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Solar Photovoltaics Development in Nigeria: Drivers, Barriers, and Policies

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Abstract

Energy access is vital to a nation's economic growth and its populace's social well-being. Still, there is a lack of adequate energy in Nigeria, negatively affecting the country's socio-economic development. Due to the inadequate energy supply, some manufacturing companies shut their operations, and most Nigerians now use backup generators (BUGs) with their attendant health hazards, environmental pollution, and global warming. The need for energy access and a sustainable energy supply through renewable energy (RE) resources necessitates adopting solar photovoltaics (PV) in Nigeria. Studies on Nigeria's energy accessibility and sustainability are generally on RE development and a few on solar PV applications. This research covers the need for an in-depth analysis of the growth of solar PV in Nigeria, and the research question is: What factors promote or limit the adoption of solar photovoltaics in Nigeria? A method of Systematic Literature Review (SLR) and Thematic Analysis (TA) is employed for the analysis. The research findings are divided into drivers, barriers, and policies. Some identified factors promoting the adoption of solar PV are energy poverty and the urgency to improve electricity supply, the ease of its operation and maintenance, and the Nigerian government's commitment to clean electricity supply with policy initiatives and increased awareness of solar PV applications. Conversely, some noticed factors mitigating the growth of solar PV are poor tariff systems, dual subsidies of electricity and petroleum, and lack of finance and economic incentives.

Keywords

Energy Access, Sustainable Energy, Renewable Energy, Solar Photovoltaics, Backup Generators, Energy Poverty

1. Introduction

Energy is a bastion of economic growth and development. The lack of adequate

energy for household consumption and industrial use in Nigeria is negatively affecting the country's socio-economic development. Bridge *et al.* [1] state that energy is fundamental to developing societies, economies, and politics. Due to the inadequate energy supply, some manufacturing companies shut their operations and relocated their branches to other countries. Most Nigerians, including corporate organisations, government offices, and industries, now use backup generators (BUGs) with their attendant negative consequences, such as environmental pollution and global warming. While environmental pollution injures health, global warming leads to the existential challenge of climate change. The lack of adequate electricity slowed Nigeria's economic growth [2] and led to mass unemployment [3]. Nigeria represents a classic paradox of abundant energy resources and widespread energy poverty, according to Halff *et al.* [4]. Amidst the abundance of natural energy resources, Nigeria continues to experience a decline in energy production with increased population and energy demand. Access to a sustainable energy supply is vital to social well-being, industrial growth, and economic prosperity. The power crisis in Nigeria will persist unless the government diversifies the energy sources and adopts new technologies [5], especially renewable energy. According to Bhattacharyya [6], renewable energies occupy an essential place in any strategy for sustainable energy development. Abdullahi *et al.* [7] suggest that solar PV electricity is the ultimate strategy to achieve sustainable development. At the same time, Muye [8] describes solar energy as the most promising renewable energy source because of its limitless potential. The need for diversification to sustainable energy generation through Renewable Energy (RE) resources necessitates the adoption of solar energy by the Nigerian government. Renewable Energy (RE) resources are primary energy sources with a capacity for regeneration [1]. Solar energy is obtained directly from the sun's radiation, while photovoltaics (PV) converts solar energy to electricity. Solar PV produces electricity directly from sunlight through a photocell [9]. Solar PV offers clean electricity, improving electricity supply and ensuring electricity generation's sustainability.

2. Literature Review

Most studies on energy access and sustainability are generally concerned with renewable energy (RE) development but are not specific on solar PV development. However, there are some studies on the development of solar PV in Nigeria [3] [5] [7] [10]-[17]. Nevertheless, these studies have yet to explain in-depth the characteristics and growth of solar PV in Nigeria. Beyond its development, it is imperative to understand the specifics of solar photovoltaics (PV), such as its classifications, limitations, advantages, and environmental pollution. And importantly, the proliferation of backup generators (BUGs) as it affects the growth of solar PV, being a readily available alternative source to grid electricity.

2.1. Classification of Solar Photovoltaic

Solar Photovoltaic (PV) applications are classified into three: solar lanterns, solar

home systems (Figure 1), and solar mini-grids (Figure 2). Solar lantern is defined as small solar units of less than 10 Wp, while the solar home system ranges from 10 Wp to 150 Wp, and solar mini-grid is defined as an isolated grouping of electricity [4]. Solar mini-grid or solar grid combines multiple solar panels and associated equipment. The different classifications of solar PV offer the users the flexibility of choice depending on the applications.

