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Coal Based Generation: A Solution to Nigeria Electricity Problem

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ABSTRACT
The problems of the Nigerian power sector are far from being over. Nigeria with an estimated coal reserve of 2.734 billion tonnes spread across 22 locations of the country is still faced with problems of gross inadequate power generation even in the midst of several clean coal generation technology options. This paper x-rays these problems, placed side-by-side with the prospects of integrating coal based electricity generation in the Nigerian power sector. It also recommends four clean coal generation technology options to improve the Nigerian energy mix.
Keywords: *coal reserve, clean coal generation, electricity, power plant*

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INTRODUCTION

Adequate power supply is an unavoidable prerequisite to any nation's development. Electricity plays a very important role in the socio-economic and technological development of every nation. The electricity demand in Nigeria far outstrips the supply and the little supply is epileptic in nature. The country is faced with acute electricity problems which is hindering its development notwithstanding availability of vast energy resources in the country. It is widely accepted that there is a strong correlation between socio-economic development and the availability of electricity in a given country. The energy woes today had continued unabated over the years since 60 percent of Nigeria's electricity – generating capacity broke down due to decades of neglect by the government [4]. The remainder serves only 40% of her citizens [5],[6],[7] at different degrees of blackouts, rolling blackouts and brownouts. This is obvious since the rapidly increasing demand for electricity in the midst of the ageing and inadequate power system infrastructure has led to the overloading of the system beyond its thermal limit. Another side to these woes is the fact that for more than three decades, Nigeria went for gas – fired power stations, in the days when there was still abundant of cheap gas. With the present skyrocket price of gas, it has become expensive to run those plants when compared to coal – fired and nuclear plants[4].

In Nigeria presently, 93% of electric power generation is provided by gas, the remainder is from hydro sources[2]. There are over 8.6GW[2] of installed capacity of generating plant made of government owned and independent power plant. Despite the large number of installed power generation capacity, Nigeria could still not meet the electricity demand of its populace which is estimated at 10GW[2]. Because of old age of the power plants and lack of new generation plants addition. Actual electricity generation is only between 2.5 – 3.6GW[2].

Even if new power plants addition were to be made, the overdependence of Nigeria's electrical system on gas which cannot guarantee longer term sustainability should be a major concern. The frequent agitation for resource control from areas with fossil fuel reserves and incessant vandalization of power plant gas supply infrastructure are threats to the continuous sustainability of the Nigeria's power system of today.

Moreover, there is an urgent need for a good energy mix in the nation's energy generation infrastructure due to the combined benefits derivable from it.

Globally, the energy industry is driving towards sustainable low carbon emitting, renewable energy sources. However, renewable as at now are still in their infant stage of commercialization and cannot help to meet Nigeria's base load electricity demand deficit. It is also worthy of mention that even in the most envisioned grid of the 21st century otherwise called the smart grid, traditional large central power plants still form the 'nucleus' of this concept both in Europe and America[5].

Coal is an important energy resources across the world, principally for electricity generation. It is the world most abundant and widely distributed fossil fuel, with global proven reserves totaling nearly 1 trillion tonnes[2].

Coal which is evenly spread across Nigerian stat es with an estimated reserve of 2.734 billion tonnes[1],[2] holds the key to Nigeria's present and even future energy security.
Within the last decade, there have been a rapidly increasing demand for coal,exceeding that of gas, oil, nuclear and renewable energy sources[2] though this demand comes at a cost of environmental sustainability. On the average, 40% of the world's electricity is generated from coal[2],[12] with a rather higher percentage as you move from one country to another. For instance, electricity generation in south Africa derivable from coal fuels is placed at about 93%, it is 92% in Poland, 79% in china, 69% in India, 49% in the USA[2],[12] but most unfortunately 0% in Nigeria.
As can be inferred from table 1.1, most developed and developing countries that have coal deposits meet their energy demands through coal based generation. Nigeria can bridge its energy demand and supply deficit by leveraging on its abundant coal deposit resources.
Nigeria cannot continue to be in the dark when there are approximately 3 billion tonnes of coal deposits spread across 22 locations in Nigeria that has not been harnessed.
[3] gave the assertion that the growing energy needs of the developing world are likely to ensure that coal remains a key component of the power generation mix in the foreseeable future, regardless of the climate change policy.
The clean coal based generation technologies – circulating fluidized bed combustion (CFBC), pressurized fluidized bed combustion (PFBC), integrated gasification combined cycle (IGCC) and top cycle, as would be considered in this paper must be critically analyzed to know which ones are most suitable in the Nigeria scenario.
For Nigeria to meet both domestic and industrial energy demand with minimal environmental consequences, clean coal power generation must be integrated in the Nigeria electricity mix.

