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Can Nigeria generate 30% of her electricity from coal by 2015?

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Abstract: Nigeria is blessed with diverse energy resources. The country had generated electricity from coal in the 1950s, but this was abandoned in the wake of the civil war (1969-1970) and the focus changed to petroleum. Nigeria now generates her electricity mostly from gas thermal plants (64.6%). Electricity in Nigeria is poor, of low quality with frequent unplanned outages. Nigeria has about 8000MW installed electricity generation capacity but only 3800-4000 MW is actually operational. The government now wishes to diversify the electricity generation mix by encouraging private sector participation in the energy sector and targeted 30% electricity generation from coal. The study reviewed policies relating to coal power generation in Nigeria and the causes of previous failures in the sector. The study found that the electricity sector reforms and other policy changes have spurred investment of nearly $10 billion in the coal sector. Five projects of 4800MW generation capacity are under construction. Of this, two projects located in Enugu state of combined capacity of 1600MW could be ready by 2015. These two projects accounted for 40% of total installed capacity, or 20% operational electricity generation in Nigeria. The paper also presents the prospects and challenges of coal power generation in Nigeria.

Keywords: Coal Electricity, Electricity Sector Reforms, Energy Mix, Energy Policy, Mining

1. Introduction

Nigeria is blessed with abundant energy resources, including over 35 billion barrels of crude oil, 187 trillion cubic feet of natural gas, 4 billion metric tonnes of coal and lignite and large reserves of tar sand, nuclear elements, hydropower, solar radiation [1], and wind energy, that have remained untapped. Ibitoye and Adenikinju [2] reported that Nigeria has hydropower capacity of 14,750 MW, 2.0 – 4.0 m/s wind speed, 3.7 – 7.0 kWh/m^2- day solar radiation, biomass potential of 144 million tonnes/year and 150,000TJ/yr of wave and tidal energy. Despite the abundant and diverse energy resources, the country is suffering from energy crises. The country produces 2.2 – 2.6 million barrels of crude oil daily, but she is dependent on foreign nations for the supply of refined petroleum products (particularly gasoline, kerosene and diesel) to meet her domestic demand [3, 4]. Electricity supply in Nigeria is very poor, though it has slightly improved recently. It is insufficient, unstable, and of low quality, with black-outs and brown-outs occurring frequently [5]. Only 40 – 45% of 167 million Nigerians are connected to the national grid, while the rest have no access to electricity or rely on self-generated electricity. ADB [6] reported that about 45% of Nigerians have access to electricity with only 30% of their demand being met.

The performance of the Nigerian electricity sector is quite poor. The sector is characterized by high rates of losses (33%), low rates of generation capacity (20%) [1] and poor revenue collection (75-80%) [7]. Ibitoye and Adenikinju [2] reported that 38% of total electricity generated in Nigeria is lost during transmission and distribution, while Ikeme and Ebohon [7] recorded 30-35% losses from generation to billing. Ikeme and Ebohom [7] also reported that the National Electric Power Authority (NEPA) that metamorphosed into Power Holding Company of Nigeria (PHCN) collects only 50% of their energy bill, while Adenikinju [1] reported that about 30 – 40% of the power supplied is never billed.

The instability and unreliability of electricity in Nigeria have been reported by several authors. Adenkinju [4] reported that on the average, firms experience outages

between 5 and 10 times weekly, with each outage lasting over an hour. Adenikinju [2] reported that the number of unplanned outages in Nigeria is at least 30 times higher than that of middle income countries in Africa. Per capita electricity consumption from the grid in Nigeria is very low being 99 kWh in 2003 [2]. Though, a higher value of 136 kWh was recorded in 2008 – 2009, it was still too low when compared to neighboring African countries like Ghana (309 kWh) and Cote D'Ivore (174 kWh) [8], but very far from that of western countries such as Norway (24,867), Canada (17,061), and USA (13,654MW) [9]. ADB [6] reported that the 125 kWh per capita electricity consumption in Nigeria is among the lowest in the World.

As a result of the poor electricity infrastructure in Nigeria, many manufacturers now depended partially or wholly on self-generated electricity. Many food and fruit processing industries rely on self-generated electricity [10, 11]. Generator importation and use have been on the increase. Between 1991 and 1992, about 7438 generating sets were imported into the country, installed and operated at high costs [7, 12]. Direct cost of self-generated electricity in Nigeria is 2.42 [13] to 3.00 [1] times the cost of public supplied electricity from the national grid. The share of self-generated electricity to the total electricity generated in Nigeria is 52% compared to less than 1% in middle income African countries [1]. Ikeme and Ebohon [7] reported that firms depend on self-generated electricity 67% of the time. It is estimated that nearly 100% (97% to be precise) of firms operating in Nigeria own private electricity generating sets. The installed capacity of privately own electricity generating set was 1760MW in 1990, accounting for about 30% of grid capacity [7, 13]. ADB [6] estimated that electricity induced indirect losses of firms accounted for 61%, followed by transportation (26%), bribery (11%), and robbery (2%) of their losses.

