Gas Monetization in Nigeria: Review of Constraints and Economic Implications

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ABSTRACT

Stranded gas has huge economic implications for Nigeria as there are 184 TCF stranded gas reserves in the country. Oil currently represents more than 90 percent of Nigeria's foreign trade earnings, hence, there is hope for expanded income from natural gas, if the gas being flared is monetized. Monetizing stranded gas reserves needs access to distribution facilities. It then becomes imperative for Nigeria to set up these facilities in order develop her tremendous stranded natural gas reserve to boost her economy, reinforce regional collaboration, and satisfy growing demand in the global market. This paper presents current innovations for monetizing stranded gas, and evaluation of Nigeria's accomplishments in monetizing stranded natural gas reserves. The monetization technologies and projects evaluated are liquefied natural gas (LNG), gas-to-liquids (GTL), compressed natural gas (CNG), gas-to-wire (gas-fired power generation), and gas-to-solid. Nigeria's accomplishments in monetizing stranded gas include the Nigeria LNG plant, Brass LNG plant, Escravos GTL plant, Bonny Non-Associated Gas plant, West Niger Delta LNG plant, Olokola LNG project, Nigeria Gas Company, and thermal power plants. A number of these projects have not arrived at operational stage, even those that have come to operational stage are partially in operation. A couple of those that were completely operational, were closed down because of poor maintenance and gas supply. The shutdown of these facilities caused a drop in power generation nationwide. Sequel to this, gas utilisation in Nigeria is still not adequate in comparison with other oil and gas producing nations of the World. The possibilities of monetizing natural stranded gas in the future are recommended for Nigeria to serve her economy, have a steady power supply, add to global greenhouse gas (GHG) decrease, and overcome the ever increasing energy and petrochemical demands in the global market. These possibilities comprises natural gas storage (to limit gas flaring and enhance oil production), enhanced gas-fired power generation, dimethyl ether (DME), and gas-to-ethylene syntheses to mention but a few.

Keywords: Natural gas, gas monetization, Nigeria, Gas utilization technologies, Stranded gas, gas flaring.

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INTRODUCTION

Natural gas as a global energy technology has been gaining extensive attention lately because of fluctuating oil prices, a requirement for energy diversification and security, the increasing global concern over environmental issues and because of the development of new gas utilization technologies. Current global reserves of natural gas is around 6,100 trillion cubic feet (tcf), as per EIA forecasts. Of these, about half are seen as stranded, that is, uneconomic to produce and convey to the market. This usually happens when reserves are in remote areas, or when they are found in deep subsea area and in complex geological formations. Another type of stranded natural gas is associated gas, or gas found in association with operations of big oil fields. While crude oil can be conveyed to far markets with relative ease, the practice in the past has been to flare associated gas at the well head (Marcano and Cheung, 2007).

Flaring natural gas is both ineffective and impacts on the environment negatively. Around 5 trillion cubic feet (TCF) of gas are flared every year (World Bank, 2009). Gas flaring is the burning of natural gas associated with oil production. It is a 160-year-old industry practice that adds to environmental challenge, producing in excess of 350 million tons of CO_2 emissions yearly, together with methane and carbon monoxide discharges. Gas flaring also wastes a significant resource that could provide energy to millions of individuals in developing nations. The practice continues till date due to different technical, regulatory, as well as financial requirements. Recently released estimates from satellite data reveals a 3% rise in 2018 to 145 billion cubic meters (bcm), which is comparable to the total yearly gas consumption of Central and South America (World Bank 2019). In the United States, gas flaring increased approximately by 50% from 2017 to 2018 because of 33% increase in oil production. In the interim, nations battling with political turmoil and struggle encountered an expansion in gas flaring. Even countries like Venezuela, Syria and Yemen which are struggling with political unrest and conflicts also experienced an increase in gas flaring.

