

## Chapter 2

# The Energy Sector in Nigeria

**Abstract** The chapter presents the status quo of Nigeria's energy sector and is divided into five sections. The first extensively reviews the various conventional and renewable energy resources in Nigeria. The second and third sections presents the primary energy supply and consumption, respectively. The forth section presents an insight into the various government ministries, parastatals, and agencies that are relevant in the Nigerian energy sector. The last section in this chapter explores the Nigerian energy policies and strategies.

**Keywords** Nigerian power sector • Conventional energy resources • Renewable energy • Nigerian energy policies • Government ministries and agencies

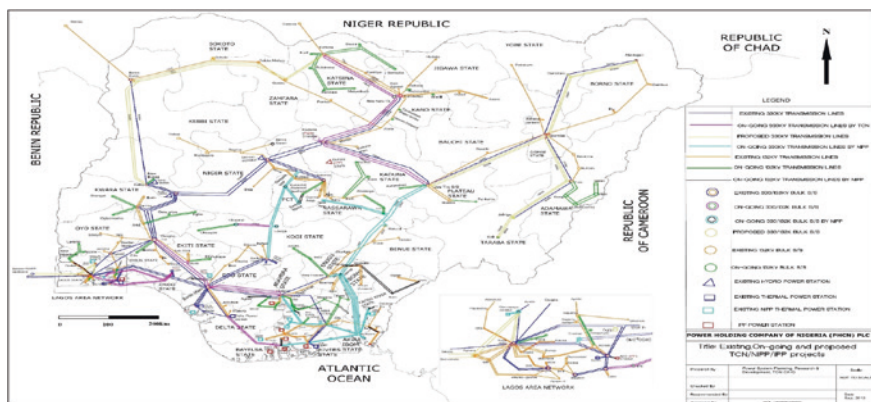
### 2.1 A Brief History on the Nigerian Power Sector

The Federal Government of Nigeria (FGN) has been responsible for the formulation of energy policy development and regulation, including operation and investment in the Nigerian energy sector before 2005,<sup>1</sup> after which the FGN established the Electricity Power Sector Reform Act (Federal Government of Nigeria [FGN] 2005). The Federal Ministry of Power (FMP) conducted regulation of the power sector, while the National Electric Power Authority (NEPA) handled operation in the sector. Part of the responsibility of NEPA was power generation, transmission, and distribution.<sup>2</sup> NEPA, however, ran a monopoly system from its inception in 1972 to its defunct in 2005, with control of power generation capacity of about 94 %, while transmission, system operators, distribution, and their marketing sector was 100 % owned by them (Nigeria Bureau of Public Enterprise [NBPE] 2015).

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<sup>1</sup>[www.energypedia.info/wiki/Nigeria\\_Energy\\_Situation](http://www.energypedia.info/wiki/Nigeria_Energy_Situation).

<sup>2</sup>[www.nigeriaelectricityprivatisation.com/?page\\_id=2](http://www.nigeriaelectricityprivatisation.com/?page_id=2).



**Fig. 2.1** Map of existing, on-going, and proposed TCN/NIPP/IPP projects for electricity transmission in Nigeria. *Source* TCN (2015), Akpan (2015)

Inefficiencies in operations and financial performance in NEPA led the amendment of the Electricity and NEPA Acts by the FGN in 1998 to remove the monopoly held by NEPA and encouraged the participation of the private sector.<sup>3</sup> A reform agenda was specified in the National Electric Power Policy in 2001, while the legal basis for the unbundling of NEPA and formulation of successor companies (including privatization) was provided in the EPSRA (National Mirror 2014). NEPA was restructured to form the Power Holding Company of Nigeria (PHCN) in 2007 which stopped existing after September 30th 2013.<sup>4</sup>

The FGN sorted various means to sell off its stake in the electricity services industry<sup>5</sup> (i.e. privatization), but retained the transmission grid as a public entity (Aladejare 2014). The generation companies are now called the GENCOs, while the distribution companies are called the DISCOs, and the FGN operates the Transmission Company of Nigeria<sup>6</sup> (TCN) (KPMG 2013). The generators and transmission lines are interconnected in the national grid system which is controlled at the National Control Center, Oshogbo. Figure 2.1 shows the TCN/NIPP<sup>7</sup>/IPP<sup>8</sup> projects in Nigeria as presented by PHCN.<sup>9</sup>

<sup>3</sup>[www.placng.org/new/laws/E7.pdf](http://www.placng.org/new/laws/E7.pdf).

<sup>4</sup>[www.nigeriaelectricityprivatisation.com/](http://www.nigeriaelectricityprivatisation.com/).

<sup>5</sup>The state-owned electricity generation companies was placed for sale by the Nigerian government in two ways in which one was the outright sale of the thermal power stations, while the other was through concession of the hydroelectric stations.

<sup>6</sup>The TCN is divided into two divisions; the systems operator division and a market operator division.

<sup>7</sup>National Integrated Power Project.

<sup>8</sup>Independent Power Producer.

<sup>9</sup>This was presented in 2012.

The FGN took the next step in setting up the Nigerian Electricity Regulatory Commission (NERC) and the Nigerian Bulk Electricity Trading Plc. (NBET).<sup>10</sup> The Operators of the Nigerian Electricity Market<sup>11</sup> (ONEM) was established with the responsibility of the wholesale market and settlement operator. After the establishment of the agencies, the FGN then placed the new NIPP power plants for sale. Although most of the GENCOs companies were bound to suffer a loss, the FGN allocated N50 billion to them so as to reduce the impact of the loss (KPMG 2013). The NBET buys electric energy generated from the GENCOs and sells it to the DISCOs for sale to the final electricity consumers.<sup>12</sup>

The steps discussed above were taken to unbundle the PHCN and this is classified as the pre-transition electricity market (pre-TEM) development.<sup>13</sup> However, until the TEM becomes fully functional, some rules govern the electricity market in which the GENCOs charge the ONEM (Detail Commercial Solicitors 2014). The financing requirements for the market are set by the ONEM on the basis of the MYTO 11.<sup>14</sup> The aim was to develop a framework which can oversee the arrangement of electricity trading during the pre-TEM period and is still in effect. The TEM will be functional when the electricity market becomes fully privatized and private sector oriented.<sup>15</sup> The location of the GENCOs (power plants) is shown in Fig. 2.2.

## 2.2 The Nigerian Energy Resources

Several energy resources are available in Nigeria in abundant proportions. This includes conventional and non-conventional (renewable) energy resources, and are vastly distributed across the regions of the country. The energy resources in Nigeria are classified as conventional and renewable energy resources, and they are discussed as follows.

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<sup>10</sup>The NBET was set-up, although not fully effective, but was intended to come into full operation when the Nigerian electricity market becomes completely privatized and then the power purchase agreements will be signed and passed on to the DISCOs (The Presidency 2013).

<sup>11</sup>This responsibility extends to the management of the metering system of the TCN, DISCOs and the GENCOs.

<sup>12</sup>See [www.nbet.com.ng](http://www.nbet.com.ng).

<sup>13</sup>For a more insight into this, see Detail Commercial Solicitors (2015).

<sup>14</sup>Multi-Year Tariff Order 2.

<sup>15</sup>See [www.lexology.com/library/detail.aspx?g=f77e24d6-8338-47d6-9e4d-ed5b89a51862](http://www.lexology.com/library/detail.aspx?g=f77e24d6-8338-47d6-9e4d-ed5b89a51862).

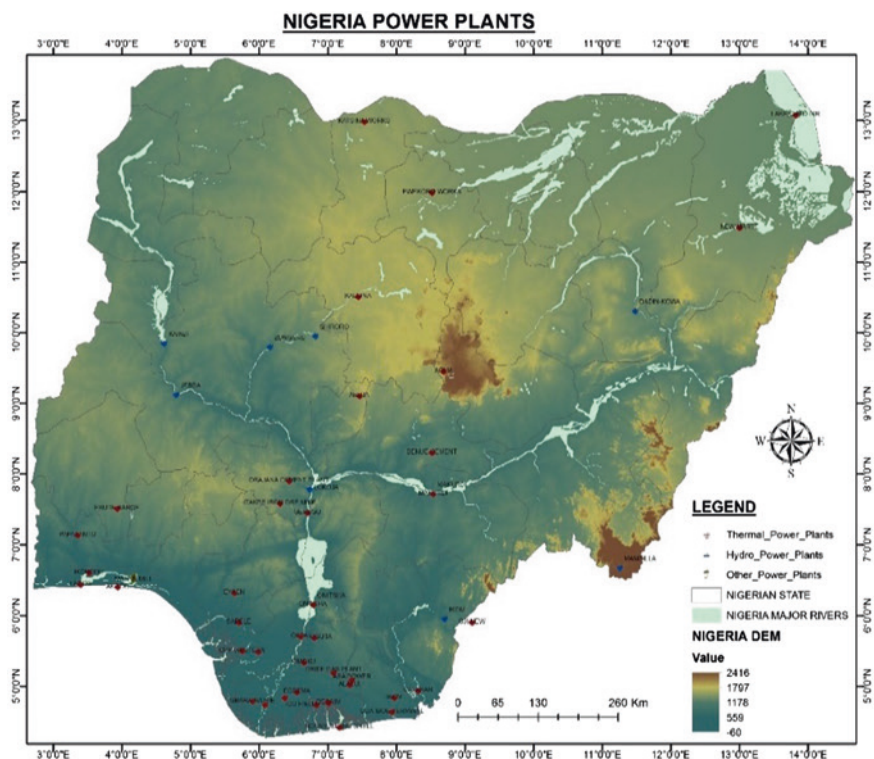


Fig. 2.2 Nigeria Power Plants. Source Nwoko (2015a)

### 2.2.1 Conventional Energy Resources

Nigeria has considerable reserves of conventional energy resources. It is one of the world's largest producers of oil and it has the largest reserves of natural gas in the African Continent. It therefore became the world's fourth leading exporter of liquefied natural gas (LNG) in 2012. Nigeria is also a member of the Organization of the Petroleum Exporting Countries (OPEC), which it joined in 1971 after over 10 years of oil production that began in the late 1950s (EIA 2014a). Coal reserves stand at 2.175 billion tons, but production has long since ceased (in the 1950s) as the government has concentrated on the oil and gas resources.

Nigeria is also rich in tar sand or oil sand, which is a combination of clay, sand, water, and bitumen (a heavy black viscous oil). Tar sands can be mined and processed to extract the oil-rich bitumen, which can be refined into oil (Oil Shale and Tar Sands Programmatic (EIS 2014). Table 2.1 presents the conventional energy reserves in Nigeria and their potentials.

According to the US Energy Information Agency estimate, the total primary energy consumption in Nigeria in 2012 was about 4.5 quadrillion Btu (British

**Table 2.1** Conventional energy reserves in Nigeria and their potentials

Resource type	Reserves		Production	Domestic Utilization (natural units)
	Natural units	Energy units (Btoe)		
Natural gas	187 trillion SCF	4.19	6 billion SCF/day	3.4 billion SCF/day
Crude oil	36.22 billion barrels	5.03	2.5 million barrels/day	450,000 barrels/day
Tar sands	31 billion barrels of equivalent	4.31	Insignificant	Insignificant
Coal and lignite	2.175 billion ton	1.52	–	–
Nuclear element	None	–	–	–

Source National Bureau of Statistics [NBS] (2007)

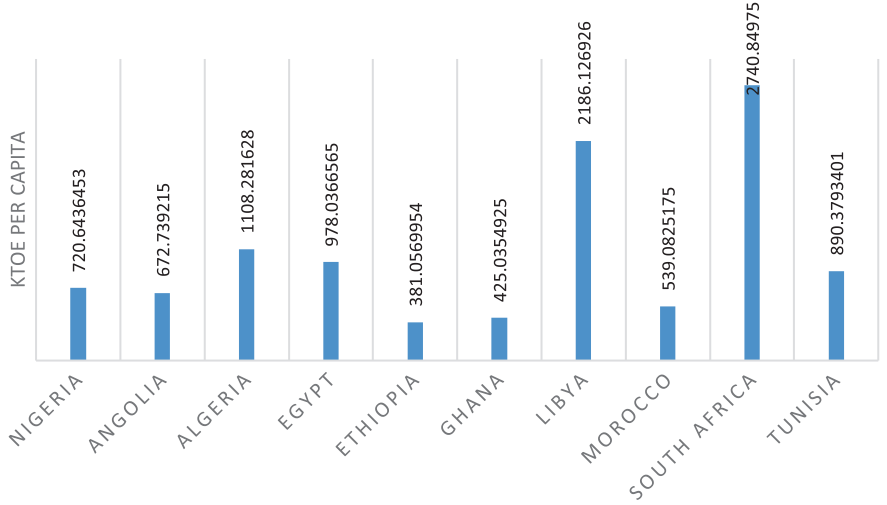
thermal units). This comprised 80 % from traditional biomass and waste (wood, charcoal, manure, and crop residue) and much smaller percentages from oil and natural gas. The Nigerian oil and gas sector is regulated by the Nigerian National Petroleum Corporation (NNPC), which was established in 1977 with the secondary responsibility of overseeing the development of the upstream and downstream oil sectors.<sup>16</sup>

Despite the large energy resources in Nigeria, energy consumption is relatively low compared with other African countries with comparable energy resources (Fig. 2.3). This low energy consumption is due to the recurrent scarcity of petroleum products at vehicle petrol stations, while frequent electricity “black-outs” have resulted in a high reliance by the Nigerian populace on personal electricity generators.

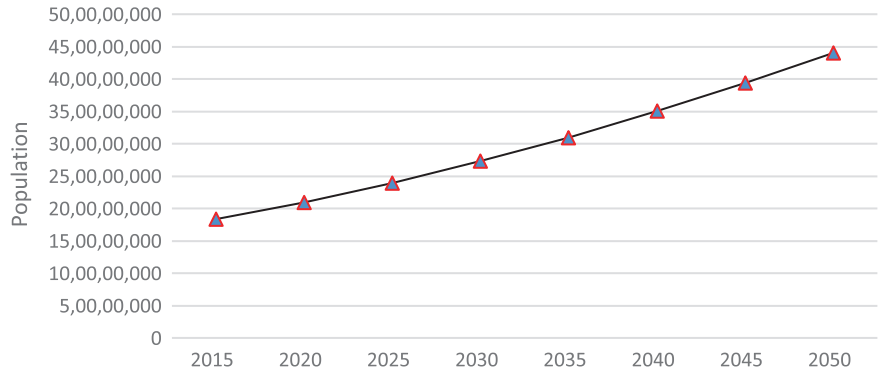
Despite the scarcity of petroleum products, energy demand has been increasing in Nigeria, because of the increase in economic development and the population growth. According to Sambo et al. (2006), the major driver behind increasing energy demand is the population growth, while the most important determinant is the level of economic activity, measured by the country’s gross domestic product (GDP).

Nigeria’s population is projected to grow from 178,516,904 (as of 2014) to 440,355,062 by 2050 (Fig. 2.4). To address the needs of this increasing population, the Energy Commission of Nigeria (ECN) analyzed the country’s energy sector from 2000 to 2030 using the Wien Automatic System Planning (WASP) package and the Model for Analysis of Energy Demand (MAED).

<sup>16</sup>See “Oil and Gas in Nigeria”. Available online at: [www.mbandi.com/indy/oilg/af/ng/p0005.htm](http://www.mbandi.com/indy/oilg/af/ng/p0005.htm).



**Fig. 2.3** Energy consumption per capita in some African countries in 2012 (The World Bank 2014)



**Fig. 2.4** Projections of population growth in Nigeria (World Meters 2015)

The results (Fig. 2.5), based on reference, high growth, and two optimistic (11.5 and 13 % GDP growth) scenarios, project that energy demand in Nigeria will increase by 2.5, 3, 3.5, and 4.5 times, respectively, from 2000 to 2015, and by 8, 13, 17, and 22.5 times, respectively, from 2000 to 2030.

