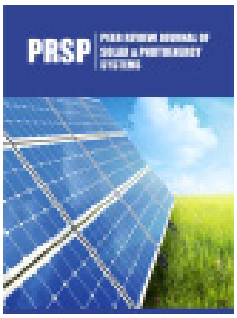
Abstract

This opinion paper seeks to emphasize the huge role the solar energy systems could play in solving (improving) the energy supply problems in the power sector of the Nigerian economy. The role the solar energy systems could play in bridging the energy supply gap would be adequately discussed and recommendations made to the relevant government authorities for possible implementation.

Keywords: Energy supply gaps; Bridging the gaps; Solar energy systems to the rescue



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Introduction

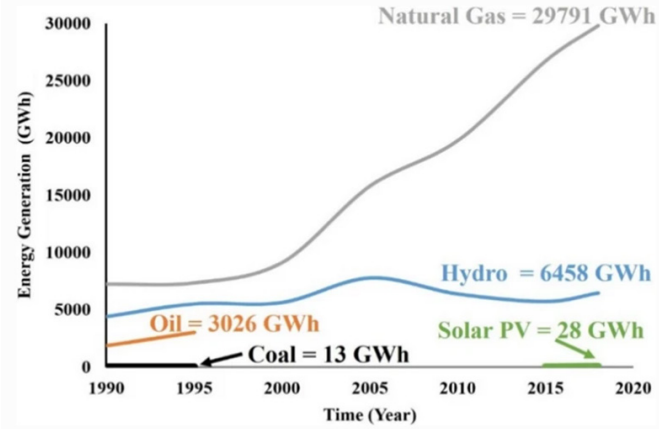

Figure 1: Variation of energy generation and its sources for over three decades [3-5].

The need for energy globally has increased drastically because of increase in development and innovations in the energy sector and increasing population. This increase in demand has resulted in the worldwide usage of the resources that are renewable in nature and methods to gather for the corresponding increase in demand and population. This is because fossil fuels cause environmental problems and would likely deplete completely. Solar photovoltaic systems use solar energy that comes directly from the sun to meet the high need for electricity. It also has the opportunity of creating a stable, safe and environmentally friendly supply of energy in the coming years. In Nigeria for instance, due to the rapid increase in population and overuse of fossil fuel, there have been significant increase in environmental, health, political, social and economic problems. The above listed factors have created a huge gap between demand and supply for energy because local production is not sufficient, hence the need for a stable and safe supply of energy for everyone. One of Nigeria's significant challenges is the ability to generate electricity to meet up with the growing demand. According to Akinyele et al. [1] the low status of the country's electricity infrastructure has resulted in high demand for fossil fuel to power generators by many Nigerians to meet their daily energy needs. This has made many citizens to adopt self-energy generation by making use of generators powered by fossil

fuel and biomass. According to Anumaka [2], electricity generation from national grid in Nigeria has been mostly dominated by sources such as oil, natural gas, hydroelectric, coal, etc. Nigeria in 2014, had produced around 30TWh of electricity spread as follows: Oil-6TWh, Hydroelectricity-6TWh, Gas-18TWh, and Solar energy-0.028TWh [3-5]. Figure 1 shows a graphical representation of the variation of energy generation and its sources for over three decades according to the International Energy Association.