Official data reveals that Nigerian oil production has tremendously increased from about 2 million bbl/d throughout the previous couple of years to 2.5 million bbl/d in 2019. Oil production levels determine the volume of associated gas (AG) produced, and thus decide the measure of flaring. On the average, approximately 1000 standard cubic feet (scf) of gas is produced in Nigeria with each barrel of oil. Consequently, with oil production of some 2.5 million barrels per day, about 2.5 billion scf of associated gas is produced each day. In the year 2000 it was estimated that gas production of 4.6 bcfd was largely wasted with almost 55 percent or close 2.5 bcfd being flared. The gross financial estimate of this gas is approximately US$2.5 billion per year to the economy, summing up to US$50 billion within 20 years. This volume of gas can be split between reinjection, NLNG feedstock, internal fuel utilization, and a little percentage sold as LPG. Best forecasts of gas-flaring profile in specific nations in the year 2018, reveals that Nigeria flares the most gas after Algeria , both flaring 9 and 7.4 billion cubic meters respectively and flaring most gas per tonne of oil recovered, Russia emerged as the world's highest flarer and venter with 21.3 billion. Nigeria till date routinely flares 63% of the associated gas produced per day during the production of crude oil (NAPIMS Bulletin, 2013). Natural gas in spite of being one of the most abundant energy sources on earth, has more than 33% of the global reserves stranded and hence cannot be economically produced and marketed (Thackeray and Leckie, 2005). About 70% of the global traded gas is exported by pipeline, and the remaining 30% by Liquefied Natural Gas (LNG). The global natural gas reserves by region reveals that Africa has 490 TCF of stranded gas resources with Nigeria having about 38% of that. Adding the flared gas resources to stranded gas reserves will create added value opportunities and secure the environment (Henry Aldorf, 2008). Though this practice is no longer acceptable because of environmental concerns and, more recently, because of the increasing monetary estimation of these reserves in a high energy value environment. The oil industry are currently hoping to utilize innovation to capture associated gas and offtake it to the markets (Marcano and Cheung, 2007). In the course of the last two decades, a few innovations have been assessed and proposed for monetizing previously remote gas reserves. These comprises Gas-To-Liquid (GTL), gas-to-wire, Compressed Natural Gas (CNG) and gas-to-solid technologies. The last two technologies are still in the development stage and, despite the fact that the capability of these alternatives has been investigated in the past decade, they are yet to be deployed on a commercial scale (Wood and Mokhatab, 2008; Lawaletal 2015). Cognizant to this, this paper evaluates gas monetization in Nigeria.

NATURAL GAS PRODUCTION AND UTILIZATION IN NIGERIA

Natural gas production has increased tremendously from 310 million cubic meters in 1961 to 101,976 million cubic meters in 2002. Though, it is essential to take note of the fact that there is virtually no exploration of gas in Nigeria. Most gas reserves were found while exploring for oil. Hence, high oil production means that extra high volumes of associated gas will be produced. The primary driver of gas utilization projects in Nigeria had been any administration's quest to create more wealth and diversify the economy of the nation. Since the 1980s, there has been increasing use of gas in Nigeria; for power, fertilizer and petrochemical manufacturing and as feedstock for direct steel reduction. But the biggest gas users are the Liquefied Natural Gas (LNG) business and the Aluminum refining industry. The National Gas Company (NGC) currently supplies gas for power generation, as source of fuel or as feedstock to industries, and the demand keeps increasing. Domestic gas demand is approximately 400 million cubic feet per day (MMcf/d) which is extremely low compared to Nigerian population of more than 200 million and its gas resources. The domestic market is constrained by the low level of industrialization and the deficiency of the gas transmission and distribution facilities.