2.2. Limitations of Solar Photovoltaic

There are some limitations to solar Photovoltaic (PV) applications, notwithstanding their general adoption. Solar PV needs an energy backup due to the intermittency of solar energy; thus, battery energy storage is applied. A feature common to renewable energy resources, especially solar resources, is light energy density, as compared to the energy from fossil fuel resources, implying larger solar energy systems are needed to produce limited electricity. The cost of installation of solar energy systems is high, especially the batteries. Solar PV limitations are summarised as storage issues and high price [1], low-energy capacities [11], intermittency of supply [3] and security of the installation, *i.e.*, the location of the solar panels.

(a) (b)

Figure 1. Solar home system (Source: Ipgrupp Engineering Limited). (a) Solar panels; (b) Storage batteries.

(a) (b)

Figure 2. Solar mini-grid (Source: Ipgrupp Engineering Limited). (a) Solar panels; (b) Storage batteries

2.3. Advantages of Solar Photovoltaic

Notwithstanding its limitations, solar Photovoltaic (PV) has some advantages that accelerate its growth as an alternative electricity supply. It has low operational and maintenance costs [12] and promotes decentralisation of Nigeria's electricity system [5]. A significant advantage of solar energy is its abundance and infinite nature. Solar energy is non-exhaustive and non-rivalrous. While the installation cost had been a cause of concern, Arent *et al.* [18] state that the cost of generating solar PV electricity has reduced considerably due to its increasing adoption. Still, Abdullahi *et al.* [7] believe that the reduction in the cost of solar PV electricity is due to technological breakthroughs. The gradual decrease in the cost of solar PV materials is due to factors such as economies of scale, technological innovations, and financial incentives. Another advantage of solar PV is its variety and flexibility of applications across solar lanterns, solar home systems and mini-grids.

2.4. Environmental Pollution from Solar Photovoltaic

Most studies present solar Photovoltaic (PV) as clean energy without a negative environmental impact and carbon emissions. It is of note that battery, a constituent of solar PV, poses a significant environmental challenge. The battery does not emit carbon during usage, but mining the raw material for its production causes substantial environmental degradation. In addition, the discharge of a used battery after its lifecycle is toxic to the environment. Lastly, storing arrays of batteries within a residential setting (**Figure 1(b)**) indirectly pollutes the household and leads to discomfort for solar PV users. Oghogho *et al.* [12] also argue that the by-products of manufacturing and utilising solar PV constitute environmental hazards.

2.5. Proliferation of Backup Generators in Nigeria

Back-up generators (BUGs) have an installed capacity of 8 - 14 GW in Nigeria, serving approximately 80 per cent of Nigerians [19]. Okoye *et al.* [14] present data about Nigeria's peak electricity generation and peak demand in 2013 and 2015. In comparing these data, it is evident that while the peak generation decreased during those years, the peak demand increased. To cover these shortfalls in electricity generation, people resolved to adopt BUGs (**Figure 3**). According to Adewuyi *et al.* [20], despite the vast potential of solar energy, with an estimated generation capacity of around 43,000 MW, many Nigerians depend on inefficient and costly diesel and petrol combustion engine generators to meet energy. However, the broad adoption of BUGs has plenty of negative consequences, as Akin [21] reveals that using BUGs affects both the local and the global environment. Locally, the use of BUGs causes significant environmental and noise pollution, while globally, BUGs constitute a substantial contribution to global warming. In addition to the environmental and noise pollution, there is continuously a record of death across Nigeria resulting from inhaling the fumes

Figure 3. Fossil-fuel backup generators in Nigeria—carbon emissions and environmental pollution [23].

from the BUGs. Oguntoke and Adeyemi [22] suggest adopting a policy regulating BUGs, while Akin [21] recommends adopting solar PV to reduce the nation's dependence on alternative energy solutions such as the BUGs. In terms of cost, the use of BUGs is more expensive compared to solar PV. While solar PV is costly at the point of installation, the zero operation and maintenance cost has given it an advantage over BUGs. Okoye *et al.* [14] compared the cost of electricity from BUGs and solar PV and discovered that it is more expensive to use BUGs than solar PV.

