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Prospect for Coal-Bed Methane (CBM) Resource Development in Nigeria: A Review

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ABSRACT

Nigeria is endowed with many natural resources, some of which are yet to be fully utilized. Amongst the many natural resources found in the country is coal, which also has the potential of being a source of methane; commonly referred to as coal-bed methane. Coal-bed methane is a form of natural gas extracted from coal beds. Natural gas, which is predominantly methane, is fast becoming an essential source of today's energy demand. Coal-bed methane (CBM) will not replace other fossil fuels in Nigeria but it will be burned in addition to the oil, coal and gas that have already been discovered to complement them. Hence, this study has presented several reported developed methods used to extract coal-bed methane, an attempts a recommendation of her application in Nigeria. Three methods of extracting coal-bed methane were examined in this study; which is pre-coal mining also known as Coal Seam Gas (CSG), Underground coal mining and Underground Gasification of Coal (UGC). The method recommended is the CSG method; the CSG distinctions have been noted over the other means of extracting methane from coal. The quality of methane that CSG method provides and the availability of the technological requirement make it more applicable to Nigeria coal deposits.

Keywords: *coal-bed methane, coal seam gas (CSG), gasification, mining, fossil fuels, oil and gas.*

INTRODUCTION

Fossil fuels comprise nearly 90% of the proved reserves of global energy.Figure 1, presents the major sources of natural gas as well as distribution. Coal is the major component of fossil fuel containing nearly 90% of the fossil fuel energy. Coal-bed methane (CBM) is a symbiotic or associated gas present in the coal seam with methane as its main component. Coal-bed methane (CBM) is an unconventional form of natural gas found in coal deposits or coal seams. Methane (CH4) is a gas formed as part of the process of coal formation. When coal is mined, methane is released from the coal seam and the surrounding disturbed rock strata. In traditional coal mining, CBM is considered a type of hazardous gas, not only because of the danger of explosions and gas outbursts, but also because of serious threat to the safety of mine production [13]. In contrast, methane, the main ingredient of CBM, it is a greenhouse gas, whose greenhouse effect is 21–23 times stronger than carbondioxide. Coal-bed methane as a natural-gas resource received a major push from the US federal government in the late 1970s. Federal price controls were discouraging natural gas drilling by keeping natural gas prices below market levels; at the same time, the government wanted to encourage more gas production. Coal-bed methane was exempted from federal price controls, and was also given a federal tax credit. In Australia, commercial extraction of coal seam gas began in 1996 in the Bowen Basin of Queensland [12] .

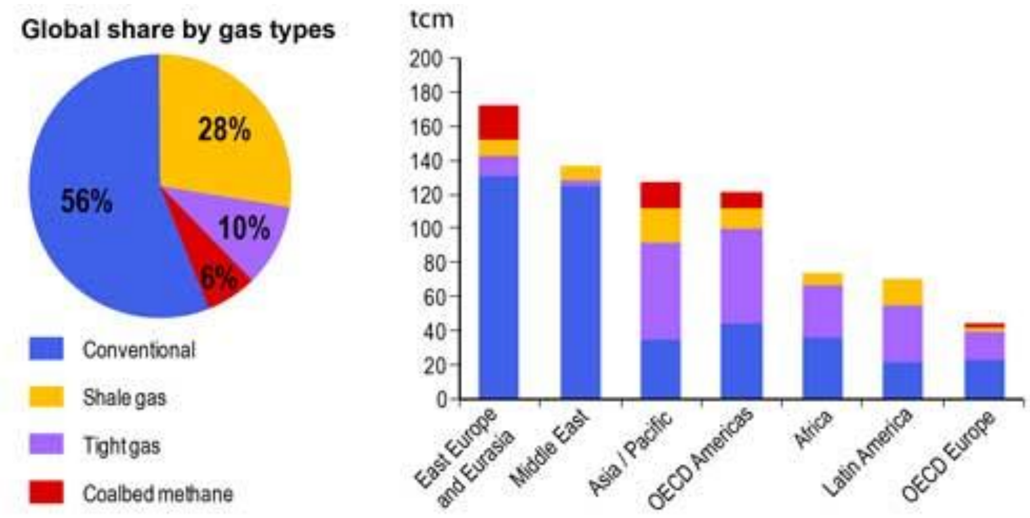

Figure 1: Global share of sources Natural gas resources by type and region

Coal-Bed Methane (CBM)

