REVIEW OF SOLAR ENERGY INCLUSION IN AFRICA: CASE STUDY OF NIGERIA

[1#]Ukoba, Kingsley; [1]Eloka-Eboka, A.C and [1]Inambao, F.L

[1]University of Kwazulu-Natal, Durban, (South Africa)

[1#]ukobaking@yahoo.com

Abstract

This work reviews solar energy inclusion in Africa using Nigeria as a case study. It reviewed studies made on viability, challenges and solutions associated with making solar energy a viable energy option in Nigeria. The study highlighted data on current industry capacity of solar energy, installed PV capacity, and solar energy application distribution. It sheds light on solar energy initiatives and projects in Nigeria and solar energy capacity development in Nigeria. Success stories of solar energy and solar cell fabrication in Nigeria are presented. Existing government policies and legislation are discussed. The authors consider the challenges faced and the current and future prospects of solar power in Nigeria, and make recommendations regarding the speedy and seamless inclusion of solar energy in Nigeria and Africa as a whole.

Keywords: solar, domestication, Nigeria, energy, Africa

1. Introduction

Sub-Sahara Africa is home to about 85 % of the 1.3 billion people in developing countries without access to electricity [1], with an estimated electrification rate of 64 % in urban and 13 % in rural areas [2]. Sub-Sahara Africa has many of the world's least electrified nations [3, 4]. A total of 70 % of such those without access to electricity reside in countries like Nigeria where the rural populace is mostly affected [5]. Nigeria is ranked seventh in world population and cannot provide electricity access to her populace both in the urban and rural areas [6, 7]. Nigeria's rural population is estimated to be about 42 % of the total population [8]. Over 60 % of the Nigerian population does not have power supply, with 40 % not on the nation's grid [9, 10]. The Nigerian grid supply of electricity is on average six hours per day rationed among inhabitants of the cities [11]. Almost all rural dwellers in Nigeria have little or no access to electricity. The majority of the electricity supply in Nigeria is generated by Kainji dam which produces about 3.2×10^8 W and 9.6×10^8 W at its peak [12, 13]. This is due to underperforming hydro dams in the country. Another factor is the high cost of distribution across the country which covers an area of 924 000 km^2 [14]. There is no uniformity in distribution of grid connection and electricity in Nigeria. About 61.2 % of households in Lagos in South-West are without access to electricity. The figure is different in Taraba in North-East where 81.3 % lack access to electricity [15]. Similarly, South-South have 61.2 % and South-East has 60 %. About 38.1 % of the rural population, 12.1% of the rural poor and 29.8% of the urban poor in Nigeria have access to electricity [16].

Erratic power supply has caused many of the inhabitants and companies in Nigeria to generate their own power. Nigeria has about 32 outages in a month with over 35 hours' outage of electricity supply [17]. Figure 1 shows the electrical outages per month and average duration in Africa [18]. Erratic supply is due to high energy losses caused by physical deterioration of the facilities for transmission and distribution, and theft of power equipment. Other causes are vandalism, the high cost of electricity production, insufficient metering system and ease of by-passing of the metering system by the consumers, poor billing system and low available capacity (only 40 % of the installed capacity of 6 000 MW) [19].

Individuals have resorted to using generators powered by petroleum fuel or diesel. This accounts for the increase in the price of petroleum products price by 70 % in 2012 [20]. The cost of generators has risen on a regular basis from 5.8 % in 2007 to 7.6 % in 2009 [21]. Generators also increase environmental pollution [22]. Electricity access has direct links to clean drinking water, good health and agricultural activities for rural dwellers [23, 24]. The lack of electricity has created, and is still responsible for, high levels of underdevelopment and poverty in the rural areas [25, 26]. Several studies attest to the fact that stable and affordable electricity contributes to higher levels of economic development [27-33].