According to ECN, the increase in energy demand will develop in line with the high level of economic activity expected in Nigeria, as measured by the total GDP. The sectorial energy demand (Fig. 2.6) shows that although the industrial sector had lower energy demand in 2005 (8.05 Million Tons of Oil Equivalent (Mtoe)), it will have the highest energy demand by 2030 at 145.21 Mtoe with GDP growth rate of 16.27 %, as the economy begins to improve based on increased industrial

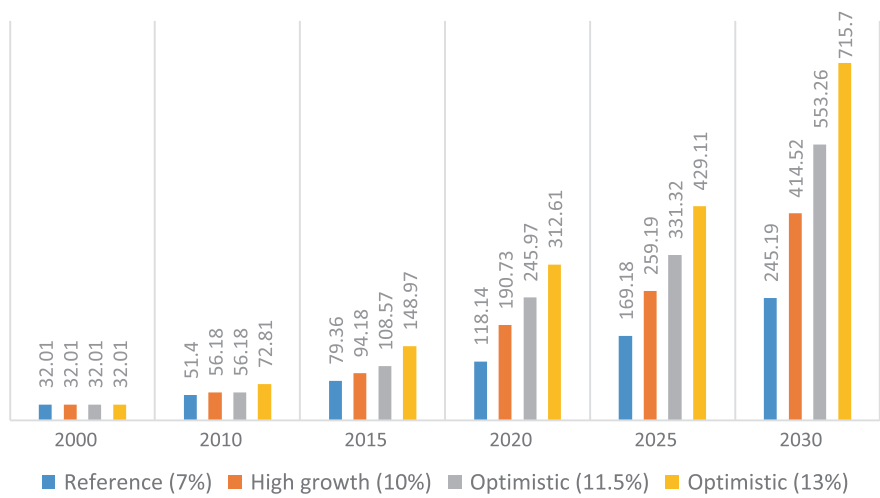


Fig. 2.5 Projections of total energy demand (Mtoe) in Nigeria

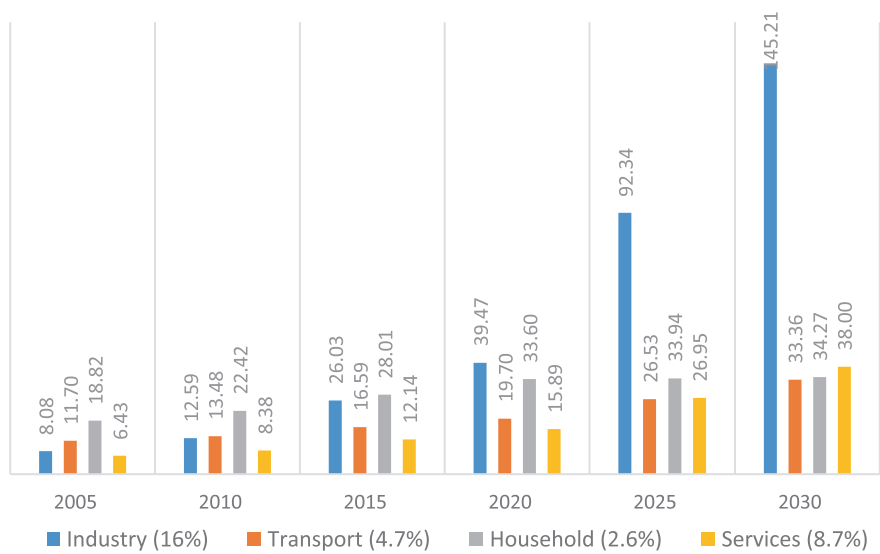
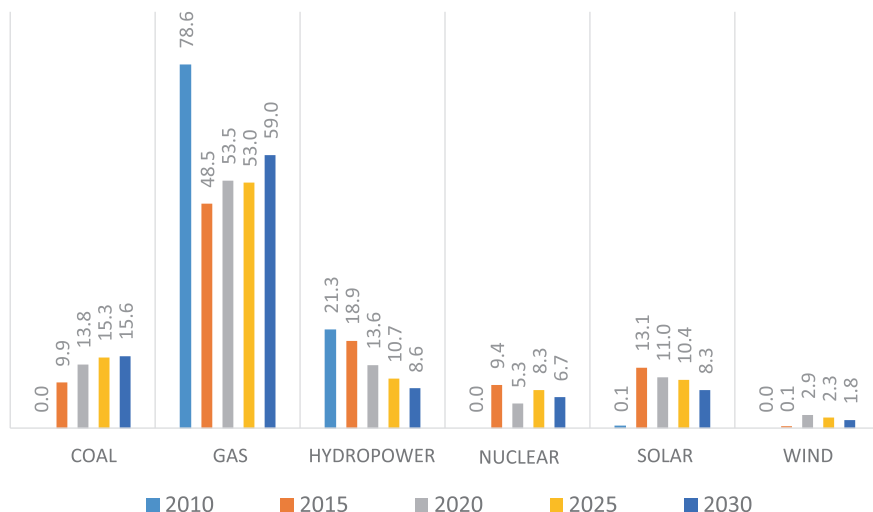


Fig. 2.6 Total energy demand (Mtoe) based on 10 % GDP growth rate

activity. The service sector is projected to have the second highest growth rate of 8.7 %, while the residential sector is expected to have the lowest average growth rate of 2.6 %. These projections for increasing energy demand can only be met if effective policies are put in place.



**Fig. 2.7** Nigeria's current and future electricity generation capacity (%) by fuel (Reference case)

The ECN undertook a study using MESSAGE<sup>17</sup> under the auspices of the IAEA<sup>18</sup> to ascertain the future fuel mix for the diversification of Nigeria's electricity supply. The study used six different types of fuel for the optimization: coal, natural gas, hydropower, nuclear, solar, and wind energy. Oil was not considered in the optimization because of its use for export to the international energy market, meeting domestic energy demand, and no current plans by the government to establish oil power plants in the future. The results are shown in Fig. 2.7.

These results were based on the reference case scenario, and show that energy from coal and nuclear sources (currently not part of the nation's electricity generation mix) will account for 15.6 and 6.7 % of the total, respectively, by 2030. The proportion of Nigeria's energy generated by hydropower will decrease from 21.3 % in 2010 to 8.6 % by 2030. The high growth and optimistic scenarios follow similar supply patterns (Sambo 2008).

### 2.2.1.1 Crude Oil

Nigeria produces mostly light sweet crude oils that are predominantly exported to the world market. Table 2.2 shows the characteristic features of the crude oils produced in Nigeria and their ports of sale used for export.

<sup>17</sup>Model for the Energy Supply Strategy Alternatives and their General Environmental Impact.

<sup>18</sup>International Atomic Energy Agency.



**Table 2.2** Characteristic features of Nigeria's crude oil

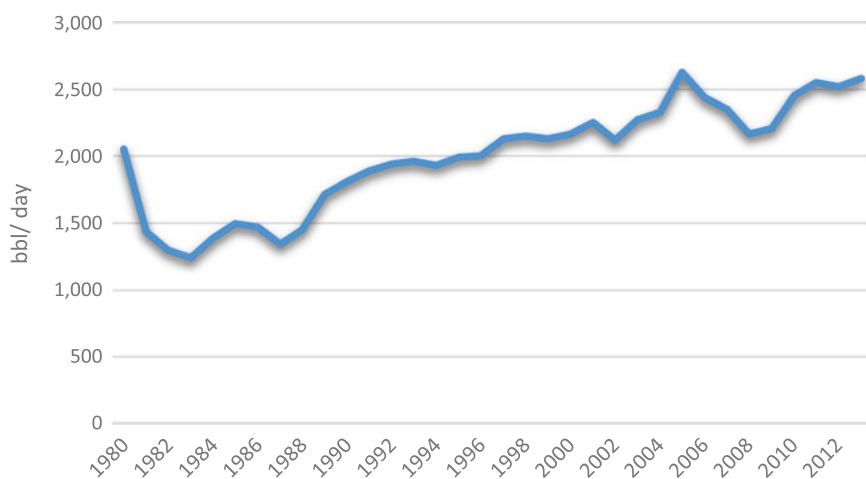
Product name	Sulfur content (as % of mass)	API gravity (in degrees)	Ports of sale
Agbami	0.044	47.2	Offshore
Amenam Blend	0.12	38.2	Unity FSO/Odudu Terminal
Amenam/Mars Blend	0.94	33.5	–
Antan Blend	0.27	26.4	Knock Taggart FPSO/Antan Terminal
Bonga	0.26	29.1	Bonga FPSO
Bonny Light	0.16	33.4	Bonny
Brass River	0.16	–	Brass River Terminal
EA Crude	0.08	35.1	Sea Eagle FPSO
Erha	0.12	31.8	Erha FPSO
Escravos	0.17	34.2	Escravos
Forcados (to Europe)	0.16	30.8	Forcados
Odudu	0.15	30.5	–
Okono	0.15	30.50	–
Oso Condensate	0.06	45.7	Qua Iboe
Qua Iboe	0.14	36.3	Qua Iboe
Ukpokiti	0.14	36.3	–
Yoho Crude	0.08	39.3	Falcon FPSO

Source Energy Intelligence (2015)

In Nigeria, commercial production of crude oil began in 1958 based on proven recoverable reserves of  $1.48 \times 10^6$  billion tons. Production rose from an initial quantity of 3.1 million metric tons to 20.3 million tons in 1960, 54.2 million tons by 1970, and 104.1 million tons in 1980, all in response to demand from international markets rather than from domestic demand. On average, local consumption accounted for just 3 % of production, while the remaining 97 % was exported. Since 1980, three domestic petroleum refineries have supplied petroleum products for local consumption: the Kaduna Refinery with a capacity of 110,000 bbl/d (barrels per day), Port Harcourt Refinery with a capacity of 210,000 bbl/d, and Warri Refinery with a capacity of 125,000 bbl/d (Oyedepo 2014).

As shown in Fig. 2.8, the production of crude oil in Nigeria increased rapidly between 1980 and 2012; however, the rate of increase was dependent on the economic and geopolitical situations in both producing and consuming countries. Nigeria's current production capacity of 2.4 million bbl/d remains low because of problems in the Niger Delta<sup>19</sup> and OPEC production restrictions. However, projections have placed future (2030) production at over 5.0 million bbl/d (Ajao et al. 2009).

<sup>19</sup>The Niger Delta region has been known for militant activity, but this activity was halted by the intervention of the late Nigerian President Umaru Yar'Adua who granted amnesty to the militants.



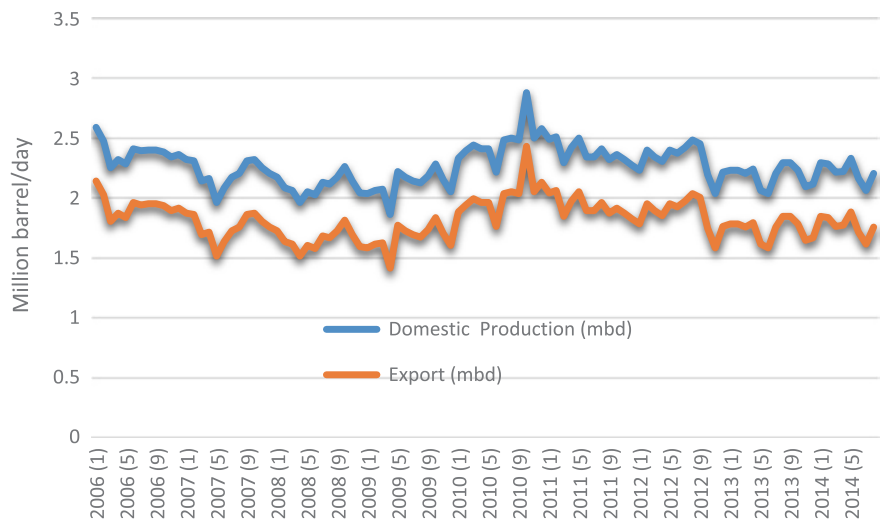
**Fig. 2.8** Crude oil production in Nigeria. (EIA 2015a)

Crude oil production reached its peak in 2005, but has subsequently declined significantly because of the activities of militants in the Niger Delta region. These activities came to a halt in 2009 when amnesty was granted to the militants and by 2010, oil production began to increase as oil companies began operating at full capacity. The Nigerian government also took drastic measures to attract investment in deep-water acreage in order to diversify the location of oil fields and increase oil production. This has resulted in the production of an additional 800,000 bbl/d since 2003. However, crude oil production declined from 2011 to 2012 because of heavy floods and supply disruptions.

In addition to the challenges faced by the government, the indigenes of the Niger Delta region suffer from the effects of environmental damages resulting from pipeline vandalism. When pipelines are vandalized, crude oil is stolen to supply illegal refineries. The result is environmental degradation and the risk of a pipeline explosion for local communities. The rates of domestic production and export of crude oil did not improve significantly between 2006 and 2014 (See Fig. 2.9) because of the issue of crude oil theft.

The oil price in Nigeria has been in line with the OPEC price and has fared well over the years, reaching its peak in 2008, but declining in 2009 (Fig. 2.10). The price of oil in Nigeria was US\$102.33 per barrel in August 2014; however, with the recent fall in the crude oil price,<sup>20</sup> which is US\$53 for West Texas Intermediate (WTI) and US\$57.33 for Brent crude, the country's economy will be

<sup>20</sup>According to [www.oilprice.net](http://www.oilprice.net) on 2nd January 2015.

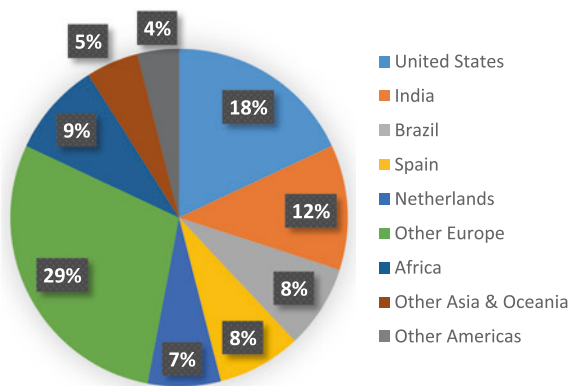


**Fig. 2.9** Rates of domestic production and export of crude oil in Nigeria (CBN 2015a)



**Fig. 2.10** Crude oil prices in Nigeria. Source CBN (2015b)

**Fig. 2.11** Crude oil and condensate exports in Nigeria in (2012) (EIA 2015b)



adversely affected. The previous rise in the crude oil price was due to high oil consumption in countries such as China and India, in conjunction with conflict in key oil exporting countries such as Libya.<sup>21</sup>

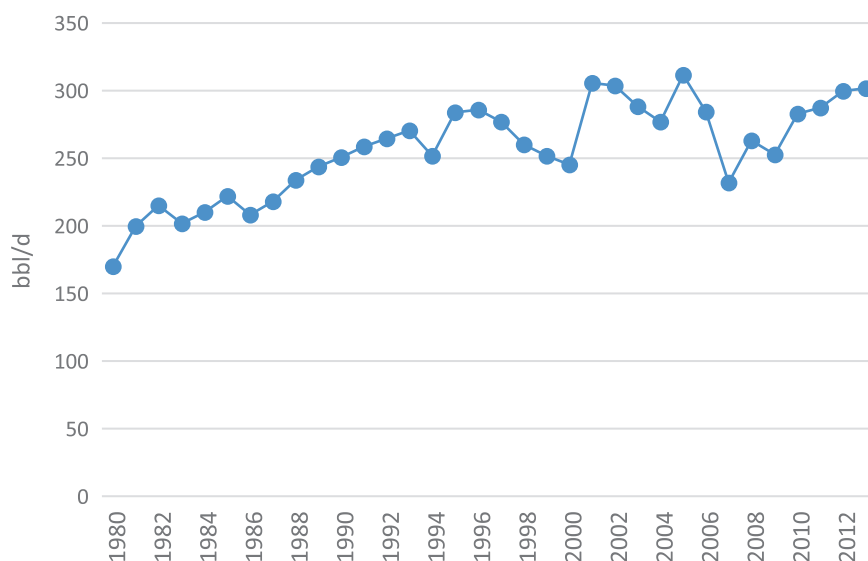
High oil prices induced companies in Canada and the United States (US) to start drilling for new hard to extract crude in North Dakota's shale formations and Alberta's oil sands. This has resulted in a "Price-War" between OPEC and the US (VOX 2015). The US, which was the largest single importer of crude oil from Nigeria (Fig. 2.11) in 2012, ceased importing oil at the end of 2014. Other countries have also reduced their oil imports from Nigeria, including the countries of the European Union.

Fuel subsidies cost the Nigerian government US\$8 billion in 2011 alone, which constituted 30 % of federal government expenditure, 4 % of the country's GDP, and 118 % of the capital budget. However, the Nigerian government removed the fuel subsidy on the 1st of January 2012. Subsequently, oil consumption in Nigeria has increased, as shown in Fig. 2.12. Downstream industries in Nigeria, which include domestic refineries and various petrochemical industries, use the crude oil produced in Nigeria. These refineries produce products such as linear alkyl benzene, benzene, heavy alkylate, and deparaffinated kerosene for domestic consumption (NNPC 2015a).