Due to the poor performance of the electricity sector, the Government is attempting to overhaul the sector through reforms and policy changes. Before October 1st 2013, grid electricity was provided mostly by the Government, now electricity generation and distribution have been privatized. Nigerian electricity is sourced mostly from petroleum and hydropower, natural gas accounted for 39.8%, hydropower 35.6%, oil 24.8%, while coal accounted for 0.4% in 2001 [7]. Since then the Government had installed several thermal power plants, and maintained the three hydropower plants (Kainji, Jebba and Shiroro) while the only coal power plant (Oji River Power Plant) is moribund. The Government now wishes to increase the diversity of her electricity generation mix by investing in coal power plants. Recently, the Nigerian President, Goodluck Jonathan pronounced that Nigeria will generate 30% of her electricity from coal by 2015 [14]. Although Nigeria has about 8000MW installed electricity generation capacity, only 3800 – 4000 MW is actually operational [6]. Thirty per cent of the operational capacity would translate to about 1200 MW, which would be generated from coal. The aim of this study is therefore to assess the possibility of Nigeria to generate about 1200 MW electricity from coal by 2015. The study will also use the opportunity to appraise the Nigerian coal sector, electricity sector reforms and policies pertaining to the electricity and coal sectors. The study commences by first reviewing the causes of failures in the first attempt (1960 -70) of Nigeria at generating electricity from coal feedstocks. The methodology used for the study is based on the review of secondary data.

2. Historical Coal Exploration, Production and Utilization in Nigeria

According to Odukwe and Enibe [15], coal must have been discovered in Nigeria in the 19th century or even earlier, but it was only in 1909 that its economic value was recognized when large deposits were found near Enugu. However, most authors report that coal was first discovered in Nigeria in 1909 at Udi (Obwette mine) near Enugu by the then Mineral Survey of Southern Nigeria [16, 17], though other authors reported slightly different dates; 1906 [18], 1908 [19] and 1916 [20]. Between 1909 and 1913 more coal reserves were discovered within Enugu area and extending northwards up to Kogi and Benue states. From 1937 to date, extensive coal exploration was carried out in the Benue trough leading to more discoveries in Northern Nigeria [16]. Various kinds of surveys have been carried out in Nigeria including high resolution air borne geophysical survey involving magnetic, radiometric and limited electro-magnetic survey [18].

Due to exploration successes, coal has now been discovered in commercial quantities in 14 out of the 36 Nigerian States, namely; Abia, Adamawa, Anambra, Benue, Cross-Rivers, Edo, Enugu, Gombe, Imo, Kogi, Kwara, Nassarawa, Ondo, and Plateau. Although there are about 22 existing and potential coal fields in Nigeria (Table 1), only few are operational/active (Okaba, Okpara, Onyeama and Owukpe), while some are historical mines (Obwette, Ribadu, Ogbete) and new discoveries are being made.

To date, the proven coal reserves in Nigeria are about 639 million tonnes, while the inferred reserve is generally reported to be 2.75 billion tonnes [19, 21- 24], but few authors reported 3 billion tonnes [19], while Adenikinju [1] reported 4 billion tonnes. Other authors such as Gulloma [14] reported that Nigeria has 360 million tonnes of proven reserve of coal, which is considered lowest among major coal producing countries, with the following million tonnes of reserve; USA (237,295), China (114,500), Australia (76,400), India (40,699), Columbia (6,746) and Canada (6,582). The majority of Nigeria's proven reserves are located in Enugu and Kogi states. Of the 22 Nigerian coal fields, two fields (Lafia/Obi and Amansiodo) contain bituminous coal, two lignite (Ihioma and Ogwashi-Uku/Azagba/Obomkpa), while the rest, which formed the majority, are non-bituminous. The Lafia/Obi and Amansiodo mine contains bituminous/ cokeable (coking) coal suitable for metallurgical applications. RMRDC [16]

and Ryemshak and Jauro [25] reported that most of the coal found in Gombe state is bituminous, however, no other report has confirmed this claim. Onyearu [18] reported that Nigerian coal consists of approximately 49% sub bituminous, 39% bituminous, and 12% lignite coals.

