Exploratory Study on the Potential of coal Fired Power Plant for Energy Production in Nigeria

Conference Paper · February 2013

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ABSTRACT

Nigeria's industrialization is dependent on the utilization of its energy sources. In Nigeria, as in many developing countries, providing energy to rural and urban areas has proved to be a great challenge. At present, the energy consumption estimate in Nigeria is reaching 19.21 billion KWh and is still rising. To counter this, the estimated generated energy, presently is 3,500MW which is insufficient to handle the Demand. This is quite low and alternative means have to be proposed. This paper looks at the potential of technologies to convert coal into fuels that can be used directly in place of gasoline and diesel. A power generating plant is proposed, which uses coal, which is in ample supply of about 396 Million Metric tons, as a feedstock. The plant is expected to use the Gasification technology, which converts solid coal to its synthetic gas form, which is further used to power Gas turbines for power generation. Its generating capacity is 750MW and has a Configuration of 2*2*2*1. This implies that it has 2 operating gasifiers/ cleaning system, 2 combustion Turbines, 2 Heat Recovery Steam Generators and 1 steam turbine.

Keywords: Coal, Power, Gasifiers.

1.0 INTRODUCTION

Demand for energy and its resources, is increasing continuously due to the rapid outgrowth of population and urbanization. Present sources of energy are not sufficient to overcome the increasing needs. The major energy demand is fulfilled from the conventional energy resources like coal, petroleum and natural gas. In Nigeria, the availability of a reliable power supply is part of the enabling environment for industrialization and therefore needs to be addressed in national policy. The utilization of renewable energy sources in Nigeria remains quite limited. Although use of solid biomass such as firewood, is prevalent and constitutes a major energy source for most rural dwellers in Nigeria; unfortunately, its continuous usage lead to deforestation.

Nigeria's industrialization depends largely on how its energy resources (oil, gas, bitumen, coal, lignite) are harnessed either as fuel or as industrial feedstock. Over-dependence on oil is evident from the fact that oil revenue, as a percentage of the nation's total export earnings, soared from 13.5 per cent in 1956 to 96.5 per cent in 1979. Since then, crude oil production has accounted for 30 per cent of GDP and about 80 per cent of total government revenue.[1]

Nigeria's usage of hydropower, geothermal and solar energy is still low. Nigeria has good radiation sites that can boost the development of solar energy; yet research efforts and government attention in that direction have yielded little results. The seasonal nature of Nigeria's rainfall limits hydropower usage from increasing in importance

Thermal power stations provide the bulk of the nation's energy needs.

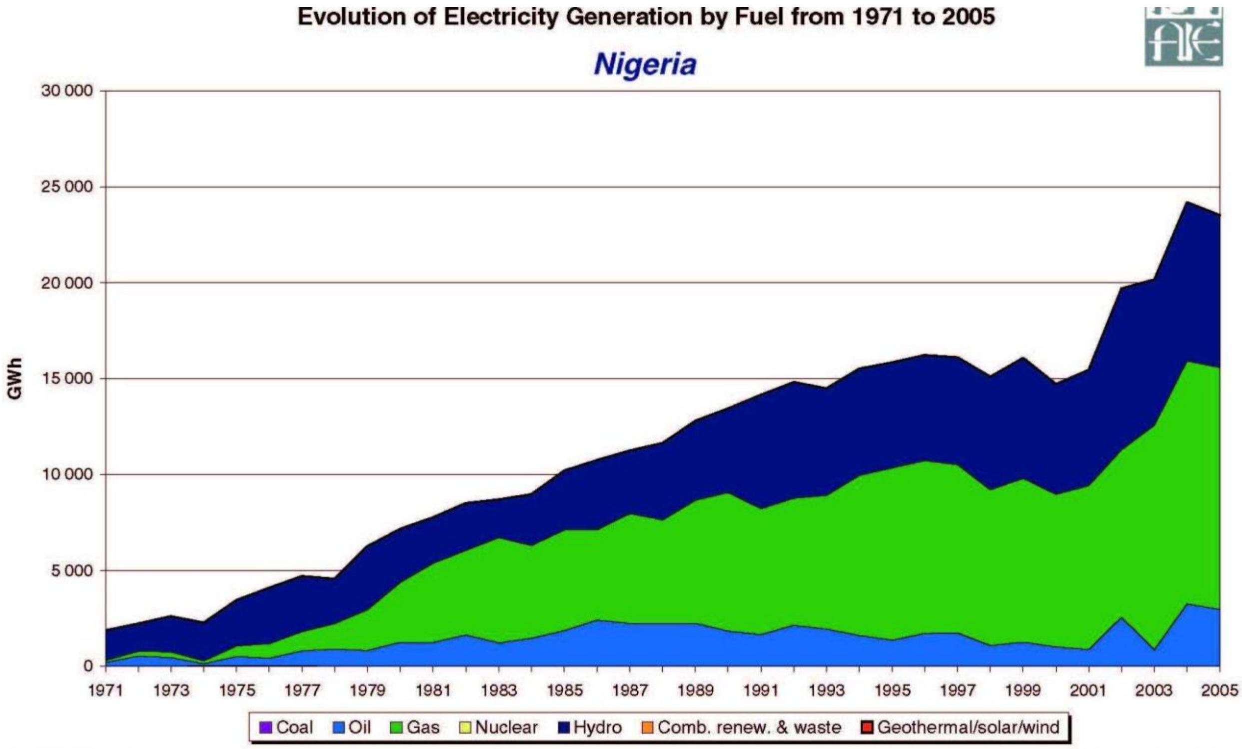
Table 1.1 below shows the nation's thermal and Hydro-power stations and their locations and Graph 1.1 shows the Evolution of Power Generation by fuel from 1971 to 2005.