LIQUIFIED NATURAL GAS (LNG) PROJECTS IN NIGERIA

The Nigeria Liquefied Natural Gas Company (NLNG) was registered as a privately held company in 1989 to exploit Nigeria's tremendous natural gas assets and to produce LNG and natural gas liquids for sale. Shell holds a 25.6% shares in NLNG together with NNPC (49%), Total LNG Nigeria Ltd (15%) and Eni (10.4%). With the completion of a 6th production train in December of 2007, the Nigeria LNG Plant at Bonny Island has a total capacity of 22 million tonnes per year of LNG and 4 million tonnes per year of LPG. It represents roughly 11% of the global total LNG capacity and is well situated to serve the European and North American markets. SPDC is the major provider of gas to the NLNG Bonny Island plant from its onshore and offshore fields (Obayemi, 2013). NLNG has a wholly owned subsidiary, 'Bonny Gas Transport Limited (BGT)', which offers shipping services to the NLNG. At present, Nigeria is constructing an LNG plant through NLNG (Nigeria Liquefied Natural Gas) Ltd, in a joint venture with three partners, namely, ELF, AGIP, and SHELL. The LNG plant site is situated at Finima in the Eastern region of Nigeria and, these three companies in joint venture with NNPC, will likewise supply up to 1 billion standard cubic feet of natural gas for feed stock/fuel to the plant from their Obite, Obiafu and Soku fields respectively. It is expected that flaring will be significantly reduced when these projects come on stream, coupled with the expected huge cash flow (Alawode and Omisakin, 2011).

NIGERIAN GAS COMPANY LIMITED

The Nigerian Gas Company Limited (NGC) was founded in 1988 as one of the 11 subsidiaries of the Nigerian National Petroleum Corporation (NNPC). It was set up to oversee the development of an effective gas industry to fully serve Nigeria's energy and industrial feedstock needs via an integrated gas pipeline system and also to export natural gas and its products to the West African Sub-region. The NGC right now operates eight (12) supply systems, namely: The Aladja Gas Pipeline System which supplies the Delta Steel Company, Aladja; the Oben-Ajaokuta-Geregu Gas Pipeline System, which will be the backbone of the proposed Northern Pipeline System, supplies Gas to Ajaokuta Steel Company, Dangote's Obajana Cement Company and PHCN Geregu Power Plant; the Sapele Gas Supply Systems which supplies gas to PHCN Power Station at Ogorode, Sapele; the Imo River-Aba System for gas supply to the International Glass Industry Limited PZ, Aba Textile Mills and Aba Equitable Industry; the Obigbo North - Afam system supplies to PHCN Power Station at Afam; the Alakiri to Onne Gas pipeline system supplies gas to the National Fertilizer Company (NAFCON) presently known as Notore Chemicals for fertilizer production; the Alakiri - Obigbo North - lkotAbasi system for gas supply to the former Aluminum Smelting Company of Nigeria (ALSCON) Plant now Rusal Industries in IkotAbasi; the Escravos-Lagos Pipeline (ELP), which supplies gas to NEPA's Egbin Power Plant close to Lagos. Subsequent lines from the ELP supply the West African Portland Cement (WAPCO) Plants at Shagamu and Ewekoro, PZ Industries at Ikorodu, City Gate in lkeja Lagos, PHCN Delta IV at Ughelli, and Warri Refining and Petrochemical Company at Warri; Ibafo – Ikeja Gas Supply Pipeline System supplies gas to Ikeja City Gate from where Gaslink disperses to the Lagos Industrial Area (LIA).

Ikeja – Ilupeju – Apapa Gas Pipeline System at present worked by Gaslink for Gas Supplies to Greater Lagos Industrial Area; Ajaokuta – Geregu Gas Pipeline System which supplies gas to the Geregu PHCN Power Plant; Ajaokuta – Obajana Gas Pipeline System which supplies gas to Dangote's Obajana Cement Plant (OCP). Every one of these facilities consist of more than 1,250 kilometers of pipelines ranging between 4 and 36 inches diameter across with a total design capacity of more than 2.5 billion standard cubic feet of gas per day (bscf/d), 16 compressor stations and 18 metering stations. The facilities represent a current asset base of more than N21 Billion (NNPC Bulletin, 2012).