Table 1. *Existing/potential coal mine locations with reserves in Nigeria.*

S/N	Mine location	State	Coal type	Estimated reserves (Million tonne)	Proven reserves (Million tonne)	Borehole record	Coal outcrop and seam thickness (m)	Coal depth (m)	Mining approach	Current status
1	Okpara Mine	Enugu	Sub-Bituminous	100	24	20	Many	180	Underground	Functional
2	Onyeama mine	Enugu	Sub-Bituminous	150	40	Many	Many	180	Underground	Functional
3	Ezimo	Enugu	Sub-Bituminous	156	56	4	10 (0.6 – 2.0)	30 - 45	Underground	
4	Inyi	Enugu	Sub-Bituminous	50	20	4	(0.9 – 2.0)	25 - 48	Open cast, Underground	
5	Amansiodo	Enugu	Bituminous (cokeable)	1000	NA	3	NA	563	Underground	
6	Ogugu/Awgu	Enugu	Sub-Bituminous	NA	NA	Nil	NA	NA	Underground	
7	Okaba	Kogi	Sub-Bituminous	250	73	Many	(0.8 – 2.3)	20 – 100	Open cast, Underground	Functional
8	Ogboyoga	Kogi	Sub-Bituminous	427	107	31	17 (0.8 – 2.3)	20 - 100	Open cast, Underground	
9	Ogwashi-Uku/Azagba/Obomkpa	Delta	Lignite	250	63	7	4 (3.5)	15 - 100	Open cast, Underground	
10	Oba/Nnewi	Anambra	Lignite	30	NA	2	14 (0.3 – 4.5)	18 - 38	Underground	
11	Ihioma	Imo	Lignite	40	NA	Nil	Many	20 - 80	Open cast	
12	Lafia/Obi	Nasarawa	Bituminous (cokeable)	156	21.42	123	(1.3)	80	Underground	
13	Owukpa	Benue	Sub-Bituminous	75	57	Many	(0.8 – 2.3)	20 – 100	Open cast, Underground	Functional
14	Afikpo/Okigwe	Abia	Sub-Bituminous	50	NA	Nil	NA	20 - 100	Underground	
15	Afuze	Edo	Sub-Bituminous		NA	Nil	NA	NA	Underground	
16	Ute	Ondo	Sub-Bituminous		NA	Nil	NA	NA	Underground	
17	Lamja	Adamawa	Sub-Bituminous		NA	Nil	NA	NA	Underground	
18	Gandi-Akwati	Plateau	Sub-Bituminous		NA	Nil	NA	NA	Underground	
19	Jamata-Koji	Kwara	Sub-Bituminous		NA	Nil	NA	NA	Underground	
20	Doho	Gombe	Sub-Bituminous		NA	Nil	NA	NA	Underground	
21	KurumuPindiae	Gombe	Sub-Bituminous		NA	Nil	NA	NA	Underground	
22	GarinMaiganga	Gombe	Sub-Bituminous		760	Nil	NA	NA	Underground	

Modified from Sambo, [17]; RMRDC, [16]; 2010; Ministry of Mines and Steel Development 2013; Ogwu, [30]
NA = not available

Data on historical coal production in Nigeria was compiled from various sources [17, 20, 27], and presented in Figure 1. Coal production increased from 24,511 tonnes in 1916 and steadily until a peak production of 925,000 tonnes was attained in 1958, after which production declined to 20,000 tonnes during the Nigerian civil war in 1968. At the end of the civil war in 1970 production had declined to 18,000 tonnes. Thereafter, attempts to revive the coal sector led to increase in production to 194,000 tonnes in 1971 and arose to a post war peak of 264,000 tonnes in 1972 and thereafter declined to 249,000 tonnes in 1976, 17,000 tonnes in 1996, and rose to 41,000 tonnes in 2002. The production of coal in Nigeria has remained at this low. Nwasike [31] reported that by 1999, coal

production has declined to 30,000 tonnes/annum being produced from only four active mines.