Table 1.1: Thermal and Hydro Power stations in Nigeria

Power station/ Location	Type	Year of commissioning	Generating capacity (MW)
Lagos station at Egbin	Thermal(gas)	1985-1987	1,320
Sapele station at Ogorode	Thermal(gas)	1978-19990	1,020
Oji	Thermal(coal)	1956	30
Ijora station, Lagos	Thermal(gas)	1978	60
Lagos IPP (Enron/AES)	Thermal		170
Kainji	Hydro	1968,1976, 1978	760
Shiroro	Hydro	1990	600

[1]

Fig. 1.1: Evolution of Electricity Generation by fuel



Energy production in Nigeria over the last 40 years varied from gas – fired, oil – fired, hydroelectric power stations to coal-fired with hydroelectric power system and gas – fired system taking precedence.

The estimate of energy consumption in Nigeria is 19.21 Billion KWh. Also, Nigeria has the Capacity to generate 5,900MW of Power but due to Operation and Maintenance issue, the capacity has reduced to 3,500MW. An estimated value of demand of electricity in the year 2020 would be about 100,000MW (Optimistic).

Therefore, alternative means of Power generation using other energy source should be analyzed.

Coal, which is under- utilized, (which is in ample supply in the Nigeria ranging in coal seam area of 1.5 million hectares) as an Energy source for Power generation, industrial and domestic use should be introduced with its new Gasification and cleaning technology.

This is predicated by the fact that the primary fuel sources (coal, oil, water, gas) for these power stations are readily available. Nigeria's coal reserves are large and estimated at 2 billion metric tons of which 650 million tons are proven reserves. About 95% of Nigeria's coal production has been consumed locally; mainly for railway transportation, Power generation and industrial heating in cement production.

There are different kinds of coal available in Nigeria but they are un-utilized to a very minute degree, whereas, there is over dependence on Crude oil. This report shows ways to utilize coal for better power generation to add to the National Power grid, industrial and domestic use with very little emission issues.

Also, Nigeria has an estimated 176 trillion cubic feet of proven natural gas reserves, giving the country one of the top ten natural gas endowments in the world and the largest endowment in Africa. Natural gas is a natural occurring gaseous mixture of hydrocarbons gases found in underground reservoirs. It consists mainly of methane (70% - 95%). With small percentage of ethane, propane, butane, pentane and other heavier hydrocarbons with some impurities such as water vapour, sulphides, carbon dioxides, etc. Apart from the export potential of the Nigerian gas, local demand opportunities are power generation, cement industry, iron and steel plants. Energy production in Nigeria over the last 40 years varied from gas – fired, oil – fired, hydroelectric power stations to coal-fired with hydroelectric power system and gas – fired system taking precedence .

The 930 billion short tons of recoverable coal reserves estimated by the Energy Information Administration are equal to about 4,116 BBOE (billion barrels of oil equivalent).[citation needed] The amount of coal burned during 2007 was estimated at 7.075 billion short tons, or 133.179 quadrillion BTU's.(EIA,2009) This is an average of 18.8 million BTU per short ton. In terms of heat content, this is about 57,000,000 barrels (9,100,000 m3) of oil equivalent per day. By comparison in 2007, natural gas provided 51,000,000 barrels (8,100,000 m3) of oil equivalent per day, while oil provided 85,800,000 barrels per day.

British Petroleum, in its 2007 report, estimated at 2006 end that there were 909,064 million tons of proven coal reserves worldwide, or 147 years reserves-to-production ratio. This figure only includes reserves classified as "proven"; exploration drilling programs by mining companies, particularly in under-explored areas, are continually providing new reserves. In many cases, companies are aware of coal deposits that have not been sufficiently drilled to qualify as "proven". However, some nations haven't updated their information and assume reserves remain at the same levels even with withdrawals. Collective projections generally predict that global peak coal production may occur sometime around 2025 at 30 percent above current production in the best case scenario, depending on future coal production rates. [8]

An experimental way of coal combustion is in a form of coal-water slurry fuel (CWS, which was well-developed in Russia (since the Soviet Union time). CWS significantly reduces emissions saving the heating value of coal.

Nigeria has major coal resources that have not been well explored or exploited. The Government has recently placed a high priority on the utilization of resources it has, to help reduce its dependency on Crude-Oil and its by-products for its Power Generation capabilities and for Household use. To this effect, the aim is to find possible ways to revitalize and reconfigure or incorporate the coal mining industry with possible expansion of power generation by developing the large resources of Coal and constructing Coal gasification/ Liquefaction facilities which could have Gas/Steam Turbines to add to the country's Power distribution Grid.(Ministry of Mines and steel Development,2008)

There is also a significant potential demand for Coal briquettes to replace wood for cooking and domestic and industrial heating.

Nigerian coal has been found from research to be suitable for boiler fuel, production of high caloric gas,, domestic heating, briquettes, formed coke and a manufacture of a wide range of chemicals including wax, resins, adhesives and dyes. Their characteristic properties (low sulfur and ash content and low thermoplastic properties), makes these sub-bituminous coals ideal for Coal-fired electric power plants. Some Nigerian coals can be used to produce formed-coke of metallurgical quality. (Ministry of Mines and steel Development, 2008)

The domestic Coal market is latently large. Beside the potential for power generation, Nigeria currently imports coal of various grades and qualities including coke, pellets, briquettes, coking coal and fine coke. There is the potential for coal exports. (Ministry of Mines and steel Development, 2008)

The Nigeria Government had earlier on, recognized the necessity to revitalize the country's coal mining/ Exploitation industry too provide fuel for both domestic use and power generation.

A feasibility study was done under Grant from the United States Trade and Development Agency (USTDA) to determine the potential for the Coal resource development. (Ministry of Mines and steel Development, 2008)

The study was conducted by an International mining consulting firm; Behre Dolbear and Company (USA) Inc. in 2005 was commission to;

- Identify Coal deposits that have the highest potential for near term development, utilizing world class coal mining practices.

