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Renewable energy expansion in Africa: An Overview of South Africa and Nigeria as a case study

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Abstract

Despite its vast natural resources, African is facing serious challenges in sustainable development in an energy sector, if addressed with dispatch could not only check its indispensable needs but also mitigate some global phenomenon at stake, such as desertification, environmental degradation, and greenhouse emission. This paper reviews the prospects of four major renewable energy sources-hydro, solar, wind and biomass- for each of the two leading countries in Africa namely South Africa and Nigeria. Based on a literature survey of energy efficiency, all two countries encourage energy efficiency in varying degrees. In the course of this review, several national energy policy frameworks of these countries were looked into, especially on how African countries could overcome the persistent energy crisis in the continent by utilizing the naturally gifted renewable energy sources. This could only be achieved if proper technology, awareness, and skills for harnessing the resources are provided. Also, lingering energy challenges such as energy efficiency measures, needs for grid extension, energy storage technology, and seasonal variation were carefully highlighted.

Keyword: Renewable energy, Energy efficiency, Energy Africa

1. Introduction

An investigation has shown that renewable energy sources such as power from the sun (photovoltaic and solar thermal), hydro, wind and biomass-derived fuel have contributed greatly to the sustainability of certain nations with several environmental and socio-economic benefits to the nations that tap them. A far bigger and wider benefit according to research, is the contribution of renewable energy in the reduction of pollution at both local and global levels, thus helping in the mitigation of climatic change which both industrialized and developing nations committed themselves to in the Kyoto protocol. It has been tested and proven that reliable and affordable power supply is an essential prerequisite for technological and economic growth. Generation of electricity from renewable energy resources can play a major role in electricity generation in African countries.

This paper presents a review of renewable energy technology development in South Africa and Nigeria which varies due to factors that included topography, characteristics of the resource, cost of labor and policy regulation. In his review of renewable energy for sustainable development in Africa, I.M. Bugaje considered the extent to which policies on solar, wind, biomass and biogas are meeting up top challenges of sustainable development in four countries namely South Africa, Nigeria, Mali and Egypt [2]. In a paper titled "The economics of renewable energy expansion in rural sub-Saharan Africa", Uwe Deichman chose Ethiopia, Ghana, and Kenya [3]. In his short

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review that focused on poverty and energy in Africa, Stephen Karekezi talked about population, energy consumption, renewable energy, fossil fuel and access to electricity [4]. In another paper titled "renewable in Africa- meeting the energy needs of the poor", Karekezi examined the large and smallscale biomass energy, solar PV, solar thermal, evaluate how each of the renewable energy technologies can meet the need of rural and urban poor [5].

In view of the absence of a paper that focuses on the two leading nations namely South Africa and Nigeria, this paper has made an extensive review of the four major renewable energy sources (hydro, solar, wind and biomass), energy efficiency of each of the two countries, energy policy, overview of conventional energy, why renewable energy? strategies towards utilization of energy efficiency in Africa, renewable energy road map in Africa, need for grid extension, energy storage system and seasonal variations in Africa.

This review paper starts with an introduction, followed by the overview of conventional energy in Africa, why renewable energy? strategies towards utilization of efficient energy in Africa, an extensive review of the four major renewable energy sources, energy efficiency of each of the case studies starting with South Africa and Nigeria, general discussion and finally ends with the conclusion.

2. Conventional Energy in Africa

With proven oil reserve which increased by 150% from 53.4 billion barrels in 1980 to 13.3 billion barrels as of 2013 (according to BP Statistical Review of Energy), Africa is second only to the Middle East in terms of oil export and it accounts for over 11% of world oil production. However, the bulk of the oil is exported as the continent accounts for only 4% of global oil consumption. Since 2013 Africa's oil export has declined from an average of 6.3million bpd to 5.2 million bpd as a result of a sharp drop in Libya's output and low production from Nigeria, Algeria, and Sudan. The four countries account for 84% of Africa's oil production (Libya 48.5 billion barrels reserve, Nigeria- 37.1 billion barrels reserve, Angola- 12.7 billion barrels reserve and Algeria- 12.2 billion barrel) and are all members of the Organization of Petroleum

Africa's natural gas proven reserve significantly increased between mid-1980 to early 2000s, due to mainly a strong increase in Nigerian reserves. West African contributed almost half of the total natural gas proven reserve increment over a period of mid-1980 to early 2000s, while the North Africa which consists of Libya, Algeria and Egypt accounted for the remaining. As at the beginning of 2014, five countries accounted for 94.4% of the total of Africa's natural gas reserves. The countries are Nigeria (5.1 trillion m^3), Libya, Algeria, and Egypt combined (8.1 trillion m^3) while Mozambique whose proven gas rose from 126 billion m^3 to 2.8 trillion m^3 from 2013 to 2014 [6–9]. Table 1 represents the non-renewable energy potential of Africa.

