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A review of renewable energy potential in Nigeria; solar power development over the years

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Abstract

Nigeria is one of most populated countries in the world. With a population of about 170 million people, the nation is enriched with diverse renewable and non-renewable energy sources. Despite this huge energy potential, only about 50% of her population have access to electricity. The main objective of this review is to present and analyze the renewable energy potentials of Nigeria with special attention and consideration to the past, present and future of solar energy development. The country aims to achieve electricity production of 9.74%, 18% and 20% of her electricity from renewables by 2015, 2020 and 2030, respectively. Solar energy is expected to produce 1.26%, 6.92% and 15.27% of the electricity consumed by 2015, 2020 and 2030, respectively. If these targets are met, the proportion of the population with access to electricity will increase drastically. Data collected from various reputable energy sources and Journals are reviewed. Nigeria has renewable energy resources including biomass, wind, hydropower and solar energy. These resources can sufficiently meet the country's energy demands, but statistics show that Nigeria still lacks adequate supplies to meet her electricity demands. The policies put in place to meet her energy targets and the current status of the country's supply and demand for electricity are discussed in detail.

Keywords: Electricity production, Solar chimney, Optimization, Wind turbine, Renewable energy systems

1. Introduction

The use of electricity generated from fossil fuels has made the earth (partially) dependent on these resources. Unlike the 18th and early 19th century, when electricity was used primarily for lighting, it is almost impossible to live a healthy life in the present global community without electricity. According to world energy council, almost half of world's population are without access to electricity, with the majority of these people living in Africa and some Asian countries [1]. Energy has become an indispensable commodity in the 21th century as the wealth of nations is now directly/indirectly related to their country's energy stability, security, and policies. World energy consumption has increased from about 9,000 Mtoe to 13,000 Mtoe within the last 15 years (Figure 1). Also, global electrical consumption (from fossil fuels) has increased from about 13 TWh in 2000 to about 21 TWh in 2015 (Figure 2) [2]. According to the REN21 2016 report, 78.3% of the global energy consumption is still produced from fossil fuels, while renewables and nuclear energy account for 19.2% and 2.5%, respectively [3].

The threat posed by greenhouse gases to the climate and the world is a major disadvantage of using fossil fuels. Fossil fuels face depletion by the year 2060 if the increase in consumption continues at its current rate [4]. This factor should also be considered. About 160,000 people died in 2010 as a (direct/indirect) result of climate change [5]. CO_2 emissions have increased from about 20,000 $MtCO_2$ in 1990 to 32,000 $MtCO_2$ in 2015, although there was a 0.4% drop in CO_2 emissions in China in 2015 (Figure 3). From Figures 1-3, it is clear that the region with the highest energy/fossil fuel consumption also has the greatest amount of CO_2 emissions. This confirms that CO_2 emissions are a function of the fossil fuels burnt in a particular region.

The strength and the future of a country's energy sector is a function of it past, present, and future energy policies. Energy policies are usually established and integrated as a framework. This framework is used to manage social, economic and environment challenges faced as they are related to energy production/consumption [6]. This policy framework consists of various targeted outcomes that could include any of the following:

a. Cleaner energy.
b. Smarter use of energy.
c. Secure and affordable energy.
d. Growth of the economy resulting from use of renewable energy.

In a bid to reduce the world carbon emission levels, the use of renewable energy has been widely encouraged. Solar energy comes from sunlight and it has served as a common replacement to electricity and heating. Efficient solar

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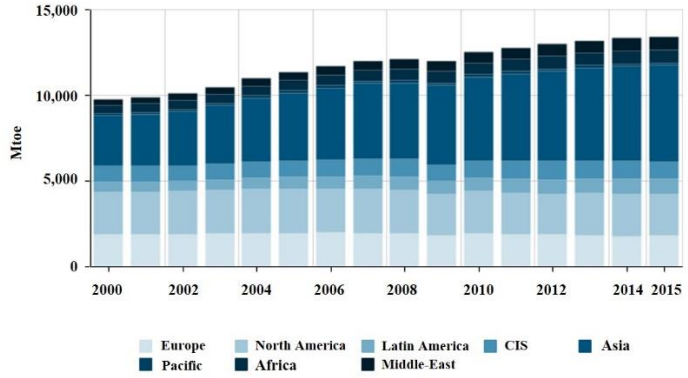