3. Methodology

The research uses secondary data and employs a Systematic Literature Review (SLR) method. A total of ninety-eight peer-reviewed journal articles on studies related to renewable energy development and solar photovoltaics applications in Nigeria were sourced from Google Scholar. In addition, twelve reports and policy documents were collected from relevant agencies and organisations. Lastly, eight books were obtained to complement the peer-reviewed journal articles, reports, and policy documents. A preliminary review of the entire secondary data was followed by a systematic literature review of thirty-four documents comprising twenty-three peer-reviewed journal articles, six reports and policy documents, and five books. A thematic analysis of the data reveals three trends: the elements promoting the development of solar photovoltaics, the factors mitigating its growth, and lastly, the policies accelerating its penetration. These three themes extracted from the SLR form the conceptual framework of this research, upon which the conclusions are drawn.

4. Results

Solar photovoltaic (PV) applications in Nigeria date back to the 1970s, and it became remarkable in 1980 when the Solar Energy Society of Nigeria (SESN) was established [24]. SESN is an association of solar products importers, marketers, and solar energy producers. The acceptance of solar PV gained momentum in Nigeria following the government's initiative to create the Council for

Renewable Energy Nigeria (CREN) in 2004 [25]. CREN is an agency of the Federal Government of Nigeria with the mandate to promote renewable energy and reduce the consumption of fossil fuels. Despite the early momentum, four decades after the establishment of SESN and nearly two decades after the creation of CREN, the adoption of solar PV technology seems to have fallen short of expectations amidst the abundance of solar resources in Nigeria. Recently, there has been a collaborative effort between the government, private solar PV producers and consumers to accelerate the growth of solar PV in Nigeria.

4.1. Adoption of Solar Photovoltaic

Nigeria receives about 4909.212 kWh of energy from the sun, equivalent to about 1.082 million tons of oil [8]. Solar radiation is fairly distributed in Nigeria, as displayed by the map of Nigeria in **Figure 4** showing the global solar irradiation. **Figure 4** indicates the spread of solar power across Nigeria, making everywhere suitable for solar PV applications nationwide. Muye [8] provides a broader range of solar irradiance in Nigeria. He says the solar energy potential in Nigeria ranges between 3.5 - 7.5 kWh/m^2/day, with peak radiation in the North-Eastern part of the country.

Amid the abundance of solar energy resources in Nigeria, only a few states, such as Bauchi, Delta, Enugu, Lagos, Oyo, and Sokoto, have used solar PV to reduce their electricity burdens [26]. Emodi and Boo [27] reveal that some Northern states of the country, such as Kano and Katsina, have solar PV projects. Though solar PV deployment in the Northern part of the country did not occur until 1985 for rural electrification, it was followed by water pumping and

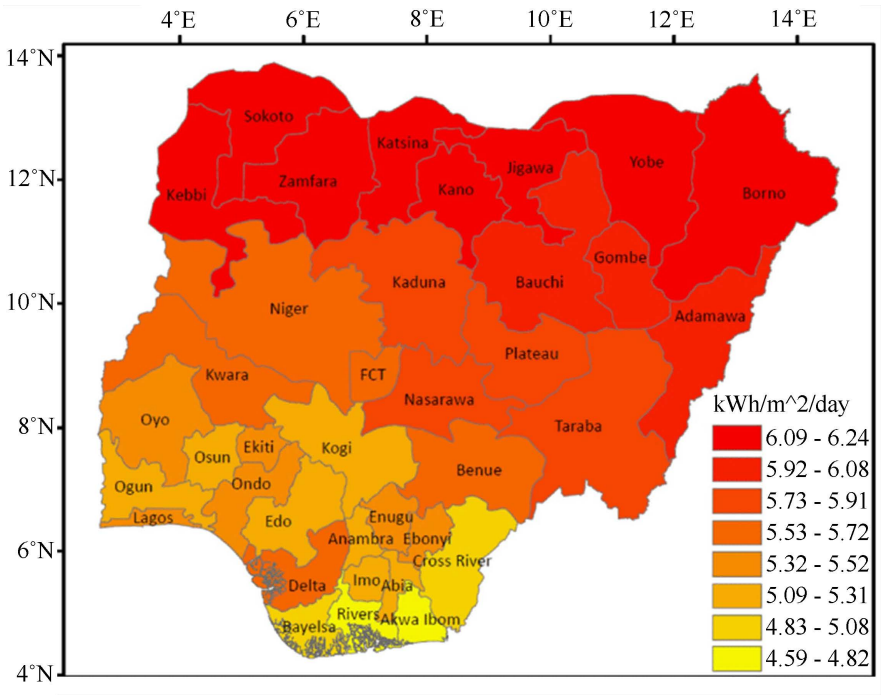

Figure 4. Map of Nigeria, showing global solar irradiation [8].