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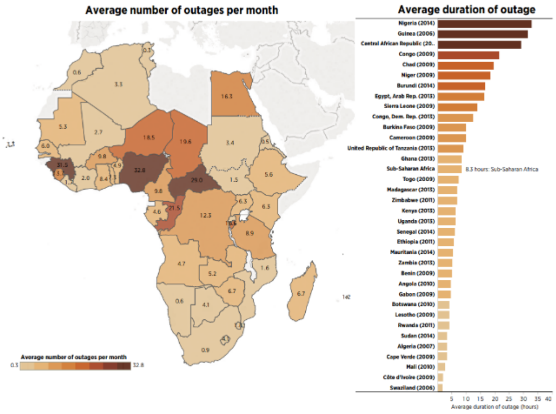

Fig. 1: Electrical outages per month and average duration in Africa [18]

Renewable energy is a tool that can end global electricity problems because supply exceeds world electricity demand [34]. It is an energy source that can be renewed indefinitely. Renewable energy sources include solar, ocean tides, geothermal, wind, hydro, and biomass [35-37]. They are used as electricity, thermal energy, fuels, mechanical force and hydrogen. These energy sources are obtained from non-fossil and non-nuclear sources [38]. They are sustainable and not harmful to the environment. Table 1 shows the vast potential of solar energy inclusion in Nigeria, shedding light on Nigeria's solar energy resources. From the data in Table 1 one can see that Nigeria only needs 0.1 % of the total solar radiation converted at 1 % efficiency to be able to meet her energy demand [39]. On average, Nigeria gets solar radiation of 20 MJ/m^2/day with minimal variation all year.

Tab. 1: Nigeria's solar energy resources [39]

Resource type	**Reserves**		**Production**	**Domestic utilization**
Natural units	**Energy units**	**Energy units (BTOE)**		
Solar Radiation	3.5 KWh/m^2/day to 7.0 KWh/m^2/day (4.2 million MWh/day using 0.1% Nigeria land area)	5.2 (40 years and 0.1% Nigeria land area)	Approximately 6 MWh/day solar Photovoltaic	Approximately 6 MWh/day solar Photovoltaic

Power generation involves the conversion of energy from an available source (sun in this case) to electrical energy in a form that is suitable for distribution, consumption and storage [40]. Solar PV is capable of powering off-grid single homes, and mini-grids incorporating from several kW to many MW [18]. Power generation using solar energy can be done in two ways, namely, solar-thermal conversion [41] and solar electric (photovoltaic) conversion [42]. Solar energy is one of the renewable energy endowments of Nigeria [43]. It can be used for powering remote villages disconnected from the nation's grid and its power can also be fed into the national grid [44]. Solar energy is used in rural clinics, powering of schools, vaccine refrigeration, street lighting, traffic lights, kiosks, among others. Solar technology is gradually being implemented in Nigeria. It is already implemented for solar crop drying, solar incubators, solar chick brooding, solar evaporative cooling and so on.

Renewable energy is capable of solving Nigeria's energy challenges [45, 46]. Several studies have looked at the viability and challenges of implementing solar energy in Nigeria. Chilakpu [47] examined renewable energy sources benefits, potentials and challenges in Nigeria. The study stated that renewable energy improves the security of a country, and reduces greenhouse gases. The study aligned with Körbitz [48] in stating that renewable energy reduces greenhouse gases by at least 3.2 kg carbon dioxide equivalents per one kilogram of biodiesel. The study observed that the challenges working against the full-scale implementation of solar energy in Nigeria include available technology, the political climate, and the weather conditions of the country. Körbitz study dwells most on hydropower and fails to shed light on other renewable energy sources, especially solar energy. Olaoye et al. [49] studied the energy crisis in Nigeria and suggested a renewable energy mix as a solution. Attention was given to the installed capacity and licensing of on-grid power generation companies. The study provided two tables which summarized the renewable energy potential of Nigeria. The data provided is limited to the capacity of solar PV panels in Nigeria. Ajayi and Ajanaku [50] examined the energy challenge and power development in Nigeria and proposed a way forward. The study suggested that 80 % of hydropower in the country is untapped, and 5.5 KW-hr/m^2/day of solar radiation is not being utilized as well as unexploited wind energy resources and the gases being flared. The study believes that utilizing these resources will put an end to the energy challenge of Nigeria. Akinboro et al. [51] studied solar energy installations in Nigeria in terms of their prospects, problems and solutions. The study set out to study the use of solar energy as an alternative energy source in Nigeria. Emphasis was on stand-alone and hybrid installations and the problems encountered during domestic and industrial solar installation. In the end, the study was only able to enumerate the challenges confronting the implementation of solar energy, its prospects and possible solutions. However, the study shed light on waste generated from gas turbines, diesel plants, solar plants, biogas plants, nuclear and small hydropower plants. There was no mention of solar installations as stated in the beginning of the study. Ezugwu [52] discussed renewable energy in Nigeria with a focus on their sources, problems and prospects. The study was able to theoretically discuss the key renewable energy sources but lacked relevant data regarding Nigeria. Emodi and Yusuf [53] discussed the need for standardization of renewable energy technologies in Nigeria. They opined that renewable energy technologies are imported into Nigeria and there are no existing local standards. The study recommended standardization as a solution to check the influx of renewable energy technologies into Nigeria. Ikem et al. [54] studied integration of renewable energy sources into the Nigerian national grid as being a way out of the power crisis. It suggested a way forward for Nigeria's government to improve the current power supply of the country by investing in renewable energy. The study encouraged the government to review the power sector. Ozoegwu et al. [43] studied the status of solar energy integration and policy in Nigeria. It did a good job in reviewing the past, the current and future status of solar integration in Nigeria. It was able to combine several data related to solar energy in Nigeria. This provided a firm basis for the case of giving solar energy a high priority in mitigating the energy problem of Nigeria. Table 2 grouped the different categories of solar PV applications under different headings.