- Evaluate and Quantify using available data, Coal resources in accordance with international accepted resource definition

- Determine the potential of developing an economically viable coal mining and power generating industry to supply electrical energy to the Nigerian Electrical Grid and

- Develop the most effective strategies to revitalize the Nigerian Coal industry

(Behre Dolbear & Company, 2005)

Coal occurs in several areas in Nigeria and ranges from bituminous to lignite. The coal deposits of the Anambra Basin, located in southeastern Nigeria, appear to contain the largest and most economically viable coal resources. This basin covers an area of approximately 1.5 million hectares and is constrained by the Niger River on the west, the Benue River on the north and the Enugu Escarpment on the east. The coal is predominantly in one seam that outcrops along the eastern side of the basin at the base of the Enugu Escarpment and dips gently toward the center of the basin.. This shows the thermal coal reserves in the eastern flank of the Anambra basin [9]. The coal resources on the eastern side of the basin occur in one primary coal seam that appears to be continuous throughout this area. Exploration within the basin is limited, but there are four small coal mines in the eastern outcrops of the basin northwest of the city of Enugu and two smaller mines farther north. In addition, 123 shallow drill holes have been drilled to depths of 335 meters or less. Not all of those holes penetrated the main coal horizon. Only minor structural faults have been identified. Where the seam has been intercepted by drilling, the potentially mineable coal ranges in thickness from less than 1 meter to over 3.6 meters and averages 2.11 meters. A number of coal sections along the eastern outcrop have also been measured, but in general these resources have not been sufficiently explored to define the potential proven reserves [9]. Furthermore, during the study, a sub-division of the Anambra Coal basin was done and the resulting in Seven Coal mining district, focusing on three major that have been explored to a greater degree than the others. They are;

- Enugu District

- Kogi District

- Benue(Orukpa-Ezimo) District

Fig 2.3: Anambra Coal Basin

2.4.3 ENUGU DISTRICT

The Enugu Coal District, covering 270,000 hectares of the coal basin, is centered around Enugu City, south of the Benue District. It has supported the largest amount of commercial mining in the past. In addition to two underground mines, there are a total of 36 drill holes drilled in the area. Previous studies have estimated the demonstrated coal resource to be 49 million tones averaging 2.2 meters thick. An additional 111 million non- reportable tons of in-place coal are inferred to exist west of the old mine workings [9].

2.4.4 KOGI DISTRICT

The Kogi Coal District, covering 225,000 hectares of the Anambra Coal Basin, lies on the northeastern side of the basin. Two areas within the district have been explored to a limited degree. The more northern of the two areas, Ogboyoga, has the greatest amount of available drill data, where 27 holes have been drilled and cored and 15 separate measurements have been taken of outcrops of the main coal seam in stream drainages.

From the exploration results,, mineral resources and ore reserves, delineate a total of 123 million metric tons of coal(Demonstrated) underlying an estimate 8,900 hectares. An additional 165 million tons of coal classed as non-reportable resource is projected to lie in the Ogboyoga area. The Coal thickness in this area is approximately 2.0 meters [9].

2.4.5 BENUE DISTRICT (ORUKPA-EZIMO)

The Benue coal district, covering over 175,000 hectares of coal basin, is immediately south of the kogi district along the eastern outcrop of the Anambra basin. It has two areas of interest;

- ORUKPA: includes a small idle surface mine and a total of 11 drill holes. Six coal-out droppings have been measured in streams in the area. Based on this data, it is estimated that a reportable coal resource of 81 million tons exist along the outcrop. Another 117 million tons of non-reportable coal is projected to exist west of the existing drills. The average thickness is 3.1 meters. Immediately south of the Orukpa area is the Ezimo area.

- EZIMO: This area has limited exploration, with only four drill holes penetrating the main coal seam. Ten coal outcroppings have also been measured. Based upon this limited data, a total of 43 million tons of demonstrated coal resource have been projected in this area. An addition 263 million tons of non-reportable coal resource is projected to exist west of the existing drilling. The average coal thickness in this area is also 3.1 meters. In total, Benue district is estimated to have a demonstrated coal resource of 124 million tons, which underlies 4,700 hectares or 3 percent of the district. The total non-reportable resource is 380 million tons [9].

2.4.6 SUMMARY OF COAL RESERVES

Within the areas of these three districts where sufficient drilling exists to make reasonable estimates of in-place coal resources, a total of 396 million metric tons can be demonstrated. An additional 1,091 million tons of inferred and hypothetical coal resources have been delineated in these three districts.

The entire currently defined coal resource for the areas studied is 1,487 million tons. The coal seam thickness averages 2.2 meters throughout the area from Enugu north to Ogboyoga. The remaining districts are essentially unexplored.

Coal in the areas studied, is considered to be an excellent thermal coal to fuel coal-fired electrical generating plants or coal gasification plants with attached gas or steam turbines or for domestic or industrial use.

Table 2.2: APPROXIMATION OF COAL QUALITY BY AREA.

	Moisture (%)	Ash (%)	Sulfur (%)	Heating Btu/Ib	Values Kcal/Kg
Ogboyoga	13.50	8.00	0.58	9.930	5.520
Orukpa	11.80	11.20	0.40	9.990	5.550
Ezimo	10.90	6.40	0.50	10.900	6.050
Enugu	7.60	6.70	0.93	11.900	6.610

From the existing data demonstrated, there is a high level of evidence that substantial, economically mineable coal reserves, sufficient to support several major coal facilities (Gasification plant/ fired power generation plants) can be proven. This research throws light on analysis and, makes recommendations on selection of major components (Gasifiers, Cooling and Cleaning components) which affect efficiency performance. From the estimated future installed electricity generation capacity by fuel, shown in the table below, the figures for the coal should be revisited as a result of the environmental issues (emissions) which, as seen in this research, can be almost totally eliminated.

