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Distributed Generation in Nigeria's Post-Privatised Power Sector - Challenges and Prospects

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ABSTRACT
Nigeria's electricity infrastructure is inadequate, outdated and ill-maintained thereby resulting in perennial epileptic power supply to the industrial, commercial and residential sectors of the nation's economy. More than half of the country's population has no access to electricity and in order to make electricity available to more consumers, many independent power producers (IPPs) are adopting the distributed generation (DG) technologies. This paper investigated the challenges and prospects of DG in Nigeria's post-privatized power sector through the extensive review of reports, position papers, legislative acts, policy documents etc. from statutory institutions and authorities in and outside Nigeria. The findings of the study show that despite the current challenges posed by underfunding, long investment neglect etc. of the energy sector, Nigeria has abundant natural resources to successfully implement and reap the full benefits of DG technologies. The paper recommends the prioritization of DG by power sector stakeholders and government at all levels in the country in order to achieve electricity supply security for the nation's industrial, commercial and residential sectors. The findings of this study will facilitate proper integration of smart grid technology into the national grid and help achieve adequate, stable and reliable electricity supply in Nigeria.

Keywords: Decentralised energy, Decentralised generation, Dispersed generation, Distributed energy, Embedded generation, On-site generation

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I. INTRODUCTION

Globally, more environment-friendly energy procurement strategies are being adopted in line with the new climate change policies and obligations. In Australia, for instance, a renewable energy target has been set for 2020 which corresponds to a tenfold percentage increase in RES. A similar plan is in place in Ontario, Canada where the statutory authority there has predicted the generation derived from wind, solar and biomass increasing from less than 1% of all generation produced in 2003 to 13% by 2030 [1].

Bangladesh made a success story from implementing off-grid power solutions. The government of Bangladesh initiated the Solar Home System (SHS) based rural electrification programme in 2003 through Infrastructure Development Company Limited under a micro-credit scheme. In 2002, only 7,000 Bangladeshi households used solar panels, but as of today, the programme has installed about 2 million SHS in the country. Also, since 2010, about four mini-grids have been installed, and nine others are to be installed in off-grid locations of Bangladesh [2].

Distributed generation (DG) has no unified definition but describes a small power plants (in the range of small kilowatts up to 10 MW) located at or near the loads and operating either in a stand-alone mode or connected to a grid at the distribution or sub-transmission level [3] to generate electricity close to the site of use thereby protecting households, businesses and institutions from unexpected power cuts as well as reducing costs and losses associated with transmission while improving energy efficiency. It is also known as: embedded generation, on-site generation, dispersed generation, decentralised generation, distributed energy, decentralised energy or small-scale generation.

Generally, DG refers to electricity generation within distribution networks or on the customer side of the electric network. A typical layout of Distributed Generation (DG) is as shown in Figure 1.

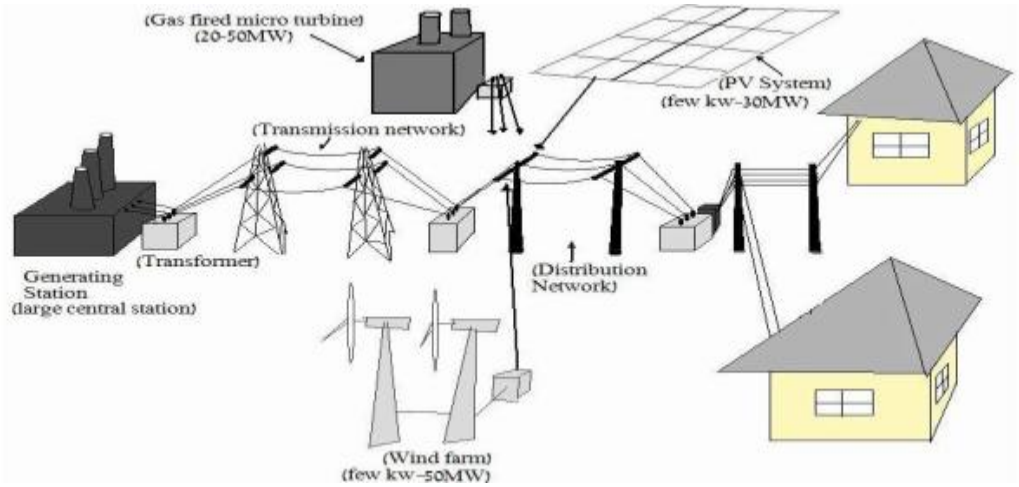


Fig 1. A typical layout of Distributed Generation (DG)

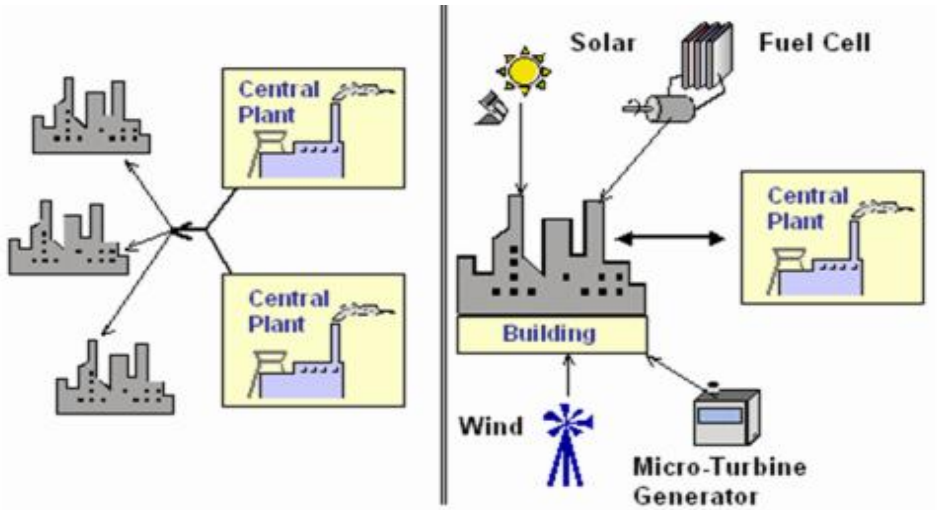
While consensus is yet to be reached about the definition of DG, the followings are some of the definitions of DG presently in common use:

