Chapter 12
Access and Limitations to Clean Energy Use in Nigeria

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Abstract The energy situation in Nigeria has always been a paradox. Despite having abundant energy resources in the country, widespread energy poverty is faced by the citizenry. About 60% (74 million) are not served with electricity, while another 94% (171 million) do not have access to clean energy. In a bid to cushion the effect of energy poverty, households and business enterprises in Nigerians relied on the constant use of generators, which is not eco-friendly, is costly and harmful to human health. The study adopted a think-through thematic methodological analysis, which involves the mapping of the country's potential clean energy sources. Thematic literature reviews were integrated to investigate the clean energy experience in the country. Taking into consideration the geopolitical classification of the country, interviews were conducted to examine the energy conditions in the country and the limitation to the maximization of clean energy within their locality, as well as the perception of its acceptability within the country. Study findings show that the main factors limiting the use of clean energy in Nigeria are exorbitant costs of installation and maintenance, inadequate investment in the energy sector; non- involvement of the private sector, and the subsidies granted to generators of energy from fossils.

Keywords Access · Clean energy · Rural · Urban · Local renewable resources · Electricity

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1 Background to the Study

Cities globally are experiencing rapid urbanization. It is envisaged that by the year 2050, the world population would have risen by 70%, with cities attaining sizes not experienced before (United Nations (UN) 2017; Food Agriculture Organisation (FAO) 2009). This implies that the global demand for energy will continue to increase since man's daily activity depends on energy. Energy is seen as an essential component of development that affects the peace, security, well-being, physical environment, and the socio-economic growth of a nation (Jatau et al. 2006; Urban 2009; Ajah 2013). The energy situation in Nigeria has always been a paradox (Eleri et al. 2012) because despite having abundant energy resources in the country, widespread energy poverty is faced by the citizenry. Approximately 60% (74 million) are not served with electricity, while another 94% (171 million) do not have access to clean energy (REN21 2018).

In a quest to achieve economic, technological, and industrial advancement, cities in both developing and developed countries depend primarily on energy from fossil fuel and other sources. Nnaji et al. (2010) reported that in a bid to cushion the effect of energy poverty, households and business enterprises in Nigeria relied much on the constant use of generators. This alternative (generator or fossil fuel) energy use is not eco-friendly, costly, and harmful to human health. REN21's (2016) report stated that 78.3% of global energy consumption was produced from fossil fuel, while 19.2% and 2.5%, accounts for renewable and nuclear energy, respectively. Studies (Uduma and Arciszewski 2010; Oyedepo 2014) have identified that the continuous use of generators and fossil fuel poses a massive obstacle to sustainable economic and social development, both in urban areas and at the grassroots level.

The increasing rate of global warming has been attributed to cities' generation of greenhouse gases owing to their enormous dependence on fossil fuel (Satterthwaite 2008). This shows that the colossal dependence on fossil fuel by cities over the world is unsustainable in terms of its global impact and depleting resources. Amidst this rising global energy use, Merem et al. (2017) opined that access to renewable energy would catalyze global and regional economic advancement. Renewable energy or clean energy is a form of energy generated from the natural resources that are constantly replenished. This form of energy includes Solar, hydroelectricity, wind, tides, and geothermal energy. According to Newman et al. (2011), renewable energy enables cities to create a healthy and liveable environment while minimizing the use and impact of fossil fuels.

Despite having high potentials of renewable energy in Africa, the continent is yet to fully harness these potentials, thus making access to energy a challenge (Kerrigan 2001). For instance, 58% of the energy supply of Africans comes from fuelwood and charcoal, and these sources (fuelwood and Charcoal) rival other sources of industrial energy such as electricity (Specht et al. 2015). This scenario is not far-fetched in terms of the situation of access to clean energy in Nigeria. With the abundance of fossil fuel and renewable energy resources in Nigeria, Nigerians still experience acute energy poverty. This connotes that Nigerians either lack access to

clean energy sources or have to cope with insufficient choice in accessing adequate, affordable, reliable, high quality, and environmentally energy services to support economic and human development (Nnaji et al. 2010).

Reports are that 55% of Nigerians are wholly reliant on charcoal, fuelwood, biomass, and animal waste for heating and cooking (Maduka 2011). This signifies that Nigerians are climbing down the energy rungs. REN21 (2018) affirms this claim by asserting that 171 million people in Nigeria do not have access to clean cooking energy, while another 74 million do not have access to electricity in the country. The "sporadic" access to clean energy experienced in Nigeria threatens the realization of goal number seven of the sustainable development goals.

Different studies and approaches have been taken by various scholars to address the issues of sustainable energy in Nigeria. Most of the studies conducted have dwelt more on exploring the potentials and conditions for renewable energy adoption in Nigeria. Additionally, ample studies carried out on sustainable energy in Nigeria were conducted in the field of engineering, with a sole focus on access to clean energy in the urban areas, thus neglecting the social aspect of the rural (grassroots) dwellers. Slightly aligning with the multi-tier energy matrix, this study using a bird's eye view, the country-wide experience shall investigate conventional energy access in Nigeria, access to clean energy, and also identify the factors that limit the use of clean energy in the country.

The driving keyword and question of this study is if local resources can be maximised to alienate a communal energy crisis. The study justification lies in and implies that the study on access to clean energy services in Nigeria with a focus on rural areas will help ameliorate the issues that accompany energy poverty at the grassroots level. This study will guide policy-makers to put in place necessary mechanisms that will aid the uptake of clean energy service development in Nigeria. This will, in turn, help in the swift realization of the SDGs across communities and the entire country at large.

2 The Energy Situation in Africa and Nigeria

The existence of a global energy crisis has been reported by Vahid-Pakdel et al. (2017). The heavy reliance of developing countries on fossil fuels as a significant source of energy presents a negative consequence of increased CO_2 emission (Jebli and Youssef 2017). In North Africa, it was reported that 92% of the energy used is from fossil fuel (coal, gas, and oil), with only 8% from renewable energy sources (United Nations Economic Commission for Africa 2012). The importance of energy in the socio-economic, political, and industrial development of any nation cannot be over-emphasized (Oyedepo 2014) because energy provides an essential ingredient for virtually all human activities ranging from transportation to communication, schools, industrial activities, agricultural activities, and other domestic activities.