Figure 1 Global energy consumption from 2000 to 2015 [2]

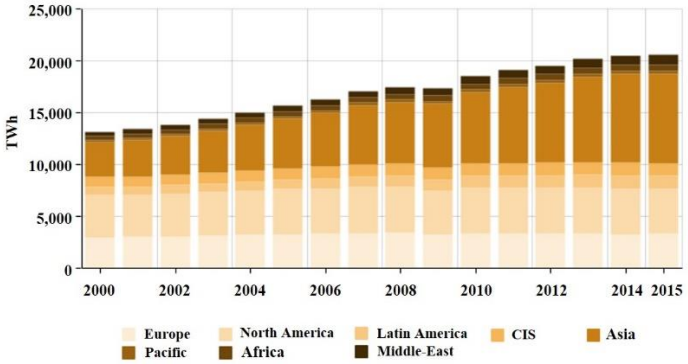


Figure 2 Global fossil fuel consumption from 2000 to 2015 [2]

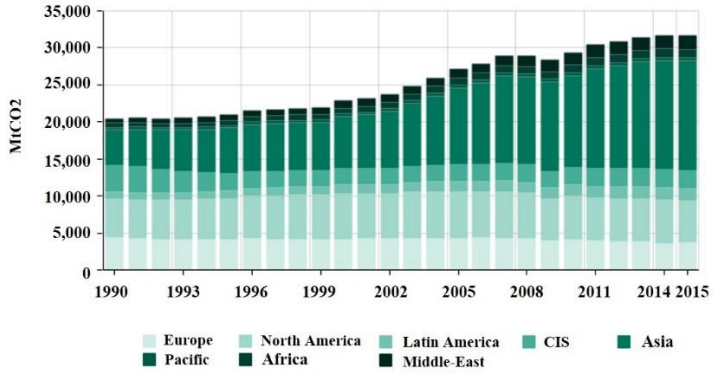


Figure 3 Global CO_2 emission from 1990 to 2015 [2]

policies can improve energy efficiency within a country when implemented, reduce oil imports and improve the reliability of a country's electric grid. It also saves consumers money, reduces air pollution caused by the release of carbon gases, creates jobs, and reduces energy prices. In the past, various countries implemented different solar energy policies in a bid to encourage the use of renewable energy to replace fossil fuels. The USA is a top ranked country in the world in the use of renewable energy. It generates 10% of its total energy from renewable energies [7-8]. According to 2014 global report on renewable energy, the USA is ranked second in CSP (concentrated solar power) installed capacity with a current installation of 0.9 GW. It is also the 5th ranked solar photovoltaic user in the world with a capacity of over 11 GW currently installed [9]. Nigeria is a developing country with a high solar energy potential [10], but its potential is underutilized. This paper reviews the solar energy policies in Nigeria, the impact of these policies on the development of solar energy/renewable energy at large.

Nigeria has vast renewable and non-renewable energy resources. Nigeria dropped to 104th position in 2016 from 101th position in 2015 in world energy council's Energy Trilemma index ranking [1]. The country is currently ranked 8th in global energy security but poor performance in energy diversification and environmental sustainability drops its overall global energy rank. 80% of the power produced in the country is from gas-fired power plants with hydro-power accounting for just 14% of electrical production. Nigeria is one of the largest oil producers in the world and the solar irradiation in this country is highly remarkable. With all these resources, only 48% of the Nigerian population has access to electricity [11].