- DG is generation of electricity by facilities sufficiently smaller than central plants, usually 10 MW or less, so as to allow interconnection at nearly any point in the power system [4, 5].
- DG unit is a generation unit that is not centrally planned, not centrally dispatched, usually connected to the distribution network and smaller than 50-100 MW [5, 6].
- DG is a generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distribution-level voltages [5, 7].
- DG unit is a modular electric generation or storage located near the point of use and which capacity is typically from less than a kilowatt (kW) to tens of megawatts (MW) in size [5,8].
- DG is any small generation unit from a few kW up to 50 MW and/or energy storage devices typically sited near customer loads or distribution and sub-transmission substations [5, 9].
- DG is an electric power source connected directly to the distribution network or on the customer site of the meter [10].

Distributed generation can be classified:

- According to the type of technology into Wind power, Solar photovoltaic, Small hydropower, Fuel cells, Micro turbines etc.
- According to the primary energy in use into Renewable energy and Non-renewable energy.
- According to the interface to power system into Associated (Electromechanical) system and through the inverted connected system.

Several efforts have been made to distinguish DG from the Central, large power generation. See Figure 2 for comparison between centralised generation and distributed generation.



(a) Centralised Generation (b) Distributed Generation

Fig 2. Centralised generation versus Distributed generation

As the world's most populous black nation, Nigeria has need for increased energy supply and improved grid reliability and security. To this end, the country has since developed a Renewable Energy Master Plan (REMP) to increase the supply of renewable electricity from 13% of total electricity generation in 2015 to 23% in 2025 and 365 by 2030. The aim being to make renewable electricity account for 10% of the country's total energy consumption by 2025.

Most of the power received by Nigerian electricity consumers is on-grid - a system whereby generated power is supplied to customers by the Distribution Companies (DisCos). The total off-grid electricity generation capacity as approved by the Nigerian Electricity Regulatory Commission (NERC) is still less than 500MW [2]. In view of Nigeria's plans to increase generation capacity in the nearest future and in consideration of the present low level of access to electricity in the rural areas, there is need for significant investments in off-grid generation [2].

Nigeria currently generates electricity from a mixture of sources. In 2015, thermal power – mainly oil and gas – constituted 82% of power generation; hydropower contributed 17.8%, while non-hydropower renewable sources made up the remainder, 0.2%. Nigeria's power composition, though relatively more diversified than other OPEC countries, the country has wide scope for the exploration of alternative energy sources such as solar and wind power. Table 1 shows the different Distributed Generation capabilities available globally today.

Nigeria is abundantly blessed with renewable energy resources e.g. Solar energy, Biomass energy, Wind energy and Hydro energy as well as non-renewable energy resources e.g. Coal, Petroleum and Natural gas. Nigeria's population is above one hundred and eighty three million and about 60 per cent of the population have no access to grid-connected electricity. Access to electricity in the rural areas is about 35% and about 55% in the urban areas [2].

Table 1. Different DG Capabilities [11].

No.	Technology	Typical available size
1	Combined cycle gas turbine	35-400MW
2	Internal combustion engines	5kW- 10MW
3	Combustion turbines	1-250MW
4	Micro turbines	35kW-1MW
5	Fuel cells, Phos. Acid	200kW-2MW
6	Fuel cells, molten carbonate	250kW-2MW
7	Fuel cells, proton exchange	1-250kW
8	Fuel cells, solid oxide	250kW-5MW
9	Battery storage	0.5-5MW
10	Small hydro	1-100MW
11	Micro hydro	25kW-1MW
12	Wind turbine	200W-3MW
13	Photovoltaic arrays	20W-100kW
14	Solar thermal, Central receiver	1-10MW
15	Solar thermal, Lutz system	10-80MW
16	Biomass gasification	100kW-20MW
17	Geothermal	5-100MW
18	Ocean energy	0.1-1MW

It is imperative that to make up for the current electricity supply shortfall and improve the economy's current GDP growth, there must be renewed investment interests in distributed generation schemes based on renewable and alternative sources of electricity. This study investigates the challenges confronting the post privatised Nigeria's power sector in implementing distributed generation and pin-points the prospects of adopting distributed generation technologies as a lasting measure against perennial energy shortages in the country.

1.1 Overview of Nigeria's Power Sector

The Nigeria power system is radial and centralised in nature thus the necessity for continuous upgrading and replacement of transmission and distribution facilities. Radial system implies that electricity flows only in one direction i.e. from the central power station through the transmission and distribution network spread over long distances to the consumers making the system prone to high distribution and transmission losses. Much of the energy is also produced by large-scale, centralised power plants using fossil fuels (coal, oil and gas), hydropower or nuclear

power thus subjecting the system to the environmental impact of greenhouse gases and other pollutants. These drawbacks, however, are absent in distributed generation (DG) because in DGs, power generated from clean and environmentally-friendly renewable energy resources (Solar, Wind, Biomass) by some small, modular energy conversion units are often located close to the point of end use and can either be stand-alone or integrated into the electricity network.