The term "solar energy" as the name implies is the energy derived from the sun, and it can come in form of heat and/or electricity. The total energy from the sun that reaches the surface of the earth is much higher than all the energy demand at present and in future demand if it is put into proper use because it can meet the world's energy needs. Solar energy when compared to other available energy sources is one of the most important and environmental friendly sources, that could be used for many years. The sun apart from being a strong source of energy also has its light as the most available source of energy that reaches the earth. The sun's intensity however at the surface is quite modest, which is mostly as a result of the earth's and the sun's distance, which causes a huge dispersion of radiation radially along the way [6]. Nigeria has also participated in the Sustainable Development Goal 7, which is Affordable and Clean energy. Therefore, as the population of Nigeria increases rapidly, there is a greater demand for energy and the need to bridge the gap in energy supply. The gap in energy supply, however, needs smart and higher quantity of safe, stable, reliable, affordable supply of energy. The reason is that depending so much on fossil fuel, which will deplete over time in energy generation for everyday consumption, also has negative impact on the environment and human lives. From the Energy Progress Report of 2022, it is estimated that about 92 million Nigerians lack access to electricity from the national grid [7]. That's a humongous proportion of the entire population of the country. Energy access is crucial to social, economic and agricultural activities as well as increasing the standard of living. About 1.2 billion people are still living with no access to consistent energy, with about 50% of this population living in Sub-Saharan Africa [8]. Nigeria which has the highest population in the sub-region has about 100 million citizens living with no safe and consistent energy [1,9]. This proportion implies that Nigeria is poor in terms of energy supply. This opinion paper, therefore, aims at creating a strong awareness of the huge role solar energy systems could play in bridging the gap in our national supply gap in our national energy generation and distribution.

Nigeria's Solar Energy Outlook

Because of the strategic location of Nigeria in the equatorial region, it has large amount of sun radiation throughout the year. Nigeria with over 2,600 hours of solar radiation per year, (an average daily sunlight of about 7 hours), is believed to have what it takes (both economic and environmental factors necessary) to invest in renewable power sources [10]. Nigeria is endowed with intensive solar radiation, averaging 6.25h per day, with 9.0h in the north and about 3.5h in the coastal areas. This means Nigeria's average daily sun radiation in the south is about 12.6MJ/m^2 and about 25.2MJ/m^2 in the far north. This will result in an overall average of 18.8MJ/m^2 per day [11-13]. The information about solar radiation throughout Nigeria as provided on the Global Solar Atlas shows an average of 724kWh/m^2 in the extreme south and 1653Wh/m^2 in the northern part. This means a photovoltaic power of 1248kW/kWp in the south and 1756kWh/kWp as shown in Figures 2 & 3 respectively. Considering Nigeria's total land mass of 923,786km^2, the impact solar radiation received is approximately 1500x10^{9}MWh yearly, with a yearly average of 19MJm^{-2} day^{-1} [13]. The electricity generated by the Power Holding Company of Nigeria (PHCN) in 2002 which is about 120,000 times approximately 1770x10^{3}TWh yr^{-1} of sunlight received in the total land mass. This energy value was estimated at 115,000 times the electrical energy generated by PHCN and about 27 times the value of total fossil fuel resources in the country [14].

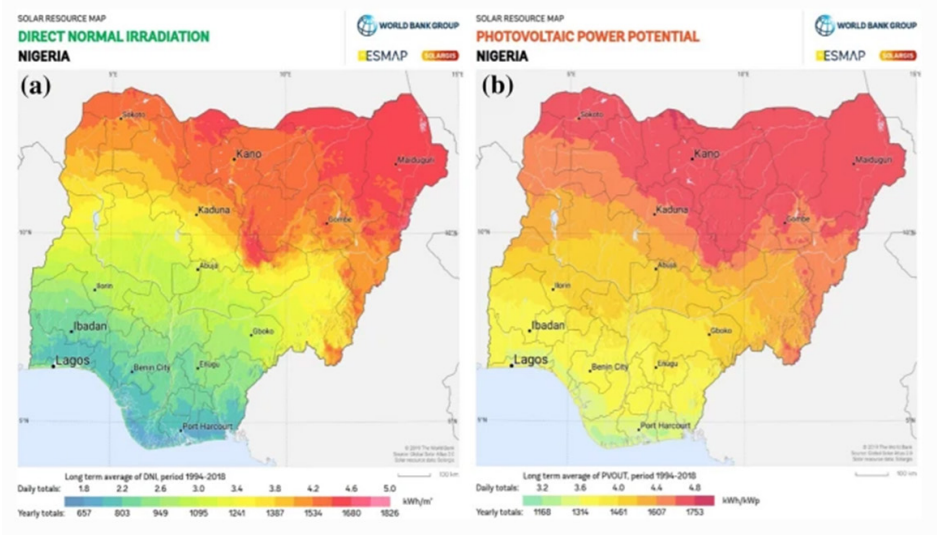

Figure 2: Direct Normal Irradiation and Photovoltaic Power Potential.