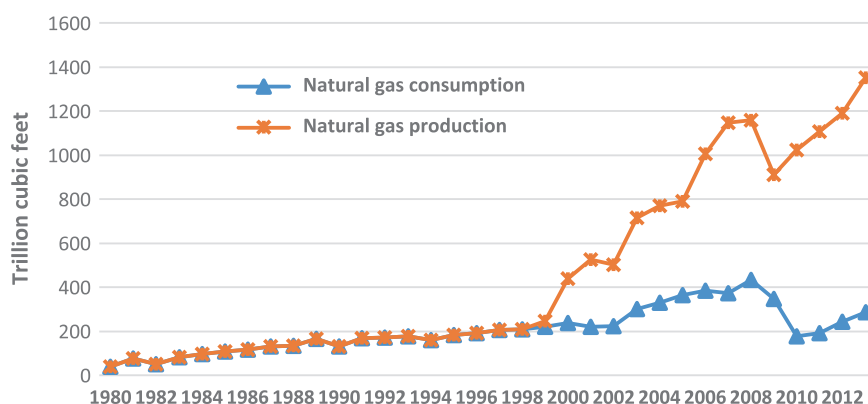
### 2.2.1.2 Natural Gas

The estimated proven reserves of natural gas in Nigeria stand at 182 trillion cubic feet (TCF) with a mean gauge pressure of about 12 bar, a calorific value of 35 MJ/m<sup>3</sup>, and a mean specific volume of  $1.56 \times 10^{-3}$  m<sup>3</sup>/kg. In 2012, the production rate was about 1.35 TCF of dry natural gas (Fig. 2.13), making Nigeria the 25th largest producer of dry natural gas in the world (ECN 2007; EIA 2015d, e).

<sup>21</sup>[www.useconomy.about.com/od/commoditiesmarketfaq/p/high\\_oil\\_prices.htm](http://www.useconomy.about.com/od/commoditiesmarketfaq/p/high_oil_prices.htm).



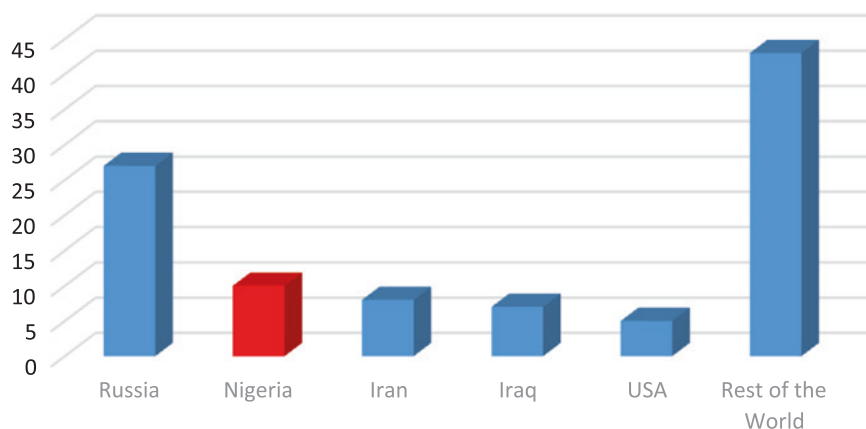
**Fig. 2.12** Crude oil consumption in Nigeria (EIA 2015c)



**Fig. 2.13** Natural gas production and consumption in Nigeria (CIA 2015a)

Natural gas reserves are located in the Niger Delta region of Nigeria (South-South). In the past, Nigeria flared about 73 % of its gas because of poor infrastructure, which placed Nigeria second in the list of gas-flaring countries (Fig. 2.14).

However, because of the efforts of the Nigerian government to reduce gas flaring through the financing and provision of relevant infrastructure to use the previously flared gas, Nigeria is now 365th on the list (Ibitoye 2014). Infrastructure that uses the previously flared gas includes the power sector, which accounts for 80 % of the total domestic consumption (Table 2.3, Fig. 2.15) and generates 81 % of the total electricity supply in Nigeria.



**Fig. 2.14** World's top natural gas flaring countries (2012) (EIA 2015f)

**Table 2.3** Current and planned power plants in Nigeria and their locations

Power station	Location	Type	Installed capacity (MW)	Year completed
AES Barge	Egbin	SCGT	270	2001
Aba	Aba, Abia State	SCGT	140	2012
Afam IV–V	Afam, Rivers State	SCGT	726	1982
Afam VI	Afam, Rivers State	CCGT	624	2009
Alaoji (NIPP)	Abia State	CCGT	1074	2013
Calabar (NIPP)	Cross River State	SCGT	561	2014
Egbema (NIPP)	Imo State	SCGT	338	2013
Egbin	Egbin	Gas-fired steam turbine	1320	1986
Geregu 1	Geregu, Kogi State	SCGT	414	2007
Geregu 11 (NIPP)	Geregu, Kogi State	SCGT	434	2013
Ibom (IPP)	Ikot Abasi	SCGT	190	2009
Ihorbor (NIPP)	Benin City	SCGT	450	2013
Okpai	Okpai	CCGT	480	2005
Olorunsogo	Olorunsogo	CCGT	336	2007
Olorunsogo 11	Olorunsogo	CCGT	675	2012
Omoku	Omoku	SCGT	150	2005
Omoku 11 (NIPP)	Omoku	SCGT	225	2013
Omotosho 1	Omotosho	SCGT	336	2005
Omotosho 11 (NIPP)	Omotosho	SCGT	450	2012
Sapele	Sapele	Gas-fired steam turbine	1020	1981

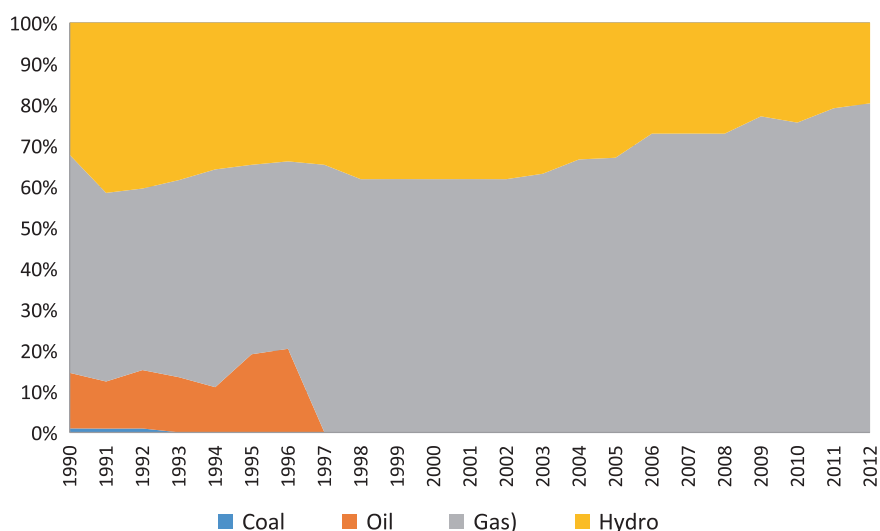
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**Table 2.3** (continued)

Power station	Location	Type	Installed capacity (MW)	Year completed
Sapele (NIPP)	Sapele	SCGT	450	2012
Ughelli	Delta State	SCGT	900	1990
Itobe	Kogi State	CFB Technology	1200	2015–2018
Kainji	Niger State	Hydro	800	1968
Jebba	Niger State	Hydro	540	1985
Shiroro	Kaduna State	Hydro	600	1990
Zamfara (Planned)	Zamfara State	Hydro	100	2012
Kano (Planned)	Kano State	Hydro	100	2015
Kiri (Planned)	Benue State	Hydro	35	2016
Mambilla (Planned)	Taraba State	Hydro	3050	2018

Source Emodi and Yusuf (2015a)

*NIPP* National Integrated Power Project, *SCGT* Single Combined Gas Turbine, *CCGT* Combined Cycle Gas Turbine, *CFB* Circulating Fluidized Bed



**Fig. 2.15** Electricity production by fuel type (%). Source Power Holding Company of Nigeria (PHCN) (2010)

Based on the current amount of gas remaining in the natural gas reserves, it is expected that they will last for about 88 years (Kennedy-Darling et al. 2008). In order to improve natural gas activities, in 1988, through the NNPC, the government created a subsidiary and strategic business unit called the Nigerian Gas Company (NGC). This company is responsible for the development of policies

for the transmission, distribution, marketing, and pricing of natural gas and all its derivatives to the market within Nigeria and West Africa (NPC 2009).

This implies that a monopoly exists in the Nigerian gas market, which also includes state and private companies such as the electricity companies and multinational companies (known as International Oil Companies; IOCs) including Shell, Chevron, and ExxonMobil who supply natural gas to the NGC (Tallapragada 2009).

Natural gas consumption in Nigeria has been increasing since its discovery and reached its peak in 2008 when a disruption in gas supply occurred (see Fig. 2.13). One of the IOCs (Shell) shut down their plants in order to repair damage to pipelines connected to the Soku plant. This damage was the result of pipeline vandalism performed by local groups that were siphoning condensate. After five months, the plants re-opened but closed again in 2009 because of operational problems. The Soku plant provides a substantial amount of gas to the NGC's liquefied natural gas (LNG) facility and, because of the supply disruption, a decline in gas production occurred (The Encyclopedia of Earth 2015).

Nigeria's exports of natural gas (in the form of LNG) in 2012 are shown in Fig. 2.16. Europe has reduced its LNG imports from Nigeria since 2012, whereas the US has completely stopped importing from Nigeria because of increasing domestic production. However, imports have increased in Asian countries such as Japan, South Korea, and India, while France, Spain, Portugal, Taiwan, and Turkey still maintain their LNG imports from Nigeria. In 2013, there was supply disruption and a temporary blockade on Nigeria's LNG shipments, which led to a fall in its production and export; however, this did not affect domestic consumption.

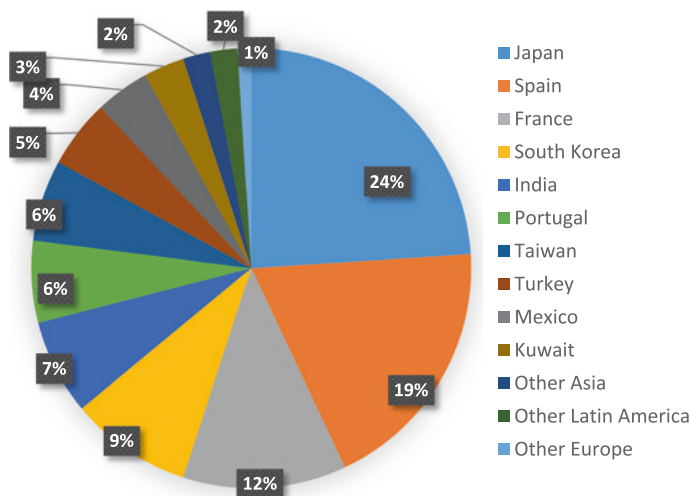


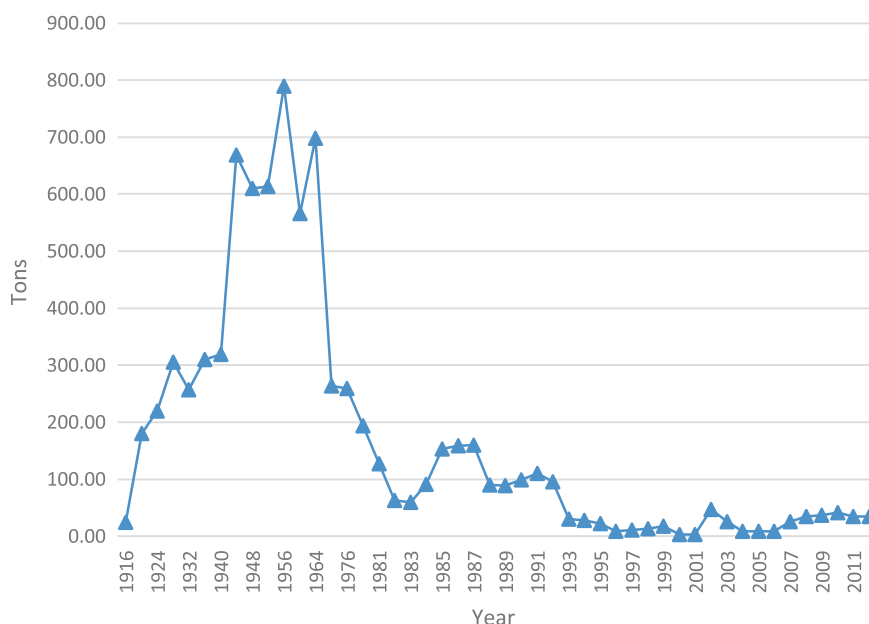
Fig. 2.16 Nigeria's LNG exports (2012) (EIA 2015g)



### 2.2.1.3 Coal

Coal was the first conventional fuel to be discovered and used in Nigeria. It was discovered in Enugu State, in the south-eastern region of Nigeria in 1909. The first coal mine, the Ogbete drift mine, was opened in 1916 with an output of 24,500 t. Its operation was merged with that of others within the country in 1950 following the formation of a new corporation known as the Nigerian Coal Corporation (NCC). The responsibility of the NCC in holding a monopoly on coal production (including coke mining) and sales was to exploit coal resources. The Polish firm KOPEX was in charge of its management from the NCC's formation until its collapse after the Nigerian Civil War in 1970 (Nwaobi et al. 2005).

Coal production reached a peak of 790,030 tons in 1956 (see Fig. 2.17) and about 70 % of this quantity contributed to Nigeria's energy generation. Production began to decline when oil was discovered in 1956 at Oloibiri in the Niger Delta by Shell-BP, which was the sole concessionaire at that time (NNPC 2015b). The Nigerian Railway Corporation was the largest consumer of coal in the country. The corporation began to convert their railway engines from coal to diesel and gas in 1955. By 1982, production of coal had fallen to 62,830 tons (TOPFORGE 2015). Another set-back in coal production was the conversion of power plants from coal to oil by the National Electric Power Authority (NEPA) (now defunct) and only one coal-fired power plant was left.



**Fig. 2.17** Coal production in Nigeria (Tons). *Source* CIA (2015b)

Following the discovery of coal in commercial quantities (1916–1980), the total cumulative production was about 25.3 million metric tons. By 1980, oil contributed 70 % to electricity generation, compared with 25 % and just 1 % for gas and coal, respectively. In terms of coal consumption, about 95 % of the coal produced in Nigeria was consumed by the Nigerian Railway Corporation, NEPA, and cement companies for heating cements. Coal consumption by the Nigerian Railway Corporation fell to 60 % in 1958, less than 30 % in 1966, and to an insignificant level by 1986. NEPA's coal consumption fell from 30 % in 1966 to an insignificant level in 1970, and the last remaining coal plant was shut down in 1992 (Fig. 2.15) (Enibe and Odukwe 1990).

Because of the loss of its largest consumers, the NCC began to export its desirable low-sulfur-content coal to the United Kingdom and Italy. In 1999, the NCC lost its monopoly over the Nigerian Coal Industry (NCI) following the implementation of the federal government's privatization policy by the then President of Nigeria (i.e. President Olusegun Obasanjo). In 2002, work stopped at all NCC-operated mines and the government established a technical advisory committee to revive the NCI (Odesola et al. 2013a, b).

Current coal reserves in Nigeria are estimated to be 2.75 billion metric tons and the nation's proven reserves stand at 639 million tons. The locations of the coal deposits in Nigeria are mostly in the eastern parts of the country, as shown in Table 2.4. However, the coal reserves have not been fully explored or even marginally developed despite the long history of the coal industry. They are mostly lignite and sub-bituminous, although some are high-volatility bituminous deposits (Akubo et al. 2013).

### **2.2.2 Non-conventional Energy Resources (Renewable Energy)**

Renewable energy plays a vital role in meeting the needs of both rural and urban areas of the country in terms of sustainable development (Hui 1997). The development and proper use of renewable energy should be given high priority, especially now that the issues of climate change and global warming are among the most critical issues discussed by the various governments of the world. Developed and developing countries are now adopting renewable resources in order to achieve energy sustainability (Oyedepo 2012).

Nigeria is blessed with an abundance of renewable energy resources that must be fully harnessed, developed, and properly used. However, the development of renewable energy has so far been slow, and the desperate situation of the energy sector in Nigeria can only be resolved if adequate policies are implemented to attract investors in renewable energy to Nigeria. Nigeria's renewable energy resources are presented in Table 2.5 and discussed in detail below.