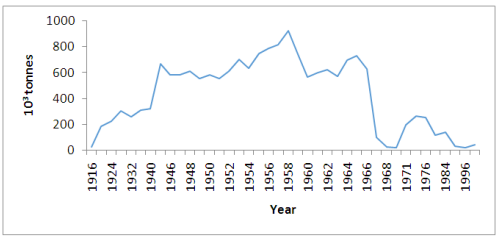

Fig 1. *Historical coal production in Nigeria. (Source: Onwuka, [27]; Sambo, [17]*

The result of the energy content and proximate analysis of selected Nigeria coal samples obtained from literature is presented in Table 2. The coal samples consist of 71 – 79% carbon, 5.0 – 6.6% hydrogen, 0.5 – 1.47% sulphur, 12.1 – 21.9% oxygen, and 1.0 – 2.1% nitrogen. The calorific value of Nigerian coal ranged from 24.3 MJ/kg at Orukpa coal field to 33 MJ/kg at Enugu. Odukwe and Enibe [15] reported the calorific values of selected coal in Nigeria to be in the range of 22.3 – 28.4 MJ/kg with a mean value of 25 MJ/kg. Some authors have reported that Nigeria's sub-bituminous coal and lignite were among the best in the world due to their high calorific values and low ash and sulphur contents [33, 37]. Ezekwe and Odukwe [38] reported that Nigerian coals have good combustion characteristics, they could be easily ignited and burns with long flames.

Historically, Nigerian coal, which was mostly produced at Enugu then, was mostly used as fuel for coal powered electricity plants, to power coal-fired locomotives (mostly trains and marine vessels) and for cement production. The Nigerian Railway Corporation (NRC) consumed about 65% of the coal produced in Nigeria then [19]. In 1956 the government established the Oji River 300 MW coal fired power plant [2], which is now moribund and rated as 30 MW (Obukwu and Okozi, 2013). Nwasike [31] reported that Oji coal power plant built in 1956 has generation capacity of 100 MW. The Nigerian Cement Company (NIGERCEM) Nkalogu that was established in 1957 used coals from Enugu for cement production. At a smaller scale, the Enugu coals were also used as fuel for domestic cooking. The coal industry also supported other industries especially in Eastern Nigeria. According to the Ministry of Mines and Steel Development [24], the coal industry gave rise to the first set of industries in Nigeria and provided all the energy requirements of these industries up to the late 1960s. These industries include the marines, NRC, NEPA and NIGERCEM. During the period of 1950 – 1959, over 3000 workers were under the employment of Enugu mines while the NRC had about 5000 workers [19]. Abraham [43] reported that the Nigerian coal industry had a workforce of 8,300 employees during the peak of coal production in 1958/59, when production was about one million tonnes of coal. Nwasike [31] reported that the coal industry was the highest employer of labour in 1959. The Enugu mines employed about 9000 workers, while mines located in the North Central states of Benue and Kogi employed 6000 workers. The country lost all these employment effects by abandoning coal.

After this period of boom, the coal industry started declining due to several factors. Firstly, commercial quantities of crude oil were discovered in 1956 [19] and the Government abandoned coal and focused on crude oil. Secondly, the NRC, which consumed 65% of Nigerian coal, replaced its coal burning trains with diesel powered engines. Thirdly, the Nigeria civil war that broke out in 1967 – 70, led to the closure of most of the mines [19, 33, 44]. Attempts to revive the mines to their original capacity failed. NIGERCEM has also folded up.

Even the Electricity Corporation of Nigeria (ECN), which later metamorphosed into the National Electric Power Authority (NEPA) that installed the Oji River Coal Power Plant abandoned coal and converted the Ijora power plant that was using coal to oil. Subsequently, other power plants that were installed in Nigeria are gas thermal plants including Afam I –VI, Delta I – IV, Sapele, Papalanto, Omotosho 1 and II, Geregu and Alaoji. Others that are still under construction are also gas fired thermal plants including Omoku, Egbema, Gbarain, Sapele, Ikot-Abasi, Ibom II, Calabar, Ihovbor. Coal contributed 0.04% to Nigerian electricity in 1972 but attained its peak of 2.27% in 1973 and thereafter declined to 0% today (Fig. 1). Table 3 showed a steady decline in the contribution of coal to the total energy consumption in Nigeria from 1972 to 1981. The contribution of coal to the total energy declined from 3.3% in 1972 to 0.7% in 1987 (Fig. 2).

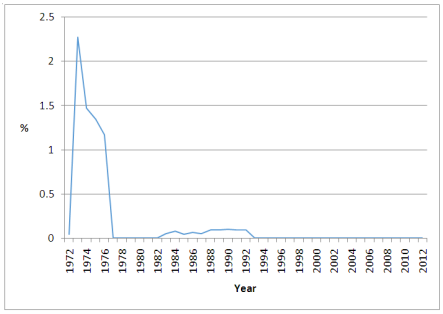

Fig 2 *Percentage electricity generation from coal from 1972-2012. (Source: www.indexmundi.com/facts/nigeria/electricity-production-from-coal-sources and other sources)*