According to the UN (n.d), energy is believed to be central to every major challenge and opportunity the world faces today, be it challenges and opportunities for

jobs, security, climate change, food production increasing incomes. Steurer et al. (2016) reported that electricity project challenges in Africa could be traced to political instability and limited private sector involvement, which can, in turn, be traced to a highly burdened regulatory framework. Although Africa is characterized by a difference in the level of connection and access to electricity, the common denominator is that many households remain unconnected to electricity (Mas'ud et al. 2015; Alnaser and Alnaser 2011). According to UNDESA (2004), one limitation to Africa's imbalance and the poor state of electricity connectivity is the imbalance between electricity generation and consumption.

Limited access to electricity services and power infrastructure is experienced in Africa (Taliotis et al. 2016). Across the rural and urban spaces, the dichotomy in electricity and energy access remains a common reality. Aliyu et al. (2018) wrote that Africa (especially Nigeria, Libya, Mozambique, Algeria, and Egypt) is blessed with a potential for energy from non-renewable sources, many of which remain under-utilized and optimized. Taliotis et al. (2016) reported that variability as much as low access is reported across Africa (85% national electrification in South Africa) and more evidently experienced in sub-Saharan Africa (3% in the Central African Republic and 4% in Chad). Hence the spatial disparity across urban and rural communities cannot be ignored. For example, in Cameroon, 88% of urban areas and 17% for rural communities are connected. Trotter's (2016) study on rural electricity experience from 46 sub-Saharan African countries, which included Ghana, Swaziland, Uganda, Senegal, and Rwanda, shows that political, economic, and demographic variables were a significant determinant of rural electrification. The study identifies the roles played by country democracy in increasing rural electrification and directly reducing electrification inequality between rural and urban areas. Furthermore, and as narrated by Pachauri et al. (2012), Fig. 12.1 presents the level of rural connectivity to electricity, which differs across global and African spaces.

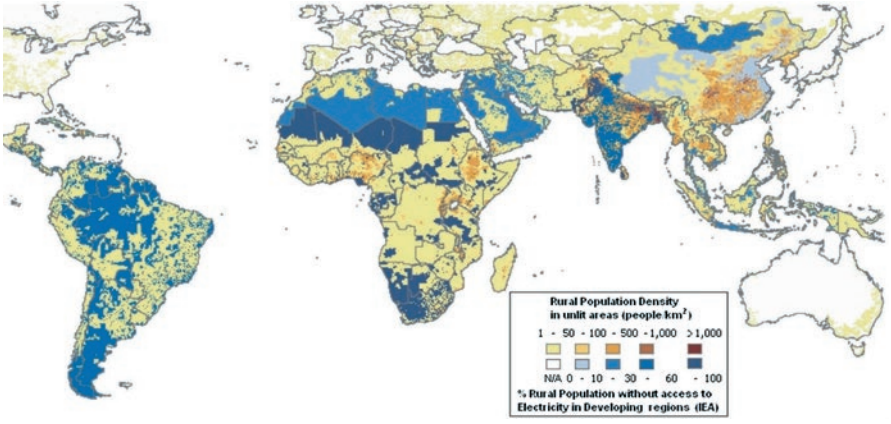

Fig. 12.1 Global Rural Electricity Access. (Source: Pachauri et al. 2012)

In Africa, sub-Saharan, Eastern, and Central African countries are characterized by the least rural population electricity accessibility ratio (Fig. 12.1).

According to Popoola and Magidimisha (2019), the solution to the increasing energy demand for Africa is for African counties, with a particular focus on Nigeria, to fully maximise and explore the integration of renewable clean energy sources into the national grid and for sparsely arranged rural households and urban poor.

3 Clean Energy in Africa and Nigeria

The global energy crisis (Vahid-Pakdel et al. 2017) led to the maximization of and diversification into the use of renewable and clean energy sources. Various scholars have carried out studies on access to clean energy. These tend to share the same perception that clean energy is a crucial component to achieving sustainable development. Oyedepo (2014) further opined that working with the goal number seven of the SDGs (affordable and clean energy) is essential as it interlinks with other sustainable development goals, which include eradicating extreme poverty and hunger; achieving universal primary education; promoting gender equality and empowering women; reducing child mortality; improving maternal health; combating diseases; and ensuring environmental sustainability.

Increased access to clean energy services in Nigeria has been identified to help ameliorate the issues that accompany energy poverty in the country. In a study carried out by Osunmuyiwa and Kalfagianni (2017) on the adoption and variation in renewable energy in Nigeria's 36 States using three analytical lenses (niches, regimes and landscape), it was revealed that a combination of regime and landscape characteristics enables states to overcome dependence on fossil fuel while triggering the adoption of renewable energy. The study reveals that States with high income and a regime featuring institutions and coalitions supporting transitions establish themselves as pioneers, while States with medium/low income and a regime characterised by a weak pro-renewable energy political coalition support emerge as laggards.

Explaining the wealth and income effect, Edomah (2016) examined the barriers of cost, pricing, legal, regulatory, and market performance to explain sustainable development in Nigeria. The study concluded that policy recommendations that will bring about infrastructure upgrades, curb pipeline vandalism, increased fossil fuel consumption, increasing demand, and increasingly scarce resource constraints are imperative to addressing the economic, social, and environmental dimensions of sustainable energy. Places forwarding a policy of bilateral arrangements in enhancing access through clean energy sources, Jebli and Youssef (2017) identified that an example of the clean energy initiative between the European Union (EU) and some North African countries which is expected to improve clean and renewable energy within the regional markets is the Mediterranean solar plan (MSP).

In the same vein, Oyedepo's (2014) opinion on energy and sustainable development in Nigeria is that energy policy and strategy for delivering access to modern

elemental energy need to be put in place by the government. Akorede et al. (2017) reported that overcoming the energy poverty in Nigeria can only be achieved through an increased exploration of the abundant renewable energy resources in the country across energy demanding sectors. It is therefore imperative for the Federal Government of Nigeria to develop a "Sustainable Clean Energy Future Framework" aimed at increasing the deployment and innovation of renewable energy in the country (Oyedepo 2014).