The Nigerian power sector is faced with many challenges which include: weak and dilapidated transmission and distribution infrastructure, underfunding, long investment neglect, generation deficit, poor performance and over dependence on fossil fuels. This is in the face of abundant renewable energy resources which if properly tapped can be used to generate electricity for many Nigerian homes, farms, businesses and industries through distributed generation. The choice of renewable energy resources is aimed at achieving two goals i.e. reducing greenhouse emissions associated with fossil fuel generation and improving electricity supply reliability.

Currently, Nigeria has an installed power generation capacity of 12,522MW out of which 10,592MW (84.6%) is gas fired while 1,930MW (15.4%) is from hydro. It is noteworthy that out of the total installed generation capacity, the maximum peak generation by power plants as at December, 2015 was 4,810MW.

Nigeria has an average annual per capita power consumption of 155 kWh, obviously among the lowest in the world. Experts have hinted that for the Nigerian economy to grow at a rate of 10%, the country's electricity portfolio must reach 30,000 MW by 2020, and 78,000 MW by 2030. Given the current scenario, however, it is doubtful if Nigeria would be able to meet that target. Except for the Nigerian Independent Power Project (NIPP) assets listed in Table 2 and the power transmission assets in which it is retaining 20% equity interest and full equity ownership respectively, the Nigerian government currently has no direct equity interest in Nigeria's power assets.

Table 2: Current NIPP Assets in Nigeria [12]

Name of Generating Company		**Location**	Design Capacity (MW)
1.	Egbema Generation Company Limited	Near Owerri, Imo State	381
2.	Gbarain Generation Company Limited	Near Yenagoa, Bayelsa State	254
3.	Geregu Generation Company Limited	Ajaokuta, Kogi State	506
4.	Benin Generation Company Limited	Ihovbor, Benin-City, Edo State	508
5.	Omoku Generation Company Limited	Near Port Harcourt, Rivers State	265
6.	Omotosho Generation Company Limited	Okitipupa, Ondo State	513
7.	Ogorode Generation Company Limited	Sapele, Delta State	508
8.	Calabar Generation Company Limited	Calabar, Cross River State	634
9.	Olorunsogo Generation Company Limited	Olorunsogo, Ogun State	754
10.	Alaoji Generation Company Nigeria Limited	Near Aba, Abia State	1131

The generation subsector in Nigeria is wholly privatized and has 6 privatised companies, 10 National Integrated Power Project (NIPP) generation companies and 40 Independent Power Producers (IPPs). The transmission subsector is 100% Government owned by the Transmission Company of Nigeria (TCN) and under management contract awarded to a utility and asset management company.

The Nigerian distribution subsector is whole privatized and is comprised of 11 distribution companies (DisCos) situated across the country. Figure 3 represents the structure of Nigeria's power sector post-privatization. National energy allocation to the DisCos is daily and often in proportion to the customer base served [13].

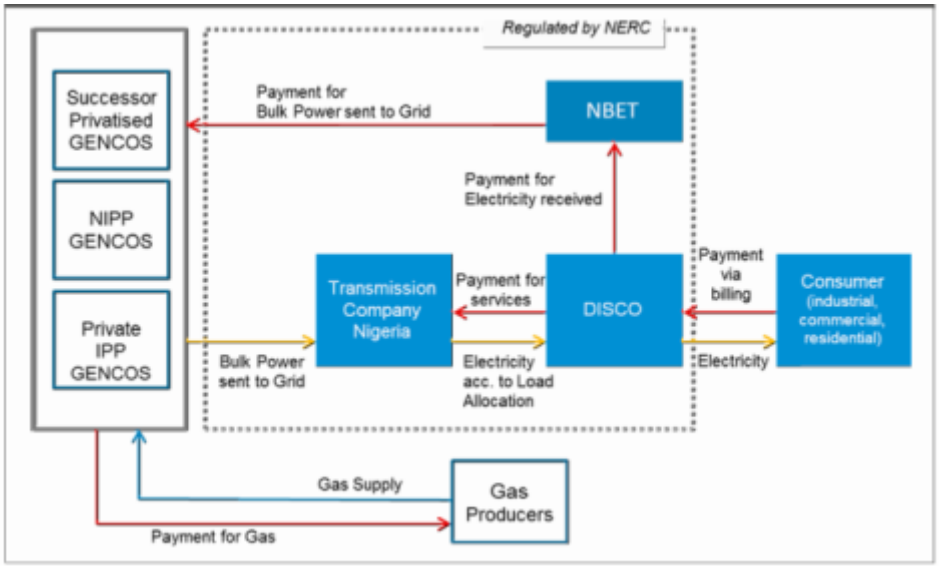


Fig 3. Structure of Nigeria's Power Sector Post-Privatization [14]

1.2 Energy Consumption in Nigeria

Nigeria has abundance of natural energy resources such as coal and lignite, natural gas, crude oil, solar, hydro, nuclear, wood fuel, geothermal, tide, biogas and biomass. However, only four (coal, crude oil, natural gas and hydro) are currently utilized in processed forms while two (wood fuel and solar) are used in their crude forms for heating, cooking and lighting. Others are still untapped due to the country's lack of policies to harness resources, develop new as well as make improvements on the existing electricity infrastructure [15, 16].