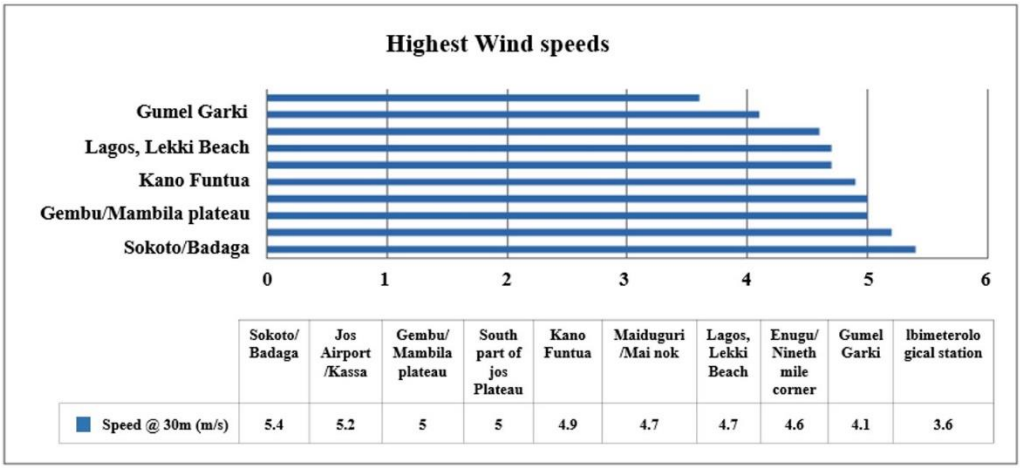
Hence, reviewing the renewable energy resources in a country like Nigeria is worth studying. The aim of this paper is to assess the renewable energy potential in Nigeria and the development of such resources. Our objective is to use previous literature to determine the level of development of renewable energy resources. Although Nigeria has diverse renewable energy resources, this study focuses on solar energy.

2. Renewable energy potential in Nigeria

Renewable energy potentials are quite high in Nigeria and this could reduce the energy gaps between the rural and urban areas in the country, especially in the north [12]. Nigeria has renewable energy resources such as biomass, wind, hydropower and solar energy [13-14]. Being mindful of climate change, the impending scarcity of fossil fuels and the need to develop a more sustainable environment, use of renewable energy has increased in many countries [13]. Most of the biomass potential in Nigeria is in the form of fuel wood, biogas and biocrops. About 90% of the energy consumed by rural people is from biomass [15-16].

2.1 Wind energy potential

Although wind energy is not in use for commercial electricity production in Nigeria, the passion to seek a lasting solution to the poor energy/power situation in the country prompted some research into Nigeria's wind energy potential [17-18]. The wind study in Umidike (South-Eastern Nigeria) assessed its economic viability. The area has a mean wind speed of 5.36 m/s according to data collected from 1994-2003 [19]. Fadare [20] found that the renewable energy potential in Ibadan (an ancient city in Southwestern Nigeria) had a mean wind speed of 2.947m/s and a solar power density of 15.484 W/m^2 [17]. The prospect of wind power has been researched in many locations in Nigeria. Regions with high wind speeds are shown in Figure 4.



	Sokoto/ Badaga	Jos Airport /Kassa	Gembu/ Mambila plateau	South part of jos Plateau	Kano Funtua	Maiduguri /Mai nok	Lagos, Lekki Beach	Enugu/ Nineth mile corner	Gumel Garki	Ibimeterological station
Speed @ 30m (m/s)	5.4	5.2	5	5	4.9	4.7	4.7	4.6	4.1	3.6

Figure 4 Summary of the high wind speed regions in Nigeria [17]