NATURAL GAS MONETIZATION TECHNOLOGIES

Gas originating from the reservoir is treated to get rid of the following:

1. Acid gas, where acid gases are expelled to prevent $CO_2$and H_2S freezing in the beginning stages of the liquefaction process. 2. Dehydration to expel the water from the gas to prevent hydrates formation in flowlines and vessels. 3. Mercury expulsion, since the presence of mercury causes consumption issues in the aluminum heat exchangers utilized in the liquefaction process.

Liquefied Natural Gas (LNG)

The LNG technology comprises liquefaction, shipping, regasification and delivery into the pipeline framework. When natural gas, essentially methane, is cooled and liquefied via cryogenic processes at a temperature of about - 260°F (- 162°C), liquefied natural gas (LNG) is formed. Thus, natural gas volume is decreased to one six-hundredth (1/600), permitting its offtake by specialized LNG tanker ships over long distances. A typical LNG receiving terminal incorporates storage tanks and facilities for the regasification processes (Alawode, and Omisakin, 2011). The LNG projects in Nigeria are Brass (BLNG) project, Olokola LNG, West Niger Delta LNG Plant, Escravos GTL (EGTL) Project, Bonny Non-associated gas plant (BNAG)

Gas-to-Liquids Technology

Gas-to-fluids (GTL) is often utilized as a general term for all technologies that convert natural gas into a liquid product, including methanol, dimethyl ether (DME) and others. However, in this paper, it is restricted to FT-based processes that convert natural gas into synthetic fuels. This have two essential processing steps (1) methane reforming, and (2) Fischer-Tropsch synthesis.

Methane Reforming

Front end of the GTL process is the conversion of natural gas to a high energy mixture of carbon monoxide (CO) and hydrogen (H_2) known as synthesis gas, or simply syngas. Reforming technologies consist of two essential categories: partial oxidation (POX) and steam methane reforming (SMR). POX reforming comprises a set of technology, however is basically incomplete combustion (oxidation) of methane to yield carbon monoxide (CO) and hydrogen (H_2). Complete combustion yields carbon dioxide (CO_2) and water

(H_2O). Though more complicated, SMR is likewise a more efficient path to syngas; therefore it is utilized most commonly to produce hydrogen, representing over 90% of this market. SMR is a high temperature (700–1100°C) catalytic process that produces syngas from methane (CH4) and steam (H2O). The reaction, provided in standard equation underneath, is reversible in nature.

$CH_4 + H_2O \leftrightarrow CO + 3H_2$ ……. (1)

Fischer-Tropsch (FT) Process

The FT process was first established by Franz Fischer and HanzTropsch in Germany during the 1920s and 1930s. The chemistry lies on making longer chain hydrocarbons from a mixture of CO and H_2 at a high pressure and temperature and in the presence of a catalyst. The reaction is exothermic and too much heat is usually expelled by boiling water. Most of the products from FT synthesis are paraffinic waxes based on the chemical equation provided in equation 2 below:

$nCO + (2n+1)H_2 \rightarrow CnH_{2}n+2 + H_2O$ ……. (2)

By-products from the FT process are lighter hydrocarbons, including methane and naphtha. After the FT process, synthetic crude can be mixed with crude oil for offtake to the world market, or be upgraded to produce distillate products, particularly diesel and jet fuel (Strange, 2003). F-T products are additionally treated to optimize their sales value or to meet specific market needs. Thus, the upgrading of paraffins and olefins is possible by utilizing standard hydro-cracking, hydrogenation, oligomerization, and isomerization processes. The products of the GTL process is naphtha 15-25%, middle distillates 65-85%, and associated LPG condensates around 0-30% (Fleisch et al., 2002).

Floating LNG (FLNG)

This concept is a combination of LNG processing and storage technologies for subsea production. experience. Floating oil production vessels have been around for almost forty years, during which time excess of 125 of such vessels have been deployed. FLNG vessels concept are attractive as a result of their capacity to be deployed in small and remote natural gas fields. Ships with liquefaction infrastructures available can be used over several fields in sequence as each field gets depleted, eliminating the need to construct new facilities. These vessels will work in association with relatively small and remote installations. Small number of personnel would be affected in case of an incident, improving safety and security due to their remoteness. This factor is of particular significance in the present day security-conscious world. Some organizations, most remarkably Royal Dutch Shell, have been effectively advancing this concept.