Coal Based Methane or Coal-bed methane (CBM or coal-bed methane), coal-bed gas, coal seam gas (CSG), or coal-mine methane (CMM) is a form of natural gas extracted from coal beds. Coal-bed Methane (CBM) can also be defined as the gas which is trapped in coal seams. Coal-bed methane is distinct from typical sandstone or other conventional gas reservoir, as the methane is stored within the coal by a process called adsorption [3]. The methane is in a near-liquid state, lining the inside of pores within the coal the matrix. The open fractures in the coal (called the cleats) can also contain free gas or can be saturated with water. Unlike much natural gas from conventional reservoirs, coal-bed methane contains very little heavier hydrocarbons such as propane or butane, and no natural-gas condensate. It often contains up to a few percent carbondioxide. During coalification, large quantities of methane-rich gas are generated and stored within the coal on internal surfaces. Because coal has such a large internal surface area, it can store surprisingly large volumes of methane-rich gas; six or seven times as much gas as a conventional natural gas reservoir of equal rock volume [32].

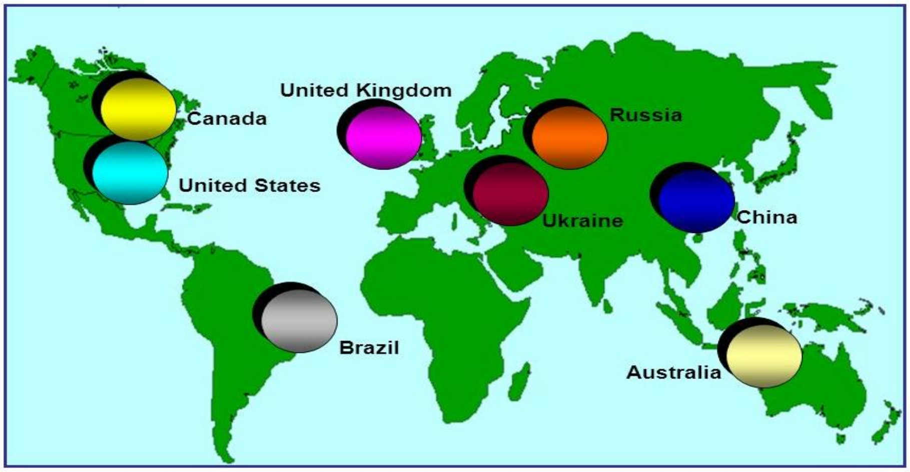

Figure 2: Countries with Coal-bed methane development programs

World Reserve of CBM

Largest proven recoverable coal reserves, according to the latest published data, are in the USA (28.6%), followed by Russia (18.5%), China (13.5%), Australia (9.0%) and India (6.7%). Shallow coal deposits in many areas, such as in the UK and in some other European nations, have been extensively mined, yet deep coal seams beyond the reach of mining operations present opportunities for development. Even with little minable coal remaining, the UK still ranks sixth worldwide in estimated CBM reserve

Table 1: Global Estimates of CBN reserve

Country	Estimated coal reserve (10^9 tons)
United States	3000
Russia	5000
China	4000
Canada	300
Australia	200
Germany	300
India	200
South Africa	100
Poland	100
Other countries Total gas in place (GIP)	200

COAL HISTORY AND PRODUCTION IN NIGERIA

Nigeria, one of the West African countries and the most populous Africa countries is a country located on the latitude 10°N longitude 8°E in Western part of the continent of Africa. One of the natural resources found in this gifted country is coal [2]. Nigeria ranks low in worldwide coal production, with less than 30 thousand tons of coal production in 2012. Nigeria estimated its coal reserves at more than 2 billion tons, with approximately 650 million tons (MMT) as proven. Although coal was the first energy resource to be exploited by Nigeria, a transition to diesel fuel for rail transport and to gas for electricity generation led to a decrease in coal production (Coal Mine Methane – CMM). Currently, there exist two types of gas operator agreements in Nigeria: joint operating agreements and production sharing agreements. Nigeria's robust natural gas industry provides a market conducive to CMM development. The expected increase in gas infrastructure will enhance the ability to move drained CMM from the wellhead to market. A mixture of gases (chiefly hydrogen, methane, and carbon monoxide) obtained by the destructive distillation of coal and formerly used for lighting and heating. Nigeria coal resources has been said to be located in the Cretaceous Anambra and Makurdi Basins, and Afikpo Syncline and occur in two levels: the lower Mamu Formation and the upper Nsukka Formation. Coal seams occur in three main stratigraphic levels [22]. The brown coals (lignite) of Ogwashi – Asaba Formation of Miocene to Pliocene ages, the upper and lower sub-bituminous coal measures of Maastrichtian age and the bituminous coals of the Awgushales of Coniacian age (CMM). This coal is predominant in several mine sites and this coal is located in Enugu, Imo, Kogi, Delta, Anambra, Bauchi, Adamawa, Ondo and Edo States of Nigeria. The Coal is mostly sub-bituminous with large output and quite deep in the ground (CMM).