Despite being endowed with enormous energy resources, Nigeria has focused only on the exploitation of hydro, petroleum and natural gas resources and virtually neglected all others sources of energy. The exploitation of energy resources in Nigeria began with coal in 1916. At the inception of the Nigerian civil war, however, many coal mines were abandoned and ever since coal production level has fallen significantly from 50% in 1960 to less than 1% in 1990 especially due to lack of imported mining equipment [17, 18]. The discovery of crude oil in commercial quantities in the Oloibiri district in the Bayelsa state by Shell Darcy on 15 January, 1956 further worsened coal production in the country. Petroleum products were cheaper and readily available. Between 1970 and 1980, the premium motor spirit (PMS) otherwise known as petrol had become the main source of energy in Nigeria necessitating the neglect of all other energy sources [19].

Like in most developing countries, Nigeria's energy consumption has continued to rise with over 23% increase between 2000 and 2008 (See Figure 4). The increase in energy consumption though consistent with GDP, the energy consumption has been increasing at a faster rate than GDP.

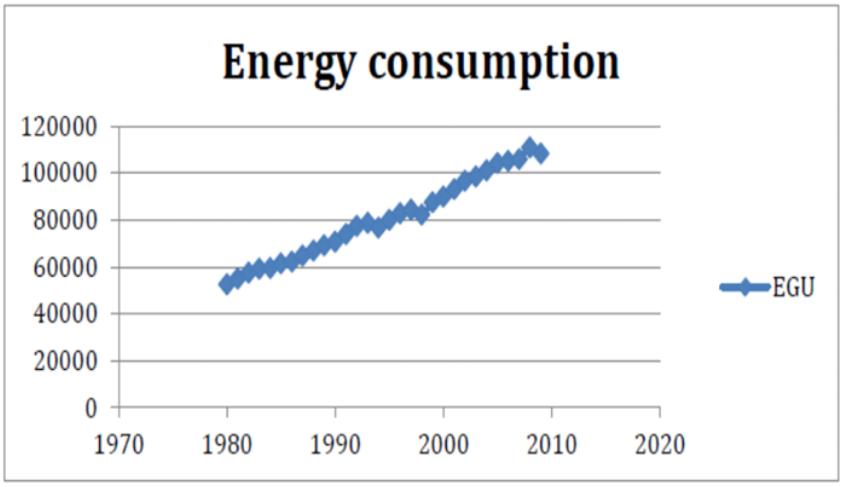


Fig 4. Energy Consumption Trend in Nigeria. [16]

Currently, the electricity demand in the country exceeds supply. For instance, whereas the peak load forecast as at December 2009 was 5,103MW, the estimated daily power generation for the same period was merely 3,700MW. Consequently, load shedding and power outages are regular features in Nigeria [17]. The epileptic nature of electricity has forced electricity consumers to resort to petrol and kerosene powered equipment and facilities thus leading to scarcity of these petroleum products. Figure 5 shows the total energy consumption in Nigeria in 2010. The importation of domestic fuel in Nigeria has risen over the years to about 75% [20] resulting in the use and overdependence on fuel-wood and causing deforestation and the attendant degradation of the environment and worsening desertification [17, 21].

Meanwhile amidst shortage of energy, other alternative and readily available energy sources such as solar and wind remain largely underdeveloped in the country. Due to inadequate energy, there is a sharp decline in industrial capacity utilization in Nigeria [22]. According to EIA estimates, Nigeria's primary energy consumption in 2011 was about 4.3 Quadrillion Btu with traditional biomass and waste accountable for 83% of the total energy consumption [15, 23].

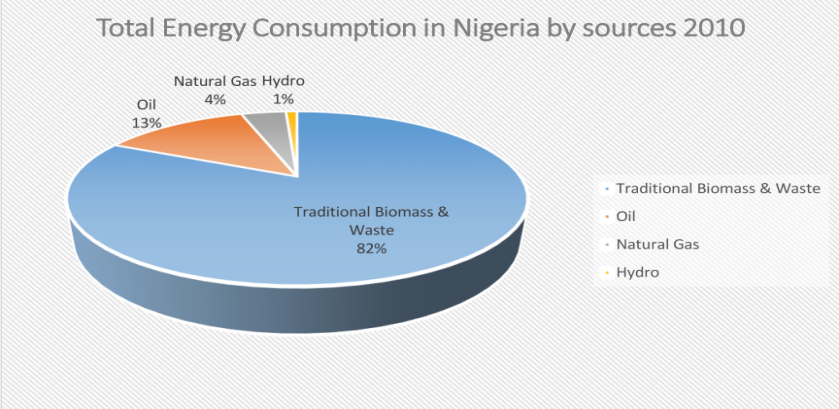


Fig 5. Total energy consumption in Nigeria in 2010

II. CHALLENGES FACING ADEQUATE AND RELIABLE ELECTRICITY GENERATION IN NIGERIA

The challenges facing adequate and reliable electricity generation in Nigeria includes:

- Access to gas, gas prices and gas supply framework
- Transmission Network – Losses and dilapidated Infrastructure
- Bulk Trader – Credibility , Standard PPA Template
- Maintenance/ Turnaround of existing FGN Discos
- Funding for NIPP Projects
- World Bank Partial Risk Guarantee
- Financing for IPPs
- Distribution Network constraints – good or bad thing?
- Credibility/Liquidity of Discos
- Regulatory, Contractual Framework & Capacity

- Eligible Customers – Classes of customers currently undefined, coul d this be a win-win situation for the Discos?
- Procurement Process – enabler or clog in the wheel?
- Cost Recovery – how will this be structured?
- Licensing hurdles for those with excess power – could there be another way out

2.2 Challenges facing Successful Implementation of Distributed Generation in Nigeria

The full implementation of DG in Nigeria meets with certain challenges, some of which are as follows:

- Currently, there are limited incentives that encourage DG connections to exiting distribution networks and/or the post-connection management services.
- DGs pose power quality problems e.g. Harmonic distortion of the network voltage and transient voltage variations.
- DG connection to distribution networks causes voltage rise which in turn produces power variations and therefore power supply instability especially in radial distribution systems due to reverse power flow introduced into the network by the presence of the DG.
- Owing to the fact that DG technologies are still new and adaptation technology still underdeveloped to many power sectors worldwide, the initial investment cost is high

- Distribution networks to which DGs are connected require special protection against the effects of such connections. Such effects include Islanding – a phenomenon which results from the tripping off of a protective device e.g. Circuit breaker or fuse from one or more generators thereby causing network voltage and frequency fluctuations and oftentimes resulting in severe damages to the affected segment of the distribution network.
- The successful implementation and sustenance of DGs require a well-articulated and clear regulatory policy framework that permits its smooth integration into available distribution networks.
- There is also licensing hurdles for prospective operators of DG Units.

2.3 Energy Sources and Potentials of Nigeria

Nigeria has an abundant supply of natural energy sources, still, the country continues to grapple with the challenges posed by serious energy crisis due to the ever increasing energy demand and the declining electricity generation from domestic owned power plants which are dilapidated, obsolete, and in the state of disrepair. The situation is worsened by the fact that successive governments in the country have failed to initiate and implement policies and technologies necessary to fully explore and exploit the God given natural resources to the benefit for the collective benefit of the citizens.

Energy resources in Nigeria are classifiable into renewable and non-renewable energy resources:

•Renewable Energy Resources. These are energy resources that can be replenished or produced quickly through natural process [24]. Examples include: Hydro, Solar, Wind and Biomass. Renewable energy is generated from sources that are derived from, and quickly replenished by the natural movements and mechanisms of the Earth.

•Non Renewable Energy Resources are energy resources which supplies are limited and they cannot be produced quickly through natural process. Fossil fuels are non-renewable and are excellent sources of energy because they are rich in hydrocarbons. Coal, oil, and natural gas are examples of fossil fuels.

Table 3 shows some of the energy resources available in Nigeria. With the rich energy resources in the country, Nigeria should not suffer from the persistent inadequate electricity generation in the country. But the contrary remains the case.

Table 3. Nigeria's Energy Resource

Energy Type	Resource Estimate
Crude Oil	Over 35 billion barrels
Natural Gas	Over 183 trillion cubic feet
Hydro Power	Over 20,000 MW
Coal	Over 2.75 billion metric tons
Solar Radiation	Over 3.5 – 7.0 KWh/m^2-day
Wind Energy	Over 2.0 – 4.0 m/s
Nuclear	Lot (Not yet quantified)
Biomass	Over 144 million tonnes/year
Wave and Tidal Energy	Over 150,000 TJ/yr (16.6 x 10^6 toe/yr)
Geothermal Energy	37 and above 100°C (Not yet expl.)

Table 4 shows the various power generating plants and the year each was established. The energy sector has suffered long neglect from successive Nigerian government. Since 1990 when the Shiroro power station came on stream, no new units has been added. Worst still the existing units have been left without maintenance for over 10 years thus facilitating the dilapidation of the power plants and equipment.

Table 4. Power Stations in Nigeria showing Location and Establishment Dates

S/N	Location	Type of Power Station	Date Established
1.	Ijora	Thermal Power Station	1956
2.	Afam	Thermal Power Station	1962
3.	Delta	Thermal Power Station	1966
4.	Kainji	Hydro Power Station	1968
5.	Ogorode	Thermal Power Station	1980
6.	Jebba	Hydro Power Station	1985
7.	Egbin	Thermal Power Station	1986
8.	Shiroro	Hydro Power Station	1990

Until recently, the state-owned PHCN generated electricity from the 9 power stations available (See Table 5). These consisted of six thermal and three hydro stations. The six thermal stations are Afam, Delta, Egbin and Ijora which run on gas, the Sapele power station which runs on gas and steam, the Oji River which runs on coal while the rest namely Kainji, Jebba and Shiroro, each runs on hydro i.e. Water [25].

Table 5. State-owned Generating stations [25]

Site	Type	Installed Capacity (MW)	Available Capacity (MW)	No. of Units
Afam	Thermal	700	488	18
Delta	Thermal	812	540	20
Egbin	Thermal	1320	1100	6
Ijora	Thermal	66.7	40	3
Sapele	Thermal	1020	790	10
Jebba	Hydro	570	450	6
Kainji	Hydro	760	560	12
Shiroro	Hydro	600	600	6
Orji River*	Thermal	60	-	4
Others	Diesel	46	18	-

* Operationally inactive

2.3.1 Hydro Energy

Nigeria is endowed with vast deposits of fossil fuel and has immense potentials in the renewable energy field; especially in hydropower generation because of its access to 840 km coastline in the South and two great rivers entering from the Northeast and Northwest [15].

Hydro-electricity comes from the conversion of potential energy water into electricity by water turbines and electric generator system. About 40% of the total electric power in Nigeria comes from hydropower derived from large rivers such as the Niger and Benue Rivers and their several tributaries and natural falls [26]. Dating back to 1968, hydropower is the most exploited renewable energy source in Nigeria. The Figure 6 shows the Shiroro Dam; one of the sources of hydro energy in Nigeria.