Table 1: Non-renewable energy resources potential of Africa [7].

Types of energy	Proven reserves	Regional distribution
Non-renewable Crude oil	132.1 billion barrels	53.2% Northern Africa 28.2% Western Africa 16.9% Central Africa 1.7% Other Africa
Natural gas	14.7 trillion m^3	55.8% Northern Africa 36.1% Western Africa 8.2% Other Africa
Coal	31.696 billion tones	95.2% Southern Africa 4.8% Other Africa
Nuclear	Reasonably assured resources: 663,400 tones Inferred resources: 286,300 tones	2.9% Northern Africa 36.7% Western Africa 2.7% Central Africa 4.2% Eastern Africa 53.5% Southern Africa

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3. Why renewable energy

The united nations have regarded Africa as one of the continents with maximum vulnerability to the effects of climatic change due to population growth and its attendant human activities, overreliance on subsistence Agric, low capacity to adapt to change and impending water crises. Whereas the quest for renewable energy in developed countries driven more by insecurity in energy supply, air pollution caused by burning fossil fuel, the need for resource diversification and the prospect of resource depletion, Africa remains vulnerable to vagaries of fossil fuel set to developed countries to which they export crude oil [10–12].
Renewable energy as an alternative is a sustainable option that can significantly overdependence on fossil fuel. Furthermore, it has the advantage of creating employment, proximity to load and in many cases, led dependence on the concentrated energy source. The use of more renewable energy would similarly reduce Africa's economic vulnerability to the adjustable and rising prices of imported fuels. Global and local communities are gradually trying to follow the renewable energy trend by shifting the economy towards greater dependence on the renewable source. It is expected that rules and regulations, as well as voluntary structures such as the "Clean Development Mechanism" and Renewable Energy Certificates, will offer better sustenance for a prolonged role of renewable energy in the economy [13].
Table 2 shows the renewable energy target of Nigeria, and South Africa, and Table 3 shows electricity access, population without access and targets access to Nigeria, and South Africa.

Table 2: Renewable energy targets for Nigeria and South Africa [14].

Country	Sector/Technology	Targets
Nigeria	Bio power	50 MW by 2015; 400 MW by 2025
	Hydropower (small scale)	600 MW by 2015; 2 GW by 2025
	Solar PV (Large scale > 1 MW)	75 MW by 2015; 500 MW by 2025
	Wind power	20 MW by 2015; 40 MW by 2025
	CSP	1 MW by 2015; 5 MW by 2025
South Africa	(Electricity)	(18.2 GW by 2030; 42% of new generation capacity installed 2010–2030)
	Solar PV	8.4 GW by 2030
	Wind	8.4 GW by 2030
	CSP	1 GW by 2030
	Others	0.4GW by 2030 [15]

Table 3: Electricity access by country (Nigeria and South Africa)

Country	The electrification rate in 2012	People without access to electricity in 2012	Targets
	Share of population with access	millions	Share of population with access
Nigeria	45%	93	75% by 2020
South Africa	85%	8	100% by 2019

4. Strategies toward utilization of efficient energy in Africa

For energy need to be attained by all and sundry, proper strategies of energy management need to be addressed at various sectors such as residential, commercial and industrial [16]. Energy management can be defined as the

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strategies of shifting or optimizing the use of energy. The main purpose of energy management is; conservation of resources, climatic protection, and energy cost-saving [17]. Energy efficiency is the act of replacing electrical equipment with less energy consumption equipment with the same output magnitude. There is a need to identify the inefficient energy equipment's and find a solution, so as to improve the efficiency of the power sector. However, ongoing monitoring and target need to be scheduled in order to measure their performance [16].
Improvement of energy efficiency is the cheapest, fastest and environmentally friendly way to meet a significant of the world's energy demand. The need for energy investment is reduced by energy efficiency which is more economical because, in the end, it reduces energy cost over time. Energy efficiency is associated with technical and cost obstacles that are subordinate to other barriers, these include; financing, creating awareness, incentives, public acceptance and proper education. Countries are encouraged to pursue energy-efficient policies more patiently in the long-term period regardless of the development of fuel prices. Energy efficiency and renewable energy policies are very vital because of their advantage - for providing energy security and mitigation of global warming [18].
To improve energy efficiency significantly, the government should employ regulations and standards such as public sector leadership in procurement, public awareness, and incentives. The points below are the strategies towards utilizing energy efficiency in Africa.