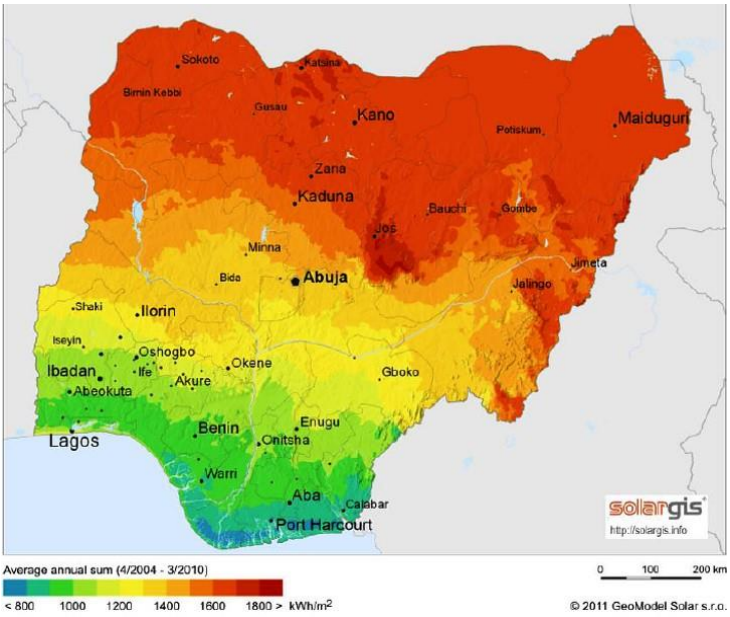


Figure 5 Nigeria's average sun hours' map

Figure 6 The Niger River region [17]

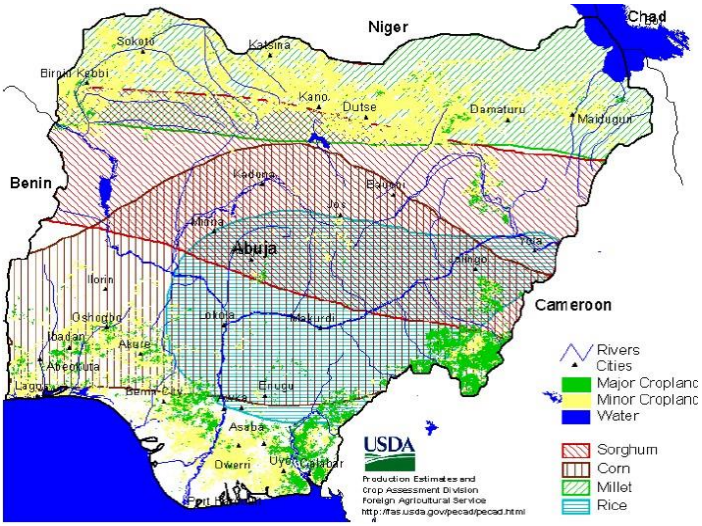


Figure 7 Nigeria's Crop Zones [17]

2.2 Solar energy potential

One of the greatest assets with respect to solar energy development in Nigeria is its geographical location (in the equatorial region). The distribution of solar energy available in Nigeria is fair with the northern part having a larger share. The average solar radiation value of the country is about 19.8 MJ/m^2 with a mean sunshine of 6 hours per day. This sunshine hours ranges from 9 hours in the far north to 3.5 hours in the coastal region [17] and [21]. The solar potential in Nigeria is enormous because of its location in the high sunshine belt (Figure 5). According to a Global Energy Network Institute report, "If solar collectors/modules were used to cover 1% of Nigeria's land area, it would be possible to generate 1850 ×103 GWh of solar electricity per year. This is over a 100 times the current grid electricity consumption level in the country". From the solar radiation map of Nigeria (Figure 5), it can be deduced that the solar capacity for Nigeria ranges between 3.5 – 7.0 kW/m^2/day and average daily sunshine of 4-7 hours [17].

All solar energy technologies are usable in Nigeria in different locations. Olusola [14] suggested that solar chimneys can be used in the desert prune regions for power generation in rural villages now without access to electricity. Shaban and Petinrin [13] also discussed how solar energy and other renewable energy sources in Nigeria can be used to meet rural needs.

2.3 Hydropower potential

Hydro energy is the only renewable energy currently used commercially for power generation in Nigeria. There are only two hydropower plants currently operating, the Shiroro and Kainji/Jebba plants. They produce for 13% of the country's power. Hydropower, although currently a major source of electricity generation in Nigeria, can play a larger role in the generation and supply of electricity [17]. Nigeria is endowed with large waterfalls, rivers and dams [13]. These can support hydropower plants. Artificial dams and hydropower sources can be built due to the large amount of water in some areas in Nigeria. The high hydropower potential in Nigeria is appreciable with an exploitable capacity of 18,600 MW. Unfortunately, only 19% of this capacity is currently used [22]. The flow of the Niger River (Figure 6) contributes to the high hydropower potential in Nigeria.