Fig 6. The Shiroro Dam in Nigeria

Water has kinetic energy when it flows from a point of higher elevation to a lower one. Hydropower is derived from the potential energy available from water due to the height difference between its storage level and the tail-water to which it is discharged [27]. Electrical power is generated by mechanically converting this energy into electricity through a turbine usually at a high efficiency rate. Hydro schemes in Nigeria are classified into large, medium, intermediate, etc. depending on the volume of water discharged and height of fall (or head). Currently, Nigeria has eight small hydro power (SHP) stations with aggregate capacity of 39.0MW installed under government/private sector partnership and located at Jos Plateau [15]. Nigeria's total exploitable hydropower potential is estimated at over 10,000 MW capable of producing 36,000 GWH of electricity annually with only about one-fifth of this potential so far developed as at 2001 [28]. Table 6 shows the location of the three major hydro power plants and hydro potential of Nigeria.

Table 6. The three major Hydro Plants

S/N	Name of Hydro Plant	Year Established	Installed capacity	Available Capacity as at June 2010
1.	Jebba	1985	578	482
2.	Kainji	1968	760	465
3.	Shiroro	1990	600	450
		Total	1,938	1,397

In addition to large hydro-electric generation, Nigeria has good potentials for both micro and mini hydro generation. Apart from tapping the hydro energy available, the country can as well source energy from the wind and even the sun. The Northern part and the Niger Delta coastal areas of the country afford wind energy owing to their peculiar topographies while due to the country's nearness to the equator, solar power with intensity of 5 to 7 Kwh/m2/day can readily be available for use 12 to 13 hours daily.

2.3.2 Solar Energy

Solar energy is the direct conversion of sunlight into electricity using semiconductor materials called photovoltaic (PV) modules. Solar energy is the energy produced from the sun and is considered as one of the most cost-effective of the renewable energy sources. A solar energy system consists of solar collector and the solar storage unit which collect solar radiations for the purpose of heating air or water. The collector collects the radiation that falls on it and converts a fraction of it to other forms of energy [29]. The storage unit conserves for such times when only a very small amount of radiation will be received. At night or during heavy cloud-cover, for instance, the amount of energy produced by the collector is usually small. Figure 7 shows some solar Panels.

The storage unit thus holds the excess energy produced during the periods of maximum productivity so as to release same when the productivity drops. In practice, a backup power supply is usually provided for emergency situations when the amount of energy required may be greater than both what is being produced and what is stored in the solar container [29].

Fig 7. Solar Panels [30]

Solar power is generated as rays emitted from the sun are collected using the solar panel which is comprised of a semi-conductive material usually silicon such that as particles of the light rays called photons hit the surface of the solar panels, it is absorbed by the solar cells which behaves like conductors. As the electrons in the solar panels get heated up, they are excited and break free and carry an electric charges. This creates a current of electrons, which are collected through metal wires, that in turn results to the generation of electricity. For electricity to be successfully generated from the sun, ample sunlight is necessary to generate enough heat energy. The quantity of electricity generated also has much to do with the efficiency of the solar panels or cells used. Solar cells are known for very low maintenance requirements as there are no moving parts. Besides, it is believed that with minimal maintenance, an efficient solar power system can last as much as 40 years and sometimes even longer.

Nigeria is well positioned to benefit greatly from solar energy generation owing to her geographical location close to the equatorial region which is full of large quantity of solar radiation. Besides, solar radiation reaches nearly every part of the country with average solar –2 -1 radiation of about 19.8 MJm day and average sunshine hours of 6 hours a day; ranging between about 3.5 hrs at the coastal areas and 9.0 hrs at the far northern boundary [15, 31]. Nigeria situates within a high sunshine belt with enormous solar energy potentials such that if solar collectors were used to cover 1% of Nigeria's land area, it would be possible to generate solar electricity per year that would be over one hundred times the current grid electricity consumption level in the country [15, 32]. Experts have estimated the solar capacity for Nigeria as being between 3.5kW/m/day – 7.0kW/m/day and average sunshine daily of 4 – 7 hours [33].

Solar energy has some unique advantages over the other sources of energy. For instance, it is free, clean, renewable and inexhaustible. However, it is costly, unreliable needing storage facilities and sometimes inefficient due to failures arising from its many panels and the associated plants.

2.3.3 Wind Energy

Wind power is converted into electrical energy in a wind turbine as magnets move past stationary coils of wire known as the stator thus producing alternating current (AC) electricity which is later converted into direct current (DC) electricity which can be used to charge batteries as a way of storing the electrical energy or fed into some special inverters for the purpose of feeding power to the electricity grid or other electricity supply system [29]. Figure 8 shows a typical wind turbine.

Fig 8. Wind Turbine [34]

The main advantages of electricity generation from the wind include the absence of harmful emissions, very clean and almost infinite availability of wind [35, 36]. Given modern technology, wind energy is one of the cost effective resources among different renewable energy technologies available today [37]. A major disadvantage of this source of renewable energy is that because the strength of the wind is not constant certain threshold of wind speed must be surpassed before wind power can actually be harnessed [38].

Although wind power is currently not used in Nigeria for electricity production, the country has high potential for generation of electricity from the wind to serve single households, small towns and rural communities. The only functional wind energy system in Nigeria is the 5kW aerogenerator, which supplies electricity to Sayya Gidan Gada Village in Sokoto State [39] shown in Figure 9.

Fig 9. A 5kW aero generator in Sayya Gidan Gada, Sokoto State [39]

Previous studies show that the northern area of the country is very close to the Sahara, hence there is enough small and medium winds for substantial power generation [15]. Studies have shown also that the North-Central and South-East of Nigeria possess enormous potential for rich harvest of wind energy with possible wind speeds reaching as high as 8.7m/s in the northern part of the country [15, 40]. There is need therefore to embark on more extensive researches to determine actual values for wind energy potential in the country. In Table 7 is shown the annual mean wind speed, maximum extractable wind power density, mean power density, wind energy class and geographical location of wind energy in Nigeria.