Table 5 : Future Installed Electricity Generation Capacity by Fuel

Fuel type	2010	2015	2020	2025	2030
Coal	0.0	9.9	13.8	15.3	15.6
Gas	78.6	48.5	53.5	53.0	59.0
Hydro	21.3	18.9	13.6	10.7	8.6
Nuclear	0.0	9.4	5.3	8.3	6.7
Solar	0.1	13.1	11.0	10.4	8.3
wind	0.0	0.1	2.9	2.3	1.8

With this, a better restructuring of the proposed electricity generation capacity by fuel can be foreseen.

2.0 METHODOLOGY

Ultimately, the goal of this Research project is to propose a facility for the conversion of Coal to Energy. To do this, data would be analyzed from the following sources below;

1. Okpara Coal Mine, Enugu
2. Coal fired Power Generation plant site , Enugu (Under Construction by ESSAR Group, India

Notwithstanding, to also do this, I had to analyze other cases of generation of electricity using coal as the primary source. Furthermore, other data from existing literature were considered for this purpose.

To propose a facility to balance the Energy consumption estimate in Nigeria, which is totaling 19.21 Billion KWh,[2] considerations have to be noted for the following;

- Primary Energy (Either Coal gas or Natural gas) - Accounts for losses that occur during combustion, cleaning, heating , distribution, storage and dispensing of the primary fuel.
- Secondary energy (Electricity)- Accounts for conversion losses at the plant in addition to losses incurred during transmission and distribution of Secondary energy to the facility and the National Electric Grid.
- Total Energy Cost –which is comprised of ;
    1. Construction Cost per KWh
    2. Production cost per KWh

There are other sources of power generation. So what we are looking at is a way of maximizing the available coal to generate power.

`From a paper being studied, the table below shows the future installed electricity Generation capacity by fuel. This is to balance the demand of electricity with an electricity supply mixture (different energy sources) [3]

Table 2.1: Future install Electricity Generation Capacity by fuel (Reference case), %

Fuel type	2010	2015	2020	2025	2030
Coal	0.0	9.9	13.8	15.3	15.6
Gas	78.6	48.5	53.5	53.0	59.0
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Nuclear	0.0	9.4	5.3	8.3	6.7
Solar	0.1	13.1	11.0	10.4	8.3
Wind	0.0	0.1	2.9	2.3	1.8

. From reports also received, it was said that coal was mainly used for the generation of Power in the early 1940s. In conclusion to quantity, total amount of coal resource in the studied areas (Enugu, Kogi and Ogboyoga) is 1,487 million tons. The coal seam thickness averages 2.2 meters[4].

From the Okpara Coal mine, the coal reserves are estimated at more than 175 million tons. It has reserves in seams greater than 1 meter in thickness which is approximately 70 million tons. Production level is expected to be between 150,000 to 400,000 tons of coal per year.

From the sample collected, the Quality of coal from the site is shown in Table 2.2;

Table 2.2: Quality of Coal

Moisture (%)	Ash (%)	Sulfur (%)	Heating value (Btu/Ib)	Caloric Value (Kcal/Kg)
7.60	6.70	0.93	11,900	6,610

The design properties of the coal are shown in Table 2.3. also based on data receive, the coal will contain approximately 16% inherent moisture, defined as the amount of moisture left in the coal after a moderate amount of low- temperature drying.

Table 2.3: Proximate Analysis (weight %)

	AR*	**Dry**
Moisture	7.00	0.00
Ash	6.00	7.70
Volatile Matter	46.65	49.45
Fixed carbon	39.42	41.61
Sulfur	0.93	1.24
Total	100	100
HHV, Btu/Ib	11,900	

Therefore, it can be noted that the quality of coal at site location will determine the Equipment and Technology selection to be used for the propose facility.

3.1 PROPOSED FACILITY

To propose a facility for generating electricity, using coal as the primary feedstock, there are various parameters that have to be considered.

Site selection criteria which involves the following;

- Site topography
- Air and Water- Environmental
- Transmission
- Fuel delivery
- Land use

These could further be broken down into the following sub-divisions;

- SITE TOPOGRAPHY: Topography and size, Expandability, Distance from waste disposal, Constructability
- AIR and WATER- ENVIRONMENTAL: Dispersion conditions, Existing air quality, CO2 sequestration.
- TRANSMISSION: Distance from transmission, transmission stability, feasibility of 2 unit transmission plan
- FUEL DELIVERY: Distance from rail or barge, Alternative transportation, Distance from Natural gas pipeline, delivery coal cost differential
- LAND USE: Existing land use, existing residences, nearby land use

3.2 FACILITY CONFIGURATION

Configuration of the facility would be a 2*2*2*1 configuration. That is to say;

- 2 Operating Gasifiers/ Gas cleanup systems
- 2 Combustion turbines
- 2 Heat Recovery Steam Generators
- 1 Steam Turbine

Net output 621MW, Heat Rate 11,900Btu/KWh (6,610 Kcal/ KWh)

- Shell Gasifiers – gives better heat rate, longer injector life and the technology is suited for lower rank subbituminous coals as well as high rank fuels
- Heat Recovery- Shell Radiant syngas cooler; heat recovery for power generation in the steam turbine.
- FT Synthesis- Water gas shift reaction for ratio adjustment, FT reactors which are Iron or Cobalt catalyst.
- Turbine Generators- two GE 7FB Combustion turbines- 232 MW each, Evaporative inlet cooling, single steam turbine- 300MW
- Emissions control systems- Selexol acid gas removal system for sulfur (H2S) removal with COS reactor, activated carbon bed for mercury removal, syngas moisturization, nitrogen diluent for NOx control
- Space provisions for future polygeneration and CO2 capture