PROBLEMS OF NIGERIA POWER SECTOR

The history of electricity production in Nigeria dates back to 1896 when electricity was first produce in Lagos[10]. It is believed that electricity showed up in Nigeria in the late nineteenth century, 20years after Washington DC got theirs. However, 118years later, Nigeria is still largely a dark country with only about 40% of her citizens connected to the national grid [5].
As presented in table 2.1 & 2.2, the country presently derives 93% of its electric power generation from gas (thermal) and 7% from hydro sources[2]. There are over 8.6GW[2] of installed capacity of government owned and independent power plant. Only 5.04GW[2] (58.6%) of this total is been generated presently.
[7] has suggested that for Nigeria to meet its energy demand (both domestic and industrial), it requires per capita power generation of 1000watts.
As of July 2013, [11] estimated Nigeria's population to be at 174,507,539 people. If these two statements are true, then Nigeria needs a power handling capacity of 175GW. The difference between where Nigeria is and where we suppose to be can only be imagined than mentioned.

Table 1.1 Top 12 Countries that use Coal for Electricity Generation

S/ No	Country	Percentage
1	South Africa	93%
2	Poland	92%
3	PR China	79%
4	Australia	77%
5	Kazakhstan	70%
6	India	69%
7	Israel	63%
8	Czech Rep	60%
9	Morocco	55%
10	Greece	52%
11	USA	49%
12	Germany	46%

Source: Coal Deposits in Nigeria: A Viable Energy Option for Industrialization.

Table 2.1 Installed and Available Capacities of Government owned Power Station in Nigeria

S/N	Station name	Type	Year Built	Location	Installed capacity (MW)	Available capacity (MW)
1	Kainji/Jebba	Hydro	1968	Niger state	760	480
2	Shiroro	hydro	1989	Niger state	600	450
3	Kainji/jebba	Hydro	1985	Niger state	540	450
4	Egbin power Plc	Thermal	1986	Egbin, lagos	1320	1100
5	Geregu Power Plc	Thermal	2007	Kogi state	414	276
6	Omotosho Power Plc	Thermal	2007	Ondo state	304	76
7	Delta Power Plc	Thermal	1966	Delta state	900	300
8	Sapele Power Plc	Thermal	1978	Delta State	1020	90
9	Afam (IV-V)	Thermal	1963/01	Rivers state	726	60
10	Calaber Thermal station	Thermal	1934	Cross River state	6.6	nil
11	Oji River	Thermal	1956	Enugu state	10	nil
12	Olorunsago Power Plc	Thermal	2008	Ogun statae	304	76
				Total	**6904.6**	**3558**

Source: [Economic Viability of Coal Based Power Generation for Nigeria - American Journal of Engineering Research (AJER), Volume 02, Issue 11, pp 14-24, 2013]

Table 2.2 Installed and Available Capacities of Independent Power Projects (IPP) in Nigeria

S/No	Station name	Location	Installed capacity (MW)	Availabl capacity (MW)
1	AES Power Station	Egbin lagos	224	224
2	SHELL- Afan VI Power station	Rivers state	650	650
3	Agip Okpai Power Station	Delta state	480	650
4	ASG Ibom Power Station	Akwa Ibom	155	76
5	RSG – Trans Amadi Power Station	PH,Rivers State	100	24
6	RSG Omoku Power Station	Omoku, Rivers state	150	30
		Total	**1759**	**1484**

Source: [Economic Viability of Coal Based Power Generation for Nigeria American Journal of Engineering Research (AJER), Volume 02, Issue 11, pp 14-24, 2013]

PROSPECTS OF COAL BASED GENERATION IN NIGERIA

Coal is a major fuel used for generating electricity worldwide. Some countries heavily depend on it to meet their electricity generation need.