Tab. 2: Categories of Solar PV applications (adapted from [18])

Item	**Stand-alone**			**Grids**		
	DC		**AC**	**AC/DC**		**AC**
System	Solar lighting Solar kits or system lanterns	DC	AC solar system: single-facility AC systems	Nano-grid grid Pico-grid grid	Micro- Mini-	National/regional grid
Application	**Off-grid**			**Off-grid or on-grid**		**On-grid**
	Lighting	Lighting and appliances	Lighting and appliances	Lighting and appliances, emergency power	All uses (including industrial)	All uses (including industrial)
Key component	Generation, storage, lighting, phone charger	Generation, storage, DC special appliances	Generation, storage, lighting, AC appliances, building wiring	Generation plus single phase distribution	Generation plus three phase distribution	Generation plus three-phase distribution plus transmission

Typical size	0.10 W	11 W to 5 kW	100 W to < 5 kW	5 kW to 1 MW	Residential (100 W to < 5 kW) Mini grid (5 kW to < 1 MW) and Utility scale (> 1 MW)

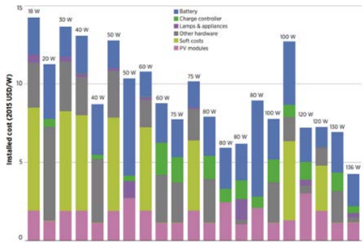

Fig. 2: Small solar system (<1 kW) cost breakdown by cost component, 2012-2015 [18]

Figure 2 presents the cost breakdown for sub-1 kW where the data are available. Battery costs account for the largest single share of these Small Household Solar Supply (SHS), with a simple average of 29 % of the total costs (USD 2.7 /W). The PV modules themselves, as well as the lighting fixtures and wiring, average around 20 % (USD 2.2 /W) of the total installed costs together, soft costs 22% (USD 2/W), other hardware 21% (USD 2 /W) and the charge controller 7% (USD 0.7/W).

Several researchers have proposed various ways in which the technology of solar can be used in Nigeria. This includes but is not limited to the following: Cota et al. [55] proposed the use of solar energy for street lighting and water pumping in the rural community of Igbelaba and Jigawa state. Kumar et al. [56] presented suggestion for replacing the usage of fossil fuel energy with solar energy for street lighting of Fugar city in Edo state of Nigeria. Ike Chinelo et al. [57] suggested the use of solar to power security lights in school hostels in Nigeria.