**Table 2.4** Coal reserves in Nigeria

Mine location	State	Coal type	Estimated reserves (million tonn)	Proven reserves (million ton)	Borehole record	Coal outcrop and seam thickness (m)	Coal depth (m)	Mining approach	Current status
Okpara mine	Enugu	Sub-Bituminous	100	24	20	Many	180	Under-ground	Functional
Onyeama mine	Enugu	Sub-Bituminous	150	40	Many	Many	180	Under-ground	Functional
Ezimo	Enugu	Sub-Bituminous	156	56	4	10 (0.6-2.0)	30-45	Under-ground	
Inyi	Enugu	Sub-Bituminous	50	20	4	(0.9-2.0)	25-48	Open cast, Under-ground	
Amansiodo	Enugu	Bituminous (cokeable)	1000	NA	3	NA	563	Under-ground	
Ogugu/Awgu	Enugu	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Okaba	Kogi	Sub-Bituminous	250	73	Many	(0.8-2.3)	20-100	Open cast, Under-ground	Functional
Ogboyoga	Kogi	Sub-Bituminous	427	107	31	17 (0.8-2.3)	20-100	Open cast, Under-ground	
Ogwashi-Uku/Azagba/Obonkpa	Delta	Lignite	250	63	7	4 (3.5)	15-100	Open cast, Under-ground	
Oba/Nnew	Anambra	Lignite	30	NA	2	14 (0.3-4.5)	18-38	Under-ground	
Ihioma	Imo	Lignite	40	NA	Nil	Many	20-80	Open cast	
Lafia/Obi	Nasarawa	Bituminous (cokeable)	156	21.42	123	-1.3	80	Under-ground	
Owukpa	Benue	Sub-Bituminous	75	57	Many	(0.8-2.3)	20-100	Open cast, Under-ground	Functional
Afikpo/Okigwe	Abia	Sub-Bituminous	50	NA	Nil	NA	20-100	Under-ground	
Afuze	Edo	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Ute	Ondo	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Lamja	Adamawa	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Gandi-Akwati	Plateau	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Jamata-Koji	Kwara	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Doho	Gombe	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Kurumu Pindiae	Gombe	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	
Garin Maiganga	Gombe	Sub-Bituminous	NA	NA	Nil	NA	NA	Under-ground	

Source Essien and Igweonu (2014)

**Table 2.5** Renewable energy resources in Nigeria and their potential

Resource type	Reserves		Production	Domestic utilization (natural units)
	Natural units	Energy units (Btoe)		
Small Hydro-power	3500 MW	0.34 (over 40 years)	30 MW	30 MW
Large Hydro-power	11,250 MW	0.8 (over 40 years)	1938 MW	1938 MW
Wind	2–4 m/s at 10 m height (main land)	0.0003 (4 m/s @ 12 % probability, 70 m height, 20 m rotor, 0.1 % land area, 40 years)	–	–
Solar Radiation	3.5–7.0 kWh/m <sup>2</sup> /day (4.2 million MWh/day using 0.1 % land area)	5.2 (40 years and 0.1 % land area)	6 MWh/day	6 MWh/day
<b>Biomass</b> Fuel wood	11 million hectares of Forest and wood land Excess of 1.2 m ton/day	–	0.120 million ton/day	0.120 million ton/day
Animal waste	211 million assorted animals	–	0.781 million ton of waste/day	None
Energy crops and agricultural residue	28.2 million hectares of arable land (= 30 % of total land)	–	0.256 million ton of assorted crops/day	None

*Source* ECN (2009)

### 2.2.2.1 Biomass Energy

Biomass energy refers to energy that is developed from organic materials like scrap lumber, forest debris, crops, manure, and some types of waste residue. Biomass is an indirect form of solar energy because it arises from the process of photosynthesis. Biomass resources found in Nigeria include wood, shrubs, forage grasses, and waste from animals, forestry, agriculture, industry, and municipal areas. Nigeria's biomass resources have been estimated at  $88 \times 10^2$  MJ.<sup>22</sup> Biomass energy from plants could be used as fuel for small-scale industries or fermented by anaerobic bacteria to produce cheap and versatile biogas (Garba and Bashir 2002).

Fuel wood is the most common form of biomass in Nigeria, with about 80 million m<sup>3</sup> used annually for cooking and various other domestic purposes (Sambo 2005). The energy content of this fuel wood is  $6.0 \times 10^9$  MJ, out of which only 5 and 12 % are used for cooking and other domestic uses, respectively (Lawal 2007a, b). In addition, increasing demand for wood by the furniture and construction industries is causing a rapid depletion of the biomass resources in Nigeria.

Shrubs and forage grasses have been estimated to produce 200 million tons of dry biomass that could release up to  $2.28 \times 10^6$  MJ of energy (Vincent and Yusuf 2014). Because of the high dependence on fuel woods for cooking and heating by rural dwellers in Nigeria, 350,000 ha of forest and vegetation are lost annually, although this is much lower than the afforestation rate of 50,000 ha per annum (Sambo 2009a).

However, soil erosion and desert encroachment will result from these activities if the situation is not properly controlled. This could be achieved by discouraging the use of firewood through the introduction of affordable solar stoves. The introduction of a three-stone stove with an efficiency as low as 15 %, which was developed locally by the ECN through its energy research centers at the University of Nigeria in Nsukka and Usman Dan Fodio University in Sokoto, will ensure the reduction of fuel wood consumption (Sambo 2009a).

Biomass is an important renewable energy source, but the sustainability of its production needs to be clearly understood. Nigeria should use its wood, municipal waste, oil palm product, sugar cane, and rice husk resources sustainably for biogas energy production. As has been practiced in South Africa and Malaysia, sugar mill companies in Nigeria could make use of their cane residues and waste, while paper and packaging mills could use their waste biomass to generate process steam (Shaaban and Petinrin 2014). Table 2.6 presents the estimated quantities and energy values of Nigeria's biomass resources.

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<sup>22</sup>Nadabo (2010).

**Table 2.6** Nigeria's biomass resources, estimated quantities, and energy values

Resources	Quantity (million ton)	Energy value (000 MJ)
Fuelwood	39.1	531.0
Agro-waste	11.244	147.7
Saw dust	1.8	31.433
Municipal solid waste	4.075	–

Source Sambo (2009a)

## Biogas

Biogas is produced from the anaerobic digestion of agricultural and animal waste in the absence of air. It has an estimated combustion temperature in the range of 65–750 °C and it is 20 % lighter than air. Biogas is similar to LPG gas because it is colorless or odorless and it burns with a brilliant blue flame. Its caloric value has been estimated to be about 20 MJ/m<sup>3</sup> and it burns with an efficiency of about 55 % in a conventional biogas stove. The gas contains a mixture of carbon IV oxide, hydrogen sulfide, methane, nitrogen, and water vapor (Opeh and Okezie 2011). The raw materials for biogas production include animal dung and waste from industry, farmland, and households.

Biogas constitutes a form of energy suitable for households and the agricultural and industrial sectors of the economy. It is a useful substitute for diesel, fuel wood, charcoal, and kerosene; it reduces GHG emissions, and it has no health risks because it burns clean (Akinbami et al. 2001). In rural areas of Nigeria, suitable feed stock has been identified and is considered economically viable for the production of biogas, including cassava leaves, dung, solid waste, water hyacinth, water lettuce, agricultural residues, urban refuse, and sewage (Akinbami et al. 1996).

Studies have shown that Nigeria produces about 227,500 t of fresh animal waste daily and 20 kg of municipal solid waste per capita annually (Mshandete and Parawira 2009; Oyedepo 2012). About 0.03 m<sup>3</sup> of gas can be produced from 1 kg of fresh animal waste; therefore, 6.8 million m<sup>3</sup> of biogas could be produced daily in Nigeria. Research conducted by Adeoti (1998) showed that a 6.0-m<sup>3</sup> family-sized biogas digester could produce about 2.7 m<sup>3</sup> of biogas per day, which would be sufficient to satisfy the cooking needs of a family of nine persons.

The initial cost of such project was estimated at US\$500 (i.e., NGN 80,100 in Nigeria Naira); annual expenditure was estimated as NGN 11,200, while the benefit was estimated as NGN 25,000. Although the project appears to have good economic potential, it might be too expensive for the low-income earners who reside mostly in rural areas. If measures are not taken to lower the costs or assist the low-income earners economically, low-income households might not accept the use of biogas (Garba and Bashir 2002).

It is of great importance for Nigeria's government to establish some biogas plants to help the development of the country's energy sector, because the technology can generate energy rapidly as the raw materials needed to feed the biogas plants are relatively abundant across the country (Opeh and Okezie 2011).

In addition to the use of biogas for household consumption and electricity generation, other areas such as the transport sector could benefit from this renewable option. The production of biogas in Nigeria would not only develop the energy sector but also aid in the reduction of urban waste.

### 2.2.2.2 Hydro Energy

Hydro energy technology is dependent on the potential energy difference between the levels of water in reservoirs, dams, or lakes and their discharge tail water levels downstream. A water turbine, which converts the potential energy of the water to shaft rotation, is coupled to a suitable generator to produce electricity (Sambo 2005).

In Nigeria, hydro energy technology is currently the prominent commercial renewable energy technology in the country's electricity supply mix. Economy of scale has enabled the development of large-scale hydropower technology to account for a large proportion of the total commercial renewable energy resources for electricity generation under greenhouse gas (GHG) emission constraints (Balogun 2010).

Apart from the problem of relative water levels, hydropower can supply uninterrupted electric power. Nigeria's total hydropower potential stands at 14,750 MW, but only 1930 MW (i.e., 14 %) is currently generated at Kanji, Shiroro, and Jebba, which represents about 30 % of the gross installed grid-connected generation capacity in Nigeria (CBN 2005). This assessment is based only on large-scale hydropower that was in operation before the 1973 oil crisis.

Clearly, Nigeria's hydropower potential has not been fully exploited. However, small hydropower (SHP) has recently received considerable global attention. This attention is because of the inherent advantages of SHP in reducing environmental impact, minimizing civil works, and offering the possibility of combining power generation with flood prevention, irrigation, and the development of fisheries. Nigeria's current SHP generation is estimated at 3500 MW, which represents about 23 % of the entire national hydro potential, as shown in Table 2.5.

A study undertaken in 12 states and 4 river basins revealed over 278 unexploited SHP sites with a total potential of 734.2 MW (Aliyu and Elegba 1990). Three of the states surveyed, Kano, Sokoto, and Plateau, had installed operating SHP generators with a total capacity of 30 MW. The Nigerian Electricity Supply Company (NESCO) is currently generating 21 MW from six other sites in Plateau state. Currently, about 5 % of the available SHP capacity is exploited, while other SHP sites have been set aside for future development. However, out of the total potential of 734.2 MW, only 32 MW have been developed. Table 2.7 shows the SHP potential in Nigeria, Table 2.8 presents the existing SHP schemes (Sambo 2009b), and Fig. 2.18 shows the various water ways within the country.

**Table 2.7** Small hydropower potentials in Nigeria

State (Pre 1980)	River basin	Total sites	Hydropower potential		
			Developed (MW)	Undeveloped (MW)	Total capacity (MW)
Sokoto	Sokoto-Rima	22	8.0	22.6	30.6
Katsina	Sokoto-Rima	11		8.0	8.0
Niger	Niger	30		117.6	117.6
Kaduna	Niger	19		59.2	59.2
Kwara	Niger	12		38.8	38.8
Kano	Hadeija-Jamaare	28	6.0	40.2	46.2
Borno	Chad	28		20.8	20.8
Bauchi	Upper Benue	20		42.6	42.6
Gongola	Upper Benue	38		162.7	162.7
Plateau	Lower Benue	32	18.0	92.4	110.4
Benue	Lower Benue	19		69.2	69.2
Cross Rivers	Cross Rivers	18		28.1	28.1
Total		277	32	702.2	734.2

Source Sambo (2009b)

**Table 2.8** Small hydropower schemes in existence in Nigeria

River	State	Installed capacity (MW)
Bagel I	Plateau	1
Bagel II	Plateau	2
Ouree	Plateau	2
Kuna	Plateau	8
Lere	Plateau	4
Lere	Plateau	4
Bakalori	Sokoto	3
Tiga	Plateau	6
<b>Total</b>		30

Source Sambo (2009b)

### 2.2.2.3 Solar Energy

Solar energy is the most promising renewable energy source because of its apparent limitless potential. The sun radiates energy at the rate of about  $3.8 \times 10^{23}$  kW/s. Most of this energy is transmitted radially as electromagnetic radiation, reaching the boundary of Earth's atmosphere at about  $1.5 \text{ kW/m}^2$ . After traversing the atmosphere, a square meter of Earth's surface can receive as much as 1 kW of solar power, or about 0.5 kW on average during daylight hours. This huge energy resource is available for about 26 % of the day (Muhammad 2012).

Solar energy can provide cheap and abundant energy for communities whose connection to the utility grid might not be economical because they are located





Fig. 2.18 Nigerian water ways. *Source* Safty4sea (2014)

too far from the nearest grid-connection point. Solar energy is therefore a very good alternative source of energy in the rural areas of Nigeria. It could aid the rapid development of small-scale industries and reduce rural–urban migration (Ojosu 1990).

Nigeria is located within a high sunshine belt and solar radiation is well distributed. The annual average total solar radiation varies from about 25.2 MJ/m<sup>2</sup>/day (7.0 kWh/m<sup>2</sup>/day) in northern regions to about 12.6 MJ/m<sup>2</sup>/day (3.5 kWh/m<sup>2</sup>/day) in southern parts. Assuming an average of 18.9 MJ/m<sup>2</sup>/day (5.3 kWh/m<sup>2</sup>/day), Nigeria has an estimated 17,459,215.2 million MJ/day (17.439 TJ/day) of solar energy arriving over its 923,768 km<sup>2</sup> land area. The annual average intensity is 6898.5 or 1934.5 kWh/m<sup>2</sup>/year (Vincent and Yusuf 2014).

As the average sunshine per day is 6.5 h, the annual solar energy available is about 27 times that of the country's total fossil fuel resource, and it is over 115,000 times the electrical power generated (Augustine and Nnabuchi 2009). This implies that about 3.7 % of the land area in Nigeria could collect an amount

of solar energy equivalent to the conventional energy reserves within the country (Shaaban and Petinrin 2014). This is in agreement with a study by Oji et al. (2012), considering that the minimum harnessing of solar power in some parts of Nigeria would be more than enough to power an average three-bedroom flat and two-room apartment that use low-power appliances. The monthly averages of daily solar radiation for 28 states in Nigeria over 25 years are presented in Table 2.9, and the annual average daily sun in Nigeria is illustrated in Fig. 2.19.