In Nigeria and Cameroon, despite solar radiation and good wind speed, poor leadership and weak governance have limited the maximization of the available clean energy sources and connection to the national grid (Mas'ud et al. 2015) for more commercial usage. Buttressing this, the International Energy Outlook report by the US Energy Information Agency (2013) reported that Africa's reliance on conventional energy sources of biomass and hydroelectricity generation is a limitation to her potential improved access to increasing energy demands. Using sources from SolarGIS (2011) analytics, Mas'ud et al. (2015) presented the solar energy potential of Nigeria using the country's irradiation map (see Fig. 12.2).

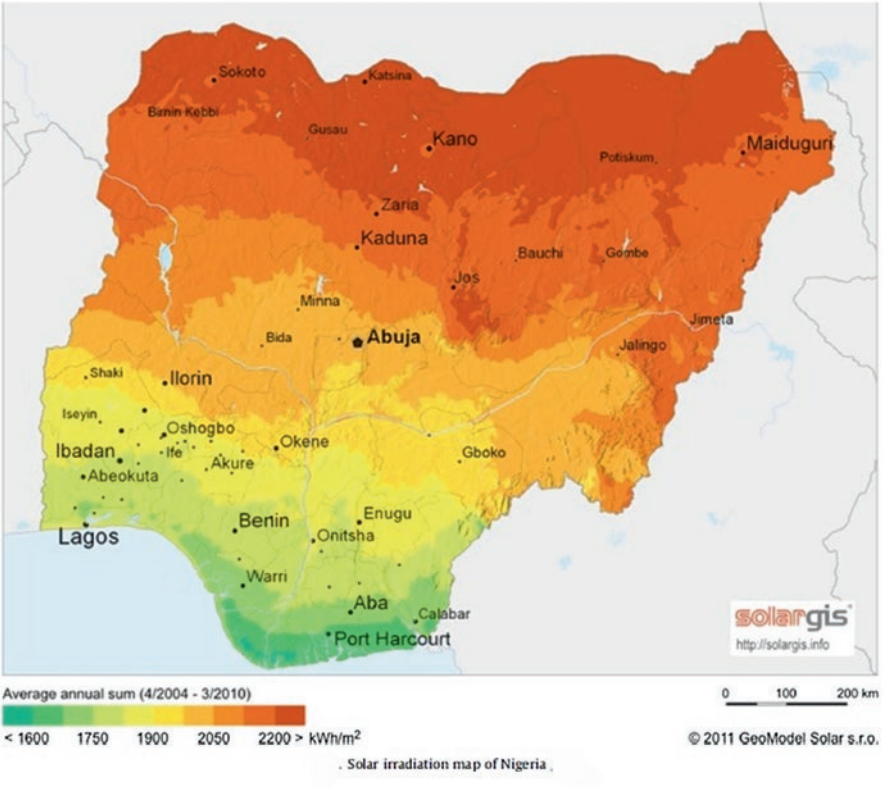

Fig. 12.2 Solar Energy Potential of Nigeria showing Sun Irradiation. (Source: Mas'ud et al. 2015 data from SolarGIS 2011)

Popoola and Magidimisha (2019) argued that with the abundance of solar radiation in Nigeria, the country limits its use to some politically motivated "streetlight show-off projects." They argue that few households, many of which are within urban areas, use solar energy sources. Aliyu et al. (2018) suggested that with South Africa, Egypt, and Nigeria being the major African energy users, renewable sources such as the sun (photovoltaic and solar thermal), hydro and wind fuel can be optimized for African consumer demand. In Northern Africa, Jebli and Youssef (2017) and the United Nations Economic Commission for Africa (2012) reported that with an over 8% annual increase in the demand for energy and, fossil fuel domination in energy sources, there is a need for an energy mix to explore the use of renewable and clean energy fully.

4 Methodology and Materials

This study involves a mixed-method approach. Primary data was obtained from the interviews conducted, and secondary data was gathered from monographs and other existing literature. The methodology involves a Think-Through Thematic Analysis, which involves the mapping of the country's potential clean energy sources. In analyzing, the geopolitical classification of Nigeria was taken into consideration in the analysis of the potential of maximizing clean energy for the easing of energy deficiency in the country. A Thematic literature review shall be integrated to investigate the clean energy experience in the country. Interviews were conducted for twenty (20) conveniently sampled stakeholders across Nigeria on the conditions of electricity, limitation to the maximization of clean energy within their locality, and perception of its access across the country (Table 12.1). The interviewee responses were transcribed and analysed using thematic analysis. Electricity access across the country was investigated and mapped using secondary data from the Nigerian Bureau of Statistics.

Table 12.1 Sampled respondents for the interview

S/n	Location/geopolitical zone	Occupation
1.	Northern Nigeria	1 Academic/lecturer
2.	South-Western Nigeria	2 Private consultant and 1 IT personnel
3.	South Nigeria	1 Spatial scientist and health consultant
4.	South-Western Nigeria	1 Rural farmer and solar panel user
5.	South-Western Nigeria	2 Researchers
6.	Eastern Nigeria	2 Academics/lecturer
7.	South-Western Nigeria	1 Planner
8.	Northern Nigeria	1 Planner
9.	Middle belt of Nigeria	1 Private consultant
10.	South-Western Nigeria	4 Peri-urban/Urban dweller
11.	South-Eastern Nigeria	3 Peri-urban dweller

Source: Authors' Compilation (2019)

5 Access to Energy (Electricity) in Nigeria

The interviewed respondents report a mix-grill experience of the electricity situation in Nigeria. Responding to the situation within the country, the energy situation in Nigeria as being deficient in energy resource generation investments and legislation was identified. The Nigerian energy sector generates far less than is required for daily use in the country, thus tremendously affecting other sectors such as the industrial, power and transportation sector that run predominantly on electricity defined energy. Nigeria's extreme electricity deficiency has been argued to be multi-facet as it represents a vehemently grossly below the national average demand. Participant 11 opined that financial, structural, and political factors cause this multifaceted deficiency, none of which are mutually exclusive. Analysing the deficiency and the geographical place of deficiency, it was identified that the urban poor and isolated rural areas (in the words of Participant 10 "the masses") are the most affected by the electricity deficiency.