Transportation of Gas

There are three gas-to-gas (GTG) alternatives to offtake gas for sale: Pipelines, Compressed natural gas and Liquefied natural gas.

In pipelines, the gas is treated to meet pipeline quality requirements and compressed for transport and distribution via a network of pipelines. In compressed natural gas, the gas is treated, compressed, and transported as compressed natural gas to the consumers. In liquefied natural gas, the gas is treated, liquefied, transported, and regasified at the receiving terminal. The GTG technologies exploit the decrease in volume of the gas to economically ship the gas.

Transportation as solid or Gas to Solid (GTS)

In the gas-to-solids (GTS) technology, the gas is transformed into a solid state called natural gas hydrates (NGH) and shipped to the market as a solid or slurry. Regasification of the hydrate is required at the receiving end. The concept of storing and shipping stranded gas to market as dry hydrates, hydrate pastes and hydrate in crude oil slurries has been extensively investigated and laboratory tested for over 10 years. Gas hydrates are clathrates in which the guest gas molecules are impeded in a lattice of host water molecules, and are usually encountered in the industry as a production issue in flowlines. BG Group, Marathon, NTNU and others have worked on some gas-to-solids offtake technologies, and tested them on pilot scale plants, where concepts incorporate storage and offtake of gas (Fischer, 2001). Gas hydrates are ice-like solid crystalline compounds formed by the chemical combination of natural gas and water (where individual gas molecules exist inside cages of water molecules, $CH_4.nH_2O$ where n is greater than or equal to 5.75), under pressure and temperature considerably higher than the freezing point of water. With free water, hydrate will form when temperature is below a specific temperature known as hydrate formation temperature. NGH can accommodate 160m^3 of methane per 1 m^3 of hydrate. Hydrate technology development has concentrated on utilizing gas hydrates to transform gas to a strong (GTS) to move natural gas to the point of sale as a low cost solution for managing associated gas in regions lacking in gas infrastructure or market. Gas hydrates form naturally in specific subsea conditions and it may provide another solution for the gas supply network. Major amounts could be stored due to the fact that volumes are reduced by a factor of around 180 which is less than the 200 and 600 volume reductions for CNG and LNG, respectively. In comparison with other alternatives, like LNG and GTL, GTS hydrates conversion is relatively straightforward, minimal cost, and does not require complex processes or extreme operating conditions. It can be small-scale, modular and especially proper for offshore associated gas applications. Simply put, the hydrate production concept entails adding water to natural gas and 'mixing' (Alawode and Omisakin, 2011).

Compressed Natural Gas (CNG)

CNG offers a proven technology that offers an economic solution for remote offshore gas developments with marginal reserves, or for associated gas reserves in large oilfield developments. CNG would be pertinent where subsea flowlines are not feasible due to distance, ocean topography, limited reserves, modest demand or environmental factors, and where LNG is additionally not economical because of its staggering cost of liquefaction and regasification infrastructure, and because of community or safety issues. Safety and security are issues for CNG, but the community-related safety and environmental issues that impede LNG receiving terminals onshore are eliminated by locating CNG offloading facilities several kilometers offshore. Energy expended in operating a CNG project is about 40% that of an LNG project, and about 15% that of a methanol or GTL project. Over 85% of CNG project expenses are associated with ships, which depend on conventional bulk carriers with at least four contending certified containment designs (Hatt, 2003).