Due to the near collapse of the coal sector, only 4 coal fields are still active (Table 1) operating at low capacities. Most of the Nigerian coal mines are now experiencing flooding problems [44]. There are indications that some of the active and abandoned mines have developed acid mine drainage (AMD) problems [45]. This is a phenomenon, common in coal mining area, which is caused by microbial and /or chemical oxidation of pyrite and other sulphur based minerals associated with coal. Ezeigbo and Ezeanyim [46] recorded a pH in the range of 2.3 – 2.8 in an active mine in Nigeria, which clearly indicated AMD conditions. The effect of AMD can be overwhelming on the

ecosystem affecting surface and groundwater quality, vegetation, wildlife and fisheries. Mine tailings/dumps can produce AMD, which can seep into surface and groundwater with severe consequences on ecology and human health. There have been reported cases of heavy metal pollution following AMD in some Nigerian mines in Benue trough [23]. Lead poisoning resulting from artisanal mining activities (though not coal) has killed several people in Zamfara state. The environmental impact of abandoned coal mines is still a challenge in the country.

Table 2. *Proximate analysis of Nigerian coal.*

Parameters	Enugu	Ezimo	Orukpa	Okaba	Ogboyoga	Ogwashi/Azagba/ Obomkpa*	Lafia	Location not stated	References
Calorific value (MJ/kg)	33	-	24.3	31.2	-	30.5	30.3		RMRDC, [28]
	32.9	31.3	30.6	29.7	29.4	30.5	-		Ezekwe and Odukwe, [38]
	-	-	-	-	-	-	-	22.3 – 28.4 (25)	Odukwe and Enibe, [15]
Ash (% dry)	11.3	-	6.5	8.8	-	14.4	15.9		RMRDC, [28]
	11.4	6.6	11.0	9.8	11.2	14.4	-		Ezekwe and Odukwe, [38]
	-	-	-	-	-	-	-	3.9 – 26.0 (14.95)	Odukwe and Enibe, [15]
Carbon (% dry)	79.3	-	-	73.9		72.1	-		RMRDC, [28]
	79.3	77.3	75.8	72.2	70.8	72.1	-		Ezekwe and Odukwe, [38]
Hydrogen (% dry)	5.1	-	-	4.6	-	6.6	-		RMRDC, [28]
	5.8	5.6	5.0	4.8	5.2	6.6	-		Ezekwe and Odukwe, [38]
Sulphur(% dry)	0.75	-	1.47	0.46	-	0.78	0.7		RMRDC, [28]
	0.8	0.8	0.5	0.8	0.7	0.8	-		Ezekwe and Odukwe, [38]
Oxygen (% dry)	12.1	14.5	16.9	20.4	21.9	-	-		Ezekwe and Odukwe, [38]
Nitrogen (% dry)	2.1	1.9	1.8	1.9	1.9	1.0	-		Ezekwe and Odukwe, [38]

*Lignite

Table 3. *Contribution of coal to total energy consumption in Nigeria.*

Year	% of total energy	
	Akujor, [26]	Onwuka, [27]
1972		3.3
1973		2.5
1974		1.0
1976	2.0	-
1977	1.9	-
1978	1.0	-
1979	1.1	1.08
1980	0.8	0.83
1981	0.7	-

3. Coal Energy Policies in Nigeria

This section of the paper focuses on the policies that led to the rise and fall of the Nigerian coal sector and the new policies that have emerged towards the resuscitation of the sector. At inception, policies were enacted that supported mineral exploration and later the establishment of the Nigerian Coal Corporation (NCC) in 1950, which was given the sole rights over all mines in Nigeria. Policies were also enacted establishing major institutions that utilize coal including the ECN/NEPA/PHCN, Nigerian Railway Corporation (NRC), and the Nigerian Ports Authority (NPA) (Table 4). This led to the boom of the coal sector until crude oil was discovered in commercial quantities in 1956. Decree No 24 of 1972 gave NEPA the statutory monopoly to generate, transmit, distribute and supply power to all sectors of the economy [7, 47]. This monopoly was broken on 1st October 2013 when NEPA/PHCN was unbundled into 5 generation and 10 distribution companies and privatized [48]. Other policies that followed, especially the indigenization decree of 1972, the switch of fuel type from coal to crude oil for rail and marine locomotives, and lack of Government focus, led to the decline and eventual closure of most of Nigerian coal mines.

Since 1999 when civilian Government took over from the military, there have been aggressive reforms towards revitalization of the mineral and power sector. Several policies towards the privatization of the mineral and power sectors have been enacted (Table 5). The BPE projected that the successful privatization of the power sector could rise electricity generation to 20,000 MW by 2018 [49]. Several incentives have been offered to encourage investment in the solid mineral sector including; 3 – 5 years tax holiday, deferment of royalty payment, waiver of import duties on mineral processing equipment, 100% ownership of mines, and extension of utilities to mining locations such as roads, water and electricity.