Participant 4 stated that there is a "…*general knowledge that the situation of energy in Nigeria is appalling. Though there are improvements on multiple fronts in the chain of production and supply of energy, the sustainability of such improvement is virtually impossible…*" This statement presents a 'seem positive' energy experience and attempts to improve the condition.

As presented by the Nigeria Bureau of Statistics (2015) and represented in Fig. 12.3, the level of access to electricity in the country continues to decline and is at the lowest in the Northern part of Nigeria.

The Western part of the country is characterised by and recorded the highest access to electricity. Reinstating the idea that poor electricity energy access across the Nigerian space cannot be unexpected based on the "welfarist approach" with which the government has handled the generation and consumption mechanism. This approach is continually characterised by massive subsidization of electricity and energy changes, pricing, and costing systems.

Awoyinfa et al. (2019) reported the thoughts of stakeholders (such as the former Governor of the Central Bank of Nigeria; the Nigerian Employers' Consultative Association; the Chartered Institute of Bankers of Nigeria; the Corporate Affairs Director; the Manufacturers Association of Nigeria; the Centre for Social Justice; and other academia) that the subsidy implementation on electricity and fuel remains unsustainable and unrealistic taking into consideration the cost implication of the subsidy on the country's debt profile. The Daily Trust (26 June 2019) reported that the complete removal of the subsidy, but in a gradual process, remains the route to solving the electricity distribution, generation, and consumption variance. This argument aligns with the views of participants who attributed the below-par energy condition of the country to its subsidization.

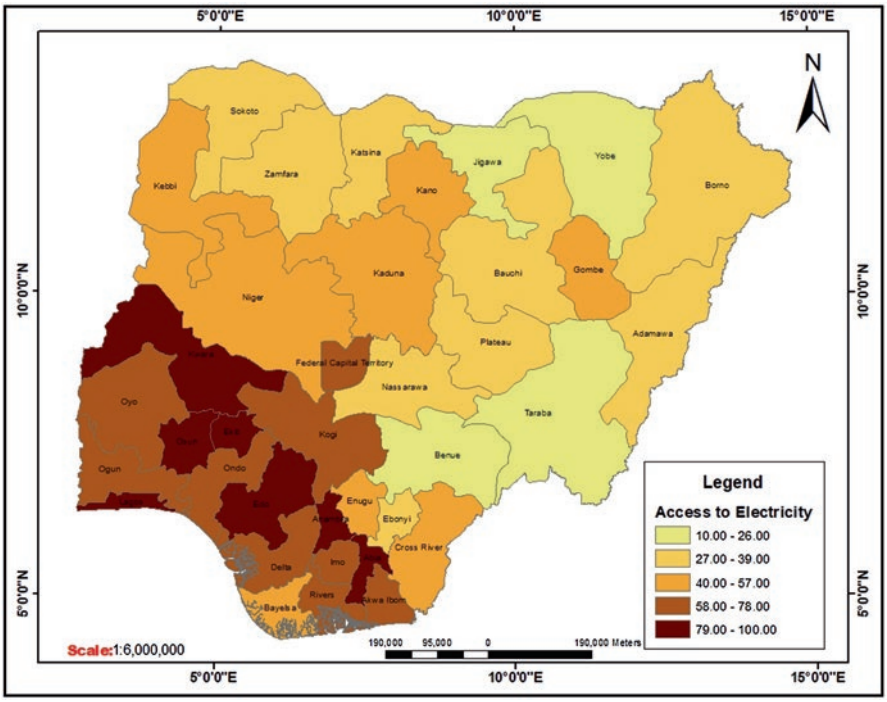

Fig. 12.3 Access to electricity in the Nigerian States (in percentage %). (Source: Authors' Mapping. Adopted from the Nigerian Bureau of Statistics, 2015)

6 Clean Energy Access and Potential Distribution in Nigeria

6.1 Understanding clean energy and access

The study attempted to investigate the understanding of the conveniently sampled respondents of what clean energy entails. The responses present four main themes, which are based on typology, limited or no waste, the capacity to not emit CO2, and the source of generation from natural sources (Table 12.2). From the responses received, clean energy is an eco-friendly form of energy that is naturally derived from sources such as sunlight, wind, and hydro and is pollution-free with no greenhouse gas emissions such as CO2.

Having presented a general perception of the understanding of interviewees of clean energy, the study attempted to evaluate the country's access to clean energy. The evidence reveals that accessibility, which is rated to be poor, to clean energy remains limited owing to the significant financial cost of installation (Participant 1); and is exacerbated by low/under-efficient facilities (Participant 3); few providers (Participant 4); is capital-intensive; lack of affordability and poor awareness (Participant 5); and weak purchasing power (Participant 13). Narrating the reasons

Table 12.2 Understanding of what clean energy entails

Participant	Response to what clean energy means
Participant 1	"…*Energy from renewable sources like Solar, Wind, and Hydro*…"
Participant 2	"…*The energy that is carbon neutral*…"
Participant 3	"…*Usage of energy with very low or no carbon pollution to the environment*…"
Participant 4	"…*Clean energy refers to an earth-friendly way of producing energy. This includes biofuel, solar*…"
Participant 5	"…*clean energy refers to renewable energy, such as wind and solar*…"
Participant 6	"…*The energy with very low or no carbon pollution to the environment*…"
Participant 7	"*Clean energy has to do with the kind of energy generated from natural sources, vis-à-vis wind, and sunlight. Moreover, little to no waste is generated*…"
Participant 8	"…*Clean energy is a way towards achieving a sustainable, healthy, friendly, and liveable city*…"
Participant 9	"…*The energy that is devoid of pollution or at low level / environmentally friendly*…"
Participant 10	"…*clean energy is the energy supplied without any detrimental effects on the people and the environment at large*…"
Participant 11	"…*The clean energy produced through means that do not pollute the atmosphere, e.g., sun, water*…"
Participant 12	"…*Clean energy is energy generated without polluting/causing harm to the environment. It can also be said to be an energy void of carbon emissions. Examples of clean energy include solar energy and wind energy*…"
Participant 13	"*...Energy from the sun and others...*"

Source**:** Authors' Analysis (2019)

why access can be limited, Participant 4 reported that with the availability of affordable solar energy solutions from the leading providers of Mobile Telecommunication Network (MTN), Solar (Yellow Box) and Novel Ltd., it is safe to assume that clean energy is relatively available for access by Nigerians.