PROCESS LAYOUT OF PROPOSED FACILITY

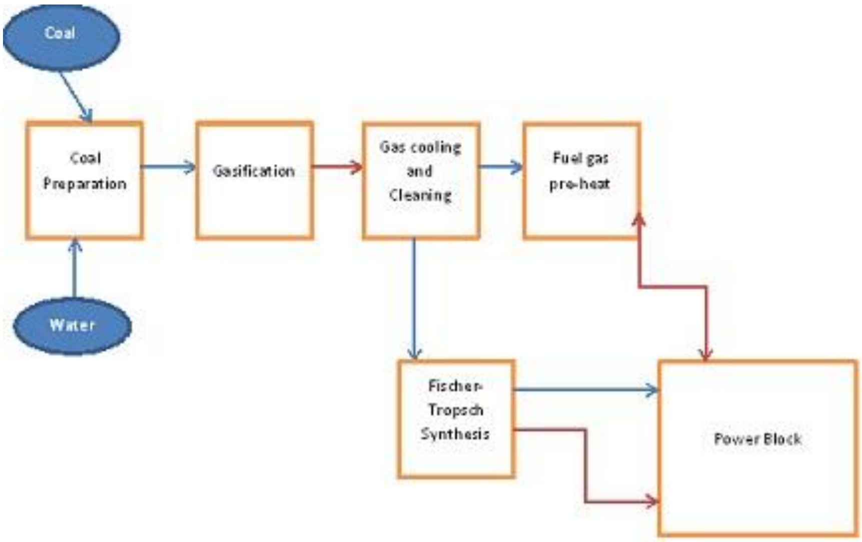

Fig 3.1: Process Layout for Proposed Power Generation facility

3.2.1MAOR COMPONENTS OF PROPOSED POWER PLANT

The major components of the above proposed coal-fired power plant include the following;

1. Coal Handling/ preparation equipments
2. Gasification
    - Oxygen-Blown Gasifiers
    - Air separation Unit
3. Gas cooling and clean-up processes
4. Fischer Tropsch Synthesis
    - Water-gas shift
    - Sulfur guard bed
    - Synthesis-gas conversion reactors
5. Power Block
    - Gas combustion turbine
    - Heat Recovery Steam Generator (HRSG)
    - Steam turbine

For further enhancement of the facility to produce substitutes for Gasoline and Diesel fuel, other process could be subsequently added after the Fischer Tropsch synthesis process, namely;

- Dehydration and compression

- Hydrocarbon and Hydrocarbon recovery
- Auto-thermal reforming
- Syngas recycle

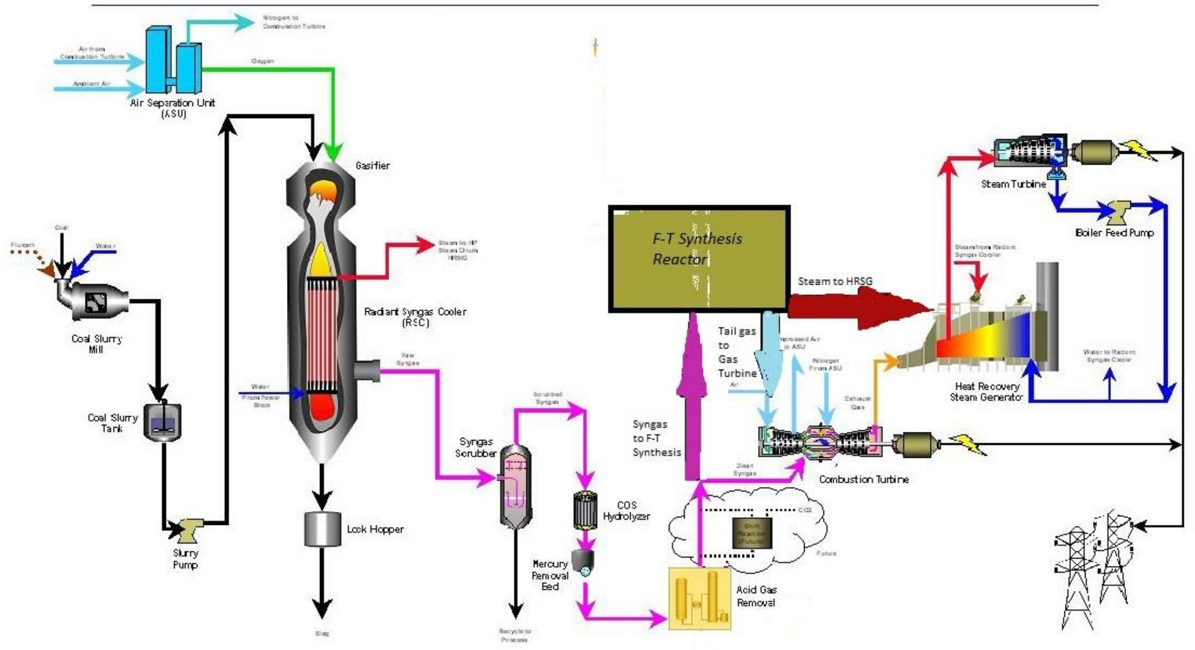

Fig 3.2: schematic Diagram of Proposed Power generation plant

3.2.2 PROCESS DESCRIPTION

Coal handling equipment provides for unloading, conveying, preparing and storing coal delivered to the proposed coal power plant. The coal handling equipment proposed to be used is largely the same in both the IGCC and Pulverized Coal power plants. Similar to the, the primary preparation of the fuel is crushing or pulverizing prior to feeding it into the gasification system as coal-water slurry***[5]***

Gasification then commences with the partial oxidation of a slurry feedstock to produce a gaseous product (syngas) which is made up of predominantly H2 and CO. the **oxygen-blowngasifier** does this at a high temperature (2,000-3,000°F) and elevated pressure (400-1,000psi) in the presence of a steam of compressed oxygen gotten from the **Air separation system** and steam. Gasification occurs in a reducing (oxygen starved) environment where insufficient oxygen is supplied for complete combustion of the slurry feedstock. Partial oxidation of the feedstock creates heat and a series of chemical reactions produce synthesis gas which contains carbon dioxide, moisture, Hydrogen sulfide and carbonyl sulfide as well as small amounts of methane, ammonia, hydrogen chloride and various trace components from the feedstock (coal).