a) The use of buildings with insulated windows, modern oil and gas furnace and efficient air conditioners, replacement of incandescent lamps with the compact fluorescent lamps, can result in 30–60% energy saving cost.
b) Industrial sector: the use of improved efficient pumps, boilers, motors, heating system and other material with high efficiency can reduce energy demand and greenhouse gases.
c) Transportation sector: the use of efficient diesel and gas vehicle and other methods of transportations.
d) Residential sector: major improvements have been made in refrigerators, water heaters, washing machines, and dishwashers. Advance technologies such as smart metering, micro combined heat and power generation CHP, fuel cells, solar photovoltaic and more efficient lighting can save energy [18].
e) Demand-side management (DSM) and energy conservation measures (ECM): DSM is an action or policies, or program tends to reduce managing energy consumption. DSM gives birth to two programs; energy efficiency, energy conservation measures, and load management. Energy conservation measures ECM is to change the consumption of energy by the consumers based on shifting their peak period energy consumption to the base period. Or the method of valley filling etc. utilities should encourage the consumers by giving incentives on less consumption of energy and enlighten the consumers on the importance of energy-efficient equipment's.
f) Installation of electrical equipment's control: electrical equipment's control such as lighting control, street light control, electric water heater control, etc. can be used to turn off or on or dimming them based on the energy output required. It makes the system flexible such that the consumption of energy can be controlled based on the usage of energy at a time.

The importance of energy efficiency is outlined into eight points, which are; (i) It improve the health of the nation, i.e. reduce the emission of harmful gases into the atmosphere. Such gases have an adverse effect on health, such as respiratory ailments, cancer, etc. (ii) Alleviates energy poverty i.e. it alleviates energy services in the environment at an affordable cost. (iii) Reduction of environmental pollution such as emission of harmful odorous gases. (iv) Improves industrial competitiveness i.e. it has been proven that, one way to maximize profit in an industry is to implement energy efficiency measures. (v) Enhances energy security i.e. it will reduce the imported sources into the country such as crude oil, coal, etc., this will strengthen the energy security of the country against price fluctuation of the products. (vi) Defers the necessity for additional power generation capacity. (vii) The country power generation is insufficient to meet consumer demand. But with energy efficiency measures it will maximize the demand. (viii) Job creation and lastly Reduce of CO_2 emission [16].
Demand-side energy efficiency enhancement determines obviously the costs of energy for end-users, while for supply-side energy efficiency i.e. (generation, transmission, and distribution) employed by the utility firms will also result into cost benefits for end-users by ensuring energy prices are well controlled. It will ensure older systems and equipment of the power system to be in good conditions because of lesser total loads which enable the operation of equipment below the maximum capacity [19].
Over 60% of the urban population in Africa do not get adequate electricity. They depend on tradition energy i.e. wood for cooking and much is spent for the purpose of energy services such as kerosene and electricity compared