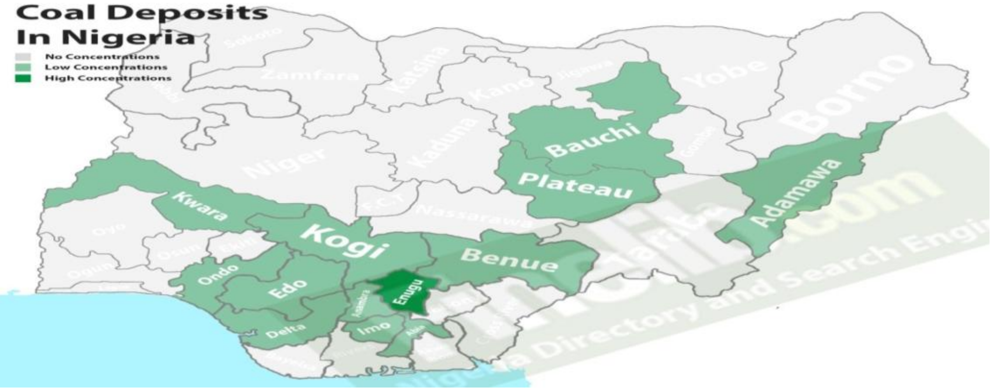

Figure 3: Coal deposits in Nigeria

Accessing the Nigeria Coal

Coal mining leases (CML) can be obtained either through an approved (by the Ministry of Mines and Steel Development) acquisition of an existing mining property or by applying for a Prospecting Right or License. Gas producers must perform gas field optimization analyses on their concessions and the government is responsible for optimization of gas field development overall. Nigeria's efforts to wean its population away from harvesting timber for cooking fuel may stimulate coal production and CBM development. As mentioned above, however, the current low level of coal production in the country is not conducive to a robust CBM development industry (CMM).

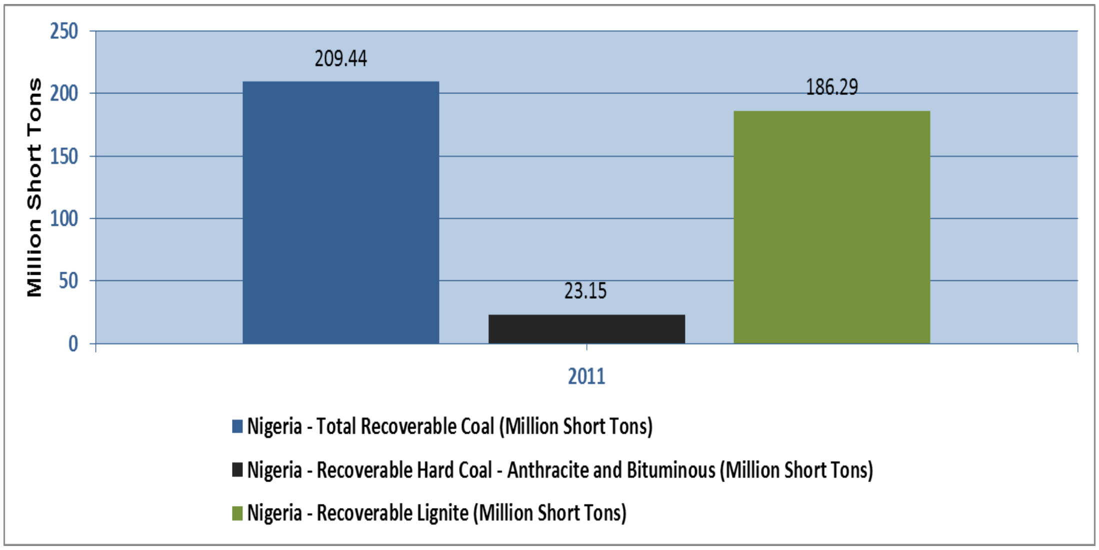

Figure 4: Nigeria Coal Reserves

Limitation to CBM Development in Nigeria

Nigeria has such substantial gas resources that supplement the streams captured at coal fields but appear relatively insignificant in comparison, thereby diluting interest in CMM development. Methane emission sources vary in Nigeria as compared to other developed countries. Emission of methane in Nigeria comes mainly from gas and oil systems (CMM). Also, the amount of CMM that can be recovered in conjunction with coal mining has been reduced over time (CMM).

The CBM/CMM potential in Nigeria is presently low. Nigeria will like to cooperate with developed partners in this area. Currently, there is no production since the emissions is low and unattractive minimal capture of CMM.