Table 4. *Coal policies in Nigeria prior to 1999.*

Policy	Effect of policy on coal development	References
Acts 29 of 1950 establishing the Electricity Corporation of Nigeria (ECN)	The law established the ECN which installed the Oji coal power plant	Akarakiri, [12]
NEPA was created by Decree No. 24 of 1972 by merger of ECN and Niger Dams Authority (NDA)	NEPA was given the monopoly for power generation, transmission and distribution	Ikeme and Ebohon, [7]

Policy	Effect of policy on coal development	References
Nigeria Coal Corporation (NCC) was established by the coal ordinance No 29 of 1950	NCC was given the mandate to solely develop coal in Nigeria	Manufacturing Today, [50]
Mineral act (Cap 121 of 1946).	The mines manual	Manufacturing Today, [50]
Quarries Decree 26 of 1969	Minerals regulations, safe mining regulation	Manufacturing Today, [50]
Quarry Regulations 1969	Minerals regulations, safe mining regulation	Manufacturing Today, [50]
The explosive Act of 1964	Regulates explosive use in mining	Manufacturing Today, [50]
Explosive regulation 1969	Regulates explosive use in mining	Manufacturing Today, [50]
Railway Corporation Act 1955	Established Nigerian Railway Corporation on 1st October 1955	Oguejiofor, [20]
Nigerian Port Authority Act *of 1954 (Cap.155)*	*The* Nigerian Ports Authority *was* established *in April 1955 following the Ports* Act *of 1954 (Cap.155)*	
1972 indigenization decree	The decree nationalized most of the mines resulting in the foreign mining companies	
NCC Amendment Act 26 of 1988	Broke the monopoly of NCC in mineral exploration	
Acts No. 63 of 1992	Created incentives for mineral exploration	
Decree 86 of 1992	Mandated Environmental Impact Assessment (EIA) for all major projects in Nigeria including mining and power generation	
Act *No. 62 of 1979*	Energy Commission of Nigeria *was* established *by* Act *No. 62 of 1979*	

Table 5. *Coal policies in Nigeria post 1999.*

Policy	Policy effects	References
Bureau of Public Enterprise (BPE) and national council of privatization (NCP) 2005	Privatization of Government owned companies including coal mines and power plants	Ikeme and Ebohon, [7]; FGN, [52]
National Energy Policy 2003	Resuscitation and extensive exploration of coal using clean technologies; private sector/ indigenous participation through adequate incentives, infrastructures, and export encouragement; enactment of environmental law in the mining activities; replacement of fuel wood with coal for domestic cooking, power generation from coal; regulation of prices of coal stove and sensitization of the people about smokeless coal briquettes as energy source	Sambo, [17]
National Energy Master Plan 2003	Intensifying coal exploration through privatisation; awareness creation; provision of incentives (i.e tax holiday) for local and foreign investors; fast-track the passage of minerals and mining bills; enhancement of transparency in the sector and provision of up-to-date quality geographical data; development of investors-friendly framework, infrastructures including the revamping of nations railway system, dredging inland systems and reactivating of coal washing plant at Ogbete, Oji River coal fired power plant and the drive to establish more coal fired power plant; encouragement of coal stove through affordable prices, research and middle level manpower; development of coal briquetting and sensitisation of the people about the efficiency of coal briquette burning stove	Sambo, [17]
Electricity sector reform act 2005	Un-bundling PHCN, Privatisation of successor companies, creation of Competitive electricity market	FGN, 2010
	Deregulation of the electricity industry	Amobi, 2007
	Expansion of power infrastructures and transmission	ADB, [6]
	Price regulation and financing by operators	ADB, [6]
	Enhancement of competition and private sector participation in order to develop a competitive power market for efficient, safe and sufficient electricity production	ADB, [6]; Ikeonu, [53]; Adoghe, [54]; FGN, [55]
]National Electricity Regulatory Commission (NERC) 2005	Establishment of power consumer assistant fund for subsidising underprivileged consumers to protect consumers and public interest through international best practice codes with stable, equitable rates; expansion of electricity to rural and urban settlers; licensing of individuals involved in electricity enterprise and settlement of dispute in the industry internally	Ikeonu, [53]; Adoghe, [54]
	Regulating the electricity sector Empowerment to generate electricity in excess of 1MW, distribute in excess of 100KW, transmission, system operation, trading and installation	Ikeonu, [53]
Nigeria export processing zones Authority (NEPZA) (2006)	Incentives of Nigerian export processing zone shall apply to coal mining	Oguejiofor, [20]
Nigerian minerals and mining act, 2007	Provision of mining incentives such as exemption of custom duty and other benefits and permission to retain and use earned foreign exchange; construction of road and use of	MMSD, [24]