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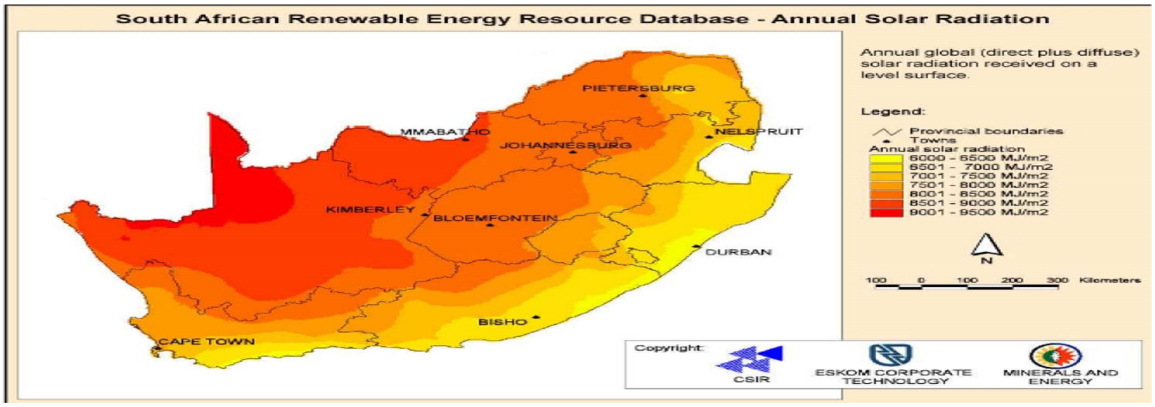
to other countries. It is estimated that the energy used in African homes consumed 56% of the entire national electricity. In large cities, the consumption is more than 75% of the whole electricity produced and the urban energy demand increases annually by 7%. The initiative of the UN secretary-general Ban Ki-moon on "sustainable energy for all" pleaded for players to join hands and efforts to; ensure the accessibility of modern energy services universally by 2030, doubling the rate of improving in energy efficiency, doubling energy efficiency improvement and the share of renewable energy in the mix of global energy [20].

The scope of increasing energy efficiency from the supply side and reduction of energy consumption at the demand side without economic output and reducing the standard of living is significant in African countries. Based on International Energy Agency (IEA) studies, shows that the African total energy consumption per GDP is twice the global average. Energy efficiency has been greatly pursued in North Africa, South Africa and a few countries in sub-Saharan Africa. The obstacles that hindered the adoption of energy efficiency programs are; initial capital cost, lack of appreciation, resistance to change, lack of policies regulatory frameworks and subsidy of the cost of energy.
To ensure economic competitiveness, Africa needs to systematically incorporate energy efficiency into the existing energy generation and use system as well as new major infrastructure projects. This could be achieved through the formation of policy and regulatory frameworks that would promote energy efficiency with appropriate policy instruments to ensure success and effectiveness.
Energy efficiency provides several benefits to Africa, as it reduces carbon mono-oxide and other greenhouse gas emission. Thus, reducing the burning of fossil fuels will address the issue of climatic change as such accelerate the use of renewable energy sources and more efficient technologies which provide "win-win" options to tackle global and local challenges. Over 75% capacity of power generation in Africa is based on thermal energy, as such improving energy efficiency in the existing systems could results to a significant money-saving by many countries and will increase competition among the local industries [21].



5. South Africa

The southernmost country in Africa is South Africa as it is circumscribed by south Atlantic, and the Indian Ocean on the north by the neighbouring countries of Namibia, Botswana, and Zimbabwe, by Mozambique and Swaziland from the eastern and northern part respectively and surrounding the kingdom of Lesotho. The 25th largest country in the world by land zone and a population of closed to 53 million people [22]. South Africa figured out the commencement of a speedy transition towards renewable energy and came up with renewable energy policy in 2003. The Renewable Energy White Paper (REWP 2003), developed by the Department of Minerals and Energy, set a target for renewable energy contribution, over and above the existing renewable energy contribution. The REWP 2003 also dedicated the country to develop a practical strategy application on renewable energy. The renewable energy resources of South Africa have large and vital potential that will contribute immensely to its energy sector, society, and the economy at large. The cost of energy is an important factor in determining the cost-effectiveness of renewable energy technologies [13].

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5.1. Hydropower

Hydropower is indirectly another form of solar energy. The vapor cycle as a result of the sun give rise to rain and eventually transform into a river which is used to generate hydroelectricity. Topography via which the flow of rivers occur normally determines the energy from hydro resources [12].
According to international standard, the widespread deployment of hydropower electricity generation has not received serious attention in South Africa. For the past two decades, the significant of hydropower development has not been recorded excepting for the new small-scale installation of 7 MW capability commissioned at the Sol Plaatjie municipality Free State area. Currently, the overall penetration of hydropower electricity is only 5% of the present total of 45,500 MW installed capacity [23].