Although it was identified that the long-term cost implications of the use of clean energy are beneficial. Based on his experience, Participant 5 reported that, "…*true-green energy is expensive to set up…"* The context of "true-green energy," as reported by the interviewee, was based on experiences of installation over the years from less technically capable companies, and sometimes that clean energy facility becomes faulty before the expected warranty period. Participant 7 stated that the installation is not subsidized, so most households and individual bears the full cost of supplementary gadgets such as batteries, Solar panels and cables and in most instances, installation technicians' end up buying sub-standard materials which make the clean energy installed not sustainable.

Participant 11 and 12 states that why there is an increase in the exposure of Nigerian society to clean energy usage; only a few have easy access to it. Participant 10 said that clean energy access to the Nigerian masses is miserable. She observed that "…99.9% of the energy used in the country is detrimental to our environment because there is emission of carbon monoxide. Be it cooking with gas, cooking with stoves, automobile emissions, and even our crude oil extraction points generate much carbon monoxide, which is detrimental to the environment…".

Bringing to fore the place of energy diversification amongst Nigerians, an interviewee observed that while the reliance on solar energy has increased over the past 3 years, solar energy is still not a product for the common man, as fuel and diesel generators locally tagged "…*I pass my neighbor*…", with all their carbon emissions and noise are still primarily used as alternatives to sporadic power from the national grid. Questioning the sustainability of some of these alternative sources, such as generators, Oyedepo et al. (2019) was of the view that increasing demand for energy; inadequate generation capacity from conventional sources; and dilapidated and limited electricity extension/distribution infrastructure mainly to rural areas are limitations to clean energy use in Nigeria. The study states that the promotion of renewable energy remains the route to promoting industrialization and sustaining the nation's economy.

6.2 Potential Clean Energy Sources

Despite the massive potential of renewable energy resources that Nigeria is endowed with, energy issues still abound in the country. Authors (Nnaji et al. 2010; Bamisile et al. 2017) believe that harnessing the full potential of renewable energy would go a long way to reducing the current energy "poverty" experienced in the country. Nigeria's renewable energy resources can be classified into four main types, namely are solar energy, hydropower, wind energy, and biomass/biogas. While the potential towards the optimization of these energy sources is undoubted, the capacity of the energy generated from these resources and sources differs in time. Table 12.3 shows the renewable energy generated in the country between the years 2008 and 2017. Table 12.3 reveals that between 2008 and 2017, a total of 20,271 Mw of energy was generated from renewable energy sources in Nigeria. The renewable energy generated was classified into off-grid and on-grid; total capacity of 131.24 Mw was generated off-grid while 20,140 Mw was generated on-grid.

6.3 Hydropower

The only renewal energy used for commercial power generation in Nigeria is hydropower (Bamisile et al. 2017). The hydropower state in Nigeria is classified into small and large hydropower stations. According to the Renewable Electricity Action

Table 12.3 Renewable energy generated in Nigeria between 2008 and 2017

Year	Renewable energy sources				Total	Total off-grid generation
	Hydropower	Solar	Wind	Biomass/biogas		Renewable energy
2008	1941	na	2	na	1943	2.200
2009	1941	na	2	na	1943	2.400
2010	1941	na	2	na	1943	2.400
2011	1941	na	2	na	1943	2.400
2012	2042	15	2	na	2060	18.540
2013	2042	15	2	na	2060	18.740
2014	2042	16	3	na	2061	19.940
2015	2042	17	3	na	2062	21.340
2016	2042	18	3	na	2063	21.540
2017	2042	19	3	na	2064	21.740
Total (MW)	**20,016**	**100**	**24**	**na**	**20,140**	**131.24**

Source: International Renewable Energy Agency (2018)

Plan (2006), hydropower stations that generate less than 30 Mw are considered to be small, while hydropower stations that generate above 30 Mw are regarded as large hydropower stations. Nigeria has six major small hydropower stations with an aggregated capacity of 30 Mw and three major large hydropower stations with an aggregated capacity of 1930 Mw (Table 12.4).

The six major small hydropower stations were all constructed by the National Electricity Supply Cooperation Limited (NESCO), a private company (Osunmuyiwa and Kalfagianmi 2017), while the Federal Government of Nigeria constructed the three major large hydropower stations. Aderoju et al. (2017) opined that the small hydropower stations are more eco-friendly than the large hydropower stations because they do not require severe deforestation, rehabilitation, and submergence.

In harnessing the vast potential of hydropower in Nigeria (Fig. 12.4), five additional large hydropower stations are under construction in the country. These include the Zungeru Hydropower plant (700 Mw), Mambilla Hydropower plant (3050 Mw), Kashimbilla Hydropower plant (40 Mw), Dadin Kowa Hydropower plant (40 Mw) and the Gurara Hydropower plant (30 Mw). Of all the large Hydropower stations under construction, the Mambilla Hydropower plant would be Nigeria's biggest power plant. This study revealed that construction work is yet to commence at the proposed site of the Mambilla hydro-power plant since the project was approved in 2017. Adetayo (2017) envisaged that the Mambilla Hydropower plant, when completed, will reduce the reliance on fossil fuel and cut the issues of climate change in Nigeria.