CBM Extraction Methods

Several methods have been developed to extract coal-bed methane gas. Generally, the gas content of coal increases with depth and rank of the coal seam. At the same time, many ways exist to develop CBM. Major way is through drilling, which involves the Conventional drilling and/or Horizontal Drilling.

The three methods of extracting coal-bed methane that will be examined are

i. Pre-coal mining also known as Coal Seam Gas,
ii. Underground coal mining and
iii. Underground Gasification of Coal (UGC)

Pre-coal Mining (CSG)

One way is to drill a well to the coal seam, fracture the coal, pump out the water, and connect the well to a pipeline. Wells are drilled down to the coal-bed or just above the coal-bed, there some gas is produced upon drilling [18]. Coal-bed methane grew out of venting methane from coal seams. Some coal-beds have long been known to be "gassy" and as a safety measure, boreholes were drilled into the seams from the surface, and the methane allowed venting before mining. Fracking is a process associated with CSG. Extraction does not always involve fracking but as gas flow starts to decline after a few years of using CSG method, wells are often fracked to increase productivity [3]. In Australia where coal seam gas is more developed, the industry estimates that up to 40% of wells end up being fracked. Fracking is the practice of using high-pressure pumps to inject a mixture of sand, water and chemicals into bore wells in order to fracture rocks and to open cracks (‘cleats’) present in the coal seams thereby releasing natural gas in the process [9]. The aim of fracking is to massively improve permeability by creating (or reopening) a locally dense network of open and connected that is, hydraulically conductive fractures [6]. CSG wells are about the size of a dinner plate. They are drilled into the ground until they reach the coal seams, and the surrounding area is lined with steel casing and a cement barrier to protect it. First, some water is extracted from the well. This reduces the pressure in the underground coal seam and allows the gas to flow into the well and to the surface. When in operation, the surface area of a fenced CSG well is generally around half the size of a netball court. Once the gas and water reach the surface, they are separated and flow along underground pipelines to nearby processing facilities. Water is sent to a treatment facility and gas is sent to a processing plant. Once the gas arrives at the processing plant, any remaining water is removed and the gas is compressed (put under pressure so it can flow) for distribution.

Figure 5: Australia Coal Seam Gas with proven reserves [10]

Underground Coal Mining

The coal is mined out and the roof collapses, creating a large void of collapsed rock called "gob". Gas accumulates in the gob and is pumped out by the existing gas well. Some success has been achieved when the drilling is coordinated with mining of the coal. A different approach to this is the drilling of gas wells into abandoned underground mines. Majority of the old underground mines are filled with methane and other gases that blend with the air already in the mine. The gas can be produced with this method but the methane gas that will be obtained in this method is generally of lower quality because it has mixed with other gases [18]. Methane released from the worked coal face is diluted and removed by large ventilation systems designed to move vast quantities of air through the mine. These systems dilute methane within the mine to concentrations below the explosive range of 5-15%, with a target for methane concentrations under 1%. The ventilation systems move the diluted methane out of the working areas of the mine into shafts leading to the surface. The methane removed from working mines via this technique is known as Ventilation Air Methane (VAM). The VAM is released through the ventilation shafts and captured for utilisation. Methane gas produced from abandoned coal mine workings are through mine entries and from boreholes drilled into underground roadways or former workings.

Underground Gasification of Coal

Underground Coal Gasification (UCG) is an alternative method of converting deep coal into gas underground using a series of boreholes operated remotely from the surface [4]. UCG differs from other ground gasification in that it is an in-situ gasification process; the coal resources are gasified while still in the coal seam [1]. According to a similar work, Underground Coal Gasification has been said to be the process of gasifying coal in-situ, that is, within an underground coal seam [23]. Gasification is a chemical process that converts hydrocarbon feedstocks (e.g. coal, biomass) into a synthetic gas consisting primarily of carbon monoxide (CO), hydrogen gas (H_2), methane (CH_4), and carbon dioxide (CO_2) [7]. Air or a combination of oxygen and steam are injected into the gasification panel within the coal seam. The coal is then heated and controlled reactions convert solid coal into product gas, known as “syngas”, which is extracted at the surface [23]. Some of the factor that affects underground mining includes dimension or size of deposit, direction and slope of the coal, age mine, value of deposits, ground water mine, facilities available etc.

Underground coal gasification (UCG) operating conditions will require injection well construction and materials to withstand the extreme thermal and mechanical stresses associated with UCG: high pressures and temperatures (up to $1500^{o}C$), sulfidation and oxidation reactions, and subsidence of the cavity roof. Wells will be cased with carbon or high-strength stainless steel. The cementing of the wells will be done above the reaction zone to facilitate the controlled introduction of air and to prevent loss through the wellbore of gases to the surface or into overlying strata.