5.2. Solar

Solar energy is one of the renewable energy resources with the highest potential in South Africa. The popularly known technologies used to produce electrical energy from solar radiation are; photovoltaic (PV) and concentrated solar power (CSP) also called solar thermal energy. In this process, CSP plants use mirrors to concentrate the energy from the sun to drive traditional steam turbines or engines that create electricity. Steam produced by the heat energy is then used to generate energy through the conventional turbine. Silicon is used in photovoltaic panels to convert solar radiation into electrical energy directly [13]. The major shortcoming of electricity generated from solar is storage problem, in an off-grid configuration, the storage technology involves a significant running cost as a result of its limited life span. However, technologies like fuel cell, supercapacitors, flywheel, and enhanced chemical batteries were used to decrease the running cost considerably provide more hope. The grid-connected system is the main international market for photovoltaic which uses the grid system as its storage alongside with dispersed storage option [12].
Fig. 4 indicates the potentials of solar energy resources in South Africa. There is a total area of approximately 194,000 km^2 of high solar radiation potential including Northern Cape which is one of the best solar resource areas in the world. Note that 1300 MJ/m^2/year is equal to 1 kW h/m^2/day.
Photovoltaic (PV) has been widely in used in South Africa for the purpose of lighting, home appliances, telecommunication, water pumps in homes and institutions in the rural areas. The price of the photovoltaic module used to be expensive but is now declining steadily over the past decade. In the developments described, it was envisioned that PV technology will be playing a very significant part up to 14 percent in supply by the year 2050 [12].

5.3. Wind

The wind is indirectly connected with solar energy, due to the fact that the energy from the sun drives the climate pattern and cyclical movement of water vapor and air. Much parts of South Africa is in the equatorial zone but also overlaps with wind regime of the temperate westerlies in the southern and northern region. Having identified as one of the countries with the greatest wind prospect in sub-Saharan Africa, it has a wind speed ranging from 7.29 to 9.70 m/s recorded in Cape Agulhas through Cape point. Although there is no record of mean annual wind speed across the country, perhaps due to variations, general use of wind machines in many parts of the country for the purpose of pumping water points to the potential of wind power even for electricity generation [5] (Fig. 5 shows the current wind atlas which is compiled from modelling that was done under two separate projects in South Africa).
Although studies have put South Africa's potential for wind energy between a minimum of 500 MW, and a maximum of 56,000 MW, only 0.05% has been generated from the ESKOM Klipheuwel demonstration plant and the Darling wind farm. A number of small turbines have also been mounted on locations along, but not connected to the national grid [12,20].

5.4. Biomass

The status of biomass will continue to increase in as much as the national energy policies and strategies are following the trend of renewable energy sources. In recent years, biomass energy source has gained specific

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interest as a result of the progressive reduction of conventional fossil fuel that led to an increase in the use of renewable energy sources [25].
The level of power generation from biomass is significant in South Africa, some of the paper packaging and sugar mills burn bagasse using biomass to generate steam, generate roughly 210 GWh of electricity each year. Biomass is considered as renewable which is free from carbon has its own downside environmentally, few among others are as follows;

a) Level of water: Water shortage still remains one of the problems encountered by South Africa
b) Food security: farmers should give emphasis to food crop not only energy crop in other to avoid food scarcity.
c) Biodiversity: the planting of single energy crop on large scale also has to some extent effect on land quality.

The areas with the greatest biomass energy in South Africa are Kwazulu-Natal and the waterways of Mpumalanga. Presently, there are about 4300 km^2ha of sugar cane plantation and forestry farm area of 13,000 km^2 in South Africa. The paper and bagasse burnt by sugar mill produce about 210 GW h annually [12].

5.5. Energy efficiency in South Africa

Improving energy-efficient technologies and renewable energy sources are very important for the sustainable development of any country. Since 1998, the Government of South Africa set up a demand-side management, energy efficiency measures and strategies in policy documents. The current drafted policy was National climate change response white paper of 2011, energy efficiency was highlighted as one of its main goals. Energy efficiency measures and strategies are also included in the national energy Act 34 of 2008 and the electricity regulation Act 4 of 2006. It's National Standards SANS 50001:2011

Table 4: South African end-users electricity consumption by sectors [26].

Sector	% (Percentage)
Domestic	17.2
Agriculture	2.6
Mining	15
Industries	37.7
Commerce	12.6
Transport	2.6
Others	12.3