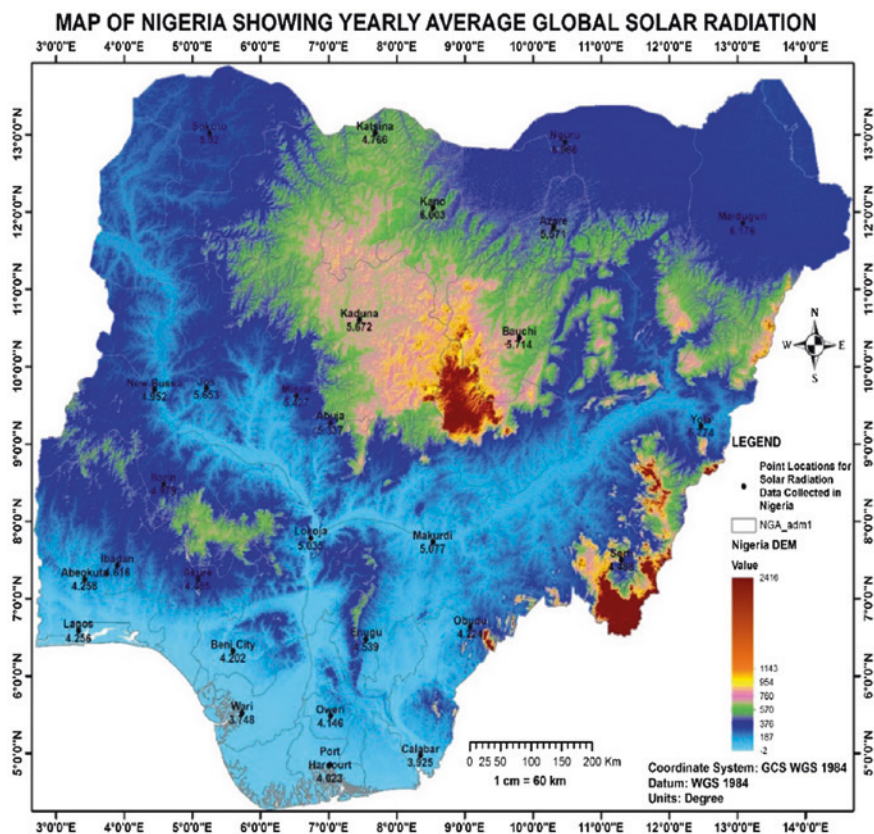
**Table 2.9** Maximum, minimum, and yearly average global solar radiation (kWh/m<sup>2</sup>/day)

Stations	Location lat. 1 N	Location long 1E	Altitude (m)	Max <sup>a</sup>	Min <sup>b</sup>	Monthly average
Abeokuta	7.25	3.42	150	4.819	3.474	4.258
Abuja	9.27	7.03	305	5.899	4.359	5.337
Akure	7.25	5.08	295	5.172	3.811	4.485
Azare	11.8	10.3	380	6.028	5.022	5.571
Bauchi	10.37	9.8	666.5	6.134	4.886	5.714
Benin City	6.32	5.6	77.52	4.615	3.616	4.202
Calabar	4.97	8.35	6.314	4.545	3.324	3.925
Enugu	6.47	7.55	141.5	5.085	3.974	4.539
Ibadan	7.43	3.9	227.23	5.185	3.622	4.616
Ilorin	8.48	4.58	307.3	5.544	4.096	4.979
Jos	9.87	4.97	1285.58	6.536	4.539	5.653
Kaduna	10.6	7.45	645.38	6.107	4.446	5.672
Kano	12.05	8.53	472.14	6.391	5.563	6.003
Katsina	13.02	7.68	517.2	5.855	3.656	4.766
Lagos	6.58	3.33	39.35	5.013	3.771	4.256
Lokoja	7.78	6.74	151.4	5.639	4.68	5.035
Maiduguri	11.85	13.08	383.8	6.754	5.426	6.176
Makurdi	7.73	8.53	112.85	5.656	4.41	5.077
Minna	9.62	6.53	258.64	5.897	4.41	5.427
New Bussa	9.7	4.48	152	5.533	4.15	4.952
Nguru	12.9	10.47	342	8.004	6.326	6.966
Obudu	6.63	9.08	305	5.151	3.375	4.224
Oweri	5.48	7.03	120	4.649	3.684	4.146
Port Harcourt	4.85	7.02	19.55	4.576	3.543	4.023
Serti	7.5	11.3	610	4.727	3.972	4.488
Sokoto	13.02	5.25	350.75	6.29	5.221	5.92
Wari	5.52	5.73	6.1	4.237	3.261	3.748
Yola	9.23	12.47	186.05	6.371	4.974	5.774

Source Okoro et al. (2007)

<sup>a</sup>Average for the months of March, April and May

<sup>b</sup>Average for the months of July and August



**Fig. 2.19** Yearly average of solar radiation in Nigeria. *Source* Nwoko (2015b)

The levels of solar energy awareness and acceptance have already gained ground in northern parts of Nigeria, as presented in a survey performed by Shehu (2012). Other studies, surveys, and pilot projects have been undertaken by the Sokoto Energy Research Centre and the National Centre for Energy Research and Development under the supervision of the ECN. They have implemented solar PV water pumping and electrification, and solar thermal installations such as solar cooking stoves, crop drying facilities, incubators, and chick-brooding systems. However, solar technology has not penetrated into the deep rural areas, especially the off-grid areas, where candles and kerosene lamps are still being used for lighting homes at night. An effective policy should be created to foster the development of solar energy across Nigeria to help reduce poverty in rural areas of the country.

#### 2.2.2.4 Wind Energy

Wind is a natural phenomenon related to the movement of air masses caused primarily by differential solar heating of the earth's surface. The seasonal variation in the energy received from the sun affects the strength and direction of the wind. The ease with which aero-turbines transform the energy of moving air into rotary mechanical energy lends itself to the conversion of wind energy to electricity. For many years, wind energy has been used for pumping water and milling grain (Sambo 1981).

Wind energy generation has gained worldwide recognition and it is the fastest growing renewable energy market in the world. The global cumulative installed capacity of wind power has increased steadily from 6100 MW in 1996 to 158,505 MW in 2009, and was expected to be over 238 GW by the end of 2014, a target that will aid the reduction of GHG emissions (WWE 2008). Currently, 82 countries generate electricity from wind energy, 49 of which have increased their installed capacity since 2009.

In 2009, Egypt, Morocco, and Tunisia were the leading countries in Africa for wind energy with installed capacities of 430, 253, and 54 MW, respectively (Adaramola and Oyewola 2011). In Nigeria, wind measurements at 10-m height show that some sites have wind speeds between 1.0 and 5.1 m/s. These wind speeds can be classified into four regimes: >4.0 m/s, 3.1–4.0 m/s, 2.1–3.0 m/s, and 1.0–2.0 m/s. Therefore, Nigeria is located within a moderate wind<sup>23</sup> regime. The wind speed in southern Nigeria is relatively low, except for coastal regions and offshore, where the high wind speeds indicate great potential for exploiting wind energy (Vincent and Yusuf 2014).

A study undertaken by the ECN revealed that the total exploitable wind energy reserves at 10-m height might vary from 8 MWh/year in Yola to 51 MWh/year in the mountainous area of Jos, and possibly even as high as 97 MWh/year in Sokoto (Sambo 1981). In addition to the study performed by the ECN, many indigenous researchers (Adekoya and Adewale 1992; Fagbenle and Karayiannis 1994; Ngala et al. 2007; Mnse and Ojo 2009; Felix et al. 2012) have analyzed wind data from various parts of the country and these data include wind speeds and power flux densities. Furthermore, the wind energy potential and the conditions that must be met before a wind turbine can be connected to the utility grid have also been studied in the literature (Adekoya and Adewale 1992; Felix et al. 2012; Shaaban and Petinrin 2014).

Adekoya and Adewale (1992) presented estimates of potential wind speeds at 10 selected sites within the country. The results were compared with wind

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<sup>23</sup>Moderate wind or breeze according to the Beaufort wind force scale gives the sea condition as small waves with breaking crests, fairly frequent whitecaps and land condition as dust, loose paper raised, small trees branches begin to move (See National Meteorological Library and Archive fact Sheet 6-The Beaufort Scale-PDF).

**Table 2.10** Summary of the measured data of annual wind speeds

Site	Land-use type	Altitude (m a.s.l)	Height (m)	Wind speed (m/s)		Differences (%)
				Measured	KLIMM	
Enugu	Complex landscape	466	30	4.6	4.4	-4.3
Jos	Complex landscape	1344	30	5.2	5.1	-1.9
Pankshin	Complex landscape	1355	40	4.9	4.7	-4.1
Sokoto	Plain surface	352	30	5.4	5.2	-3.7
Kano	Plain surface	340	30	4.9	5.1	4.1
Gumel	Plain surface	393	30	4.1	4.2	2.4
Maiduguri	Plain surface	373	30	4.7	4.6	-3
Ibi	River valley	300	30	3.6	3.3	-8.3
Gembu	Highly complex landscape	1800	40	5	5.2	1
Lagos	Coastal area	2	30	4.7	4.9	4.3

Source Adekoya and Adewale (1992), Felix et al. (2012)

**Table 2.11** Estimated gross energy yield

Site	Gross energy yield measurement (MWh)		
	Model FL 100, 100/20 Rotor dia. 21.0 m Hub height 34.5 m 100/20	Model FL250, 250/50 Rotor dia. 29.5 m Hub height 42.0 m 250/50	Model V52, 850/52 Rotor dia. 52.0 m Hub height 44.0 m
Enugu	92.9	217.9	734.20
Jos	129.6	299	1025.80
Pankshin	117.1	272.1	936.60
Sokoto	153.5	358.8	1235.80
Kano	116.3	281.2	963.60
Gumel	73.4	197.2	681.40
Maiduguri	102.7	262.2	906.10
Ibi	49.8	141.3	481.20
Gembu	112.9	253.9	855.30
Lagos	129.3	386.1	1402.80

Source Adekoya and Adewale (1992), Felix et al. (2012)

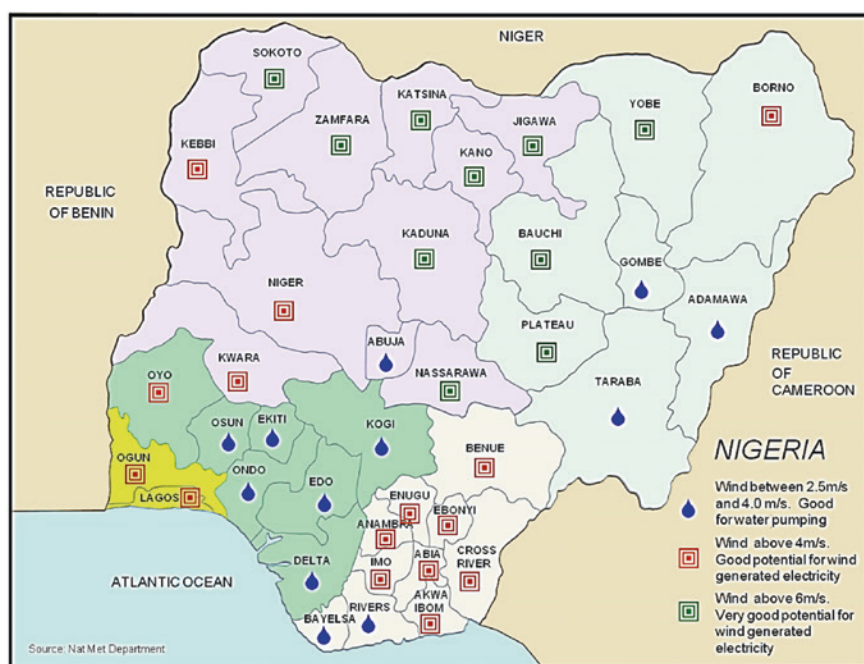
speeds calculated by the Mainz climate model, which revealed a discrepancy of -4.3 to 4.1 %, which is within acceptable error limits. The results, presented in Tables 2.10 and 2.11 list the estimated gross energy yield, while Table 2.12 presents the estimated wind energy potential of some selected states in Nigeria. Figure 2.20 shows the potential of wind energy locations in Nigeria.

According to Shaaban and Petinrin (2014), assuming a medium generation capacity of 5 MWh/km<sup>2</sup> with (a) a 30 % capacity factor and (b) using only 1 % of

**Table 2.12** Estimated wind energy potentials

Selected state	Area (km <sup>2</sup> )	Wind area (%)	Effective wind area (km <sup>2</sup> )	1 % area (km <sup>2</sup> )	Potential capacity (MW)	Potential generation (MWh/year)
Adamawa	37,957	45	170,80	171	854	2244
Bauchi	48,197	50	24,098	241	1204	3166
Borno	72,767	100	72,767	728	3638	9561
Gombe	17,428	100	17,428	174	871	2290
Jigawa	23,415	100	23,415	234	1170	3076
Kaduna	44,217	60	26,530	265	1326	3486
Kano	20,389	90	18,350	184	917	2411
Katsina	23,822	100	23,822	238	1191	3130
Kebbi	36,320	25	9080	91	454	1193
Plateau	26,539	90	23,885	239	1194	3138
Sokoto	32,146	90	28,931	289	1446	3801
Taraba	58,180	40	23,672	237	1183	3110
Yobe	44,880	100	44,880	449	2244	5897
Zamfara	33,667	80	26,933	269	1346	3539
Total				3809	19,043	50,046

Source Adekoya and Adewale (1992), Felix et al. (2012)

**Fig. 2.20** Wind energy potentials and locations in Nigeria. Source Nee Nigeria (2015)



**Table 2.13** Wind energy estimates at 25 m height

Site	Mean wind speed at 25 m level (m/s)	Monthly mean wind energy (KWh)	Annual wind energy (KWh)	Annual wind energy from a wind turbine (KWh)	
				10 m blade diameter	25 m blade diameter
Benin City	2.135	2.32	27.86	2,18.81	13,673.78
Calabar	1.702	1.12	13.42	1,053.69	6587.53
Enugu	3.372	7.83	93.91	7375.75	46,097.96
Ibadan	2.62	4.15	49.78	3909.70	24,436.19
Ilorin	2.078	1.23	14.73	1157.06	7230.57
Jos	4.43	16.05	192.64	15,129.60	94,559.98
Kaduna	3.605	9.91	188.88	936.81	58,355.08
Kano	3.516	8.57	102.86	8078.61	50,491.28
Lagos (Ikeja)	2.671	4.36	52.32	4099.78	25,682.52
Lokoja	2.235	2.6	31.21	4451.23	15,320.17
Maiduguri	3.486	8.42	101.01	7933.61	49,583.17
Mina	1.589	1.05	12.60	989.60	6185.01
Makurdi	2.689	4.44	53.27	4183.51	26,148.85
Nguru	4.259	14.48	173.74	14,645.19	85,284.42
Oshogbo	1.625	1.07	12.81	1006.60	6288.09
Port Harcourt	2.64	4.17	49.98	3925.48	24,533.88
Potiskum	3.636	9.44	113.25	8894.35	55,591.46
Sokoto	4.476	16.47	197.68	15,525.75	97,035.94
Warri	2.027	2.02	24.20	19,00.66	11,879.15
Yelwa	3.36	7.76	93.13	7314.88	45,714.59
Yola	1.824	1.45	17.34	1,361.88	8511.75
Zaria	2.891	5.32	63.88	5,017.26	31,357.02
Total		134.23	1680.50	120,078.90	790,548.39

Source Adekoya and Adewale (1992), Felix et al. (2012)

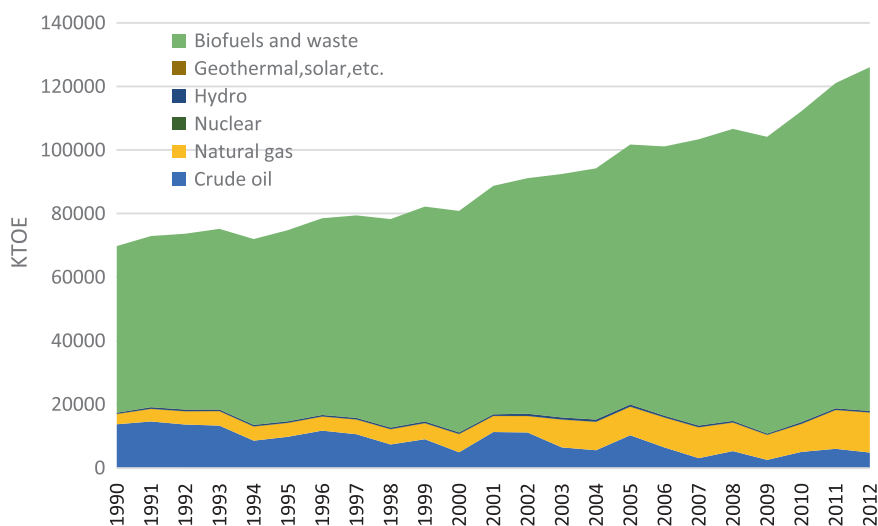
the effective wind area of the selected states, Nigeria has the potential to generate about 50,046 MWh/year of electricity. The detailed potentials and wind energy densities at 25-m height for 22 selected states in Nigeria are presented in Table 2.13.

Currently, no commercial wind power plants are connected to the national grid in Nigeria. The few power plants that exist are those installed in the 1960s in five northern states and the 5-kW wind electricity conversion system installed in Sayyan Gidan Gada in Sokoto state. However, the latest development in wind energy generation in Nigeria is the ongoing installation of wind turbines in Katsina state, which is expected to generate 20 MW of electricity on completion. The progress of harnessing the potential of wind energy is too slow. Most communities in northern parts of the country are not connected to the electricity grid and therefore, the federal government must do more regarding the exploitation of wind power, especially in the northern areas where the wind speed is high.