telecommunication in the subsequent years [15]. Yahaya and Sambo, cited in [15], identified some of the solar PV projects in the North as the 7 kWp Gotomo village solar PV lighting in 1985 and the 7.2 kWp Kwakwalawa community solar PV electrification in 1993. The Nigerian telecommunications carrier, Nigeria Telecommunications (NITEL), recognised the positive impact of solar PV and incorporated it into the NITEL system in 1991; the Federal Ministry of Water Resources and Rural Development also installed solar PV water pumping machines across Nigeria in 1998 [15]. Despite these seemingly progressive developments of solar PV in Nigeria, Ohunakin *et al.* [13] believe that the deployment of solar technology in Nigeria is slow, corroborated by Bamisile *et al.* [11] with their opinion that solar PV is less utilised in Nigeria.

4.2. Integration of Solar Photovoltaic into the Electricity Mix

Solar PV has not been integrated into the national grid because Nigeria lacks utility-scale solar PV plants. While the Nigerian government targets a 2785 MW installed capacity of solar PV by 2020 [28], Ozoegwu *et al.* [3] confirm that grid-connected solar PV does not currently exist in Nigeria. A report obtained from the Energy Commission of Nigeria [29] shows that in 2016, the Federal Government (FG) signed a Power Purchase Agreement (PPA) with local and international utility-scale developers expected to add 1200 MW solar PV capacity to the grid, as shown in Table 1. However, findings reveal that as of 2018, all the

Table 1. Power Purchase Agreement (PPA) with local and international utility-scale developers [29].

Company/Developer	Capacity (MW)	Location (State)
Access Power	50	Kaduna
Afrinergia	50	Nasarawa
Anjeed Innova	10	Kaduna
CT Cosmos's	70	Plateau
En Africa	50	Kaduna
GreenWish Partners/Motir DuSable	100	Enugu
GreenWish Partners	50	Kaduna
GreenWish Partners/Oriental Renewable	50	Jigawa
Kvk Power's	100	Sokoto
LR Aaron Power	100	Abuja
Nova Scotia Power Development	80	Jigawa
Pan Africa Solar & JCM Power	75	Katsina
Middle Band Solar One	100	Kogi
Motir Dusable	100	Nasarawa
Nigerian Solar Capital Partners	100	Bauchi
Nova Solar 5	100	Katsina

projects have yet to commence due to bureaucratic delays from NBET [19]. How the 1200 MW solar capacity would be added to the grid is unclear because the Nigeria grid network is overloaded, resulting in frequent grid collapse.

4.3. Drivers of Solar Photovoltaic in Nigeria

The main driver of solar Photovoltaic (PV) in Nigeria is energy poverty and irregular electricity supply. The consumer's choice of solar PV over the existing systems also stems from the need for reliable electricity. Despite Nigeria being a signatory to the Paris Agreement, climate change mitigation does not form part of solar PV development drivers in Nigeria. A 2018 report from the Intergovernmental Panel on Climate Change (IPCC) cited in [30] states that policymakers are not cognisant of the climate impact of the existing electricity sources. Most of the policies or strategies of the Nigerian government to promote the growth of solar PV are to bridge the gap in electricity generation and demand, not for climate change mitigation (**Table 2**).

4.4. Factors Mitigating the Growth of Solar Photovoltaic in Nigeria

A comprehensive list of barriers to the emergence of solar PV in Nigeria, as revealed by different authors and their recommendations, is compiled and presented in **Table 3**.

4.5. Policies Aim at Promoting the Emergence of Solar Photovoltaic in Nigeria

Energy policy combines intergovernmental responsibilities and market agreements, leading to complex regulatory and action frameworks [33]. The Federal Government of Nigeria plans to incorporate solar PV into the electricity mix so that solar PV electricity would constitute 1.26 per cent, 6.92 per cent, and 15.27 per cent of Nigeria's electricity mix by 2015, 2020, and 2030, respectively [11]. Consequently, the following policies have been formulated: Public-Private Partnership (PPP) [7], National Renewable Energy and Energy Efficiency Policy, and National Renewable Energy Action Plan [28]. **Table 4** reveals other policies

Table 2. Drivers of solar photovoltaic development in Nigeria (Source: Compiled by the author).