1.1 Data on solar energy capacity in Nigeria

The industry capacity of solar energy was a total of 33 active companies by 1999. There are no vendors or contractors for the supply and installation of solar equipment. Nigeria cannot boast of a company that manufactures the major components of solar systems, not even the basic solar cells [58]. However, NASENI assembles PV panels in Karachi, close to Abuja. Nevertheless, the country can boast about 200 installed solar PV installations with a capacity of about 3.5 kW to 7.2 kW [59]. This is insignificant when compared with the population of Nigeria and installed capacity in other Africa countries like South Africa. Figure 3 provides a vivid picture of installed solar PV capacity in watts per capita in Africa in 2015.

A survey was conducted in the northern part of Nigeria to show the application distribution [58]. It shows that domestic water pumping accounts for 57%, domestic lighting and rural for 8%, experimental room air conditioning for 1%, rural clinic refrigeration of clinic items like vaccines and lighting of the clinic and surrounding for 24%, and communications (TV and radio) for 10% (see Table 3).

In terms of installed PV in regions of Nigeria, Lagos has the highest with 23.6% closely followed by Yobe state with 16.3%. Kano and Akwa Ibom have 8.6%. The funding of such installations is principally by the federal government, state, local government, and international donors like the European union, Mobil and in some states like Lagos by private individuals. There are about one or two PV installations working or moribund in the 26 states out of the 36 states in Nigeria including the capital Abuja [59].

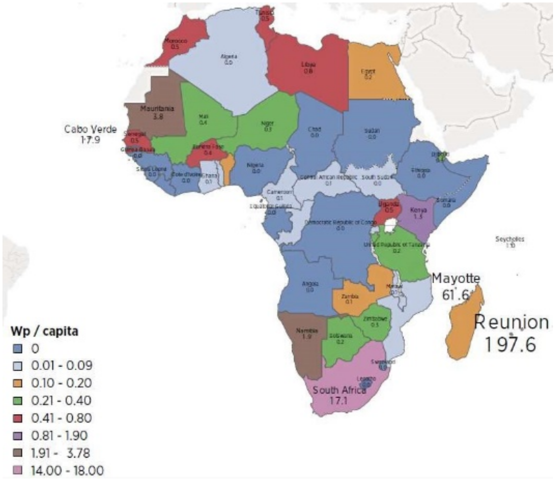

Fig. 3: Map of installed solar PV capacity in watts per capita, 2015

Tab. 3: Installed capacity of PV technology in Nigeria [59]

S/N	APPLICATIONS	PV CAPACITY (%)
1.	Residential (mostly lighting)	6.9
2.	Rural electrification and Television	3.9
3.	Commercial lighting and equipment	3.1
4.	Street, Billboard and other lighting	1.2
5.	**All lighting**	15.1
6.	Industrial	0.4
7.	Health center/clinic	8.7
8.	Telecom and radio	23.6
9.	Water pumping	52.2
	Total	**100**

2. Solar Project initiative in Nigeria

Some striking projects on solar energy have been executed in Nigeria. The Jigawa state government embarked on a project of rural electrification of the state [60]. This was funded 60 % by the United States government through USAID and department of Energy (DOE) and 40 % by the Jigawa state government. This project demonstrated inclusive solar usage for electricity generation in rural communities. The project targeted water supply, education, health, agriculture, security, opportunities for trade and commerce [61]. Several PV water pumping, electrification, and solar thermal installations have been executed by Sokoto Energy Research Center (SERC) and the National Center for Energy Research and Development (NCERD) under the supervision of the Energy Commission of Nigeria (ECN) [62]. A breakdown of the pilot projects by ECN include the 7.2 kWp solar-PV village electrification in Kwalkwalawa in Sokoto state, 1.87 kWp village electrification and TV viewing centre in Iheakpu, 1.5 kWp water pumping scheme in Nangere, Sokoto state. Solar dryer projects in Nigeria include: 2-tonnes solar rice dryer in Adani, Enugu state and 1.5 tonnes solar forage dryer in Yauri, Kebbi state.

The World Solar Programme designed for promotion of solar energy penetration worldwide has also provided about five high priority projects in Nigeria. They are; (i) the solar village; (ii) the upgrading of facilities and personnel of renewable energy R & D establishments, and development of renewable energy curricula; (iii) training workshops and colleges in renewable energy technologies (solar-PV and solar-thermal); (iv) Rural health delivery and potable water supply using solar-PV; and (v) International Solar Energy Institute. The projects are threatened by inadequate funding. As a result, only projects (i) and (iv) have made significant progress.