## 2.3 Primary Energy Supply in Nigeria

According to the International Energy Agency, Nigeria's total primary energy supply for 2012 was 126,097 ktoe (excluding electricity trade and oil product import), and this was almost double the amount in 1990 (i.e. 69,810 ktoe). In the primary energy supply mix, biofuels and waste had a percentage share of 85.8 %, while crude oil, natural gas, and hydro had 3.8, 10 and 0.4 % respectively. Crude oil exported out of the country in the same year (2012) was 126,413 ktoe, natural gas was 21,032 ktoe, while oil products were 755 ktoe. Oil products of about 8440 ktoe were also imported, so as to augment supply and meet the growing demand for petroleum products.

As previously stated, Nigeria is among the world's largest oil and gas producers, but depends heavily on the importation of oil products due to the low production capacity of the nation's crude oil refineries. However, with the abundant energy resources available in Nigeria, the largest energy consumption has been biofuels and waste, of which fuel wood or firewood is the primary biofuel source. This is shown in Fig. 2.21, where biofuels and waste have been the main fuel for energy supply from 1990 to 2012. The primary energy supply has been on the decrease, while natural gas has gradually been increasing. This may be due to the price of oil which was higher than natural gas, hence the increase in gas supply. Also, with the increasing construction of gas power plants in Nigeria, the supply of natural gas is expected to increase more than the 2012 values.



**Fig. 2.21** Nigeria's total primary energy supply (1990–2012). *Source* IEA (2015a)

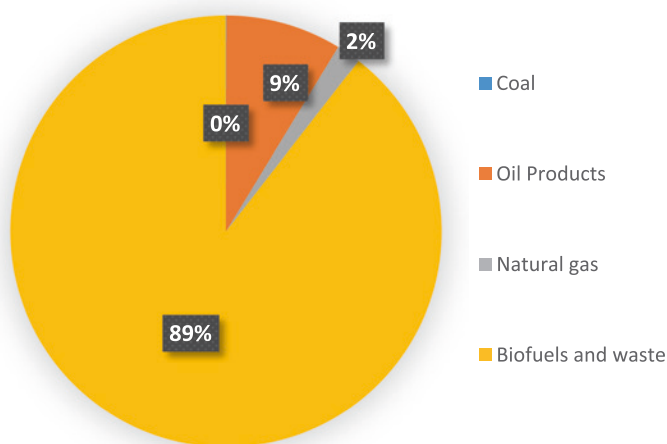


## 2.4 Primary Energy Consumption

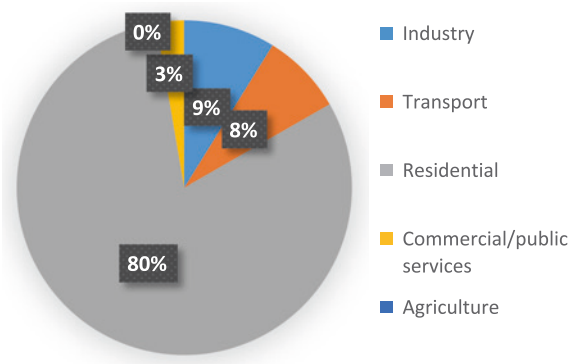
Among the primary energy consumption in Nigeria, biofuels and waste comprise about 89 % of the total primary energy consumption in 2012 alone, while oil products which are mainly imported and natural gas comprise 9 and 2 % respectively (Fig. 2.22). Continuous utilization of biofuels (especially firewood) has been the single most important factor for the increase in deforestation and increase in desert encroachment in most parts of Nigeria. The rate of forest tree replacement is lower than fuel wood (from forest trees) consumption in Nigeria. This will be on the increase as the rate of population in the rural part of Nigeria tends to increase; the total population of Nigeria is forecasted to increase to about 400 million by 2050 (see Fig. 2.4).

According to the study by Zaku et al. (2013), the increase in firewood consumption can be attributed to the increase in poverty, as firewood is usually free, sometimes affordable, and easily accessible to the rural dwellers. However, some studies such as those by Naibbi and Healey (2013), Mandelli et al. (2014), Eludoyin (2015) and Oladimeji et al. (2015) show that firewood consumption is higher in the northern part of Nigeria, while the southern part diversifies energy consumption.

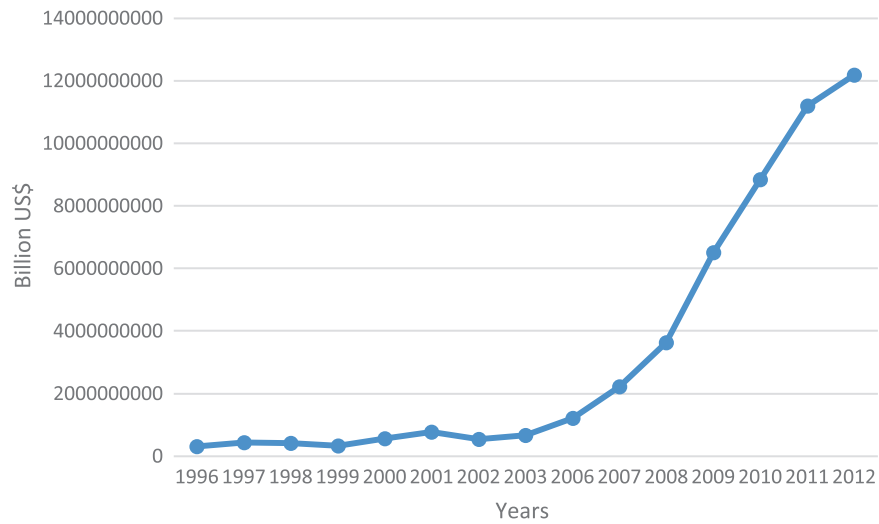
Other studies such as Audu (2013) who used descriptive and comparative methods to analyze the fuel consumption in Nigeria and desertification, shows that in Nigeria, firewood is about the only source of domestic fire in the desert-prone states leading to desertification. This is also reported by Al-Amin (2014) study as it extends the issue to other parts of the country and suggested an immediate action by the Nigerian Government. The total primary energy consumption in Nigeria by sector is shown in Fig. 2.23.



**Fig. 2.22** Primary energy consumption in Nigeria by fuel (2012). *Source* IEA (2015b)



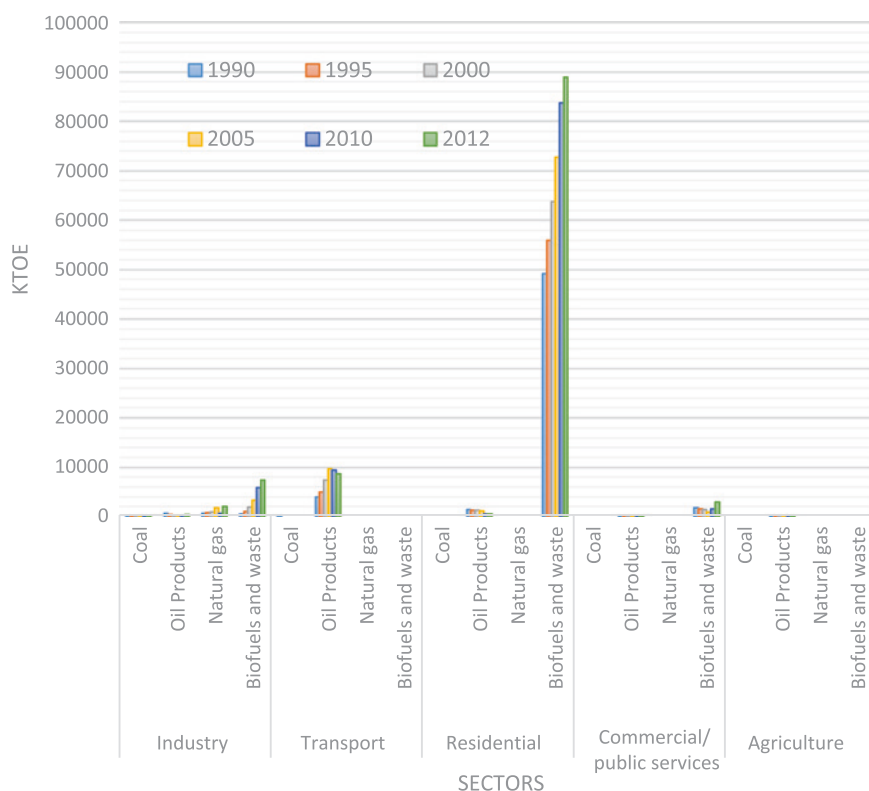
**Fig. 2.23** Total primary energy consumption in Nigeria by sector. *Source* IEA (2015b)



**Fig. 2.24** Automobile import in Nigeria. *Source* NCS (2015)

As shown in Fig. 2.23, the highest final energy consumption in the various sectors in Nigeria is the residential sector with 80 %, while the industrial and agricultural sectors account for 9 and 8 % respectively. With the rapidly increasing numbers of vehicle import in Nigeria (see Fig. 2.24), the rate of energy consumption is expected to increase in the transportation sector just as in other sectors of the economy. This growth with the number of imported vehicles was on the increase from 2006 (about US\$1.2 billion) to 2012 (about US\$12.2 billion).

The rate of utilization of oil products such as petrol and diesel in the transportation sector is the highest in the total energy consumption as compared to other sectors such as the industrial, commercial/public services, and residential sectors

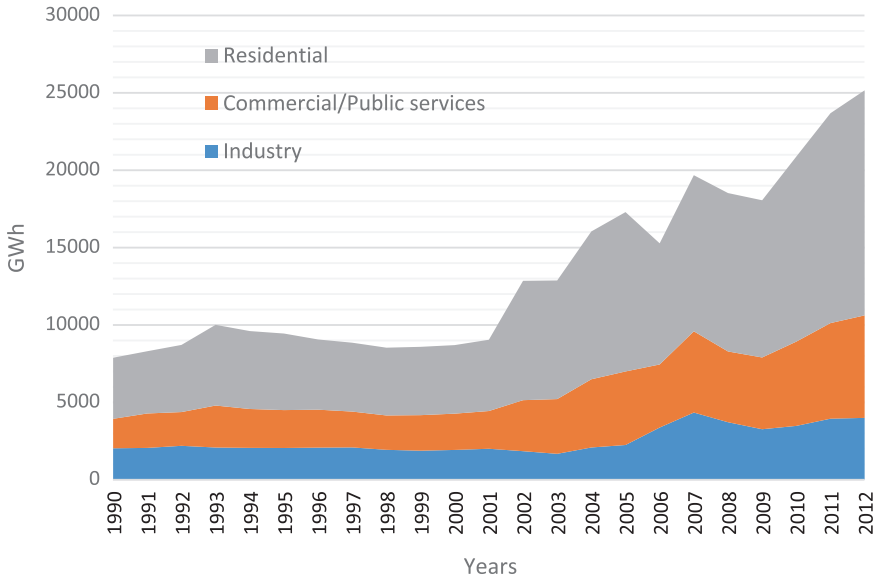


**Fig. 2.25** Total primary energy consumption by fuel and sectors. *Source* IEA (2015b)

which mainly use diesel for electricity generation. This is observed in Fig. 2.25, which shows the combination of primary energy consumption by both fuel and sectors.

To address the issue of desertification in Nigeria, the Nigerian Government prepared the National Report titled, “Combating Desertification and Mitigating the Effects of Drought in Nigeria”, which contains various strategic policies (FRN 1999). A more recent strategic plan by the Nigerian Government was the “National Strategic Action Plan” which was developed in 2012 by the Ministry of Environment (FME 2012). These documents as developed by policy makers face some implementation challenges such as the provision of alternative source of fuel other than firewood, since the population of the rural population is expected to rise. There is also the issue of urbanization as rural dwellers will migrate to urban areas when there is no longer firewood and diesel is readily available in the urban areas.

On electricity consumption in Nigeria (Fig. 2.26), the growing trend of energy consumption rate is also observed for electricity consumption in the residential sector, from 3,949 GWh in 1990 to 14,549 GWh in 2012. The commercial/public services electricity consumption was 6,627 GWh in 2012, while the industrial electricity consumption was 3,983 GWh. Considering Fig. 2.26, electricity



**Fig. 2.26** Electricity consumption by sector. *Source* IEA (2015c)

consumption in the industrial sector did not increase much in 2012, as compared to 1990. This low electricity has forced most industries to depend on private generators to run their operations and businesses (Emodi and Boo 2015a). The South African mobile phone company MTN who operates the largest mobile phone company in Nigeria is estimated to have installed 6,000 generators to supply its base stations for up to 19 h a day. This cost the company \$5.5 million a month on diesel in order to run the generators (Lawal 2007).

## 2.5 Relevant Government Ministries, Parastatals and Agencies in the Nigerian Energy Sector and Their Roles

The relevant government ministries, parastatals, and agencies are presented as follows.

### 2.5.1 The Energy Commission of Nigeria (ECN)

The Energy Commission of Nigeria (ECN) was established by Act No. 62, as amended by Act No. 32 of 1988 and Act No. 19 of 1989. It commenced operation in 1989 and is in charge of the energy sector planning and policy implementation.

The ECN promotes the use of renewable and alternative energies in the country's energy mix, as well as fulfils the role of strategic overall planning, coordination and effective direction of Nigeria's national energy policies and strategies. The Commission (i.e. ECN) has the following responsibilities (ECN 2015):

- To serve as a center for gathering and dissemination of information relating to national policy in the field of energy;
- To serve as a center for solving any inter-related technical problems that may arise in the implementation of any policy relating to the field of energy;
- To advise the government of the Federation or a State on questions relating to such aspect of energy as the Government of the Federation or a State may from time to time refer to it;
- To prepare after consultation with such agencies of government whose functions relate to the field of energy development or supply as the Commission considered appropriate, periodic master plans for the balanced and coordinated development of energy in Nigeria and such plans include:
  - Recommendations for the exploitation of new sources of energy as and when considered necessary, and
  - Such other recommendations to the Government of the Federation relating to its functions under this Decree as the Commission may consider to be in the national interest;
- To lay down guidelines on the utilization of energy types for specific purposes;
- To inquire into and advise the Government of the Federation or of the State on the adequate funding of the energy sector including research and development, production and distribution;
- To collate, analyze, and publish information relating to the field of energy;
- To carry out such other activities as are conclusive to the discharge of its functions under this Decree;
- To monitor the performance of the energy sector in the execution of government policies on energy;
- To promote training and manpower development in the energy sector;
- To liaise with all international organizations in energy matters.

### ***2.5.2 Federal Ministry of Environment (FME)***

The Federal Ministry of Environment (FME) was established in 1999 by the Federal Government of Nigeria with the statutory responsibility of protecting the natural environment against pollution, degradation, and conservation of natural resources. The Ministry (i.e. FME) is officially charged with environmental responsibilities and also with coordinating all climate change matters under its Special Unit Climate Change (SUCC). The unit also represents the Ministry at international climate negotiations. The Special Unit on Renewable Energy (SURE) acts as the voice of the ministry regarding renewable energy and energy efficiency issues. The

objective of the unit is to develop and implement strategies that will achieve clean, reliable energy supply mechanisms in order to develop the sector based on international best practices and in order to showcase viability for private sector participation. The official mandates of the FME are presented as follows (FME 2015);

- To prepare a comprehensive National Policy for the protection of the environment and conservation of natural resources, including procedure for environmental impact assessment of all developing projects.
- To prepare in accordance with the National Policy on Environment, periodic master plans for redevelopment of environmental science and technology and advise the Federal Government on the financial requirements for the implementation of such plans.
- To advise the Federal Government on National Environmental Policies and priorities, the conservation of natural resources and sustainable development and scientific and technological activities affecting the environment and natural resources.
- To promote cooperation in environmental science and conservation technology with similar bodies in other countries and with international bodies connected with the protection of the environment and the conservation of natural resources.
- To cooperate with the Federal and State Ministries, Local Government, statutory bodies, and research agencies on matters and facilities relating to the protection of the environment and the conservation of natural resources,
- To prescribe standards for and make regulations on water quality, effluent limitations, air quality, atmospheric protection, ozone protection, noise control as well as the removal and control of hazardous substances, and
- To monitor and enforce environmental protection measures.

### ***2.5.3 Federal Ministry of Lands, Housing, and Urban Development (FMLHUD)***

The Federal Ministry of Lands Housing and Urban Development (FMLHUD) is an important arm of the Nigerian government that is charged with the implementation of all policies and regulations relating to lands, housing and urban development in the country. The FMLHUD has the mandate to enforce regulations in buildings in all the sectors of the economy. This involves the ministry's strategic role in energy efficiency in the residential, industrial, as well as commercial/services sectors. This is carried out under the Architectural Services under the FMLHUD and the inclusion of energy efficiency under the newly developed building code. Other mandates of the FMLHUD are the establishment of sustainable housing delivery system which ensures easy access to home ownership and rental schemes by the Nigerian populace in an environment where basic physical and social amenities are available (FMLHUD 2015).