In terms of estimated coal reserves, Nigeria with 2.734 billion tonnes is above the USA, India, Australia, Poland, South Africa, just to mention a few. It ranks just a little below china with 3.162 billion tonnes[12]. Nigeria has all the needed advantages to integrate coal based generation in its energy mix. Due to the global campaign against the emission of greenhouse gas (GHG) to the environment where coal combustion is a major contributor, clean coal generation technology options are recommended as Nigeria kick start this integration.

CLEAN COAL TECHNOLOGIES

Subcritical, supercritical and ultra-supercritical pulverized coal

In terms of the turbine inlet pressure and main steam temperature, pulverized coal technology (PCT) is classified into three (3): subcritical, supercritical and ultra-supercritical PCT. A typical existing subcritical unit is designed to operate at a turbine inlet pressure of 2400psi, with main steam temperature at 1000F, reheat to 1000F, and an overall net output efficiency of about 35%. A supercritical unit will operate at a pressure of at least 3500psi with main and reheat temperatures of 1051F or higher, and an efficiency of 38% or more. An ultra-supercritical unit might operate at 4500psi, with temperatures of 1100F or higher, and an efficiency of 42% or more. For generation efficiency to be further increased, new coal – burning units must be designed to operate at even higher steam temperature and pressure. As temperature and pressure increase, the technology moves from subcritical to supercritical to ultra-supercritical steam parameters[9].

The subcritical PCT which is one of the most predominant, conventional and commercialized method of coal conversion to electricity has been in use for over 40 years now[2]. Here, the current and developmental clean coal technologies which are being considered for application in many countries[8] are briefly analyzed.

Table 3.1 Existing Coal Deposit in Nigeria

S/N	Mine Location	State	Type of coal	Estimated Reserves (Mil. T)	Proven Reserves (Mil. T)	Borehole Records	Coal Outcrop and seam Thickness (M)	Depth of coal (M)	Mining Method
1	Okpara Mine	Enugu	Sub-Bituminous	100	24	20	Many (1.5m)	180	Underground
2	Onyeama Mine	Enugu	Sub-Bituminious	150	40	Many	Many (1.5m)	180	Underground
3	Ihioma	Imo	Lignite	40	N.A	Nil	Many	20-80	Open-cast
4	Ogboyoga	Kogi	Sub- Bituminous	427	107	31	17 (0.8.2.3m)	20-100	Open-cast/ Underground
5	Ogwashi Azagba/ Obomkpa	Delta	Lignite	250	63	7	4(3.5m)	15-100	Open-cast/ Underground
6	Ezimo	Enugu	Sub-Bituminous	156	56	4	(10.06-2.0m)	30-43	Open-cast/ Underground
7	Inyi	Enugu	Sub-Bituminuos	50	20	4	(0.9-2.0m)	25-78	Open-cast/ Underground
8	Lafia/Obi	Nassarawa	Bituminous (Cokable)	156	21.42	123	Nil (1.3m)	80	Underground
9	Oba/Nnewi	Anambra	Lignite	30	N.A	2	14 (0.3-4.5m)	18-38	Underground
10	Afikpo/Okigwe	Ebonyi/Imo	Sub-Bituminous	50	N.A	Nil	N.A	20-100	Underground
11	Amasiodo	Enugu	Bituminous (Cokable)	1000	N.A	3	N.A.	563	Underground
12	Okaba	Kogi	Sub-Bituminous	250	3	Many	(0.8-2.3m)	20-100	Open-cast/ Underground
13	Owukpa	Benue	Sub-Bituminous	75	57	Many	(0.8-2.3m)	10-100	Open- cast
14	Ogugu/Awgu	Enugu	Sub-Bituminous	N.A.	N.A.	Nil	N.A.	N.A.	Underground
15	Afuji	Edo	Sub-Bituminous	N.A.	N.A.	Nil	N.A.	N.A.	Underground
16	Ute	Ondo	Sub-Bituminous	N.A.	N.A.	Nil	N.A.	N.A.	Underground
17	Doho	Gombe	Sub -Bituminous	N.A	N.A	Nil	N.A.	N.A.	Underground
18	Kurumu	Gombe	Sub -Bituminous	N.A	N.A	Nil	N.A.	N.A.	Underground
19	Lamja	Adamawa	Sub -Bituminous	N.A	N.A	Nil	N.A.	N.A.	Underground
20	Garin maigungu	Bauchi	Sub -Bituminous	N.A	N.A	Nil	N.A.	N.A.	Underground
21	Gindi Akwati	Plateau	Sub -Bituminous	N.A	N.A	Nil	N.A.	N.A.	Underground
22	Jamato koji	Kwara	Sub -Bituminous	N.A	N.A	Nil	N.A.	N.A.	Underground