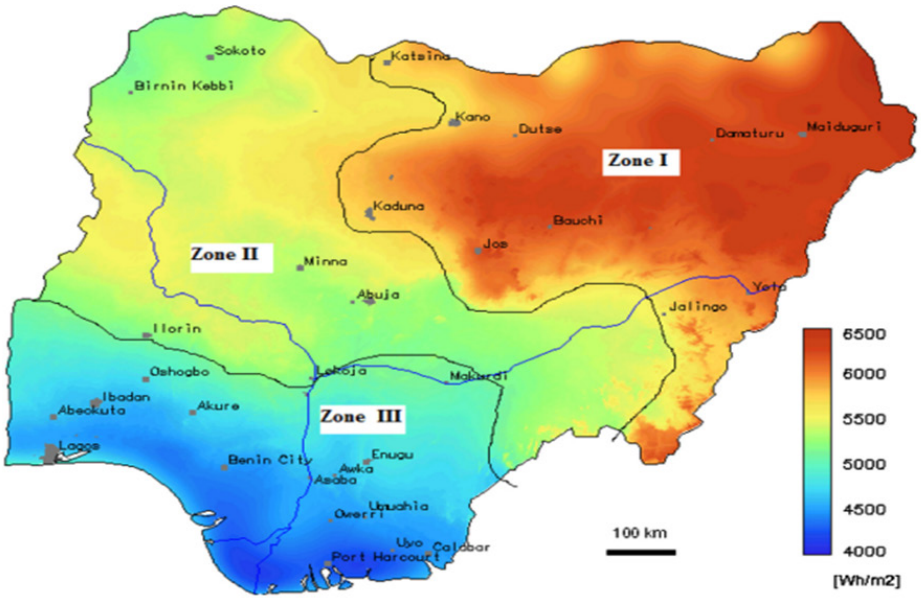

Figure 3: Solar Radiation Map of Nigeria.

Penetration of Solar Energy in Nigeria

More solar radiation is received by the northern part of Nigeria. Because of this reason, it would be more appropriate for the generation of solar electricity in those regions. According to Sambo & Bala [15], if only 1% of the land mass of the northern part of Nigeria is used to generate electricity from the sun using 5% efficiency; it means that about 333,480MW of electricity can be generated from solar system at a 26% capacity. A former President, Goodluck Jonathan in 2014 launched Operation Light Up Rural Nigeria (OLRN) project that was designed to use renewable energy to power 109 rural communities in 16 states. The project, however, was abandoned at initial stage. Former President Muhammadu Buhari, who took over power from Jonathan, renamed OLRN to Renewable Energy (Solar) Micro Utility (REMU). It was responsible for installing three solar mini-grid projects in the six geopolitical zones of the country. These projects, however, have experienced bottlenecks and haven't been realized as of today.

Recently, the Federal Government of Nigeria had launched the National Renewable Energy and Energy Efficiency Policy with the aim of integrating solar energy into the supply mix. This in essence is intended to upgrade the solar energy's contribution to the overall energy supply mix to about 6% by 2030 as the minimum contribution [16]. In 2016, the Federal Government launched the Energizing Education Program (EEP) to assist 37 federal universities not to depend on national grid through the introduction of solar power in the institutions. In the same vein, an establishment, NASENI was formed to develop, promote and encourage the penetration of solar photovoltaic technology in the country [17]. Large solar farms have been commissioned in recent times to achieve the mandate of NREEEP. These include 1MW (Nigeria Electricity-Hub, 2018), 7.1MW in Bayero University, Kano [18], and 1.2MW in Usman Dam, Abuja. Similarly, other projects involving solar farms are under construction, like 100MW in Sokoto State, 50MW in Nasarawa State, 100MW in Katsina, Kaduna and Bauchi States.