#### ***2.5.4 Federal Ministry of Power (FMP)***

The Federal Ministry of Power has the official responsibility of ensuring a robust power sector that fully supports the socio-economic needs of the nation. The main goal of the ministry is directed at initiating, formulating, coordinating, and implementing broad policies and programmes on the development of electricity generation from all sources of energy. FMP is also charged with the responsibility of developing and deploying electricity-related renewable energy policies in Nigeria. The FMP also ensures that Nigeria is provided with adequate and reliable power supply by implementing generation, transmission, and distribution projects in the sector and facilitates the emergence of a private sector led competitive and efficient power industry. In a view to diversify the nation's energy mix, the FMP encourages the utilization of renewable energy for power generation in both the urban and rural areas (FMP 2015).

#### ***2.5.5 Federal Ministry of Water Resources (FMWR)***

The Federal Ministry of Water Resources (FMWR) was created in its current form in April 2010 with the responsibility of providing sustainable access to safe and sufficient water to meet the socio-economic needs of all Nigerians. This is achieved through efficient water resources management for basic human needs, irrigated agriculture, hydropower generation, and the promotion of healthy population while maintaining the integrity of fresh water bodies. The FMWR is involved in numerous renewable energy and rural electrification activities through its Department of Dams and Reservoir Operations. To increase energy supply in order to meet the nation's energy demands as mandated by the government, FMWR is collaborating with the FMP on the aspect of handling the area of power generation component, while the ministry handles the aspect of civil works in all the dam projects with hydropower potential. Small hydropower schemes have been integrated into some dam projects across the country in order to increase the energy supply of the nation (FMWR 2015).

#### ***2.5.6 National Power Training Institute of Nigeria (NAPTIN)***

The National Power Training Institute of Nigeria (NAPTIN) was established on March 23rd 2009 and commenced full operation in September, 2009. The primary purpose of its establishment is to provide training for power sector personnel and coordinate training activities in the sector. In pursuit of this mandate, NAPTIN has taken over the management of existing seven regional training centers of PHCN. NAPTIN reports directly to the FMP and it is supervised by a board of directors appointed by them (NAPTIN 2015).

### ***2.5.7 Nigerian Bulk Electricity Trading Plc. (NBET)***

In 2001, the Federal Government, in a bid to address the deficiency in power sector supply, adopted the National Electric Power Policy for the reform of the sector. Following suit, the Electric Power Sector Reform Act (EPSRA), was passed into law in March 2005. A key thrust of the sector reform is the transfer of the control and operations of the industry from public sector to private sector. In furtherance of this goal, the Act saw the creation of the Power Holding Company Nigeria (PHCN) which assumed the assets, liabilities, and employees of the erstwhile Nigeria Electricity Power Authority (NEPA); the subsequent unbundling of PHCN into 18 successor companies, the establishment of the Nigerian Electricity Regulatory Commission (NERC); the establishment of the Rural Electrification Agency (REA) and the provision for the establishment of two special purpose vehicles (SPVs) to undertake electric power trading and management of extant liabilities respectively.

In line with the “Road-map to Power Sector Reform” of August 2010, and, in fulfillment of the requirements of EPSRA, the Nigerian Bulk Electricity Trading Plc., (NBET) aka the Bulk Trader, was incorporated on July 29, 2010 as the SPV for carrying out, under license from National Electricity Regulatory Commission (NERC), the bulk purchase and resale function contemplated by the EPSRA. As such NBET has been set up to “engage in the purchase and resale of electric power and ancillary services from independent power producers and from the successor generation companies” (NBET [2015](#)).

### ***2.5.8 Nigerian Electricity Regulatory Commission (NERC)***

The Nigerian Electricity Regulatory Commission was established as an independent regulatory agency in 2005 under the EPSR Act 2005. Its mandate is to monitor and regulate the electricity industry of Nigeria, and ensure compliance with market rules and operating guidelines. NERC is responsible for assessing applications for licenses to operate an independent power plant larger than 1 MW, and thus approves eligibility of prospective companies to negotiate a power purchase agreement with the central off-taker in the current transitional market, the NBET. The NERC also plays a crucial role in consumer protection by ensuring the development of customer service standards, fair pricing rules, and the provision of dispute resolution if a situation arises (NERC [2015](#)).

### ***2.5.9 Nigerian National Petroleum Corporation (NNPC)***

The Nigerian National Petroleum Corporation (NNPC) is the corporation through which the federal government of Nigeria (the Department of Petroleum Resources, DPR) regulates and participates in the country’s petroleum industry. NNPC was



established on April 1, 1977 as a merger of the Nigerian National Oil Corporation and the Federal Ministry of Mines and Steel. NNPC by law manages the joint venture between the Nigerian federal government and a number of foreign multinational corporations, which include Royal Dutch Shell, Agip, ExxonMobil, Chevron, and Texaco (now merged with Chevron). Through collaboration with these companies, the Nigerian government conducts petroleum exploration and production.

NNPC has the sole responsibility for upstream and downstream developments, and is also charged with regulating and supervising the oil industry on behalf of the Nigerian Government. In 1988, the corporation was commercialized into 11 strategic business units, covering the entire spectrum of oil industry operations: exploration and production, gas development, refining, distribution, petrochemicals, engineering, and commercial investments (The Economist 2007; NNPC 2015c). The NNPC is also exploring the biofuel option for the transportation sector and this includes mainly ethanol and biodiesel which are mixed with conventional fuel.

### ***2.5.10 Presidential Taskforce on Power (PTFP)***

The Presidential Task Force on Power (PTFP) was established in June 2010, to drive the implementation of the reform of Nigeria's power sector. It brings together all the agencies that have a role to play in removing legal and regulatory obstacles to private sector investment in the power industry. It also has the mandate to monitor the planning and execution of various short-term projects in generation, transmission, distribution, and fuel-to-power that are critical to meeting the stated service delivery targets of the power reform roadmap (PTFP 2015).

The PTFP collaborates closely with various ministries and agencies that have specific contributions to the reform process, including the Federal Ministry of Power (FMP), the Federal Ministry of Finance (FMF), Ministry of Petroleum Resources (MPR), the Bureau of Public Enterprises (BPE), the Nigerian Electricity Regulatory Commission (NERC), the Nigerian National Petroleum Corporation (NNPC), the Bureau of Public Procurement, National Gas Company Limited (NGC) and the Power Holding Company of Nigeria (PHCN).

### ***2.5.11 Rural Electrification Agency of Nigeria (REA)***

The Rural Electrification Agency (REA) was established in 2006 under Section 88 (I) of the Electric Power Sector Reform Act (EPSRA), 2005. Its vision was to mobilize capital for sustainable private sector driven investment in rural electricity development in Nigeria dedicated to the goal of improving the living conditions in rural areas through enhancing agriculture, commercial, industrial, and domestic

activities. The core functions of the REA are to promote and coordinate rural electrification projects, implement and manage the Rural Electrification Fund, and regulation of rural electrical sector. The REA projects center on grid expansion to rural areas via funding from the federal government's annual budgetary allocation; most recently it has broadened its ambit to include the deployment of off-grid and mini-grid renewable energy generating systems to accelerate the pace of improvement (REA 2015).

### ***2.5.12 Standards Organization of Nigeria (SON)***

Established by the Federal Government by the Act No. 56 of 1971, the Standards Organization of Nigeria (SON) is entrusted with the responsibility to ensure imported and manufactured products in Nigeria are kept at stipulated standards (SON 2015). Other functions of the SON include the following:

- To ensure the compliance of designated and approved standards by the Council;
- To undertake investigations as necessary into the quality of facilities, materials, and products in Nigeria, and establish a quality assurance system including certification of factories, products, and laboratories;
- To provide reference standards for calibration and verification of metering and metering equipment;
- To compile an inventory of products requiring standardization;
- To prepare Nigeria Industrial Standards;
- To foster interest in the recommendation and maintenance of acceptable standards by industry and the general public;
- To develop methods for testing of materials, supplies, and equipment;
- To register and regulate standard marks and specification.

Some renewable energy and energy efficiency standards have recently been developed and adopted by the SON. This includes among others, a code of practice for the deployment of outdoor solar lighting, design qualification and type approval of PV modules, safety standards for use of PV power converters, etc. (Ley et al. 2014).

### ***2.5.13 Council for Renewable Energy in Nigeria (CREN)***

The Council for Renewable Energy Nigeria is a multi-stakeholder association, which promotes the appropriate use of renewable energy technology in Nigeria and the reduction of greenhouse gases through reduced consumption of fossil fuels. CREN aims to bring together the professional sector, government and civil servants, academics, associations, industry, financial institutions and services, the

not for profit sector, and end-users to act as a forum where they can work together for efficient, appropriate renewable energy implementation and to develop a comprehensive sustainable energy strategy for Nigeria.

The Council works with all stakeholders to address the challenges of awareness, availability, cost, and appropriate implementation of renewable energy technologies in Nigeria. Also, CREN creates public awareness and fosters the emerging availability of reliable, economically viable renewable energy systems by supporting policy information and implementation, research, development and use of such systems (CREN 2015).

#### ***2.5.14 Green Building Council of Nigeria (GBCN)***

Although Nigeria is a prospective member of the World Green Building Council, the Green Building Council of Nigeria (GBCN) will aid in the development of green building rating system in Nigeria. The council will also provide a single useful metric for the establishment of green building actions and address the issue of climate change in Nigeria (WGBC 2015). Some rating systems that would be adopted include the following;

- BEREEM (Building Research Establishment's Environment Assessment Method)
- CASBEE (Comprehensive Assessment System for Building Environmental Efficiency)
- SBTool (Sustainable Building Tool)
- Green Globes
- LEED (Leadership in Energy and Environmental Design).

### **2.6 Nigerian Energy Policies and Strategies**

The Nigerian energy policies and strategies are summarized in this section from the earliest to the latest.

#### ***2.6.1 National Electric Power Policy (NEPP), 2001***

The National Electric Power Policy (NEPP) was the first of its kind in the wake of reforms in the Nigerian power sector. Its development was due to the recommendations of the Electrical Power Implementation Committee (EPIC), which was the body in charge of reforms and transformation of the power sector in 1999.

The NEPP was created in March 2001,<sup>24</sup> and presented three bold steps in achieving the goal of reforming the power sector. The first step was to privatize NEPA which was state owned and introduce Integrated Power Producers (IPPs) of electricity. The next step was to increase competition between participants in the market, gradually remove subsidies and sell excess power to the DISCOs. In the last step, it was expected that the market and competition would have been more intense and allow for full cost-reflective pricing of supply, and liberalization of the electricity market would have been complete (Maduekwe 2011). The NEPP had the following as critical objectives for Nigeria's electric power sector:

- Ensure that the power sector attracts private investment both from Nigeria and abroad;
- Drafting of a new electricity law to provide the legal framework for the reform agenda;
- Establishment of an independent regulatory agency;
- Development of a wholesale electricity market;
- Establishment of a consumer assistance fund to ensure the efficient and targeted application of subsidies to less privileged Nigerians;
- Establishment of a Rural Electrification Agency ("REA") to manage the rural electrification fund.

### **2.6.2 National Energy Policy (NEP) (2003), (2006), (2013)**

Before the Federal Government of Nigeria approved the energy policy in the year 2003, there was no comprehensive energy policy. The established energy policy was called the National Energy Policy (NEP) which was developed by the Energy Commission of Nigeria (ECN). The National Energy Policy (NEP) sets out government policy on the production, supply and consumption of energy reflecting the perspective of its overall needs and options.

The main goal of the policy is to create energy security through a robust energy supply mix by diversifying the energy supply and energy carriers based on the principle of "an energy economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy throughout Nigeria, thus contributing to sustainable development and environmental conservation". Importantly, the national policy already outlines the key elements for development and application of renewable energy as:

- To promote decentralized energy supply especially in rural areas, based on RE resources;
- To develop, promote, and harness Renewable Energy (RE) resources of the country and incorporate all viable ones into the national energy mix;

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<sup>24</sup>See [www.nigeriaelectricityprivatisation.com/?page\\_id=2](http://www.nigeriaelectricityprivatisation.com/?page_id=2).

- To promote efficient methods in the use of biomass energy resources;
- To de-emphasize and discourage the use of wood as fuel;
- To keep abreast of international developments in RE technologies and applications.

The NEP was first revised in 2006 to incorporate some changes and improvement, while the last draft revised edition was done in 2013. The 2013 draft revised edition includes environmental and climate change policy, policy on other energy issues such as RandD, bilateral, regional, and international cooperation, local content, manpower development and training, and Gender issues. Other areas included are policy on energy financing, planning, and policy implementation (see NEP 2003, 2006, 2013).

### ***2.6.3 National Economic Empowerment and Development Strategy (NEEDS) (2004)***

The National Economic Empowerment and Development Strategy (NEEDS) was developed by the National Planning Commission (NPA) in 2004 and was intended to develop and alleviate poverty in the country. This involves the action of human resources on the natural resources to produce goods necessary to satisfy the economic needs of the community.<sup>25</sup> On infrastructure, NEEDS promotes the privatization of government infrastructure and was one of the key instruments in achieving a revamped service delivery.

The Nigerian government will however, fund projects that have very low attractiveness and high investment cost to investors such as those in rural areas. Furthermore, the increased share of renewables in the national energy mix was further encouraged in the NEEDS. This involves the suggestion for the creation of renewable energy agency and technologies which will be funded under the National Power Sector Reform Act. This was a milestone towards the adoption of renewables in the power sector and their utilization for rural electrification (NEEDS 2004; Marcellus 2009).

### ***2.6.4 National Power Sector Reform Act (EPSRA), 2005***

The National Power Sector Reform Act established in 2005 ensured the liberalization of the Nigerian power sector. The Act was due to the NEPP developed in 2001 and made provision for new legal and regulatory framework for the power

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<sup>25</sup>[www.omojuwa.com/2014/06/national-economic-empowerment-and-development-strategy-needs%E2%80%8F-ayorinsola-obisanya/](http://www.omojuwa.com/2014/06/national-economic-empowerment-and-development-strategy-needs%E2%80%8F-ayorinsola-obisanya/).

sector.<sup>26</sup> The Act gave way to unbundling and privatization of the power sector, which intends to introduce competition in the electricity market, enhance rural electrification, while protecting consumer rights and developing performance standards in the power sector.<sup>27</sup> The main provisions of the Act include the following:

- Creation of the initial Holding Company (PHCN) to assume the assets, liabilities and employees of NEPA;
- Unbundling of PHCN into successor companies and ensuring greater operational autonomy;
- Market development;
- Privatization of successor companies which empowers the Bureau to undertake this responsibility;
- Establishment of the Nigeria Electricity Regulatory Commission (NERC);
- Establishment of the Rural Electrification Agency and Fund to provide access to electricity to the rural areas as well as fund rural electrification projects, respectively;
- Power consumer assistance fund to bridge the funding gaps for low income earners.

The Act also provides for an investment-friendly environment for potential investors in the power sector by transforming the integrated structure of the sector (as in the period of NEPA) into vertically unbundled segments: generation, transmission and distribution (Ajumogobia and Okeke 2015). The Act ensured a transition in the reform process, providing necessary criteria for the advancement of power generation reforms. As part of the process in the Act, a wider mandate for power market regulation was established (Ayanruoh 2012).

### ***2.6.5 Renewable Electricity Policy Guidelines (REPG) 2006***

Developed by the federal Ministry of Power and Steel in December, 2006, the Renewable Electricity Policy Guidelines (REPG) mandated the Nigerian government on the expansion of electricity generation<sup>28</sup> from renewables to at least 5 % of the total electricity generated and a minimum of 5 TWh of electricity generation in the country (REPG 2006). This policy document presents the Nigerian government's plans, policies, strategies, and objectives for the promotion of

<sup>26</sup>[www.reegle.info/policy-and-regulatory-overviews/ng](http://www.reegle.info/policy-and-regulatory-overviews/ng).

<sup>27</sup>[www.nigeriapowerreform.org/index.php?option=com\\_content&view=article&id=79:policy-framework&catid=41&Itemid=304](http://www.nigeriapowerreform.org/index.php?option=com_content&view=article&id=79:policy-framework&catid=41&Itemid=304).