2.1 Solar energy capacity development in Nigeria

The federal government of Nigeria has mandated the ECN with the responsibility to carry out research and development of the nation's energy needs. ECN has two centers dedicated to renewable energy spread evenly in the north and south of the country, namely, the National Centre for Energy Research and Development (NCERD) at Nsukka, in the south of Nigeria, and the Sokoto Energy Research centre (SERC) in Sokoto state, in the north of Nigeria. Apart from the research and development mandate of the centres, they are also responsible for personnel development, dissemination and promotion of renewable and alternative energy technologies. The other government agencies that have renewable energy components in their mandates are: Federal Department of Meteorological Services (FDMS), Power Holding Corporation of Nigeria (PHCN). Others are Project Development Institute (PRODA) Enugu, Nigerian Building and Road Research Institute (NBRRI), Federal and state owned Universities and Polytechnics, and the Federal Institute of Industrial Research, Oshodi (FIIRO), National Centre for Energy Research and Development (NCERD), Nsukka, Centre for Energy Research and Training (CERT), located in Ahmadu Bello University, Zaria, Centre for Energy Research and Development (CERD), located in Obafemi Awolowo University, Ile-Ife.

Some successes have been achieved in solar energy technology development in the country. These include, but are not limited to, solar crop dryers of various capacities. Worthy of note is the 2-tonne capacity rice dryer developed at the NCERD and a 2-tonne capacity forage dryer constructed by the SERC. Also, a solar manure dryer for poultry waste developed by NCERD, Nsukka. The dryer was able to reduce moisture content of manure from 71 % to 35 % in 22 hours of peak solar intensity of 600 W/m^2. Flat and concentrated solar cookers have been constructed and tested at NCERD and SERC. The flat plate cooker attained a record cooking time of 4.5 minutes at solar intensities of 850 W/m^2. Solar water heaters comprising horizontal and vertical tanks with natural circulation have also been constructed and are available at Usman Danfodiyo University, Sokoto, and solar chick brooders at NCERD, Nsukka.

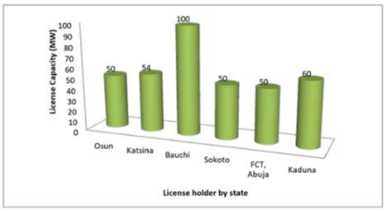

Fig. 4: Nigerian Electricity Regulatory Commission licensed solar power projects in Nigeria

Licenses for solar energy projects in the country have been awarded by the Nigerian Electricity Regulatory Commission as shown in Figure 4. As at 2014, seven companies have been awarded licenses in different states of Nigeria. Bauchi has the highest capacity with 100 MW awarded to Nigeria Solar Capital Partners. Kaduna have two licenses awarded to Quaint Global Nigeria Ltd and Anjeed Kafanchan Solar Ltd with a capacity of 50 MW and 10 MW respectively. Others are Lloyd and Baxter LP in Abuja, KVK Power Pyt Limited in Sokoto state, Pan African Solar in Katsina and Rock Solar Investment Company in Osun state. Due to fluctuation in generation capacity caused by water shortages in the dry season, Shiroro Hydroelectric Power Station in Niger State of Nigeria plans to construct a 300 MW PV solar power plant.

Some memorandums of understanding have been signed for solar projects in Nigeria. New Horizon Energy Resources proposed the building of a 100 MW solar plant in Nasarawa. Delta state government signed an MoU with Yutal Li Ltd for a 100 MW solar power plant in 2016 in addition to a 300 MW power plant signed for in 2014 with SkyPower FAS Energy. The federal government of Nigeria also signed a 300 MW solar power with Super Solar.

2.1.1 Solar cell fabrication and research in Nigeria

Limited work has been done on materials for solar cell fabrication and thin film growth in Nigeria at Obafemi Awolowo University (OAU, Ile Ife) and NCERD, Nsukka respectively and in some laboratories in the country.