Furthermore, since the gasification system operates at high temperature and produces raw, hot syngas, the temperature has to be reduced (cooled) from around 2,000°F to below

1,000°F (and the heat recovered). Cooling could be achieved either by using **waste heat boiler or a direct quench process** that injects either water or cool, recycled syngas into the raw syngas. If the waste heat boiler is used, steam produced in the boiler is typically routed to the HRSG to augment steam turbine power generation.

What follows after the process of cooling is the clean-up which generally entails removal of particulate matter, sulfur and nitrogen compounds from the synthesis gas before it is directed to the power block. The particulate removal could be achieved by **warm gas water scrubbers** located downstream of the cooling device. These particulate materials mostly include char and fly ash, could either be recycled back to the gasifier or purged from the system as a byproduct. When filters are used, they are cleaned by periodically back pulsing them with fuel gas to remove trapped material. Next, the synthesis gas is treated in **"cold-gas" clean-up process** to remove most of the Hydrogen sulfide, carbonyl sulfide and nitrogen compounds.

The next process is that of the Fischer-Tropsch synthesis which involves using a catalyst to convert syngas to hydrocarbon products. Since the produced synthesis gas is primarily hydrogen and carbon monoxide with ratios of H2: CO ranging from 0.4:1 to 0.9:1. For the F-T conversion, the desired ratio is 2.1:1. The Ratio adjustment can be achieved using the water-gas shift reaction which is a criteria for conversion of syngas to FT Hydrocarbons. This can be done bya catalytic shift converter which has an added advantage of eliminating CO_2 from FT reactor tail gas and simplifying carbon capture.

After the gas clean up and Fischer Tropsch Synthesis, part of the syngas from the gasification and the tail gas from the Fischer Tropsch process are sent to the combined cycle power block. In the combine cycle system, the first generation cycle involves the combustion of the primary fuel (which can be the **syngas** from the fuel gas preheat or**tail gas** from the Fischer Tropsch process) in the gas turbine. The Gas turbine powers an electric generator, which can provide air to the air separation unit, and produce hot exhaust gases that are captured and directed to a Heat recovery steam generator (HRSG) to produce steam for a steam turbine to complete the combined power cycle. Steam is also gotten from waste heat boiler and also the Fischer Tropsch process.

Consequently, the synthesis gas fuel can essentially be interchanged with natural gas as fuel for modern combustion turbines, but there are variations in performance. The primary difference is that the volumetric heating value of cleaned syngas is about 20-30% that of natural gas, so a much larger volume of fuel is required with syngas firing to provide the necessary energy input to the Gas (combustion) turbine. This large volume requires different piping, control valves and burners and this results in a larger total mass flow through the combustion turbine. As a result, the power output of the combustion turbine increases.

For instance, a combustion turbine, GE Frame 7FA+e, has an output rating is 172MW on Natural gas, but an output rating of 197MW on syngas.

3.2.3 POWER BLOCK DESCRIPTION

Key elements of the combined cyclepower block are two units of General Electric MS 7001FA High-Temperature Gas Turbine/Generator, two units of Heat Recovery Steam Generator(HRSG), and one unit of steamturbine.

. The combustion turbines are based on anadvanced F-Class design that generates 232 MWe on syngas. With two combustion turbines, the combined grossgas turbine output is 464

MWe.The advanced gas turbine technologyincorporates redesigned air compressorand turbine stages, higher firing temperatures,and a higher pressure ratio. . The Brayton cycle is integrated with a conventional subcritical steam Rankine cycle consisting of twoHRSGs and a steam turbine, operating at 12.4 MPa/566°C/566°C (1,800 psig/1,050°F/1,050°F) in cases withoutCCS[6].

The two cycles are integrated by use of the combustion turbine exhaust heat for generation of steam inthe HRSGs, by feed-water heating in the HRSGs, and by heat recovery from the IGCC and FT processes. Recirculatingevaporative cooling systems are used for cycle heat rejection. The average efficiency of the cases without CCS is 39.5% HHV for a plant with a nominal gross rating of 750 MWe.

Gas turbine exhaust heat is recovered toproduce steam for production of electricity.Flue gas is emitted to the atmospherevia a 225-ft stack **[7].**

4.0 Results and Discussions

Coal characteristics affect nearly every operational facet of the proposed power plant, including construction/ production cost, operation/maintenance cost, emissions, net plant heat rate and ability to meet full load. From the study on the future install electricity generation capacity by fuel (Sambo A S, 2008), the percentage of electricity generation using coal is 13.8% for the year 2020 of a total of 19.21 Billion KWh, which is the Electricity demand. Therefore it is required that Coal Energy produces a total of 2.65 Billion KWh to balance its quota.

Cost Estimate Calculation of Proposed Power Plant

Most of the generating technologies discussed in this research are capital intensive; that is they require a large initial construction investment relative to the amount of generating capacity built. Power plant capital costs are often discussed in terms of dollars per kilowatt (kW) of generating capacity.

Capital cost practically comprises of the following;

Engineering, Procurement and Construction (EPC) cost: This is the cost of the primary contract for building the plant. It includes cost of designing the facility, buying the equipment and materials, and construction.

Owner's Cost: These are construction costs that the owner handles outside the EPC Contract. This could include arranging for the construction of transmission and fuel delivery facilities (such as Natural gas pipeline or Railway track for the Coal) to the power plant.