2.4 Biomass potential

Biomass is the largest renewable energy source used (actively or passively) in Nigeria. This country is very rich in biomass resources such as forage grasses and shrubs, wood, forest wastes, municipal and industrial wastes, agricultural waste and aquatic biomass. Figure 7 shows Nigeria's crop zone. All regions are major producers of one economic crop or another. Nigeria's biomass is estimated to

contain 8 x 10^2 MJ with 80 million m^3 worth of firewood used annually for cooking and other domestic purposes [13]. About 6 x 10^8 MJ is produced from firewood. About 95% of the firewood in Nigeria is used for domestic cooking, industrial activities such as baking bread, cassava processing, oil seed processing and for cottage industries. In 1973, the available biomass energy in Nigeria was estimated to be 9.1 x 10^{12} MJ [16]. Currently, 2.18 x 10^6 MJ of energy can be obtained from dry biomass such as forage grasses and shrubs [23].

3. Solar integration past, present and future status in Nigeria

Information about Nigeria's solar energy technology, capacity and projects is lacking. This has made its solar integration status quite difficult to assess. In a recent study [22], solar integration was classified into grid connected, off-grid hybrid and stand-alone systems. The study reveals that grid connected and off-grid hybrid solar project do not exist in Nigeria. Most of the solar systems projects are either stand-alone mini-grid or off-grid power applications. No comprehensive database exists about Nigerian solar energy applications and projects. Data from various websites and other sources are difficult to harmonize [23]. Although solar thermal power plants are developing on the global scene with some countries investing in the technology due to it benefits, Nigeria has no grid connected thermal power generation system [24]. There have been no solar energy integrated grid systems in the past in Nigeria.

Discussing the current status of solar integration and development in Nigeria maybe counterproductive as the data collected in the course of this research has many discrepancies. The best and most reliable data is from the solar integration projects endorsed by Nigeria Electricity Regulatory Commission (NERC). This data is presented in Table 1 and was first published in 2014 [25]. According to the timeframe allocated to each project, some projects should have been implemented but there is no data to back this assertion.

Active solar energy applications in Nigeria are mostly not supported with any form of technology and solar science. These applications primarily include the use of solar energy for drying (preservation) purposes. The materials dried includes damp and wet items (furniture, laundry, clothings), agricultural crop residues and food crops, products of livestock husbandry and forest biomass [23].

Solar technology and scientific projects in Nigeria mostly have low-energy capacities. They include solar refrigerators, street lghtining, solar-powered water pumps and solar-powered chargers for various devices. According to the Ren 21 2015 report [26], over 100 streets in Abuja (Nigeria federal capital city) are being powered by solar streetlighting systems. Also, there are about 58 solar projects supported by the Energy Commission of Nigeria (ECN) 50 of which target rural electrification [23], [27]. According to Muhammad [28], 22 remote communities are currently enjoying solar electrification in Zamfara, Nigeria. The Rural Electrification Agency (REA) was established in 2005 to coordinate rural electrification (maintaning and harvesting rural renewables). They indicate that about 600 solar projects have been installed for Nigeria rural people, although the details of these projects are not supplied.

4. Existing Nigerian solar energy targets and policies

Nigerian solar energy targets are basically for electricity generation. Tables 2 and 3 summarize the solar targets in the electricity sectors. Nigeria aims to produce 9.74%, 18% and 20% of her consumed electricity from renewables by 2015, 2020 and 2030, respectively. Solar energy is expected to produce 1.26%, 6.92% and 15.27% of the electricity consumed in Nigeria by 2015, 2020 and 2030, respectively [23]. As of 2016, there was no data available to show that the 2015 solar energy targets were met. Over the long term, solar energy is expected to produce 76.36% of the total electricity consumed. Other targets were set for solar energy use. They are summaried in Table 3 [29].