Soboyejo and Kana have led some research studies at Africa University of Science and Technology (AUST, Abuja) and Sheda Science and Technology Complex (SHESTCO, Sheda), on organic solar cell materials fabrication. Fabian Ezema has worked extensively on Chemical Bath Deposition (CBD) for solar cell deposition at the University of Nigeria, Nsukka. The National Agency for Science and Engineering Infrastructure (NASENI) is also worthy of mention in terms of solar cells research and development and solar panels. NASENI, in Nigeria is leading the effort to make solar panels available at a reduced cost. It has a dedicated solar panel assembly plant in Karachi, Nigeria. Most of the solar PV studies conducted in Nigeria are on solar PV components and system testing, pilot plants and other application projects. The KwalkwalaWa 7.2 kW village electrification in Sokoto state is the largest single pilot plant established by the Energy Commission. It is used for pumping water, powering health centres and rural lighting and entertainment. Other developments include solar air heaters, solar stills for water purification, solar absorption and absorption refrigerators.

2.1.2 Solar data collection in Nigeria

Efforts are being intensified in solar energy data collection in Nigeria. Data such as solar radiation intensities (such as global, direct and diffuse), relative humidity, precipitation and ambient temperatures have been collected for over 64 towns by the Meteorological Services Department. About 33 % of these stations have been in existence for over 50 years. About twelve research institutes and centres located in and outside universities in the country are also involved in solar data collection and analysis. The Energy Commission is currently developing an Energy Data Bank for renewable energy data.

3. Existing government policies and legislation

A National Energy Policy was developed in 2003 by the Nigerian government, primarily for efficient management of the country’s energy resources. It focuses on conventional and renewable energy sources for sustainable development of the country with full private sector participation.

The policy is summarized as; extensive crude oil and natural gas exploration and development shall be pursued with the view to increasing their reserves base to the highest level possible. Lastly, the nation shall continue to engage extensively in the development of electric power with the view to making reliable electricity available to 75 % of the population by 2020; as well as to broaden the energy options for generating electricity.

The Nigerian Electricity Regulatory Commission and the Rural Electrification Agency were established in 2005 with in order to liberate the electricity sector. The Nigeria Renewable Energy Master Plan (REMP) is a policy aimed at making electricity more available through renewable energy. It envisions renewable energy providing a minimum of 10 % of total energy consumption in Nigeria by 2025 [63]. It was produced in 2006 with United Nations Development Programme support, and outlined the road map for more renewable energy usage in Nigeria’s quest to meet her energy demands and improve grid reliability and security [64]. The policy hopes to meet this goal by providing an enabling platform for renewable energy, legal instruments, technical-know-how, manpower, infrastructure and the markets.

The objectives are; expanding access to energy services and raising the standard of living, especially in the rural areas; Stimulating economic growth, employment and empowerment; Increasing the scope and quality of rural services, including schools, health services, water supply, information, entertainment and stemming the migration to urban areas; Reducing environmental degradation and health risks, particularly to vulnerable groups such as women and children; Improving learning, capacity-building, research and development on various renewable energy technologies in the country; and Providing a road map for achieving a substantial share of the national energy supply mix through renewable energy.

4. Challenges

The high cost of implementation of renewable energy technologies, particularly solar, is the major impediment militating against their widespread use [65]. High cost is not unconnected to the fact that nearly all the parts are imported from overseas at a very high cost. Most of the personnel and technologies are sourced abroad [58]. The key challenges facing the successful deployment of solar energy technologies can be grouped into cost, policy, technical, people and environment. Some of the key challenges of solar energy in Nigeria are discussed below. Firstly,cost plays a major role in the life of people and the success or failure of a technology. Nigeria is a developing country home to both rich and poor, living in rural and urban areas. Initial investment in the cost of solar energy infrastructure is one of those factors militating against penetration of solar energy in Nigeria. The lack of adequate funding for solar energy development poses a high risk to the success of solar energy in Nigeria. Also, the general absence of comprehensive national energy policy. Nigeria has never formulated a comprehensive energy policy; only sub-sectoral policies have been formulated. Since such a policy is pivotal to using energy efficiently and solar energy, the lack of such a policy has, to a large extent, contributed to the lack of attention to solar energy. Thirdly, lack of technological capability is an issue in penetration of solar energy in Nigeria. The bulk of the technologies for solar energy are imported thereby increasing the high investment cost of solar energy. Cultural and low level of public awareness is also another challenge. The cultural inclination in some parts of Nigeria coupled with public awareness of renewable energy sources and technologies in Nigeria and their benefits, both economically and environmentally, are generally low. Consequently, the public is not well-equipped to influence the government to begin to take more decisive initiatives in enhancing the development, application, dissemination and diffusion of renewable energy resources and technologies in the national energy market.