Table 7. Annual mean wind speed, maximum extractable wind power density, mean power density, wind energy class and geographical location of wind energy in Nigeria [41]

Locations	Mean Wind Speed (m/s)	Maximum Extractable Wind Power Density (w/m^2)	Mean Power Density (w/m^2)	Wind Energy Class	Geographical Location
Jos	9.47	304.53	519.91	7	North
Kano	9.39	297.43	501.79	7	North
Sokoto	7.21	134.56	229.73	7	North
Gusau	6.18	84.47	144.22	2	North
Enugu	5.73	67.41	115.08	2	South
Minna	5.36	55.12	94.10	1	North
Potiskum	5.24	51.72	88.29	1	North
Maiduguri	5.23	51.18	87.37	1	North
Kaduna	5.13	48.32	82.49	1	North
Ilorin	5.04	46.00	78.53	1	North

2.3.4 Biomass

Bioelectricity is electricity generated from biodegradable biomass e.g. residues and wastes from agriculture, forestry and related industries, municipal and industrial wastes as well as energy crops and plantations [39]. Biomass energy thus refers to renewable energy that is biologically derived from wood, aquatic plants, corn cobs and stalks, rice hulls, nut shells, orchard prunings, alcohol fuels, vegetable oils, and municipal and animal wastes and such other organisms. The commonest being dead trees, wood chips and tree trumps. Biomass energy include also plants or animals that are used for production of chemicals and fibers as well as waste that is biodegradable or easily burnt as a fuel [29].

Fig 10. Generation of energy from biomass [34]

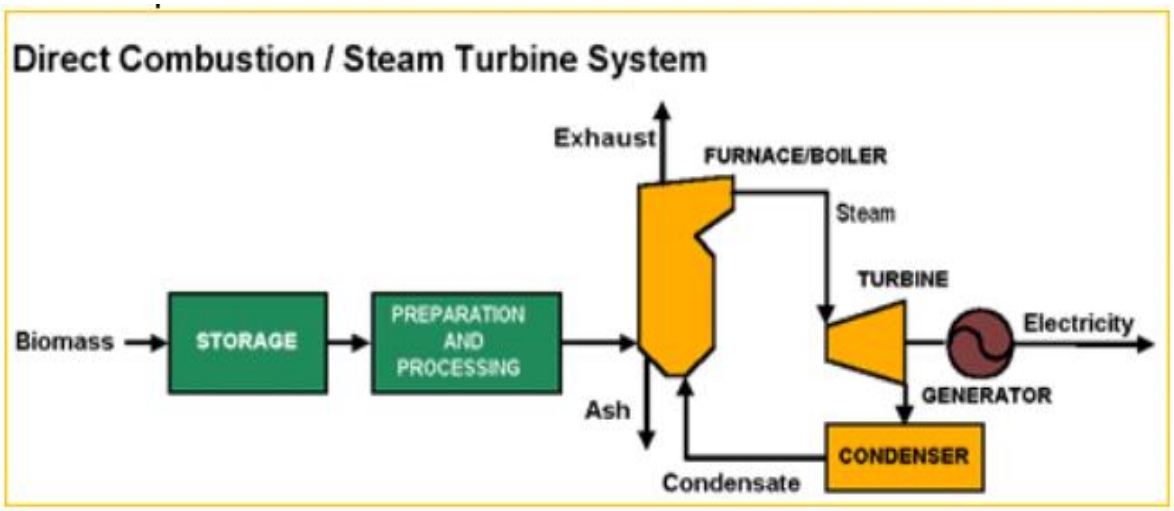


Fig 11. Generation of electricity from Biomass: Direct Combustion System [41]

Most developing countries use wood as a fuel. The practice has become so commonplace that that wood is now poached from forest reserves to the detriment of the ecosystem. In order to protect the natural environment, therefore, there is need for alternative sources of energy capable of meeting the people's needs. Biomass offers the best alternative due to its ready availability and the cheap cost with which energy is produced from it [29].

The biomass resources of Nigeria have been estimated to be about 144 million tonnes/year and these include sources such as wood, forage grasses and shrubs, residues and wastes as well as aquatic biomass [42, 43, 44]. Wood, apart from being a major source of energy in the form of fuel wood is the cheapest and most accessible source of fuel even among urban households in Nigeria. Wood, in the form of plywood, sawn wood, paper products and electric poles is used as well for commercial purposes [43].

2.3.5 Coal

There are estimated three billion tonnes of coal reserves in seventeen identified coalfields in the country. These include Onyeama and Okpana (150,000-400,000 tonnes/year), Onwuka (2500 tonnes/year) and Okaba (15,000-300,000 tonnes/year) just to name a few. Figure 12 shows a heap of Coal

Fig 12. A heap of Coal

2.3.6 Oil

Since after the civil war, oil has become the major source of income for the country and accounts for over 95% of its foreign exchange earnings. Nigeria generates most of its electricity from fossil fuel or hydro [45]. According to the state-owned Oil firm, the Nigerian National Petroleum Corporation, Nigeria's oil reserve currently stand at 37 billion barrels thus ranking the country as the largest oil producer in Africa and one of the largest in the world [46]. Figure 13 shows one of the Oil refineries in Nigeria.