Transportation of Gas or Gas to power (GTP)

The gas-to-power (GTP) technology, also referred to as gas to wire (GTW), entails the conversion of natural gas to electrical power and transmission of this power to end users. Gas-to-Wire High Voltage DC transmission lines offer the most technically feasible solution for conveying large amounts of electric power over large distances (up to about 1,500 km), and keeping line losses under 10%. Alternating current technology is only practical over short distances before suffering extreme line losses. Nonetheless, HVDC is capital intensive and requires very expensive converter stations at either end of the transmission line. Costs for a 1,200km, 500-kV bipolar HVDC line to transmit 3 GW of power would cost about US$2 billion. Extra costs for installing, operating and maintaining gas turbines at the remote site would be incurred. (Hill et al, 2002).

Transportation as liquid or Gas to fluids (GTL)

As opposed to the GTG and GTS gas monetization technologies, which depend on a physical conversion process, gas to liquids (GTL) is a chemical conversion process which involves the rearrangement of molecules. According to Panahi et al. (2012), "A GTL (gas to liquids) plant comprises three main sections: synthesis gas production, Fischer-Tropsch (FT) reactor, and FT products upgrading". It is the process of utilizing using natural gas, where the hydrocarbon feedstock (natural gas or any Gaseous feedstock) can be converted into synthesis gas (contains mainly Hydrogen and Carbon Monoxide), and later the produced syngas go through Fischer-Tropsch reactor to convert it into hydrocarbon liquids. These liquids can be utilized as transport fuels like gasoline or diesel, or some other desired liquid products, such as kerosene for jets, naphtha for petrochemical use and so forth. The syngas process incorporates auto-thermal reforming, compact reforming, and catalytic and non-catalytic partial oxidation". GTLFT process (referred to as GTL in the rest of this paper) is a unique technological development that offers an alternative source of energy that can be utilized to handle the global concern of possible oil depletion and to offer solution for the continuous rising concern of the tremendous global stranded and associated natural gas reserves. GTL processes are classified into direct and indirect processes.

CONSTRAINTS TO GAS COMMERCIALIZATION AND MONETIZATION IN NIGERIA

Regardless of advancements made lately and endeavors of the World Bank-led Global Gas Flaring Reduction Partnership (GGFR), flaring of natural gas continues being an environmental issue and a misuse of resources. From certain assessments, as much as 3.5% of worldwide gas production is flared or vented. In addition to wasting a non-renewable, marketable resource, flaring and venting represent a significant source of avoidable CO_2 and CH_4 emissions that emit tremendous amounts of greenhouse gas with no offsetting benefits. According to Elvidge, Ziskin, Baugh,Tuttle, Ghosh, Pack, Erwin, Zhizhin (2009) study utilizing Fifteen Year Record of Global Natural Gas Flaring Derived from Satellite Data, gas flaring efficiency was determined as the volume of flared gas per barrel of crude oil produced. It was observed to be stable within the last 15 years, in the range of 140 to 170 billion cubic meters (BCM). They also found that global gas flaring has declined by 19% since 2005, driven by gas flaring reductions in Russia and Nigeria which are the two nations with the most significant gas flaring levels in the first half of 2016; Nigeria flared more than 3 billion cubic meters (Bcm) (10^6 Bcf) of gas, worth an estimated value of about US$300 MM. Reasons for flaring and venting include the cost of capture, processing and treating of gas, and the absence of facilities and access to funds to capture and convey the gas to viable markets, some monetary terms for Production Sharing Contracts (PSCs) or other contracts and low regulated gas prices and inability to appropriately encourage gas use. Sour gas or gas with large amounts of non-hydrocarbon diluents, though not applicable to Nigerian gas, further complicates commercialization. An absence of coordinated efforts among operators and regulators additionally adds to inappropriate development planning. Retrofitting expenses and mature fields, lack of focus on gas specific exploration, deficient gas terms in PSC agreements, insufficient incentives to develop gas reserves; changing scenario of the global gas markets because of emergence of unconventional gas (shale gas, and so forth); gas reserves accessibility in the short term and stranded reserves and absence of a bankable commercial framework for gas development all further complicates gas use. Natural gas is of little value except it can be brought from the wellhead to the market, consequently another constraint or limitation is distance of transportation and landscape which might be several thousand kilometers from the source. Since natural gas is relatively low in energy content per unit volume, it is costly to ship. The cost to ship energy as gas is significantly greater than for oil. This is one of the key obstacles to the increased utilization of gas. The most well-known approach to transport gas from the source to the market is via pipelines. For onshore and near-shore gas, pipeline is a proper option to offtake natural gas to the

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market. However, as transportation distances increase, pipeline use becomes uneconomical.