Fundamentals of Photovoltaic (PV) Cells

Photovoltaic solar energy involves the transformation of energy from the sun (light) into electricity that can be used to power up equipment and appliances in our households or for industrial applications. Solar cells receive sunlight directly and transform it into electricity in the process known as the photovoltaic effect. As sunlight falls on the junction between them, electrons within the semiconductor gain more energy and become excited. This makes the electrons to loose and free themselves from it, thus moving to opposite side in one direction, producing a small electric voltage in the cell. Small solar photovoltaic cells are commonly used in low-power devices, like calculators, watches and flashlights. These smaller cells, however, can be joined together and connected to produce a single solar photovoltaic panel. Solar PV panels can be used singly or connected together either in series or parallel to give panel arrangement that gives a greater amount of electricity. A solar photovoltaic system consists of many parts or components such as the photovoltaic panel. Other components include a battery used in off-grid photovoltaic systems to preserve the produced energy, a charge controller used to regulate, control the charge and protect the battery. An inverter is another component used to convert direct current produced by the solar panels into alternating current which can then be used in our different homes.

Solar Energy Farms

Solar photovoltaic power plants also called solar farms work in the same manner as a domestic photovoltaic system. Photovoltaic power plants, however, are usually connected to the power grid and are known as grid-connected centralized photovoltaic plants.

These power plants give a huge amount of energy to the associated grid using the centralized energy generation. A photovoltaic energy generation system is usually seen as a power plant when its total power output is not less than 1MW.

Gridding Systems for Solar Energy Systems

Solar power is transmitted into the grid network using gridding systems. The power plant's substation includes equipment such as grid interface switch-gear, circuit breakers and disconnects used to shut down the system wherever there is fault. Similarly, there is also generation and supply metering equipment that act as safety devices for isolation of photovoltaic power plant.

Solar Photovoltaic (PV) Deployment

Solar power has proven to be an efficient form of energy because photovoltaic systems have gained wider acceptance and usage in many households across Nigeria. Solar photovoltaic modules have gained wider acceptability recently because of many positive impacts they offer [19]. Solar photovoltaic systems mounted on the rooftop are very modest in terms of size and output compared to general use-scale solar PV power plants with capacities in the MW range. Solar photovoltaic systems on residential rooftop normally have a capacity of 5-20kW, whereas photovoltaic systems on commercial rooftop can easily reach 100kW to 1MW as a result of the size of the building, the available space and the number of installed solar modules [20]. On big rooftops such as large factory roofs, larger industrial-scale photovoltaic systems ranging from 1 to 10MW can be installed. Rooftop solar photovoltaic systems vary in construction and components used, all the systems needs components like photovoltaic solar panels required to transform sunlight into electricity. Other components such as mounts and clamps are also used to fix and install the modules on a set of racks; inverters for DC/AC conversion; batteries for storage, cables and other accessories [21]. Figure 4 below shows the way solar energy is linked with the three pillars of sustainable development, indicating the very reason research and the implementation are required for solar energy plans in every sector of Nigeria's economy to guarantee us a safe, stable and reliable future. Figure 5 shows an on-grid solar system. Photovoltaic panels commonly used have percentage of energy efficiency that lies between 16% and 22%, a number that is considered low and would require using a higher number of panels in order to produce enough power output to support the grid [22,23].

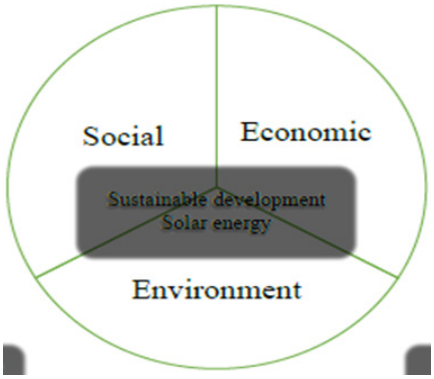

Figure 4: Solar Energy and the three pillars of Sustainable Development.