Source: Prospects of a 100MW Coal-Fired Power Plant in Benue State of Nigeria

Circulating Fluidized Bed Combustion (CFBC)

This offers a viable alternative to conventional pulverized fuel – flue gas desulphurization (PF - FGD)[8]. It is particularly suitable for plants rating below 200MW[8]. As the name implies, coal is burnt with air in a circulating fluidized bed. Crushed coal and limestone are fed into the fluidized bed, where the limestone exposed to the heat of coal combustion undergoes calcinations to produce lime. The fluid bed consists mainly of coal, limestone reaction products and ash. CFB operates at relatively low temperatures, which favors low NOx formation while SO_2 is captured by the lime. Due to the relatively low temperatures at which the bed operates, CBF unit with rating higher than 500MW is yet to be constructed[9].

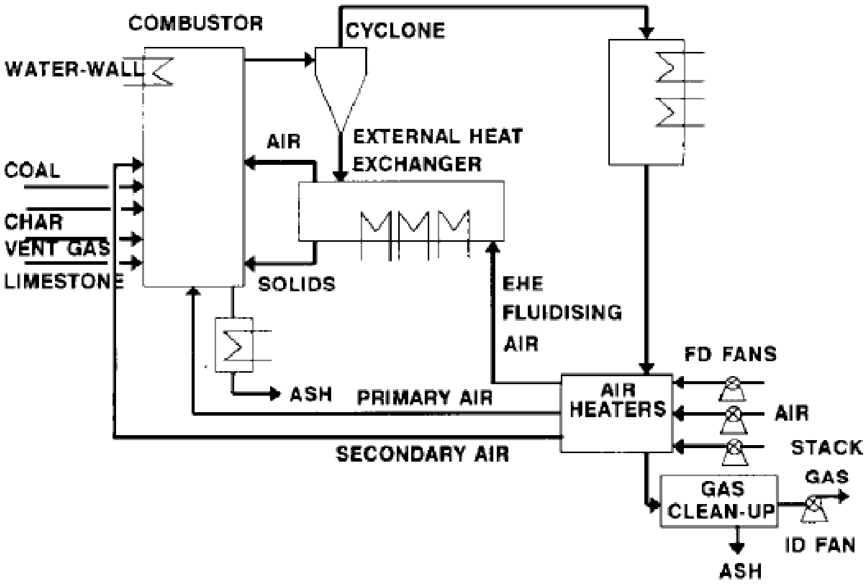

Figure 4.1 Circulating Fluidized Bed Combustor

Pressurized Fluidized Bed Combustion (PFBC)
Here, coal is burnt at elevated pressure in a deep bubbling bed. It is just a modified CBFC. As in CBFC, the fluidized bed contains sorbent – limestone which when exposed to heat undergoes calcinations to produce lime for SO_2 retention. Flue gas at a high temperature coming out of the combustor is passed through a gas turbine to produce electricity.
Integrated Gasification Combined Cycle (IGCC)
The IGCC technologies offer utility a flexible design option and can be adopted to meet current and future needs[8]. The gasification of coal has been a popular technology in the production of chemicals from coal, synthesize gas (syngas) and as fuel in power plants[9]. Synthesize gas from the gasifier can be cleaned of particulate and sulphur and either used as fuel for electricity production in gas turbine or further processed to create methane and put into a pipeline to replace natural gas. Alternatively, syngas also can be sent to a chemical processing unit to produce fertilizer, clean transportation fuels, and hydrogen as final product.