<sup>28</sup>[www.businessdayonline.com/2015/02/reviewing-the-legal-framework-for-renewable-energy-projects-in-nigeria/](http://www.businessdayonline.com/2015/02/reviewing-the-legal-framework-for-renewable-energy-projects-in-nigeria/).

renewables in the power sector (Iwayemi et al. 2014). The policy goals and strategies of the REPG are as follows:

- Expansion of the market for renewable electricity to at least five percent of total electricity generating capacity and a minimum of 5 TWh of electric power production;
- Establishment of stable and long-term favorable pricing mechanisms and ensuring unhindered access to the grid with guaranteed purchase and transmission of all electricity produced by renewable electricity producers and obliging the grid operators upgrade the system accordingly;
- Construction of independent renewable electricity systems in areas not covered by the electricity grid;
- Development of innovative, cost-effective and practical measures to accelerate access to electricity services in rural areas through renewable sources;
- Setting up of a Renewable Electricity Trust Fund to be governed by the Rural Electrification Fund;
- Creation of a multi-stakeholder partnership for the delivery of renewable electricity to meet national development goals;
- Broadening international cooperation in expanding the role of renewable electricity for meeting national development goals and contributing to global efforts in addressing climate change.

### ***2.6.6 Renewable Electricity Action Programme (REAP) (2006)***

Developed in relation to the REPG by the Federal Ministry of Power and Steel in 2006, the Renewable Electricity Action Programme (REAP) set out a roadmap for the implementation of the REPG. The document presents an overview of the Nigerian electricity sector and relates it to renewable energy development. The documents also reviews government targets and provides strategies for renewable energy development such as leveling the playing field for renewable electricity producers, multi-sector partnerships, demonstration projects, supply chain initiatives, etc. The study also made provision for financing renewable programs and explored the roles of government ministries and agencies, then concludes with risk assessment, monitoring, and evaluation (REAP 2006). The Ministry of Power and Steel has however been restructured to the Ministry of Power and this programme may have been abandoned.

### ***2.6.7 Nigerian Biofuel Policy and Incentives (NBPI) (2007)***

The aim of this policy was to develop and promote the domestic fuel ethanol industry through the utilization of agricultural products. This was in line with the government's directive on an Automotive Biomass Programme for Nigeria in August

2005. The NNPC was mandated to create an environment for the take-off of the ethanol industry. The policy further aimed at the gradual reduction of the nation's dependence on imported gasoline, reduction in environmental pollution, while at the same time creating a commercially viable industry that can precipitate sustainable domestic jobs. The benefits of this policy were to create additional tax revenue, provision of jobs to reduce poverty, boost economic development and empower those in the rural areas, improve agricultural activities, energy and environmental benefits through the reduction of fossil fuel related GHGs in the transport sector.

The targets of the NBPI are as follows:

- To ensure the contribution of all biofuel companies with 0.25 % of their revenue towards funding research into feedstock production, local technology development and improved farming practice;
- To develop an import duty waiver for biofuels granted for 10 years;
- An exemption from taxation, withholding tax and capital gains tax imposed in respect of interest on foreign loans, dividends, services rendered from outside Nigeria to biofuel companies by foreigners;
- To launch a special kind of loan for investors in the biofuel industry to aid the development of large-scale schemes and large-scale integrated operation including plantation, a plant and within-the-gate collocated power generating plants;
- To achieve the blending of up to 10 % of fuel ethanol with gasoline to achieve a blend to be known as E-10 during the seeding phase of the programme;
- To achieve 100 % domestic production of biofuels consumed in the country by 2020;
- To ensure an off-take agreement by NNPC for biofuels as buyer of last resort.

The implementation of the NBPI was set to be undertaken in two phases. The first phase is called seeding the market which involves the importation of cargoes of fuel ethanol until the domestic market is matured. The seeding phase was expected to begin with initial penetration of selected cities during the first 3 years, while the nationwide roll-out is expected within 5–10 years. Phase 2 which is called biofuel production programme, will begin concurrently with the seeding programme. It was the core agriculture integration programme and ensures the establishment of plantations and the construction of a bio-fuel distillers and plants in Nigeria (NBPI 2007).

### ***2.6.8 Nigerian Gas Master Plan (NGMP) 2008***

In line with the Nigerian government's plan to become a major international player in the international gas market as well as to lay a solid framework gas infrastructure expansion within the domestic market, the Nigerian Gas Master Plan (NGMP) was developed and approved on the February 13th, 2008.<sup>29</sup> The NGMP

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<sup>29</sup>See [www.nercng.org/index.php/myto-2](http://www.nercng.org/index.php/myto-2).



envisages a wholesale transition to decentralized privately held electricity generation gas plants from the erstwhile public power utility. The plan also aims to stem the huge waste associated with gas flaring and to put to more productive use the nation's large gas reserves. What the Gas Master Plan does not clearly mention is that the utilization of compressed natural gas (CNG) can play a major role in transforming the nation's transportation sector if adopted on a large scale (Emodi and Boo 2015c).

### ***2.6.9 Roadmap for Power Sector Reform (A Customer-Driven Sector-Wide Plan to Achieve Stable Power Supply 2010) and (Revision 1, 2013)***

The first Roadmap for Power Sector Reform was developed by the Presidential Task Force on Power (PTFP) in 2010 and based on it, the revision was carried out and presented on the August 30th, 2013. This document includes review and strategic plans by the government to finalize the reforms in the power sector, while setting the nation on a steady path of clean electricity generation at competitive rates. The Roadmap is not in itself a policy document but a set of strategies to fast-track the achievement of the NEP (2003) as stated in the EPSRA of 2005. The Roadmap explores some key aspects of the power sector and development such as generation, transmission, distribution, NIPP and fuel supply to power plants (see RPSR 2010, 2013). Some recommendations and proposals of the reforms are given below:

- Improvement of collection efficiency and returns to the market during the pre-Transitional Electricity Market (TEM) declaration stage;
- The commencement and conclusion of all labor negotiations, settlement of liabilities, rationalization and eventual winding down of the Power Holding Company of Nigeria (PHCN);
- The continuation of the clear and firm political will to resist efforts that could undermine privatization and the reform;
- The development of an optimal transmission capacity expansion plan and funding strategy to provide a reliable highway for wheeling generated power;
- Acceleration of the management and operational efficiency levels of the Transmission Company of Nigeria (TCN);
- More commitment to deliver the gas development and transportation infrastructure projects earmarked for gas-to-power alignment;
- Prevention of frequent acts of vandalism to pipelines such as the Trans-Forcados and Trans-Niger crude oil lines, and the Escravos Lagos Pipeline Systems (ELPS) gas pipelines.
- Clarity on the interim operation and maintenance of the National Integrated Power Projects (NIPP) generation assets;

- More firm commitment from NIPP to deliver its critical transmission projects scheduled for 2013 as well as the Omoku, Gbarain, and Alaoji power plants to come on stream without further delay;
- Meeting of the conditions precedent to the declaration of TEM, before handing over the successor companies to the new owners.
- Positioning a well-capitalized Nigerian Electricity Liability Management Company (NELMCO) to address post hand-over fall outs from creditors.
- To secure a minimum, transitional service-delivery level through project and process optimization.

### ***2.6.10 Renewable Energy Master Plan (REMP) (2005), (2012)***

The Renewable Energy Master Plan (REMP) was developed by the Energy Commission of Nigeria (ECN), in collaboration with the United Nations Development Programme (UNDP) in 2005 and was later reviewed in 2012 (REMP 2005, 2012). The REMP expresses Nigeria's vision and sets out a road map for increasing the role of renewable energy in achieving sustainable development. The REMP is anchored on the mounting convergence of values, principles and targets as embedded in the National Economic Empowerment and Development Strategy (NEEDS), National Energy Policy, National Policy on Integrated Rural Development, the Millennium Development Goals (MDGs), and international conventions to reduce poverty and reverse global environmental change (REMP 2012).

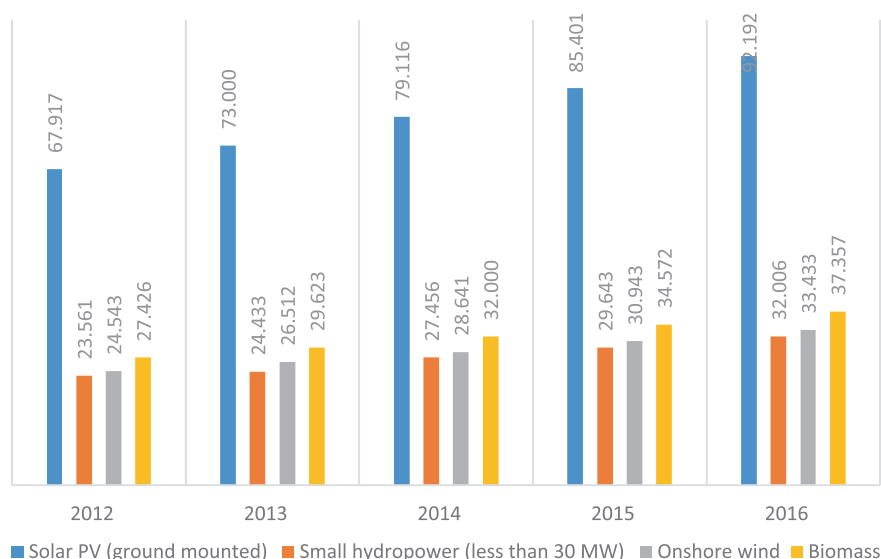
The REMP stresses the need for the integration of renewables in buildings, electricity grids, and for off-grid electrical systems. Further, the importance of solar power in the country's energy mix was also highlighted in the policy document. According to the REMP, Nigeria intends to increase the supply of renewable electricity from 13 % of total electricity generation in 2015 to 23 % in 2025 and 36 % by 2030. Renewable electricity would then account for 10 % of Nigeria's total energy consumption by 2025. However, the REMP has not been approved by the National Assembly to be passed into law.

### ***2.6.11 National Renewable Energy and Energy Efficiency Policy (NREEEP) (2014)***

The National Renewable Energy and Energy Efficiency Policy (NREEEP) outlines the global thrust of the policies and measures for the promotion of renewable energy and energy efficiency. The FMP developed the NREEEP in 2014 and

is awaiting the approval of the Federal Executive Council. The objectives of the NREEEP are presented as follows (NREEEP 2014);

- To set out a framework for action to address Nigerians' challenge of inclusive access to modern and clean energy resources, improved energy security, and climate objectives;
- To recognize the national significance of renewable electricity generation activities by providing for the development, operation and maintenance, and upgrading of new and existing renewable electricity generation activities;
- To declare that the proportion of Nigeria's electricity generated from renewable energy sources shall increase to a level that meets or exceeds the ECOWAS regional policy targets for renewable electricity generation and energy efficiency for 2020 and beyond;
- To declare energy efficiency to be a major, low-cost, and under-utilized Nigerian energy resource offering savings on energy bills, opportunities for more jobs, improving industrial competitiveness, and lowering air pollution;
- To recognize that poverty mitigation and environmental protection are hindered by the continued predominance and inefficient use of oil and natural gas in meeting our energy needs;
- To take a step in the right direction and broaden the definition of energy security to include renewable energy and energy efficiency as equally important indigenous sources of energy, in addition to oil and gas;
- To incorporate provisions for renewable energy and energy efficiency generation activities into government policy statements and plans, and recognize the importance of enabling framework conditions for private investment in renewable energy and energy efficiency;
- To set national targets for achievements in electricity from renewable energy and energy efficiency capacity addition by 2020 and beyond;
- To require the preparation of a national action plan for renewable energy and for energy efficiency, and set a time frame within which implementation is required;
- To recommend that the signatory parties to this policy should collaborate in preparation of the action plans and work together in achievement of the final mandatory targets;
- To make it mandatory for the Ministry of Power to facilitate the development of an integrated resource plan (IRP) and ensure the continuous monitoring and review of the implementation and effectiveness of the action plans prescribed under the national policy statement;
- To take steps away from the overheated rhetoric that Nigeria's future energy independence be secured by ever more gas and oil consumption; and
- To facilitate the establishment of a framework for sustainable financing of renewable energy and energy efficiency projects and programmes in Nigeria.



**Fig. 2.27** Nigeria's MYTO 2 FiTs for 2012–2016 (N/Per MWh)

### 2.6.12 Multi-year Tariff Order (MYTO), 2008 and 2012

In 2008, a 15-year roadmap towards cost-reflective tariffs called the Multi-Year Tariff Order (MYTO 1) was developed by the Nigerian Electricity Regulatory Commission (NERC). The first two phases, 2008–2000 and 2012–2017, were designed to keep consumer prices relatively low, through affecting the price increases in a gradual manner. The final regime is intended to provide the necessary incentives for power producers and investors to operate and maintain electricity infrastructure (Emodi and Yusuf 2015a). The NERC has released the Multi-Year Tariff Order 2 (MYTO 2), which has similar features to MYTO 1 but includes some improvements, and will be effective from June 1st 2012 to May 31st 2017. The retail tariff in MYTO 2 will be reviewed bi-annually and changes may be made for all electricity generated at wholesale contract prices, adjusted for the Nigerian inflation rate, US\$ exchange rate, daily generation capacity, and accompanying actual CapEx and OpEx requirements that will vary from those used in the tariff calculation. Figure 2.27 shows the MYTO 2 feed-in tariffs from 2012 to 2016 in Nigeria (Nigerian Naira per MWh (N/MWh) and the dollar equivalent).<sup>30</sup>

The review of all inputs to the tariff calculation is expected to begin by 2016 as the basis of a new Multi-Year Tariff Order (MYTO) designed to kick-start the next five years starting from June 1st 2017. The MYTO 2 contains a 15-year

<sup>30</sup>[www.nercng.org/index.php/myto-2](http://www.nercng.org/index.php/myto-2).

tariff pathway for electricity generated from RE, with bi-annual minor reviews and major reviews every five years. The MYTO 2 tariffs are negotiable if a generator can prove to the NERC that their costs for electricity generation from renewables are not in line with the assumptions of the MYTO 2 (Emodi and Boo 2015c).

2.6.13 Draft Rural Electrification Strategy and Implementation Plan (RESIP) (2014)

The Power Sector Reform team initially prepared the Rural Electrification Strategy and Implementation Plan in 2006 (RESIP 2006). However, a committee involved in the power sector reviewed and redrafted the RESIP in 2014. It was expected to establish a clear institutional step-up for the sector and set a roadmap which will result in the development of an enabling framework for rural electrification in Nigeria. The primary objective of the RESIP is to expand access to electricity as rapidly as can be afforded in a cost-effective manner. This includes the use of on-grid and off-grid means of electricity supply. The draft is ready and awaiting approval from the government. A general overview of the various Nigerian energy policies, legislations, regulations, standards, programmes and incentives, their achievements, gaps, alignment, overlaps, and opportunities is presented in Fig. 2.28.

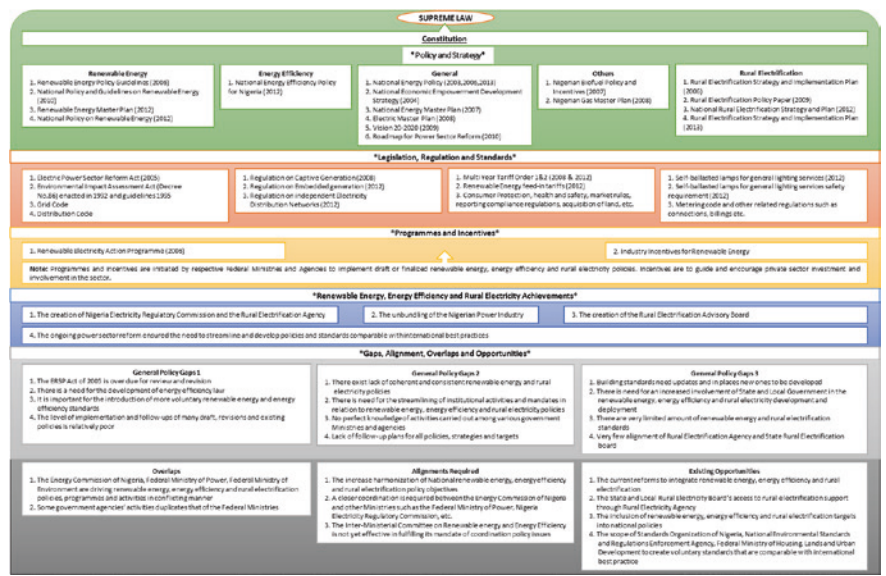


Fig. 2.28 An overview of the Nigerian energy policies. Source Ley et al. (2014), Energypedia (2015)

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