ENVIRONMENTAL IMPACT OF CBM

Generally, the unconventional means of deriving coal-bed methane are associated with some environmental issues. Unconventional Gas exploitation and production may have unavoidable environmental impacts. Some risks result if the technology is not used adequately, but others will occur despite proper use of technology.

Unconventional Gas production has the potential to generate considerable Green House Gas (GHG) emissions, can strain water resources, result in water contamination, may have negative impacts on public health (through air and soil contaminants; noise pollution), on biodiversity (through land clearance), food supply (through competition for land and water resources), as well as on soil (pollution, crusting). By developing these new energy extraction techniques we are expanding global reserves of hydrocarbons and increasing emissions. The chemistry of the atmosphere is changing and due to drought, flood and starvation the global death toll already stands at 450,000 annually [27]. The presence of Coal-bed methane gas is well known from its occurrence in underground coal mining, where it presents a serious safety risk. Coal-bed methane can be found almost anywhere there is coal. It is considered as a dangerous nuisance in the mining industry [1].Globally, exploiting the world's reserves of unconventional gas could lead to a temperature rise of 3.5 degrees Centigrade. This is way above the 2 degrees rise that the UK and other developed countries has said is necessary to avoid dangerous climate change.The chemicals used in CBM drilling mud can be just as toxic as those used in fracking, and there are the same risks of spills and leakages [3] and because CBM is typically found at much shallower depths than shale gas, risks such as groundwater contamination are increased [1]. In another related research CBM waste water was said to be extremely salty and has been found to contain not only harmful chemicals from the drilling fluids used, but also highly toxic BTEX (benzene, toluene, ethylbenzene and xylenes) chemicals including known carcinogens, and naturally-occurring radioactive materials [28]. Spills and leaks of drilling fluids can also contaminate agricultural land and harm livestocks [1].

Evidence is emerging from Australia that existing treatments cannot remove all the toxins found in CBM wastewater. Extracting water from coal seams can also lead to depletion of groundwater. Communities living near CBM extraction sites in Australia have complained of respiratory problems, rashes and irritated eyes. But the long-term health impacts could be more severe. Research from the USA has found that people living less than half a mile from unconventional gas wells have a higher excess lifetime risk for cancer, based on their exposure to air pollutants. Large quantities of methane, hydrogen-sulphide, nitrogen oxides (NO_x) and other pollutants are emitted from site equipment, diesel generators and trucks. Noise pollution and further emissions of methane and airborne pollutants occur as the gas is processed and pressurized in sprawling temporary infrastructure. Flare stacks burn off unwanted gases and cause noise and light pollution and more toxic emissions [27]. The pipelines used for transporting gas and waste create the additional danger of leaks and explosions. Pipeline construction cuts scars across the countryside and blights surrounding areas with planning restrictions. Flare stacks burn off unwanted gasses on every site and cause noise or light pollution and toxic emissions. Noise pollution and further emissions of methane and airborne pollutants occur as the gas is processed and pressurized [27].

Environmental Implications of Fracking Process

Fracking as one of the methods of extracting CBM that is associated with

Coal Seam Gas Method has been noted as a process that attention needs to be given to. The social and environmental impact of fracking is an emerging issue of concern around the world, including Australia. Fossil fuels are the world's main source of energy, accounting for 81% of global primary energy use in 2010 [15]. However, as conventional reserves are depleted and demand for energy rises, there is increasing pressure to exploit unconventional energy sources [29]. Unconventional gas has triggered both strong opposition and heightened economic interest [31]. The social and environmental impacts of fracking cut across many issues including: climate change; sustainable/renewable energy; hazardous waste disposal; air, soil and water pollution; and land and water use [9]. Road damage is an inevitable consequence of CBM exploration due to intensive transportation of materials and machinery. The cost caused by road damage due to fracking traffic has surpassed the tax revenues generated by fracking in most U.S states [27].