5. Prospects for solar energy in Nigeria

Geographically, Nigeria lies within a high sunshine belt on longitude 3º and 14º East of Greenwich and latitude 4º and 14° north of equator [66] and thus has enormous solar energy potential [67]. The country has an annual average daily solar radiation of about 5.535 KW/m^2 /day [68]. The minimum average is about 3.55 kW/m^2/day in Katsina in January. It is 3.4 kW/m^2/day for Calabar in August. And the maximum average is 8.0 kW/m^2/day for Nguru in May [69]. This puts the solar radiation figure at an average of 19.8 MJ/m^2/day and is fairly distributed.

The country's annual average daily sunshine is 6.25 hours per day, the coastal areas are 3.5 hours and 9.0 hours at the far northern boundary [70]. Nigeria receives about 4.851×10^{12} KWh of energy per day from the sun [71]. This is equivalent to about 1.082 million tons of oil equivalent (mtoe) per day, and is about 4 000 times the current daily crude oil reduction, and about 13 000 times that of natural gas daily production based on energy units. This huge energy resource from the sun is available for only about 26 % of the day. This data couple with the prevailing efficiencies of commercial solar-electric generators and if solar collectors or modules were used to cover 1% of Nigeria's land area of 923 773km^2, it is possible to generate 1.804×10^{15} kWh of solar electricity per year. This is over one hundred times the current grid electricity consumption level in the country [72]. The annual solar energy insolation is 27 times the nation total conventional energy resources in energy units. This is over 117 000 of the electric power generated in 1998 in Nigeria [40]. Only about 3.7 % of Nigeria's land area is required for solar energy to meet the electricity demand of the country.

5.1 Future prospects

Though the bulk of the prospects for solar energy in Nigeria are in the off-grid areas and rural electrification, some areas on the grid and in urban areas also hold some prospects. Areas that provide opportunities for application include, but are not limited to: power plants, non-thermal electricity generation, large scale and family scale cooking, heating, drying of farm produce, water purification, clean water provision for humans and animals, aerospace development of the country, provision of light arms and ammunition for the Nigeria Army especially as they combat Boko haram terrorism and militants in the Niger Delta of the country. The future prospects of solar PV are shown in Figures 5 and 6.

The major focus on renewable energy in Nigeria is on transportation and electricity generation. Electricity generation from renewable energy in Nigeria is estimated to be 9.74 % for 2015, 18 % for 2020 and 20 % for 2030. However, electricity generation using solar is projected to be 1.26 % for 2015, 6.92 % for 2020 and 15.27 % for 2030. The targets of renewable electricity from solar alone is projected to be 12.96 %, 38.43 % and 76.36 % for these years. This shows that solar progressively dominates in the long-term. Figure 6 shows the targets for solar PV application in Nigeria for year 2020 and 2030.

Figure 6 shows the targets for solar thermal energy application in Nigeria for year 2015, 2020 and 2030. This is too dismal to be commended even in the long-term.