Paper	Drivers of Solar Photovoltaic in Nigeria
Okoye *et al.* [14]	Development of a Renewable Master Plan. Establishment of a Taskforce on Power. Privatisation of the Utilities Companies.
Abdullahi *et al.* [7]	Research Centres and Energy Institutions. Electricity production deficits. International Agencies.
Ugulu [17]	Power outages. Energy cost-savings. Access to finance.

Table 3. Barriers to solar photovoltaic development in Nigeria (Source: Compiled by the Author).

Paper	Hindrances	Recommendation
Adewuyi *et al.* [20]	Poor tariff system. Outdated metering. Political dynamics. High capital cost.	Rehabilitation of existing infrastructure. Investment in research and development. Decentralisation of the electricity market.
Oyedepo [5]	Sales of electricity to incompetent private investors. Remote and rural areas are not attractive to private investors.	Full exploitation and promotion of renewable energy resources. Energy efficiency practices and energy conservation measures.
Ajayi and Ajayi [10]	Weak government motivation. Lack of economic incentives. Multiple taxation. High customs and excise duty. Unfavourable land use act.	Provision of tax holidays and harmonisation of tax payments. Obligation of utility company to purchase RE electricity. Legal framework to connect RE to the national grid.
Ojo [31]	Overlapping regulatory roles. Finance and investment. Technology development. Limited public awareness. Poor quality control measure.	Viable legal and regulatory framework. Attraction of Foreign Direct Investment. Public Private Partnership. Feed-in tariffs. Financial incentives.
Osunmuyiwa *et al.* [26]	Rigid, complex, and centralised electricity system. Double subsidies on petroleum and electricity.	Cost-effective electricity tariffs. Private sector participation.
Shaaban and Petinrin [32]	Renewable Obligation. Feed-in-Tariffs. Energy efficiency.	Decentralised electricity generation from solar PV. Joint participation of private sector and consumer.
Bamisile *et al.* [11]	Politics and Poor Governance. Non-implementation of solar PV policies. Lack of private investors. Energy literacy of people.	VAT reduction on solar equipment. Feed-in-tariffs Capital grants, subsidies, or rebates. Biofuel obligations.
Okoye *et al.* [14]	Lack of solar radiation measuring device.	
Oghogho *et al.* [12]	Long energy pay-back time. Ignorance of the benefits of technology. Requirement of a large expanse of land. Low efficiency of PV panels. Lack of policies and legislation.	The political will to formulate policies geared to promote the application of solar PV. Commitment to investment in solar PV project. Local capacity development through the manufacturing of solar components.
Oji *et al.* [9]	Financial constraints. Technological incapability.	Subsidies on the importation of solar equipment. Restriction on importation of diesel and petrol generators.
Abdullahi *et al.* [7]	Inadequate solar initiative research. Lack of technological know-how Short-term policies Political instability.	Sensitisation and awareness initiatives. Introduction of courses on handling solar equipment in higher institutions. A special fund to subsidise the production of solar equipment.

Continued

Ugulu [17]	Use of sub-standard products Lack of government incentive Lack of protection for the infant industry.	Regulatory intervention Promotional strategies Financial support to facilitate uptake.
Nwokocha *et al.* [16]	Market failure and distortions Security of installations	Renewable energy education Resources planning and administration.
[19]	Poor wheeling capacity of transmission line and unreliable network system. Development of standardised business models Legal and Administrative bottleneck. Natural disasters, such as heavy winds.	Power Purchase Agreements. Tariff regulation. Codes and Standards. Loan, leasing, and grant. Favourable import condition.

Table 4. Policy statement aims at accelerating the emergence of solar photovoltaic in Nigeria [34].

Policy	Statement
Solar	The nation shall aggressively pursue integrating solar energy into the energy mix. The nation shall keep abreast of worldwide developments in solar energy technology. The nation shall utilise solar energy resources where it is more cost-effective. The nation shall support the establishment of local manufacturing industries for solar energy. The nation shall encourage individual and corporate bodies to generate solar power and feed into the grid. The nation shall encourage research and development in solar energy technology.
Electricity	The nation shall create an enabling environment to ensure a reliable and competitive electric supply. The nation shall continue to promote private sector participation in the electricity sector. The nation shall continue to pursue measures to ensure a strong and diversified energy mix. The nation shall pursue market competitive and sustainable power. The nation shall encourage the state and local governments to provide access to electricity to the rural areas through off-grid.
Finance	Investments in the nation's energy sector shall be accorded high priority. The nation shall provide a financing policy framework for achieving sustainable development. The nation shall explore local and international financing options for exploiting its energy resources. The nation shall encourage an increase in domestic and foreign private investments. The nation shall implement an Integrated Infrastructure Master Plan for cross-sectoral harmony and a financing framework.
Local content and Manpower development	The nation shall encourage the use of locally available Resources in all aspects of the energy sector in Nigeria. The nation shall promote manpower development and training in the nation's energy sector.
Research and Development (R & D)	The nation's energy resources shall be developed and utilised sustainably through research and development. All viable innovation generated from R&D activities should be protected with Intellectual Property (IP) rights.