Environmental Implications of Underground Gasification of Coal

The major environmental implication of underground gasification of coal is groundwater contamination. During the energy crisis of the 1970s, U.S. interest spiked in all forms of alternative energy, and the Department of Energy (DOE) invested billions of dollars to develop efficient coal-gasification technologies for power generation. Over 30 underground coal gasification (UCG) pilot tests were run across the U.S. At that time, the hydrogen byproduct of UCG was viewed as a liability, reducing the perceived quality of the gas. In addition, groundwater-contamination problems resulted at two sites [20] A review of past UCG projects indicated that the risk of contamination of groundwater through gas escape and leachate migration was the most significant environmental issue of UCG [5]. Several steps can be taken to avoid groundwater pollution. One is balancing operating conditions to minimize the transport of contaminants from over-pressurized burning zones. Another is to locate a UCG site where natural geologic seals isolate the burn zone from surrounding strata. Isolating the site from current or future groundwater sources and understanding how UCG affects the local hydrogeology are essential. Another environmental concern is that the void created by gasification may cause the land surface to subside. Subsidence is likely to be more of a problem if gasification occurs in a shallow coal seam, closer to the surface. This phenomenon also often occurs above long-wall underground coal mines but is less of a problem if the seam is deep [20]. CBM would also have a significant impact on local landscapes [3]. Subsidence and earthquakes may be caused by the process and are quite common in conventional coal mining [27].

UNDERGROUND COAL GASIFICATION DISTINCTION

Due to the various environmental effects caused by Coal Seam method of extracting Coal-bed methane and the low quality associated with Underground Mining of Coal method, these made underground coal gasification(UCG) method to stand out. UCG distinctions have been noted over the other means of extracting methane from coal. According to Carbon Energy Fact Sheet [4], it identifies ways in which UCG is distinct above any other method of extracting coal methane; UCG delivers 20 times more energy from the same coal resource than what's possible from CSG. Also, UCG does not reduce the natural groundwater pressure. UCG does not pump groundwater to the surface and UCG does not involve "fracking". UCG offers the potential to use the energy stored in coal deposits that are uneconomic to mine by conventional methods that is underground coal gasification allows access to coal resources that are not economically recoverable by other technologies, e.g., that are too deep, low grade, or seams too thin.. The use of UCG could potentially increase global coal reserves from 900 billion tonnes to 1.5 trillion tonnes [33]. Livermore and Linc Energy claim that UCG capital and operating costs are lower than in traditional mining.UCG product gas is used to fire combined cyclegas turbine (CCGT) power plants, with some studies suggesting power island efficiencies of up to 55%, with a combined UCG/CCGT process efficiency of up to 43%. CCGT power plants using UCG product gas instead of natural gas can achieve higher outputs than pulverized-coal-fired power stations (and associated upstream processes), resulting in a large decrease in greenhouse gas (GHG) emissions. No need to mine the coal or build a surface plant for gasification. Elimination of the safety hazards associated with underground coal mining. The syngas product can be used in a variety of industrial processes including power generation, liquid fuel production and chemical manufacture [23]. Significant environmental benefits, such as reduced surface disturbance and land use conflicts (compared with coal mining and oil and gas operations), avoidance of greenhouse gas production associated with coal mining and a relatively small physical footprint for large amounts of energy extraction.

UTILISATION OF CBM

According to a report earlier cited, CBM has been said to have potential as an abundant clean energy supply to help replace other diminishing hydrocarbon reserves [1]. Recent developments in technologies and methodologies are playing a large part in harnessing this unconventional resource. In recent decades it has become an important source of energy in United States, Canada, Australia, and other countries. It is well documented that long term global economic growth cannot be achieved without adequate and affordable energy supplies, which will require continuing significant contributions from fossil fuels, including coal. As such, coal plays a unique role in meeting the demand for secured energy, as it is globally the most abundant and economical of fossil fuels. At current production levels, proven world coal reserves are estimated to last 147 years, in contrast to oil and gas which are estimated to last 41 and 63 years, respectively [17]. Capturing methane as a marketable resource has the potential to benefit the coal industry. One possible solution to methane control is commercial production of the gas before coal mining takes place. This gas could be accumulated locally and used to generate power or be transported by pipeline to serve other markets, depending upon the quantity and quality of the gas [13].

TECHNOLOGY AVAILABILITY

The availible technology in Nigeria favours the use of CSG i.e pre-coal mining method since the same method is applicable to oil and gas industry in Nigeria. Also, the availability of underground mines in Nigeria is limited to the few ones that are present in the country.

Injection Process

The injection process uses the control refinery injection process (CRIP). In the CRIP process, the production well will be drilled vertically, and the injection well is drilled using directional drilling techniques so as to connect to the production well. Once the channel is established, a gasification cavity will be initiated at the end of the injection well in the horizontal section of the coal seam. Once the coal near the cavity is used up, the injection point is retracted (preferably by burning a section of the liner) and a new gasification cavity is initiated. In this manner, a precise control over the progress of gasification will be obtained. The CRIP process retracts the combined steam and oxygen injection point to control the location of the combustion front. The syngas, which was more than a third hydrogen in many of the early UCG pilots, (remainder is Carbondioxide, Carbon-monoxide,methane and higher hydrocarbons) will be brought to the surface and processed to remove particulates. The syngas flows from the gasification chamber through the horizontal connection in the coal seam and flows to the surface through another well (production well). The composition of the gas produced depends on many factors including coal type, operating pressure and temperature, water ingress to the process, and the type of oxidant used (air or oxygen).