Policy	Policy effects	References
	mining roads; prohibition of road use hindrance; participation of small scale miners; environmental consideration and right of host communities	
	Regulation of Nigerian mining industry, establishment of incentives such as tax holiday for 3 – 5 years, royalty payment deferment, extension of basic infrastructure such as road and electricity and 100% foreign owning of mining centers	
	Establishment of mining cadaster and saddled with autonomous responsibility of minerals titles in Nigeria	Onyearu, [18]
Road map for power sector reform (2010)	Private sector driven power supply	FGN, [52]
	Recommended coal for electricity generation	
Vision 20: 2020	Nigeria requires 20,000 MW to be among the 20th industrialized nation by 2020.	

4. Drivers and Prospects of Coal to Power in Nigeria

Having previously failed in sustaining coal to power in Nigeria and having learnt some lessons, the country have enacted more robust policies that will support coal to power projects. The policies have yielded some early fruits with five coal-based power plants already announced (Table 6). These projects involved the construction of 5 coal based power plants of 600 – 1200 MW that could supply a total of 4800 MW to the national grid. When completed, these projects will not just supply the 30% promised by the President, but could double Nigeria's electricity generation. It appears that only the two projects located in Enugu state (one Federal and one state) that can be fully completed by 2015, have a combined capacity of 1600 MW, whereas it only requires 1200 MW from coal to supply 30% of electricity generation in Nigeria. Obiukwu and Okozi [39] had projected that coal could generate 9.9%, 13.8%, 15.3% and 15.6% of Nigeria's electricity in 2015, 2020, 2025 and 2030 respectively. Similarly, Sambo [17] projected that coal could generate 1200 MW, 4400 MW, 15,400 MW and 53,900 MW of electricity by 2015, 2020, 2025, and 2030 respectively.

Table 6. *Emerging coal electricity projects in Nigeria.*

S/N	Project	Capacity (MW)	Coal source	Project location	Value of project ($ Billion)	Investor s	Project duration	References
1	Enugu Coal power plant (FGN)	1000	Ezinmo	Nsukka	3.7	HTG-Pacific Energy (Chinese)	2013 – 2015	Ige [41]; Adetayo [42]
2	Enugu Coal power plant (State Govt.)	600	Enugu, Inyi	Enugu	0.6	ESSAR Group (Indian)	2011 – 2015	Obiukwu & Okozi [39], Dike [40], Olayinka [32]
3	Kogi Coal power plant (FGN)	1000	Okaba & Ogboyoga	Odu & Abocha	1.5	Skipper & Energy Co. Swiss)	2013 -?	Mmaduakolam [33]
4	Gombe Coal power plant (FGN)	1000	Lamja, Doho, Garin, Maigagan		NA	NA	2013 - ?	Daily Trust [34], Anuforo & Onyedika [35]
5	Benue Coal power plant (FGN)	1200	Orukpa	Gboko	4	Sepco III-Pacific Energy (Chinese)	2013 -?	Emmanuel [36]
	TOTAL	4800			9.8			

FGN = Federal Government of Nigeria
NA = not available

The target of 30% of electricity generation from coal by Nigeria by 2015 is lower than the world average of 41% in 2009 [56, 57]. At 30%, Nigeria will rank lowest among major coal power generation countries such as Botswana (100%), South Africa (93%), China (79%), India (69%), Israel (63%), USA (49%) and Germany (45%) [56-58]. Recently, despite the challenge of CO_2, coal electricity has increased in many countries especially South Africa, Germany and China. Between 2008 and 2018, South Africa is planning to increase coal production by 200 million tonnes/annum, which would requires the investment of R100 billion for the development of 40 new mines [59]. Germany commissioned 2 new coal power plants in 2012, 6 new plants in 2013 and additional 8 are due to be completed in 2020, which could add 11,755 MW (i.e. about 19% increase into the national grid) [60].