6.4 Solar Power

Solar energy can be described as energy generated from the sun in the form of electric or thermal energy (Energysage 2019). Solar energy can be captured either through the use of a photovoltaic solar panel or solar thermal conversion (Aderoju et al. 2017). Studies have shown that Nigeria is situated within a high sunshine belt

Table 12.4 Small and large hydropower stations in Nigeria

No.	Hydro power station	State	Installed capacity (MW)
Small hydropower station			
1	Bagel I	Plateau	1
	Bagel II	Plateau	2
2	Ouree	Plateau	2
3	Kurra	Plateau	8
4	Lere I	Plateau	4
	Lere II	Plateau	4
5	Bakalori	Sokoto	3
6	Tiga	Kano	6
Total			**30**
Large hydropower station			
1	Kainji	Niger	760
2	Shiroro	Niger	600
3	Jebba	Niger	570
Total			**1930**

Source: Renewable Electricity Action Plan (REAP) (2006)

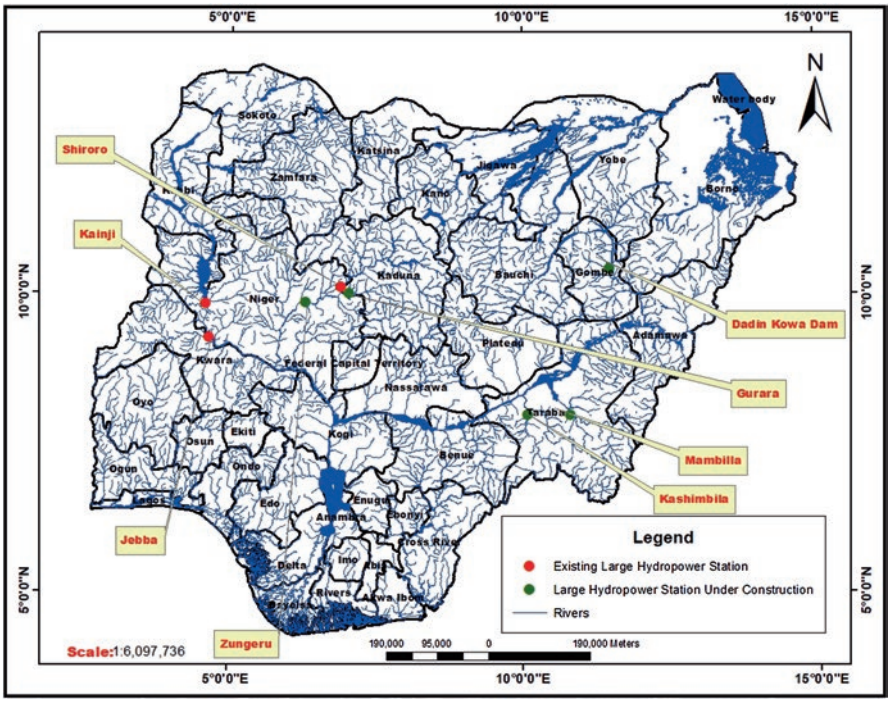

Fig. 12.4 Hydropower Sites and Potentials in Nigeria. (Source: Authors' Mapping 2019)

and the solar radiation is equitably distributed across the States of the federation (Oyedepo 2014; Adebayo 2014; Bamisile et al. 2017). According to Oyedepo (2014), annual average solar radiation ranges from 12.6 MJ/m^2-day (3.5 kWh/m^2-day) at the coast to about 25.2 MJ/m^2-day (7.0 kWh/m^2-day) in the far north. This implies that Nigeria's solar potentials, if adequately harnessed has the possibility of generating 1850 × 10^{3}GWh of solar electricity per year, which is a hundred times the current electricity grid consumption in Nigeria (Uzoma et al. 2011 in Adebayo 2014).

Amidst the vast potential of solar radiation that abounds in Nigeria, only 12 States out of the 36 states in the country have been able to generate electricity from Solar energy. These states include; Delta, Sokoto, Lagos, Bauchi, Edo, Enugu, Nasarawa, Benue, Jigawa, Bayelsa, Katsina, and Ogun (see Table 12.5). Of all these States, Osunmuyiwa and Kalfagianni (2017) referred to Delta, Sokoto, and the Lagos States as the pioneer states because of their comprehensive policy on renewable energy. The laggard states were referred to as states with no visible form of renewable energy adoption or programs (Osunmuyiwa and Kalfagianni 2017).

6.5 Wind Energy

Nigeria falls within the moderate wind regime with an energy reserve at 10 m height, which implies that some regions in the country have a wind regime between 1.0 and 5.1 m/s. The wind regimes in Nigeria can be classified into four, namely 44.0 m/s; 3.1–4.0 m/s; 2.1–3.0 m/s; and 1.0–2.0 m/s (Oyedepo 2014). Wind data collated by Nigerian Metrological Agency (NIMET) from 44 stations across the Nigeria States (See Fig. 12.5) revealed that the wind regime in the country lies majorly between poor to moderate regime with the Southern States having their

Table 12.5 Solar energy generated in Nigerian states

S/no	States	Solar energy (KW)	Ranking
1	Delta	8000	Pioneer
2	Sokoto	2045	Pioneer
3	Lagos	1814	Pioneer
4	Bauchi	600	Semi laggards
5	Enugu	64	Semi laggards
6	Nasarawa	30	In case laggards
7	Ogun	5	In case laggards
8	Jigawa	10	In case laggards
9	Kastina	10	In case laggards
10	Benue	10	In case laggards
11	Edo	36	In case laggards
12	Bayelsa	10	In case laggards

Source: Osunmuyiwa and Kalfagianni (2017)

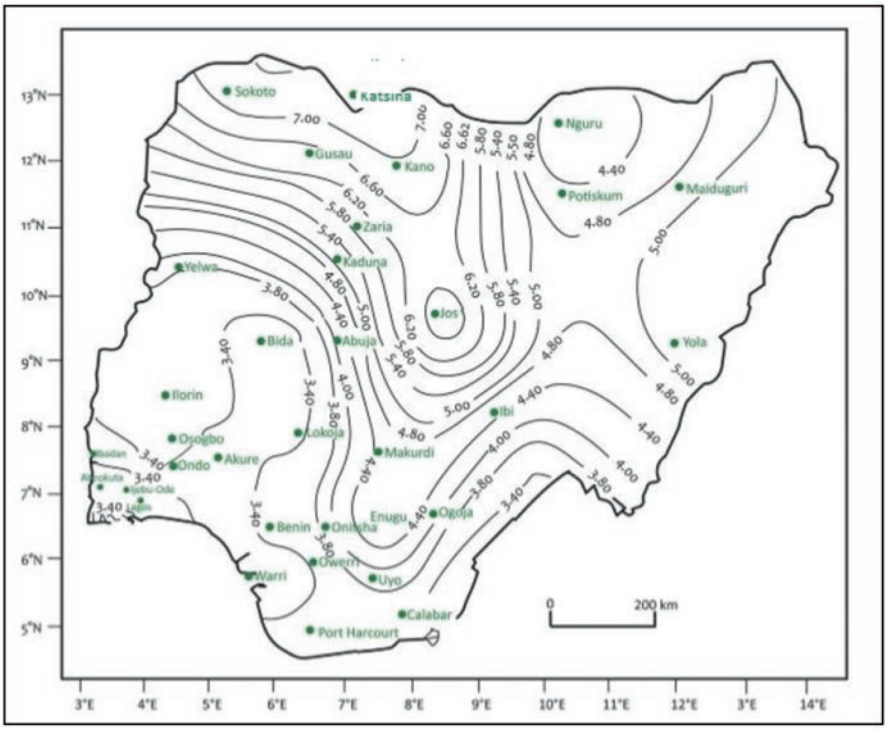

Fig. 12.5 Isovents (M/s) Across Nigeria. (Source: NIMET 2009)