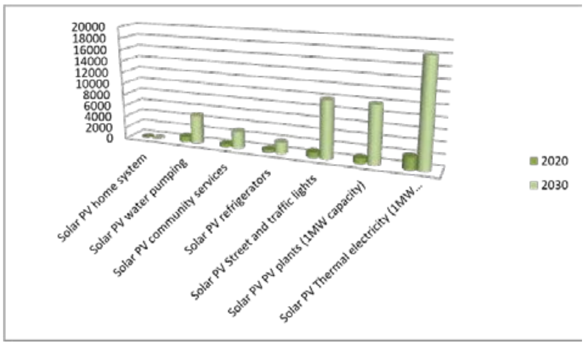

Fig. 5: Solar PV application in Nigeria for year 2020 and 2030

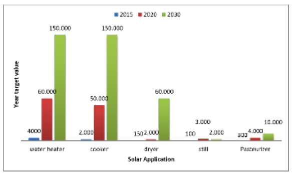

Fig. 6: Targets for solar thermal energy application in Nigeria for year 2015, 2020 and 2030

For example, consider the targets for solar cookers. Suppose each solar cooker is constructed to cook for five people as proposed by Saxena et al. [73]. With a population growth rate of 3.2 % per annum, the population in 2015, 2020 and 2030 population becomes 186 458 723, 218 263 539 and 299 073 660 respectively. The penetration level which represent the percentage of the population supplied with solar cooking energy becomes 0.0054 %, 0.1145 % and 0.2508 % respectively. Although this figure indicates a rising trend into the future, the penetration level is minor and does not reflect the energy crisis in Nigeria. This is because in 2014 about 80 % of the population were exposed to health issues. Many of these health issues arose from the heating and cooking used in the rural setting, using mainly biomass and waste resources. The maintenance-free and cheap nature of solar box cookers makes them well suited to developing countries.

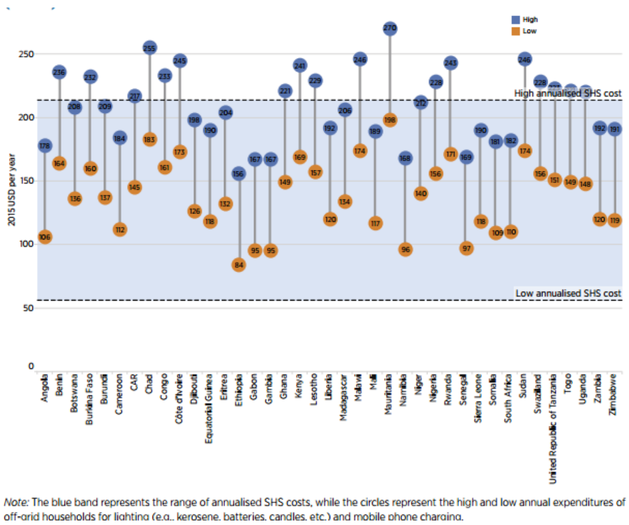

Fig. 2: Africa annual off-grid household expenditure on lighting and mobile phone charging compared to solar home system (< 1 kW) annualized costs, by country in 2015 [18]

Figure 8 gives the annual expenditure for off-grid lighting and mobile phone charging in Africa in 2015. The blue band represents the range of annualized solar system costs. Circles represent the high and low annual expenditures of off-grid households for lighting (e.g., kerosene, batteries, candles, etc.) and mobile phone charging. Expenditure in Nigeria is USD 140 per year. The lowest expenditure in Africa is in Ethiopia (USD 84) and the highest is

Mauritania (USD 270). Therefore, solar systems can be a very economical solution for powering homes in Africa

6. Conclusion

Nigeria has the capacity to use solar energy to end the problem of an erratic power supply facing her. This work has been able to shed light on solar energy domestication in Nigeria, reviewing work that has been done relating to solar energy in Nigeria, and the prospects and challenges of the technology. A lot of brilliant studies have been conducted. Well-articulated policies have been made and signed with memorandums of understanding on the part of the government but well monitored implementation seems to be an issue working against the full success story of solar energy utilization in Nigeria. Research into in-country fabrication of solar cells, thin films and solar panels is highly recommended for both public and private partnership in Nigeria. The windows of opportunities for solar energy inclusion in Nigeria are enormous. These are: solar power generation, increased internally generated revenue through manufacture of solar panels, capacity building in the field of solar energy technologies, supply of renewable energy equipment and accessories, and contracts in solar energy projects. The rest of Africa can benefit from the success story of Nigeria if well implemented.

7. Recommendation

More education should be conducted to sensitize the populace on the benefits of solar energy and the government should encourage more research on solar energy, especially the setting up of and/or funding of solar cells research centres.

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