Four of the five new coal power plants under construction (Table 5) have injected $9.8 billion into the Nigerian economy. This investment is quite relevant coming at a time when some multinational oil companies are divesting from Nigeria due to insecurity. The investment injected into the coal power sectors could have

multiplier effect on other sectors and could lead to wealth creation and employment. Such a high level of investment could boost the mining sector, which had consistently performed poorly over the years accounting for less than 1% of Nigeria's GDP [50]. The electricity sector (generation, transmission and distribution) also accounted for less than 1% of Nigeria's GDP [51]. The projects when completed could diversify the energy sources of Nigeria and contribute towards energy security. Coal power is not subjected to climate changes like biomass or seasonal water level changes like hydropower, nor can it be easily/illegally bunkered like petroleum. Besides, coal reserves are more evenly spread geographically than petroleum, which is located in many troublesome areas of the world including Nigeria's Niger Delta. Because of its wider geographic distribution compared with crude oil, coal is less affected by local, regional, national and global politics. The World Coal Institute [61] reported that coal has a vital role to play in securing energy supply. The production and utilization of coal is based on well-established and widely used technologies. Investment in the coal sector can become the driver for employment, wealth creation, and economic growth and could spur industrialization, especially in chemical industries. A variety of chemicals such as ammonia, methanol, liquid fuel (dimethyl ether, gasoline, diesel) and gas can be produced from coal feedstocks via gasification, liquefaction and pyrolysis [62-65]. Coal can also be used for firing of kilns during cement production as was practiced in NIGERCEM before it folded up. Also, Ashaka Cement factory in Gombe state has commenced the use of coal for cement production. Coking coal found in Lafia/Obi and Amansiodo is good for iron and steel production. There are projections that the Ajaokuta steel company will require 200,000 tonnes of coking coal per annum when it becomes fully operational. Coal can also be used for the production of smokeless briquettes for household cooking.

5. Challenges of Coal Electricity Sector

Despite the potentials and successes recorded in the Nigerian coal power sector, there are still some challenges that must be addressed for the sector to work effectively. One of the challenges is policy. Despite memoranda of understanding (MOU) that have been signed and some have started construction, power purchase agreements (PPA) have not been signed with the investors. Investors and /or their funding partners will require PPA in order to make final investment decisions. Globally, there is negative publicity of coal electricity principally due to CO2 emissions, Green Peace considers coal as "dirty". Clean coal technologies (CCT) such as carbon capture and storage (CCS), supercritical turbine concept, integrated gasification combine cycle, coal washing and beneficiation have been used to reduce the environmental aspects of coal energy. Algal photo-bioreactors are currently being integrated into high CO_2 emitting facilities such as coal power plant and oil and gas flow stations [66].

Another challenge that could be faced by the new investors in the coal mines is the issue of AMD. Some of the abandoned and active mines are flooded with acidic water. Management of AMD is critical towards the rehabilitation of the coal mines. Because of weak enforcement in developing countries like Nigeria, most multinationals pay less attention to environmental issues. Although, AMD is difficult to control, once it has started physicochemical and microbiological approaches can be combined to treat mine drainages.

Infrastructural challenges, particularly poor rail and electricity, persist in Nigeria. The Government, as part of incentives is extending these infrastructures to coal project sites. For instance, Kogi state on 3 October 2013 commissioned an access road to the Okaba coal mine. Historically, the Nigerian Railway Corporation was set up to transport coal from Enugu to the north and to Port Harcourt for export and marine transportation to Lagos. The Federal Government is currently rehabilitating the Nigerian railways.

Another challenge of the coal sector is the lack of current geophysical data. Active and continuous exploration was not carried out in the coal sector for a long period, hence most of the available data are obsolete and many of the reported coal findings in Nigeria are yet to be fully characterized.

6. Conclusion

Nigeria is a rapidly developing country. With the country's visions 20:2020, Nigeria plans to be ranked among the 20^{th} largest economy by 2020. This vision requires a power requirement of 20,000MW, but the country has installed power generation capacity of 8000MW with about 50% operational. The country's electricity is generated mostly from gas thermal plants and to a lesser extent from hydropower. Electricity in Nigeria is poor, of low quality with frequent unplanned outages. The per capita electricity consumption is low (99 -125 kW/h). Although Nigeria has about 8000MW installed electricity generation capacity, only 3800 – 4000 MW is actually operational. The government now wishes to diversify her electricity generation mix by encouraging private sector participation in the energy sector and targeted 30% electricity generation from coal. This study reviewed policies relating to coal power generation in Nigeria and the causes of previous failures in the sector. The study found that the electricity sector reforms and other policies changes have spurred investment of nearly $10 billion in the coal sector. Five projects of 4800MW generation capacity are under construction. Of this, two projects located in Enugu state of combined capacity of 1600MW could be ready by 2015. The challenges of coal power generation in Nigeria include policy, environmental and infrastructural.

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