POTENTIAL BENEFITS OF GAS MONETIZATION AND COMMERCIALIZATION IN NIGERIA

The possibility of monetizing an ever increasing portion of flare gas in Nigeria has numerous benefits, including improving the environment for those living close to oil and gas operations; cost savings and new incomes for project sponsors; greater assurance for lenders, and the potential substitution of costly and polluting diesel-powered devices. Akpan (2009) in his study stated that the only option for harnessing the country's natural gas is to encourage the development of gas-based petrochemical complexes that can make use of huge volume needed to eliminate gas flaring. He suggested that Nigeria can make steady foreign trade profit on the long term by appropriately harnessing their natural gas through setting up a gas based petrochemical companies. Likewise, several monetary and sustainability benefits, even social benefits can come from the monetization of natural gas since it has the potential to open up the market for related products, for example, methanol, ammonia, diesel, gasoline (PMS), LNG, CNG and also create some socio-economic benefits (jobs) along the whole value chain.

CONCLUSION AND RECOMMENDATIONS

Nigeria being Africa's top oil marketer is evaluated to have at least 188 trillion cubic feet in natural gas reserves, making it the most endowed nation in Africa as far as gas reserves is concerned followed by Algeria, Egypt and Libya. High volume of natural gas accumulation is concentrated in Nigeria particularly in the Niger-Delta; and considerable discoveries have been made in the deep offshore area and exploration endeavors in the Benue Trough, Borno Basin and Anambra basins can possibly add to national gas reserves volumes. A lot of the nation's gross natural gas production is flared on the grounds that a portion of the oil fields do not have the infrastructure needed to capture the natural gas produced with oil, referred to as associated gas. During the process of processing and transportation, huge amount of natural gas is flared resulting in enormous revenue loss for the government.

Flaring and venting gas ought to be inconsistent, brief and effective. This paper presented an assortment of strategies to monetize small to medium volumes of gas, alongside approaches to limit flared and vented gas. The relative volumes of gas required for a wide range of utilizations are evaluated, including distributed power, CNG, methanol, GTL and other emerging technologies such as mini and micro scale LNG.

Natural gas could likewise be utilized for domestic market, power, industrial and commercial purposes. As at 2015, 12 percent of gas realized were totally in the domain of flaring. Nigeria requires investments of somewhere in the range of $1billion to $2 billion every year in gas pipelines and processing plants, particularly as it hopes to drive monetization of its gas reserves through the production of power or fuel as indicated by Abel Nsa. Nigeria has not fared too well in spite of the issuance of the gas master strategy and policies, such as the national domestic gas supply policy which seeks to guarantee the accessibility of gas locally, especially for the electric power sector. There are a few difficulties impeding the gas production development in the country, for example, poor infrastructure and pipelines vandalism; key difficulties though are poor pricing and poor policy implementation.

In the area of commercial sector, gas is conveyed to commercial sub-sector for use as fuel, captive power and related use. Gas is profoundly significant in the domain of gas based industrialization, can create regional hub for gas-based companies, like fertilizer, petrochemical and methanol and change gas sector to value added sector.

There is need to consolidate Nigeria's position and market share in high value export markets, regional gas pipelines-consolidate national footprints and impact. The Nigeria's gas development is perplexed with the following difficulties; absence of focus on gas specific exploration, absence of gas terms in PSC agreement, insufficient incentives to grow gas reserves; changing scenario of the global gas markets because of emergence of unconventional gas (shale gas, and so forth); gas reserves accessibility in the short term and stranded reserves and absence of a bankable commercial framework for gas development.