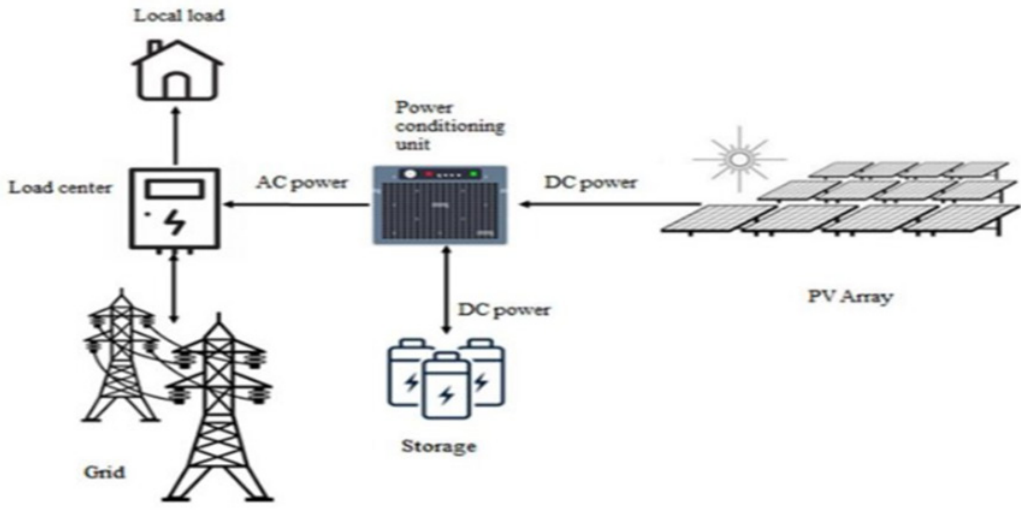

Figure 5: Schematic of an on-grid solar system.

Modules of Photovoltaic (PV) Systems

Photovoltaic power plants consist of a greater number of photovoltaic cells connected together to give photovoltaic modules, which in essence, are also connected together, resulting in PV strings necessary to generate the desired power output. Solar photovoltaic modules are the most important parts of a photovoltaic plant, whose major function is to take the solar radiation that falls directly from the sun and change it into electrical energy through the photovoltaic effect. The generated electrical output is in direct current form. Solar photovoltaic modules have the highest cost of components in a photovoltaic power plant because of the large number of modules that are deployed.

Inverter

This is a device that converts direct current from the solar panels into alternating current to supply into the grid. Inverters can be categorized into two main forms namely, central inverters and string inverters. Central inverters have multiple strings of solar panels that are connected to a single central inverter. These strings convert a large quantity of power unlike string inverters which use a separate inverter for each string of panels.

Transformers

Transformers are important and necessary in photovoltaic plants. Transformers are used to increase the voltage because the output voltage from the inverters is usually lower than that of the alternating current grid. This is to match the required voltage of the grid so that, anytime the photovoltaic is connected to the grid for distribution, electricity is fed directly into it. Similarly, to increase the voltage more and more, transformer of the grid is required when the plant is connected to a transmission network. Figure 6 above shows a schematic of the main components of a solar power plant while Figure 7 shows the layout of a grid-connected solar rooftop system.