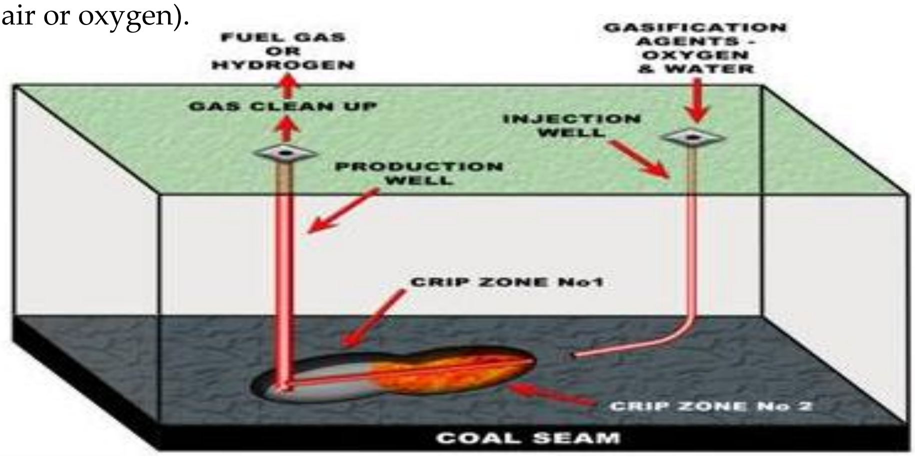

Figure 6: Underground Coal Gasification

According to U.S Coal Mine Methane Emissions Inventory 2013, more methane gas is emitted by Underground mining method through VAM follow by Surface Mine. Next is Post Mining Underground and Abandoned underground mine

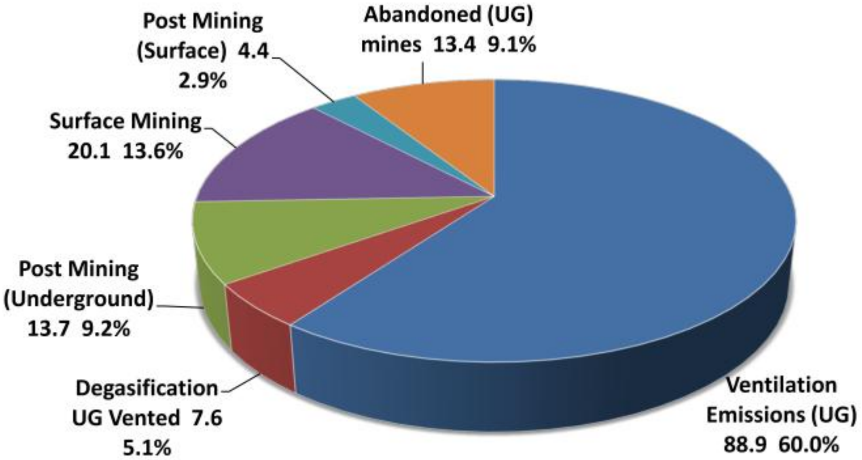

Figure 7: 2013 U.S Coal Mine Methane Emissions Inventory

This plot in the figure below shows the probable decline rate of emission of methane from an abandoned underground mine using Central Appalachian Mine which was closed in 1980 as an illustration. It is observed that emission rate from an abandoned mine decreases over the years.