mean wind profile at 10 m height between 3.0 and 3.5 m/s and the Northern States having a mean wind speeds of between 4.0 and 7.5 m/s (Okoro et al. 2007 in Adejoru et al. 2017). Oyedepo (2014) also asserted that the coastal areas from Lagos State through Ondo, Delta, Rivers, and Bayelsa States to Akwa-Ibom State have strong potential for wind energy throughout the year. Although the coastal and Northern areas of Nigeria are perceived to have great potentials of wind energy. Despite this, little effort has been made by these States to harness the potentials of wind energy. In a study carried out by Osunmuyiwa and Kalfagianni (2017), only Enugu State was able to generate 26 kw in 2010, amongst the States with high wind speeds.

6.6 Biomass/Biogas

Actively or passively, Biomass is the largest renewable energy source used in Nigeria (Bamisile et al. 2017). The biomass resources identified in Nigeria include wood, forage grasses and shrubs, animal waste, agricultural and forest residue, municipal and industrial activities as well as aquatic biomass. Biogases are fuel

gotten from plant biomass which is often fermented by anaerobic bacteria to produce a very versatile and cheap fuel (Nnaji et al. 2010). To improve biomass utilization in Nigeria, the government has encouraged the use of biomass in the transportation sector, which prompted the 2007 bio-ethanol policy that calls for a 10% inclusion of ethanol into petroleum products in the country (Oyedepo 2014). It is estimated that around 61 million tonnes/year of animal waste can be obtained and which translates into about 83 million tonnes/year of crop residue (Oyedepo 2014). The vast potential of biomass/biogas in Nigeria does not have a significant effect on power generation. It was revealed that of the 36 States of the federation, only Lagos, Oyo, Sokoto, Niger, and Enugu had explored the biomass potentials (Osunmuyiwa and Kalfagianni 2017). The study further revealed that 17.9 Kw, 10 Kws, 35 Kws, and 63 Kws of electricity were generated in Lagos, Enugu, Sokoto, and Niger States, respectively. Oyo state was the only State to have generated 500 Kw within the period under study (2010–2014).

6.7 *Household Electrification Rate in the Six Geo-Political Zones of Nigeria*

The household electrification rate in the six geopolitical zones of Nigeria is explained in Table 12.6. The table revealed that 55.6% of the total households in Nigeria have access to electricity, while 44.2% do not have access to electricity. This implies that there is tremendous energy poverty in Nigeria. This is evident in the sporadic power supply experienced in the Country. Oyedepo (2014) also affirmed this claim. According to Oyedepo (2014), household access to electricity services in Nigeria is low, and about 60% of the population (over 80 million people) are not served with electricity. Table 12.6 explains the household electrification rate across the six geo-political zones of the federation.

Table 12.6 Household electrification rate in the geo-political zones of Nigeria

Zones	Have electricity (%)	No electricity (%)	Missing	Household surveyed
North Central	48.7	51.2	0.1	5942
North East	29.3	70.1	0.3	5115
North West	42.2	57.7	0.1	9992
South East	66.4	33.6	0.0	4687
South South	68.3	31.3	0.4	5239
South West	81.1	18.8	0.1	7546
Total	55.6	44.2	0.2	38,522

Source: NBC (2014) in GIZ (2015)

7 Limitations to Clean Energy Access and Utilization in Nigeria

There exists a dichotomy in rural and urban access to clean energy. Based on transcribed data, evidence shows that access to information and finance between urban and rural areas has been identified to be the reason for this scenario. Participant 16 revealed that one limitation to Nigerians accessing clean energy is poor access to information, lack of awareness, and poverty, which has limited the capacity of the people to access this energy source. He argued that where there might be an abundance of renewable sources to be used, the limited capacity of households (most notably in rural areas) limits their access. This was also mentioned in the SWOT analysis of clean energy systems by Dincer and Acar (2015). In their analysis, public perception, lack of information and training, and infrastructure changes were identified as weaknesses while market enhancement, climate change effects, and energy security are the opportunities mentioned. Financial investments, complexity, over-burdened regulatory guidelines, and the low price of conventional energy systems were seen as threats.

In this vein, an interviewee stated that the limited capacity is a reflection of weak government policies and energy process corruption. An interviewee reported that energy corruption is mainly a reflection of the lack of political will, which is often regime based rather than a system of government that is incremental and continual in policy and funding processes. The role of the government as an advocator and major marketer of clean energy was reiterated by Participant 20. She responded that with the government not encouraging the use of clean energy amongst households through sensitization and subsidies, the use would continually remain limited amongst the households. In Nigeria, Corfee-Morlot et al. (2019) and the Nigeria Gas Policy (2017) reported that a quick approach to the implementation of the LPG Availability Intervention Fund of about $160 million and, a reduction in the capital cost of using the LPG stove, gas, and cylinder for household cooking must be enhanced to bring about an easy route for clean energy use.