There are three primary renewable energy policies in Nigeria. These include the Nigeria Renwable Energy Master Plan (NREMP), Nigeria Feed-in Tarriff for Renewable Energy (RNSE) and the Multi-Year Tariff Order (MYTO) [30]. According to Ozoegwu et al. [23] and REN21 2015 [26], five policies supporting renewable energy are currently in place. These policies are: (1) Reductions in

Table 1 Proposed Nigeria solar energy project details as of 2014 [26]

Licensee	Capacity (MW)	State	Geopolitical Zone
Rook Solar Investment Limited	50	Osun	South-West
Quaint Global Nigeria Limited	50	Kaduna	North-West
Nigeria Solar Capital Partners	100	Bauchi	North-East
Anjeed Kafanchan Solar Limited	10	Kaduna	North-West
Lloyd and Baxter LP	50	Abuja	North-Central
KVK Power Pvt Limited	50	Sokoto	North-West
Pan-African Solar	54	Kastina	North-West

Table 2 Nigeria solar energy electricity target summary [29]

Activity/Item	Year		
	2015	2020	2030
Solar PV home systems (SHS)	5	10	15
Solar PV water pumping	50	1,000	5,000
Solar PV community services	45	500	3,000
Solar PV refrigerator	20	500	2,000
Solar PV street and traffic lighting	100	1,000	10,000
Solar PV large-scale PV plants (1 MW capacity)	80	990	9990
Solar thermal electricity (1 MW capacity)	300	2136	18127

Table 3 Nigeria solar energy application future target summary [29]

Application	Year		
	2015	**2020**	**2030**
Solar water heaters	4,000	60,000	150,000
Solar cookers	2,000	50,000	150,000
Solar dryers	150	2,000	60,000
Solar stills	100	3,000	2,000
Solar pasteurizers	300	4,000	10,000

sales, VAT, CO_2, energy or other taxes, (2) feed-in tariff/premium payments, (3) public investments, grants or loans, (4) capital grant, subsidies or rebates, and (5) biofuels mandate/obligations.

While Ifeoluwa et al. [30] only listed the policies mentioned above, a detailed discussion was done on the five aforementioned policies by Ozoegwu et al. [23] but there were some additional policies mentioned. The disparity in the information suggests a lack of cordination in solar energy development in Nigeria. Although these policies are said to be in active use, there is little to no publicity of these policies. This has made implementation of these policies inadequate . Political instability and electricity generation problems in the country are some of the issues affecting full implementation of these policies.

5. Challenges and proposed solutions

Politics and inadequate publicity are the two major challenges working against solar energy development in Nigeria. Poor governance has led to inadequate and exiguous implementation of most of the renewable energy policies. This is evident in the misappropriation of funds released for these projects. Nigeria can learn from developed countries like Germany, Spain, the USA, and China by implementing some of the policies adopted by these countries. The government should prioritize renewable energy for power production to maximize the available energy potentials in the country. More publicity should be given to renewable energy policies in educational institutions, by policy makers, in the private sector and implementation agencies. This will increase the cognitive knowledge of Nigerians about the benefits of investing in renewable energy. It will also encourage private investors to fund small and large scale renewable power projects. The government should also start taking tangible actions to implement policies.

For Nigeria to solve its current power supply problem, renewable energy must be integrated into its electricity sector on a larger scale. Currently, the renewable energy potential in Nigeria is more than enough to meet the energy demands of all sectors. While biomass and solar energy are in passive use, resources such as wind and geothermal energy are more or less redundant in the country. Nigeria's hydroelectric power generation is commendable as 13% of the country's total electricity generation is from this source.

6. Conclusion

This study reviews the renewable energy potential in Nigeria and also gives overview information of the past, present and future of solar energy in Nigeria. Solar, biomass and hydroelectric power have the greatest potential, while wind and geothermal energy potential are only available in some parts of the country. The solar radiation distribution of the country is suitable for all solar technology applications. The lack of specific data from reliable sources made this review a Herculean task as some information had a level of disparity.

At present, there is no active commercial solar energy plants in Nigeria. Solar energy is basically deployed primordially, mostly for drying purposes. There are good targets and policies in place in Nigeria's renewable energy sector currently, but there is no data to confirm that the 2015 solar energy electricity generation target was met. Inadequate publicity given to renewable energy policies has hindered the development of solar and renewable energy technologies.

It is highly recommended that more attention be given to renewable energy development, especially solar energy. This will help solve electricity production issues in Nigeria and reduce energy poverty in the country. Renewable energy policies should be publicized all over the country and the energy literacy of the populace should be improved. Periodical review of renewable energy policies should also be encouraged to monitor the development and the implementation of these policies.

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