were published in July 2011 with the aim of improving energy management (EnMS) standards through energy performance, energy efficiency, and consumption uses and pattern of a building. The standard lead to two important factors, first, reduction in greenhouse gas emission and other environmental impacts and secondly, reduction of energy cost through the energy programs mentioned.
South Africa has the capacity of energy efficiency of 20–30% across various sectors as stated by the Department of Energy in 2010. The end user's electricity consumption in the country is
depicted in Table 4.
International energy association IEA introduced 25 energy efficiency recommendation in 2011 upon which South Africa is not a member and some of the recommendations are; industries should be reporting their energy saving, energy management measures, etc. [26]. In South Africa, there is a program named EEDSM. Its main function is to develop and implement energy efficiency measures, by public awareness, understanding the energy efficiency and implementation of incentives for the participates of energy efficiency [27].
In 2008, the major reorganizations have led to new legislation and entities to govern and implement energy efficiency in South Africa. In 2009 the department of minerals and energy divided into two and becomes a department of mineral resources and department of energy. However, the department of energy drafted the energy efficiency policy under the authority of national energy Act. Also, the department of trade and industry serves as an actor in implementing for energy efficiency policy especially standard and labelling (S & L). In 2008 energy Act established the South Africa national energy development institute (SANEDI) aimed to conduct public interest energy research.

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The South African government introduced an allowance for energy efficiency via section 12I and section 12L.

a) The 12I incentive is designed to support cleaner production investment in manufacturing expansion.
b) The 12L gives an allowance for energy-saving achieved through energy efficiency. In has not been effective.

The key measures implemented by the South African government to support energy efficiency include the public sector, manufacturing sector, building codes, energy efficiency management and carbon tax [28].

6. Nigeria

Nigeria is in West Africa, bordered by Niger to the north, Benin to the west, Cameroon to the east, Chad to the northeast and the Atlantic Ocean to the south. It lies between latitude 4 4 16 0 i and13 53 0 i to the north of the equator and longitudinal 2 40 0 i and 14 24 0 i to the east of the Greenwich meridian [52]. It has 923,768 square kilometre land area and over 170 million population [53]. Nigeria is blessed with abundant solar biomass, wind, hydroelectricity and tidal energy sources that can address the problems associated with the non-renewable energy source. In November 2005 the Nigerian government approved the country's Renewable Energy Master Plan (REMP) that was drawn by the Energy Commission of Nigeria (ECN) with assistance from the United Nations Development Program (UNDP) [54]. The Master Plan is set to articulate the framework for the development of renewable energy policies, legal instruments, technologies, manpower, infrastructures, and market to ensure that vision, mission, and the target is achieved [55]. Table 10 shows Nigeria renewable energy sources and the estimated reserves. In the process of promoting the potentials of renewable energy sources in Nigeria, the country has set a vision 20–2020 for the use of renewable energy sources to meet the national electricity demand which comprises of energy measures and strategies. Table 11 shows the renewable energy supply projection in MW in Nigeria. Some of the highlighted goals in the draft document are;

a) Achieving a contribution of hydropower to Nigeria's power generation mix of 15% and 20% by the year 2015 and 2020 respectively
b) 1% wind energy contribution in the generation mix by 2020
c) c) 1% solar energy contribution in the generation mix by 2020.
d) d) Replacing 50% of firewood consumption for cooking with biomass energy technology by 2020.
e) e) Generation of 1000 MW power capacity using biomass resources.
f) f) Use of locally made renewable biofuel from secondary biomass to reduce the use of fossil fuel for transport.

Table 5: Nigeria renewable energy sources [56].

Sources	Estimated Reserved
Small hydropower	3500 MW
Large hydropower	11,250 MW
Solar radiation	3.5–7.0 kW h/m^2/day
wind	2–4 m/s at 10 m height
Biomass	
Fuelwood	11 million hectares of forest and woodland
Animal waste	211 million assorted animals
Energy crops and Agric residue	28.2 million hectares of arable land

Table 6: Renewable electricity supply projection in MW (13% GDP growth rate) [57]

S/N	Resources	Now	Short	Medium	Long
1	Hydro (LHP)	1938	4000	9000	11,250
2	Hydro (SHP)	60.18	100	760	3500
3	Solar PV	15	300	4000	30,005
4	Solar Thermal	–	300	2136	18,127
5	Biomass	–	5	30	100
6	Wind	10	23	40	50
7	All renewable energy sources	2025.18	4628	15,966	63,032

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8	All energy renewables	8700 installed gen. capacity	47,490	88,698	315,158
9	% of renewable energy sources	2.3%	10%	18%	20%
10	% RE less LHP	0.4%	1.3%	8%	16%

Short – 2015. Medium – 2020. Long – 2030.