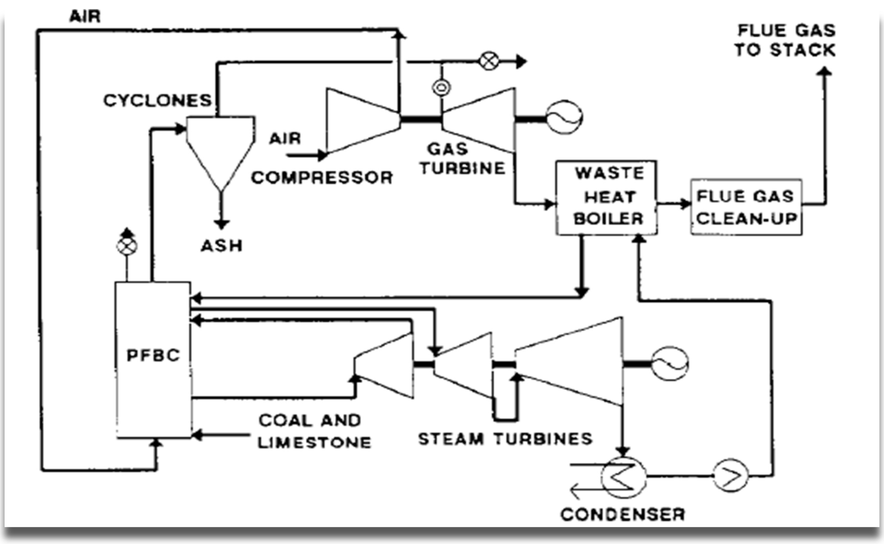

Figure 4.2 Pressurized Fluidized Bed Combustor

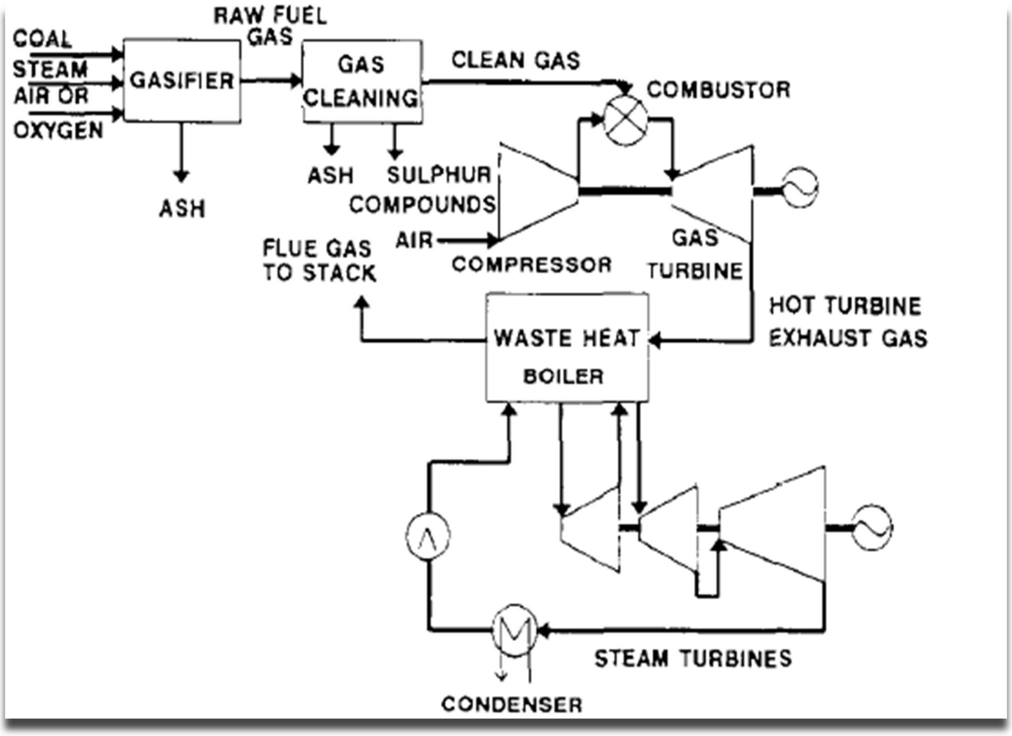

Figure 4.3 Basic Features of IGCC

Operation: finely ground coal is mixed with oxygen or air and steam in a gasifier. The oxygen is provided by air separation unit, and the partial oxidation of coal raises the temperature to assure complete carbon conversion with steam to form a gas mixture that is largely hydrogen and carbon monoxide which is the syngas. The gas is cleaned and burned in a combustor of gas turbine to produce electricity. Hot exhaust from the gas turbine raises steam in a waste heat boiler which is sent to a steam turbine in the combine – cycle power block for additional electricity production.

Top Cycles

The top cycle as shown in figure (4.4) has a pressurized fluidized bed gasifier and a CFBC compartment for burning of residual char.

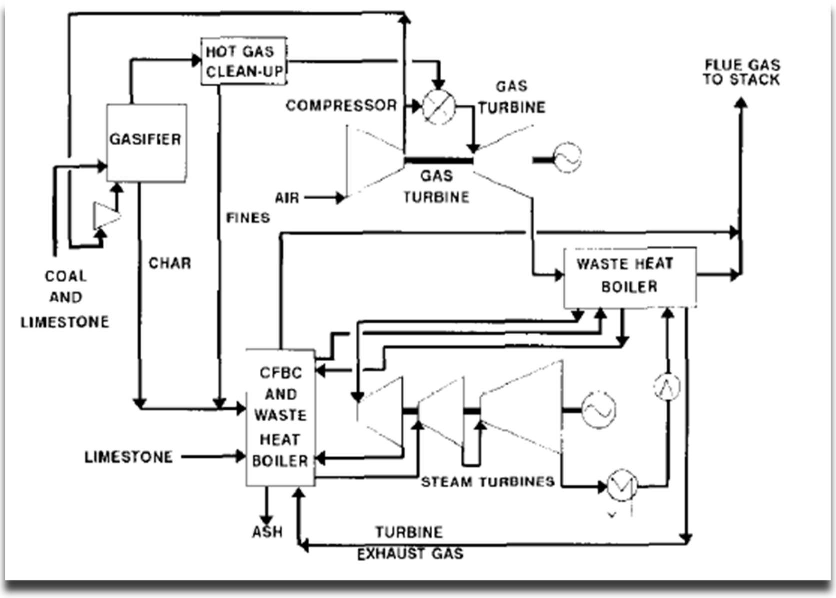

Figure 4.4 Basic Features of a Coal Topping Cycle

The gasifier is pressurized and is designed to operate at a high temperature of about 950 – 1000C[8]. Here, about 80% of the mass of the coal is converted into gas of low calorific value and about 90% of the sulphur content in the coal is retained using limestone. The low calorific value gas is fired in a high efficient turbine, and exhaust gas is used in a waste heat boiler integrated into the steam system. The residual gasifier char is fed to the CFBC unit to raise steam for a reheat steam cycle. Reheating, single or double, increases the cycle efficiency by raising the mean temperature of heat addition to the cycle.

CONCLUSION

Clean coal based generation has been a major source of power in so many countries with coal deposits like Nigeria. The economic growth of countries like the USA, China, South Africa, Australia, India, Germany, to mention just a few has correlation with their level of generation which is boosted by clean coal based generation. Nigeria with estimated coal reserve of 2.734 billion tonnes spread across 22 locations cannot continue to solely depend on oil and hydro sources for its power needs in the midst of continuous widening of the gap between Nigeria's electricity demand and supply.

Nigeria must key into one or more of these clean coal generation technology options if it is to come out of the dark that it has been for over a century. To reinforce its economic and social development and compete economically with the developed countries of the world, the integration of clean coal power generation in the Nigeria electricity mix is imperative. This will not only guarantee the steady power supply that has eluded it for over a century, but will also ensure security of energy supply and stability in energy prices which are recipes for economic development.

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