Fig 13. Oil refinery in Nigeria

2.3.7 Natural Gas

Unlike coal or oil, natural gas is a relatively new type of energy source in Nigeria. Until 1999, more coal was in use in the country than natural gas (See Figure 14 for a typical Natural gas power plant). Roughly 2.5 billion cubic feet of Nigeria's gas associated with crude oil is wasted through flaring daily thus placing the country among the highest emitters of greenhouse gases in Africa and among the highest carbon monoxide (CO) emitters in the world [47]. The quantity of Nigeria's gas flared is equal to 40% of all Africa's natural gas consumption in 2001, while the annual financial loss to the country is about U$2.5 billion [48]. Nigeria has the largest reserves (5,100,000,000 billion cubic-metres) of natural gas in Africa and the ninth largest in the world [49].

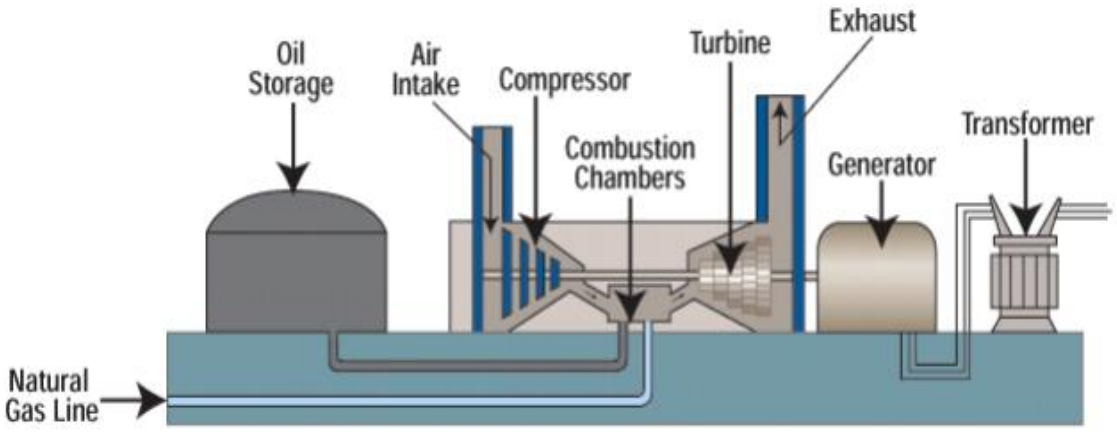


Fig 14. A typical Natural Gas Power Plant

III. PROSPECTS OF DISTRIBUTED GENERATION IN NIGERIA [50]

Besides Nigeria's natural endowment with both renewable and non-renewable energy resources, distributed generation has additional prospects of being successful in Nigeria owing to the following reasons:

- DG will facilitate the achievement of Nigeria's aspirations for a safe, reliable and adequate electricity supply within a shorter time;
- Reduced technical losses because of proximity of DGs to the network;
- Discos would have access to more power supply which means there will be more cash flows and more satisfied customers that would be willing to pay for electricity consumed;
- DG will afford Discos opportunities to improve distribution network (either by themselves or by the EGs) as well as service performance;
- Deepen the electricity market – capacity, standards, contracts and more bankable deals;
- IPPs with excess power within a distribution network are able to sell their excess power to Discos;
- Industrial consumers can have the option of choosing the most suitable suppliers for them;
- Introduces competition in the market;
- DG would also afford States the ability to achieve power supply aspirations within their borders;
- Power to be supplied to strategic state infrastructure and institutions: Water Plants, Hospitals, Schools, Courts, Offices, Street lightning, etc.;
- More Industrial clusters and businesses with better power supply = more without constitutional constraints investment in and ownership of Discos could work to State business, stronger economy, perhaps more willing tax payers;
- IPPs can sell excess power to Discos;
- Cost reflective tariff (different fuel sources and cost of building infrastructure considered);
- Potential market for power supply to Housing Estates, Industrial Estates/clusters, State Governments and Telecom Installations;
- Option to also supply power to eligible customers;
- No distribution lines ordinarily required when connected to a Disco;
- No transmission costs;
- No distribution license required;
- Reliable electricity supply;
- Clean and efficient choice for better climate [10].

IV. FINDINGS AND DISCUSSION

This paper investigated the challenges and prospects of DG in Nigeria's post-privatized power sector through the extensive review of reports, position papers, legislative acts, policy documents etc. from relevant statutory institutions and authorities in and outside Nigeria. The study found that Nigeria's power sector suffered long period of total neglect and poor funding particularly between 1982 and 1999 and this action resulted in the dilapidated state and stagnation of power infrastructure expansion and technology upgrade in the country. The situation also led to the limited development of the sector thus the dismal performance of the sector over the years in providing adequate and reliable power for economic and development activities [51].

The findings of the study further show that despite the current challenges posed by underfunding, long investment neglect etc. of the energy sector, Nigeria has abundant natural resources to

successfully implement and reap the full benefits of DG technologies.

V. CONCLUSION AND RECOMMENDATION

The availability of reliable and adequate energy sources is essential to sustainable industrial and socio-economic development of any nation. Distributed Generation evidently has great prospects in Nigeria. There are abundant renewable and non-renewable energy resources which if properly harnessed, appropriated and managed will put an end to the current problem of epileptic electricity supply arising from perennial energy shortages in the country. The paper recommends that power sector stakeholders and government at all levels in Nigeria should prioritize DG in order to achieve electricity supply security in the country. Efforts should also be geared towards the enactment of the necessary legal, regulatory, contractual and financing framework. Government, in particular, should adopt prudent energy policies that encourage energy conservation as well as promote researches into the area of renewable energy resources with the aim of discovering and appropriating in full the nation's energy potentials thereby stimulating the much desired industrial and socio-economic growth of the country. The findings of this study will facilitate the proper integration of smart grid technology into the national grid and help achieve adequate, stable and reliable electricity supply in Nigeria.

Conflicting Interests

The author declares that no conflicting interests exist.

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