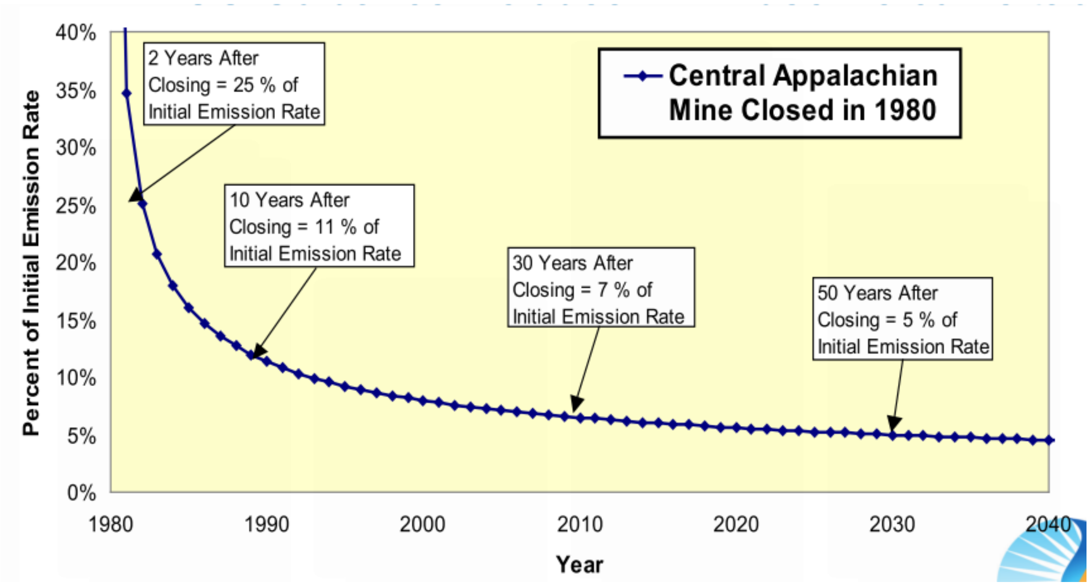

Figure 8: Decrease in underground emission rate for a typical abandoned underground mine

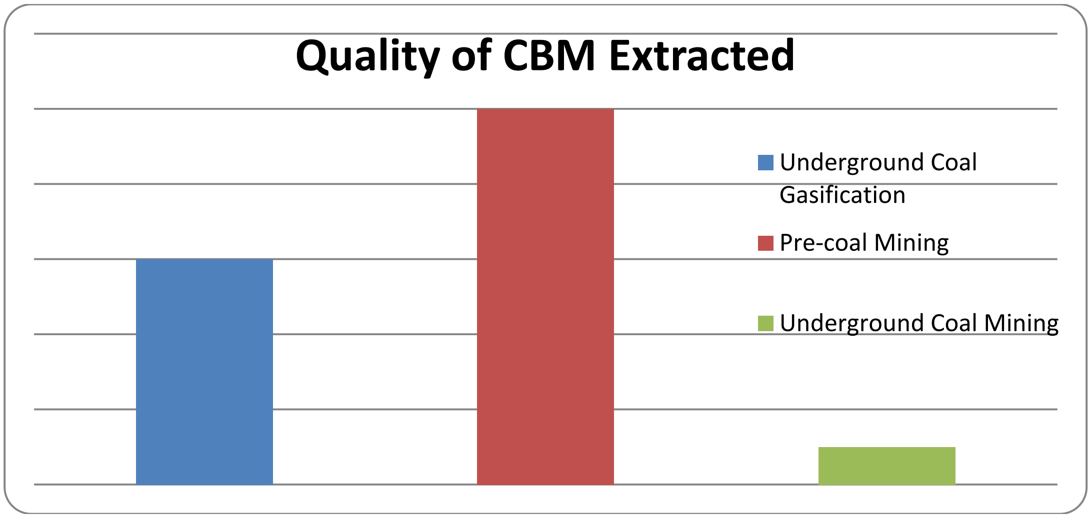

Figure 9: Quality of methane generated through each method

Methane gas that is obtained using Underground Coal Mining method is generally of lower quality because it has mixed with other gases. Also, the production of methane from Underground coal gasification is associated with some particulates.

CONCLUSION

Since Nigeria has few available underground coal mine. The available ones majorly located in Enugu state. The underground method of extracting methane may not be recommended. The quality of methane that CSG method provides and the availability of the technological requirement make it more applicable to the Nigeria coal deposits.

Nigeria coal methane is to be tapped because Coal is one of the Indigenous Energy Resource in the Nigeria. Natural Gas is the Most Convenient and Cleanest Consumer Fuel for Heat, Power & Automotive Use. Transportation and Distribution of Natural Gas by Pipeline is Widely Available and Economical. Natural Gas Resource in the Nigeria is Limited. Natural Gas Demand is increasing. Coal-bed Methane (CBM) Production is increasing in supply in the advanced countries.

RECOMMENDATION

Methane should be used to supplement the existing gas system in Nigeria since it has been said that CBM will not replace other fossil fuels, it will be burned in addition to the oil, coal and gas that has already been discovered. The method of CSG should be employed in accessing the methane contained in the Nigeria Coal since this method generates good quality of methane from coal and the technology is locally available. Some of the available options of profitable use of methane include natural gas pipeline injection, power production, co-firing in boilers, district heating, coal drying, and vehicle fuel. Government should invest in the development of methane from coal in Nigeria and create the enabling environment in which investors can come and develop the Nigeria methane from coal. Investors should consider the vast deposit of Nigeria coal as a possible area to investment in the development of the world methane.

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