Further interviews with Participant 5, found that Nigerian society is stuck in non-renewable energy source/use. The majority of rural dwellers still rely on firewood for cooking, while the majority of urban dwellers rely on fossil fuels. She further stated that while there is an abundance of energy from renewable sources, a lack of awareness regarding the affordability of clean energy especially amongst the rural population along with poverty levels depriving them access to credit and ultimately the weak perception of the benefit of the energy source continues to erode the citizens and country in terms of maximizing its use. Participant 6 mentioned that dwellers might be limited by inadequate funding; the cost of maintenance and weak purchasing power for prior implementation that urban dwellers like him might be limited by. In his words, *"…for instance solar energy - without a solar panel, there is no way to access this energy. The question is, how many people can afford the solar panel. I use the inverter in my house, and I spent almost 2million (5,714 USD at 350/USD. How many people can afford it?…"* This same issue was seen as a challenge to using renewable energy in Nigeria (Newsom 2012).

Participant 9 mentioned that the limitation to rural people making use of clean energy might be based on their cultural beliefs. He used an example of the use of firewood in a modern kitchen without a chimney, as in the case of resettled fishermen in New Bussa, Niger State, Nigeria. Bisu et al. (2016) identified that religious beliefs are a significant determinant of the use of fuelwood in the rural areas of Bauchi, Northern Nigeria. The study shows that large Muslim households and cultural alignment during festive periods are the factors that account for increased fuelwood use and the preference for conventional energy usage by these households. In their study, household size, dwelling ownership status, change of season, income, level of education, dwelling location, availability, and affordability are factors found to influence household cooking energy choice. It was further narrated that instances where cultural attachments are not the limiting factor; rural spatial alienation limits exposure to clean energy. This was evident in the views of Participant 11, 18 and 20 who were of the views that clean energy is needed in urban areas than rural areas as demand for electricity and energy is more in the urban space owing to the concentration of industries in these areas and the location of administrative offices where policies are introduced.

In summary, one of the interviewees (a private consultant) states that the main factors that limit the use of clean energy in Nigeria are the high cost of installation and maintenance; poor investment in the energy sector; weak and limited involvement of the private sector; and subsidies granted to generators of energy from fossils. These factors have shaped his perception that access to clean energy is more in urban than in rural areas. Explaining further, he observed that urban areas are associated with better education, higher standards of living, and individuals who could facilitate the installation and maintenance of these forms of energy without the government's assistance or subsidy. However, for these forms of energy to be accessible in the rural areas, it would involve significant investments from the government. Which is presently limited and slow. Brew-Hammond (2010) also pointed this out. He argued that for Africa to muddle through the energy crisis, there is a need for increased involvement of local actors (entrepreneurs, companies, capacity developing institutions) in energy production, generation and consumption markets. He also advocated for improved utilization of a wide range of modern technologies and resources available within the space.

8 Conclusion and Way Forward

Electricity generation in Africa still leaves Sub-Saharan Africa with the lowest generation capacity. This is evident in the electricity condition of Nigeria. The general perception of the people shows that many households remain under-served when energy access is taken into consideration. While the country's energy condition is considered to be below average, the study identified that Nigeria's energy situation remains sporadic, and variance exists in the access of states in the country to electricity infrastructure. This variance in electricity access amongst states can be traced to available energy resources and the location (urban, the capital city, historical

administrative capacity, and proximity to energy generation sites). Concerning location, the Northern region of the country remains largely under serviced by the electricity infrastructure.

Expressing the views of the research evidence on the state of access to clean energy remains restricted to neighbourhood and circulation lighting systems and water infrastructure (mainly SDG water projects in rural communities and health centers). The pointers, as identified in the study, show a need for increased investments in the sensitization of access to clean energy in the country. The relevance of energy governance to explore the decentralization of Nigerian settlements away from the national grid towards the maximization of the location of specific clean energy resources needs to be explored and implemented.

It is argued that with the maximization of "place-specific clean energy resources," the drive at eliminating the urban-urban or South-Western and Northern energy dichotomy can be achieved. Based on the interview results, it is identified that achieving this will depend on the introduction of energy policies that reduce clean energy costs of purchase, maintenance and also improve on public sensitization to the opportunities available for households, settlements and sectoral activities in the use of clean energy at a subsidized local level in their various households or small-scale businesses. This assertion of better electricity access if a clean energy source was invested upon is shown in Fig. 12.6.

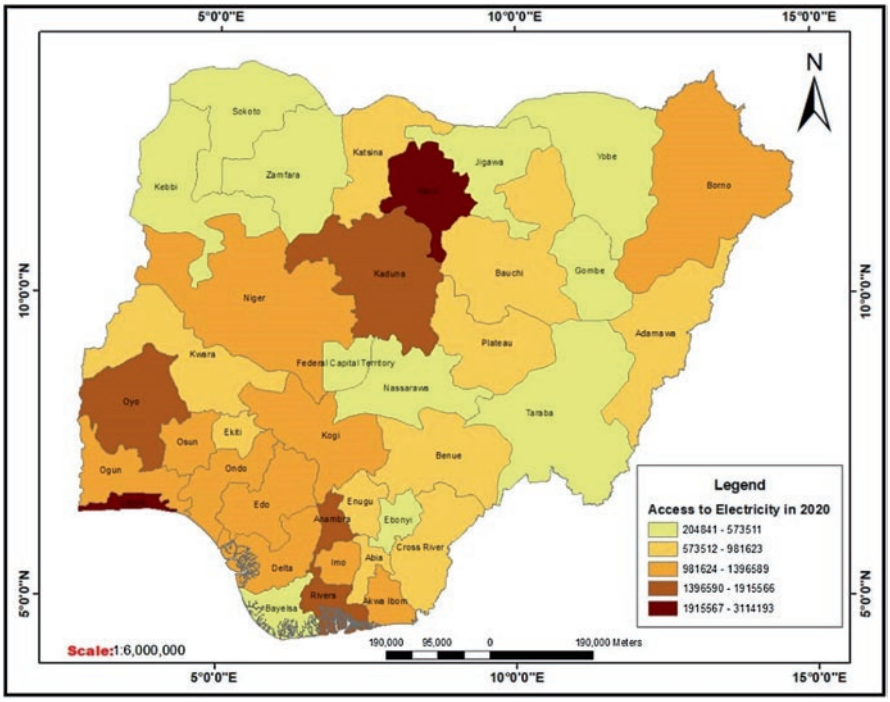

Fig. 12.6 Projected access to electricity in Nigerian States by 2020 (in %). (Source: Authors' Mapping 2019. Adopted from The Nigeria Bureau of Statistics, 2015)

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