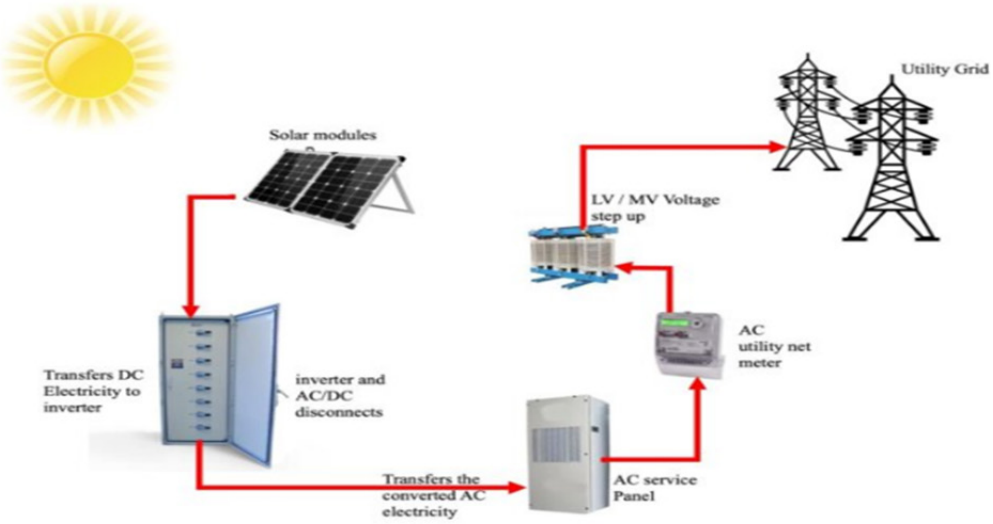

Figure 6: Schematic showing main components of a solar power plant.

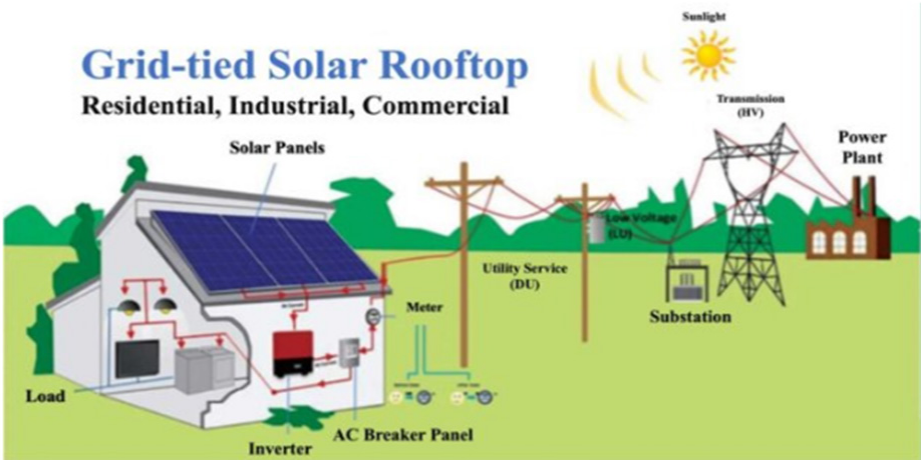

Figure 7: Grid-connected solar rooftop system.

Recommendation

The government of Nigeria is strongly encouraged to explore this renewable energy resource and tap into its full potentials by way of investing massively and sufficiently into deployment of renewable energy in strategic regions to complement the energy gotten from other sources, in a bid to meeting our growing energy needs. Because of the drawbacks of conventional sources of energy over solar, efforts should be put in place to improve solar efficiency using a photovoltaic device. Nigeria needs to reposition itself by investing in this renewable (solar) energy resource to ensure energy sufficiency in the country in the not too distant future.

Conclusion

Electricity production from renewable sources, especially solar energy in Nigeria is increasing although the solar energy target of providing 80% of the population with clean energy of 500MW by 2025 has not been met. The demand for electricity consumption in Nigeria is forecasted to reach an estimated peak demand of 24,481MW, the annual demand of 115,466GWh, the peak demand of 18,270MW, and annual demand of 86,175GW even before the SDG's deadline of 2033. Investing in solar-powered plants could increase electricity and make it available for many Nigerians who currently do not have any access to electricity. This means that a transition to solar-based energy could also help to diversify Nigeria's energy sector and reduce high electricity tariffs. This will go a long way to stopping over-dependence on fossil fuels, which comes with debilitating environmental challenges such as pollution, gas flaring, and oil spillage which all contributes to climate change.

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