In calculating the main cost components of energy, considerations are given to both the construction cost and production cost. Total cost per KWh can be calculated by taking the per KWh cost of construction plus the per KWh cost of production.

Total cost per KWh = Construction cost per KWh + Production cost per KWh

Construction cost per KWh will be estimated at $6,370/KW

So, therefore, to calculate the total cost of the proposed facility, the following are required;

Total Construction cost per KW= $6,370/KW. For the 750MW (750,000KW) power plant, the overall construction cost of the power plant will be;

=$6,370 * 750,000KW

= $4,777,500,000

Production Cost /KWh

To get the cost of production/KWh for the proposed power plant, various considerations have to be taken, namely;

i. Influence of federal and state incentive
ii. Higher Cost in fuel price
iii. Uncertainty in capital costs
iv. Carbon control/ Emission control and cost.

The object of this analysis is to provide insight on how key factors influence the costs of power plant. These estimates are approximations subject to high degree of uncertainty. The ranking of the technologies by cost are therefore also an approximation and should not be viewed as definite estimates of the relative cost competitiveness of each option of power generation.

The base case has the following characteristics:

i. The analysis is for new projects beginning operation in 2020
ii. Estimate of fuel prices, allowance prices, and most operational characteristics are from the EIA's reference case assumptions for the 2008 Annual Energy outlook
iii. The 2008 overnight capital cost for each technology are estimated from U S public information on recent projects
iv. The base case excludes "discretionary" incentives
v. Base case includes no carbon emission controls or costs

From the given assumptions, Table 4.1 presents the resulting annualized cost of power per MWH for each technology.

Table 4.1: Estimated Base Case Result of Power plant technologies

Technology	Non fuel O&M Cost	Fuel cost	SO2 and NOx Allowance cost	CO2 Allowance cost	Prod. Tax credit	Total operating Cost	Capital Returns	Total Annualized $/MWh
Coal: Pulverized.	$5.57	$11.13	$0.61	$0.00	$0.00	$17.31	$45.79	$63.10
Coal: IGCC	$5.46	$10.41	$0.10	$0.00	$0.00	$15.97	$67.02	$82.99
NG Combine cycle	$2.57	$30.57	$0.14	$0.00	$0.00	$33.27	$28.50	$61.77
Nuclear	$6.13	$5.29	$0.00	$0.00	$3.18	$8.23	$74.99	$83.22
Wind	$6.67	$0.00	$0.00	$0.00	$0.00	$6.67	$74.07	$80.74

Geothermal	$13.69	$0.00	$0.00	$0.00	$0.00	$13.69	$45.54	$59.23
Solar	$13.71	$0.00	$0.00	$0.00	$0.00	$13.71	$86.61	$100.32

Source: CRS estimates

Note: Projections are subject to a high degree of uncertainty. These results should be interpreted as indicative given the projection assumptions rather than a definite estimate of future outcomes. MWh= Megawatt hour, IGCC=Integrated Gasification Combine cycle, NG= Natural gas, O&M=Operation and maintenance.

Therefore, in calculating the production cost per KWh, the following costs are considered for this;

- Estimated Operation and maintenance cost
- Estimated Fuel cost
- Estimated allowance for SO2 and NOx
- Estimated Capital Return

From the table above, the estimated value for the required cost under the Coal: IGCC is used.

Production Cost/MWh= Est. O&M cost+ Est. Fuel Cost+ Est. Allow. For SO2 and NOx+ Est. Capital .Return

Production Cost /MWh= $5.46+ $10.41+ $0.10+ $67.02

=$82.99/MWh

To convert the figure to per KWh

Production Cost/KWh= $82.99/ 1000

=$0.083/KWh.

Production cost per KWh for the period of Useful life of 30 years

=$0.083 *750,000 * 30 *365 * 24

=$16,359,300,000

Therefore, the Total cost per KWh of the proposed Power plant

=$16,359,300,000+ $4,777,500,000

=$21,136,800,000

4.1.1 **Share Percentage of Major Components of Proposed Plant**

Furthermore, the construction cost can be sub-divided into the equipment for the different processes. These costs are shared by percentage. They are as follows;

- Coal Handling Equipment
- Gasification, ASU and Syngas Cooling
- Gas Cleanup and piping
- Fischer Tropsch synthesis reactors
- Combine cycle Power Block
- Remaining components/ Control systems

The Table 4.1 shows the share by percentage of the construction cost of the Process equipments;

Table 4.2: Major components of proposed plant and approximate share of Construction cost

Process Description	**Function**	**Share of Construction. cost (%)**	**Approximate cost ($)**
Coal Handling Equipment	Receives, prepares and feeds cool feedstock into the gasifier	11%	$525,525,000
Gasification, ASU and Syngas Cooling	Gasify coal into syngas, produces pure oxygen steam for gasification process, and cools raw syngas	27%	$1,289,925,000
Gas Cleanup and piping	Remove particulate and acid gases from syngas	7%	$334,425,000
F-T Synthesis Reactors	Converts syngas to F-T syn-crude(Liquid Hydrocarbons) and also produces Tail gas	11%	$525,525,000
Combine Cycle Power Block	Generate electricity with syngas and tail gas using a CT and steam turbine cycle	30%	$1,433,250,000
Remaining components/ Control system	Cooling systems, spent ash and sorbent handling, controls and structures	14%	$668,850,000
	Total	**100%**	**$4,777,500,000**

4.1.2 **Distribution of Construction Cost**

The distribution of the construction cost is shared amount the major components responsible for the operation of the proposed plant. The main components of the proposed plant include, coal handling equipment, Gasifiers, Air separation Unit, cooling equipment, cleanup reactors, Fischer Tropsch reactors, and the most important part, the combine cycle power block.