extracted from the National Energy Policy [34] adopted to fast-track the emergence of solar PV in Nigeria. The slow emergence of solar PV in Nigeria is attributed to poor policy implementation Ozoegwu *et al.* [3]. Oghogho *et al.* [12] advised that the government should make a pragmatic effort to implement the adopted policies.

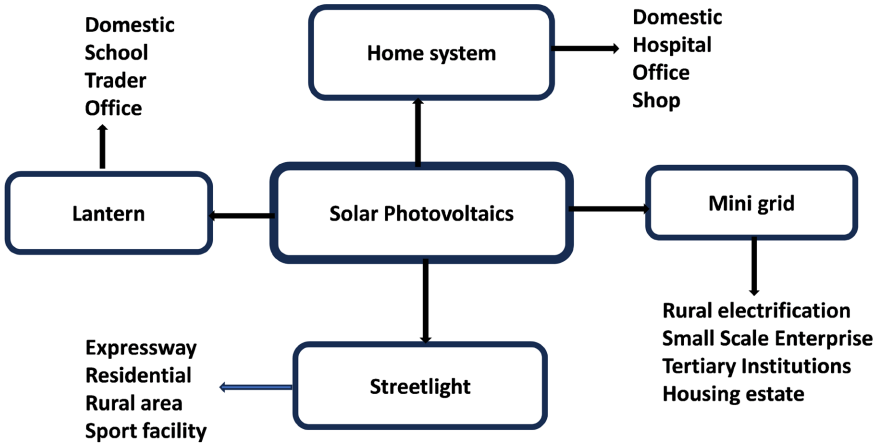

Figure 5. Applications of Solar Photovoltaics (Source: Author).

5. Conclusion

This research offers a comprehensive qualitative review of the characteristics and development of solar photovoltaics (PV) in Nigeria. It presents a broad understanding of solar PV, its technology, and the attendant adoption of Backup generators (BUGs). The research also explores and summarises the drivers, barriers, and policies of solar PV development in Nigeria. While the lack of access to electricity resulted in the general shift to alternative energy sources, specifically backup generators, the Federal Government has several policy initiatives to accelerate the development of solar PV. Currently, solar PV application in Nigeria is mainly solar home system with limited solar mini-grids and a noticeable absence of grid-connected solar power. Nevertheless, there is increasing adoption of the solar mini-grid across the country due to the collective effort of government, international agencies, and private developers.

5.1. Recommendation

The research makes the following critical recommendations: the removal of the double subsidies on electricity and petroleum products; the introduction of import duty tax on BUGs; the implementation of government policies or strategies to facilitate the development of solar PV in Nigeria; the introduction of incentives for solar PV applications; the creation of awareness of the policies and incentives towards the promotion of solar PV applications; and broadening the applications of solar PV across various usages such as lanterns, home systems, street lighting, grid and off-grid, as revealed in Figure 5. The research also recommends that the Federal Government establish an agency, Solar Photovoltaics Development Commission (SPVDC), whose sole mandate would be to Fast-Track the solar PV development and the deployment of its technologies in Nigeria.

5.2. Implication

Implementing the research recommendations offers the government of Nigeria a

two-pronged solution to the challenges of energy accessibility and sustainability, alleviating energy poverty and mitigating climate change. In 2015, Nigeria joined other United Nations (UN) countries in France to sign the Paris Agreement to mitigate climate change by reducing global warming associated with carbon emissions, mainly from fossil fuel energy resources. Similarly, in the same year (2015), the United Nations (UN) Sustainable Development Goals (SDGs) advocated for sustainable energy for all by 2030 (Goal 7) and urged for climate action (Goal 13). Thus, the outcome of this research is relevant to two UN SDGs and the Paris Agreement.

Conflicts of Interest

The author declares that there is no conflict of interest concerning this research. The research was part of the author's MSc dissertation at the University of Sussex, Brighton, United Kingdom. The author also proclaims that no funding or scholarship was received for the MSc or this research.

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