6.1. Hydropower

Hydropower in Nigeria ranges from micro-mini-small (< 1 MW) to large (< 100 MW). According to a survey conducted before the 1973 oil crises, the total estimated capacity of large hydropower in Nigeria is 14,750 MW. However, only about 1930 MW representing 14% is generated at the two main hydroelectric power plants located at Shiroro, Kainji and Jebba [58]. Small hydropower plants predate Nigeria's independence. Presently, there are 8 SHPs with a capacity of 37 MW located in Kano, Sokoto and plateau and Ogun. The planned total of 270 sites is yet to be developed [59]. According to ECN report for the year 2001, Nigeria uses only about 21.5% or 6989 GW/yr of her potential despite the dire need in rural areas and the danger of fossil fuel pollution [60]. Nigeria has been positioned as the 9th African country with the technical and economic feasibility of hydropower energy at 32,450 GW h/yr and 29,800 GW h respectively. According to ECN, it uses about 21.5% (6986 GWh/yr) of her potential for the year 2001 [54]. The 3050 MW capacity Mambila hydroelectric power plant is located at the Mambila Mountain in the Taraba State of Nigeria. The project which took off in 1982, has suffered a decade of neglect but has resumed with a target completion date of 2018. Fig. 10 shows the Mambila hydropower plant site under construction [61,62].

6.2. Solar

Solar is the backbone of all other renewable energy resources such as biomass, wind, hydroelectric and wave [60]. Nigeria which lies in the region that has a great amount of solar energy potential [64], has an average daily solar radiation ranging from 14.4 MJ m−2 day−1 in the southern part to 21.6 MJ m−2 day−1 in the northern part [65]. If the country's average sunshine of 6 h a day, is tapped over 1% of land area for the PV power plant, will be capable of generating 1850,000 GW h of energy per year constituting over one hundred times the current amount of electricity it generates [66]. There are two energy sources tapped from solar- thermal and photovoltaic, as well as being non-polluting resources and environmentally friendly. Solar thermal has a wide application which solar cooking, solar water heating, for industries solar incubators, solar crop drying, hospitals, and household, etc. PV modules have a 25-year lifespan, requires very little maintenance and is simple to operate, making it ideal for use in rural areas for pumping water, refrigeration of vaccines, basic lighting [67]. A French oil company launched one of the biggest PV projects in Nigeria's northern region to generate 1000 MW of solar power. The region is the most suitable location for the project not only because it receives a very high level of solar energy but also because it has a very large percentage of the scattered population that is ideal for provision of solar power [68]. Fig. 11 shows the yearly average of daily sums of global horizontal irradiation in Nigeria

6.3. Wind

The wind is one of the fastest developing alternative energy technologies in the world. It costs very little to maintain, environmentally friendly and is the cheapest resource per unit of generated electricity. Wind energy is hugely abundant in Nigeria but is mainly used for irrigation and domestic water supply in rural areas [70]. According to studies conducted by Energy Commission of Nigeria (ECN), total exploitable energy reserve at 10 m height may range from 8 MW h/yr in Yola in the North-East to 51 N W h/yr on the Jos plateau in central region and up to 97 MW h/yr in Sokoto near the Sahel region in the North-West and as low as − 3 m/s in the southern region expect the offshore and coastal region [60]. Currently, the percentage of wind energy consumption in Nigeria is very low with no connection to the national grid [66]. A report compiled by Lahmeyer international reveals that wind energy estimation for the speed of the wind at 10 (ten) selected sites across the country is from 3.6 m/s to 5.04 m/s [70]. The first wind farm project in Nigeria is the 10 MW farm located at Rimi village 25 km south of the state capital, Katsina. The average annual mean monthly wind speed for Katsina state has been computed to be 6.044 m/s. The wind farm comprises 37 wind turbines of 55 m height with 275 kW rated power.

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At 98% completion as at May 2015, the project is fully supported by the Federal Ministry of Power and Steel and envisioned by the Katsina State government. The average annual mean monthly wind speed for Katsina state has been computed to be 6.044 m/s [71,72] and the 10 MW wind farm site at Rimi, Katsina State