Furthermore, the piping, other components and control systems are introduced to monitor the flow, temperature and pressure of the synthesis gas in motion. The figure 4.1 below, show the distribution of the construction cost among the components of the proposed plant.

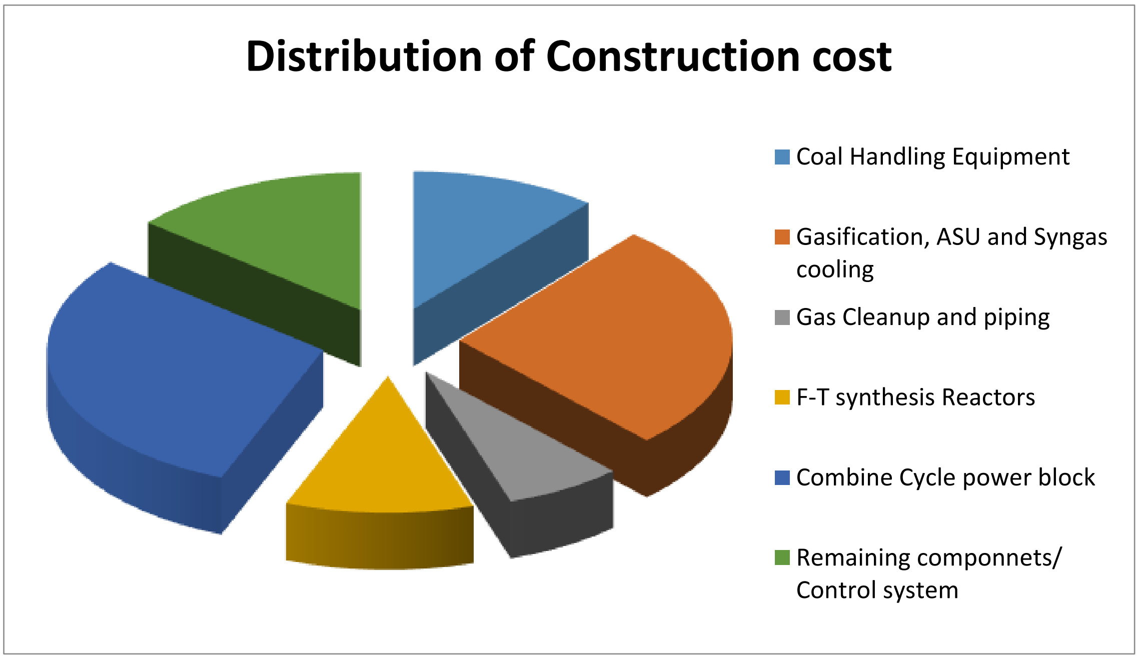

Fig 4.1: Distribution of construction cost

CONCLUSION

In conclusion, the proposed facility is a combination of the Integrated Gasification Combined Cycle and the Fischer Tropsch Synthesis without the inclusion of the Refining process (Product Upgrading) since the purpose of the Facility is to generate Energy for Power generation. The syngas produced from the Gasification cycle could also be used as a substitute for Natural Gas (Methane).

In subsequent time, the FT syn-crude could be passed through a refinery upgrading facility to produce Gasoline and Diesel fuel, or to a Naphtha Steam cracker to give Ethylene and propylene. The major components for the power generation are in the power block which consists of Gas turbines, a Heat Recovery Steam Generator (HRSG) and Steam Turbine. The Quantity of Units involved would determine the Total Gross output of the Power block. The

Gases are being produced. All we need do is to utilize their usage to the utmost capacity. This explains why for the proposed power plant, shell gasifier (dry feed) is selected for the gasification of coal to give syngas. Furthermore, the computation shows that for high moisture coals treated in efficient drying processes, the use of lower heating value in efficiency calculation overstates the efficiency. This study evaluates the technical, economic and financial viability of a Gasification/ liquid fuel production/Power generation plant to be sited near a revived coal mine site in Enugu state, Nigeria. Electricity generated from this plant would primarily be used to support power generation in Nigeria through the National power grid, while the liquid fuel (F-T syn-crude could be marketed to Refineries for production of commodities to be used in-state. Key components of the proposed power generation plant include:

- Shell Gasifier- dry feed gasification using coal as feedstock
- 95% purity of Oxygen production using the Air separation unit (ASU)
- Syngas cooling through Waste heat boiler or direct quench process
- Warm gas water scrubber for particulate removal
- Cold gas cleanup process for Hydrogen sulfide, Carbonyl sulfide and nitrogen compound removal
- Mercury removal using Activated carbon bed
- Fischer Tropsch syn-crude production including Tail gas recycle for gas turbines
- Power production from Power block consisting of Gas turbines, Heat Recovery steam generators and steam turbines

The proposed power generation plant would use indigenous coal to produce synthesis gas for the powering of Gas turbine and exhaust gas from it, passed through the HRSG to power a steam turbine. It is estimated to produce at least 725 MW net of power with useful life of at least 30 years. Economically, the most challenging aspect was in the estimation of financial performance of the plant using pre-existed past values which includes the EPC cost, while plant availability would have the largest impact on ROI (Return on Investment), with power generation being of greatest significance. Environmentally, coal used in power plants accounts for over 28% of global CO2 emissions, a share that is still rising. An absolute priority of the proposed plant is to enhance plant efficiency, which can significantly reduce CO2 emissions, not forgetting SOx, NOX and PM pollutants. The plant is also proposed to have the lowest collateral solid wastes and waste water and not to mention, the potential for lowest cost removal of Mercury and CO2. Coal based thermal power stations are the leading provider of electricity in the world. To continue this way without affecting the environment in the negative way, Integrated Gasification Processes are involved which results in the removal of the harmful gases and particulate matter, constituted as components of coal. To achieve this, policy makers must reflect on what steps are needed to improve the overall efficiency of power generation from coal.

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