In the event that Nigeria intends to meet the national domestic gas supply and pricing regulation that was set up in 2008 to facilitate in-country commercialization of gas in assistance with the financial development and aspiration of Nigeria to meet the Sustainable Development Goals (SDGs) of addressing to the issue of GF, some of the SDGs that could be partially addressed include Goal 3 (Ensure healthy lives and promote well-being for all at all ages); Goal 11 (Make urban areas and human settlement inclusive, safe, resilient and sustainable); Goal 13 (Take urgent action to combat climate change and its effects) and Goal 15 (Protect, restore and promote sustainable utilization of terrestrial ecosystems, sustainably oversee forest, combat desertification, and halt and reverse land degradation and stop biodiversity loss), the way forward is to promote and add incentives to gas specific exploration, government should develop fiscal terms for gas development in the PSCs, utilisation of existing monetization technologies to harness stranded gas resources and promote cooperation among industry players combined with the key objectives of the legislative framework for domestic gas supply.

The Federal Government must establish robust approaches to leverage gas resources towards economic growth to guarantee sufficient supply to meet domestic gas need; boost the domestic market; accomplish full commercialization in domestic gas market and elimination of routine gas flaring; ascertain the domestic gas requirements of the country; allocate the gas domestic supply obligation to operating firms; to guarantee working organizations agree to their local commitments, order and uphold working organizations to assemble, process and convey flared gas volumes to the domestic market and encourage competent third party firms to take gas from flaring operating organizations and channel it to the domestic market.

The Nigeria's domestic gas development can only happen through the following; sustained implementation of the transitional pricing system prompting willing purchaser-willing seller status, facilitating the implementation of swap arrangements, encourage new players and attract investments, robust infrastructure development of pipelines to connect supply sources to demand centers and full implementation of the national gas transportation system code. There are some legislative interventions and operational endeavors that should be deployed and aimed at gas flare reduction in Nigeria, such as review and update regulations and guidelines on gas flaring, efficient monitoring of gas flare-down projects, maintaining firm position against further natural associated gas (NAG) development fields that flare significant volumes of associated gas (AG), upholding no new oil field development without gas utilization plan, plans to allocate gas flare points to third party investors, implementing overhaul/revamp of ageing facilities and enforcement of the $3.50/1000scf flare penalty. There ought to also be a resolve to eliminate gas flares by implementation of key enablers required to deliver projects, encourage infrastructure, advocate for efficient guidelines and strong policies and attracting fiscal terms to encourage gas utilization.

Stranded natural gas has enormous economic impacts on Nigeria since there are tremendous volumes of stranded gas reserves in the country. Oil accounts for more than 90 percent of Nigeria's foreign exchange profit, there is hence hope for increased income from natural gas, if the gas being flared is monetized. Monetizing stranded gas reserves requires access to distribution infrastructure. It becomes essential and pertinent for Nigeria to set up these infrastructures in order to develop vast stranded natural gas reserves to serve her economy, reinforce regional cooperation, and meet increasing demand in the global market.

Current technologies are essentially required for monetizing stranded gas, and appraisal of Nigeria's accomplishments in monetizing stranded natural gas reserves. The monetization technologies and projects evaluated are liquefied natural gas (LNG), gas-to-liquids (GTL), compressed natural gas (CNG), gas-to-wire (gas-fired power generation), and gas-to solid.

To truly support gas monetization in Nigeria, the following primary issues must be put in place: attractive and competitive business environment, initiate aggressive gas exploration to grow reserves, focused implementation of flares out solutions, implementation of Petroleum Industry Bill (PIB) and sustenance of infrastructure development. The potential outcomes of monetizing natural stranded gas in future are proposed for Nigeria to serve her economy, have a constant power supply, contribute to global greenhouse gas (GHG) reduction, and meet growing energy and petrochemical demands in the global market. These potential outcomes comprises natural gas storage (to limit gas flaring and enhance oil recovery), improved gas-fired power generation, dimethyl ether (DME), and gas-to-ethylene syntheses to mention but a few.

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