6.4. Biomass

Biomass is positioned third-largest energy sources in the world after coal and oil. Biomass energy is defined as the energy obtained from biological plants and animals' matter that can be used to generate electricity. Biomass consist of four main classes which are; agricultural sources, forest and their derivatives, municipal solid waste and animal dung [74]. Nigeria is blessed with abundant biomass sources, the most notable of which is fuelwood, which provides 80 million cubic meters (43.4 × 109 kg) annually for cooking and other domestic purposes [75]. The 6.0 × 109 MJ content of wood energy would make a much higher contribution to Nigeria's fuelwood energy profile but for the fact that more than 350,000 ha of forest and natural vegetation are lost to bush fires, land clearing and other factors annually, adversely affecting the 904,100-ha forest land or 9.9% of the country's total land area. About 200 million tons of dry biomass can be obtained from forage grasses and shrubs realizing 2.28 × 106 MJ of energy content. Biomass is one of the key alternative energy resources whose sustainability needs to be carefully understood [60]. According to 1985 estimate, Nigeria generates 6.1 million tons of crop residues and waste with an energy content of 5.3 × 1011 MJ as well as 227,500 t of animal and poultry waste with 2.2 × 109 MJ energy content when converted to biogas at 2.93 × 109 kW h with 5.36 × 109 m3 order. Currently, Nigeria is considering introducing biomass utilization in the transport sector. On the whole, the estimated biomass contribution to the country's energy potential is totally insignificant and not available [75].

6.5. Energy efficiency in Nigeria

Like other developing countries, Nigeria was not left out for the campaign and programs of energy efficiency savings, despite the fact that the major focus on the energy sector is on improving electricity generation. The main functions of energy efficiency are; mitigation of environmental effects, reducing the emission of greenhouse gases and saving the cost of energy consumption which is proportional to the energy saving. This will also give the policymaker greater latitude for reducing electricity subsidies. However, two stages upon which the potential of energy efficiency can be exploited. Firstly, how energy is being generated, transmitted and distributed and secondly how energy is consumed in various sectors such as residential, commercial and industrial. In the process of Nigerian government promoting the use of energy-efficient equipment's. The energy commission of Nigeria ECN in partnership with the Cuban government and with the support from ECOWAS has been distributing of million compact fluorescent lamp (CFL) free to replace the incandescent lamps. National Center of Energy Efficiency and Conservation (NCEEC) in partnership with the University of Lagos are researching and developing in energy efficiency and conservation as such promote the use of energy-efficient appliances and lighting lamps. The project titled "promote energy efficiency in Nigerians residential and public sectors" 2011–2015 which is managed by UNDP and implemented by an energy efficiency unit in ECN aims to introduce energy efficiency policies and measures including standards and labels for refrigerators and lighting lamps in Nigeria. To promote energy efficiency, proposed policy measures have been drafted by National renewable energy and energy efficiency policy (NREEEP) which are; a) Campaign and training of the public on the importance of energy-saving equipment's. b) Enforcement of incentives for consumers that adopts energy-saving technologies. c) Giving incentives for retailers and importers of energy-efficient products and promotion of local productions. d) Active replacements of inefficiency equipment are in governments and public places. e) Integrating measures for energy efficiency and saving in electricity tariff. f) Development of energy efficiency building codes. g) Conduction of research and development activities on energy efficiency and conservation. h) Improving public awareness of the benefits of improved energy efficiency equipment. The policy has set a target which is; a) Drafting on all the key components of energy efficiency by 2020. b) Enactment of all relevant legislation required for policy implementation by 2020. c) Attain replacement of 40% of old inefficient equipment with the efficient ones by 2020. d) Sustain best energy efficiency practices beyond 2030 [76]

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7. Conclusion

Africa is endowed with abundant energy sources especially renewable energy, yet it is facing a serious crisis as a result of failure to harness renewable energy resources, failure to deploy appropriate technology, failure to support stakeholder agencies in the private sector and overdependence on fossil wood and waste of wood resources with its attendant consequences of desertification. This review study focuses on the two major African countries, South Africa and Nigeria. South Africa has the greatest model for approaching its energy challenges. This review study focuses on the two major African countries namely South Africa and Nigeria. Of the two, South Africa has the best model for tackling its energy challenge through the use of wind and solar energy. Nigeria has great potential but very weak hydro, solar and wind power in that order. In the two countries and indeed across the African continent access to renewable energy for off-grid, small scale application is key to a successful resolution to the energy crisis, sustainable development, and fighting climate change. Energy storage technologies are very vital for storing electrical energy and be released when needed. Even though, the selection of an energy storage system for a particular application depends on the response time, application power and energy ratings, volume, weight and operating temperature. Feed-in-tariff and net metering are both methods designed to accelerate investments in renewable energy technology and very essential programs that promote the use of renewable energy technology

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