

## **INTERNATIONAL OIL CORPORATIONS (IOCS), ASSOCIATED GAS UTILIZATION TECHNOLOGIES AND GAS FLARE ELIMINATION STRATEGIES: IMPLICATION FOR ZERO-GAS FLARING REGIME IN NIGERIA**

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### **ABSTRACT**

The purpose of this study is to determine if the adoption of inefficient gas utilization technologies and gas flare elimination strategies by IOCs hinders their compliance to the zero-gas flaring deadlines resulting to the failure of zero-gas flaring policy in Nigeria. By adopting rentier state theory, using qualitative methods and relying on secondary sources of data, the study concludes that adoption of ineffective gas utilization technologies and gas flare elimination strategies by oil multinationals impedes them from complying with the zero-gas flaring regime leading to the failure of zero-gas flaring policy in Nigeria.

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## INTRODUCTION

Most IOCs operating in the Nigerian upstream oil subsector such as Shell, Agip, Elf, Texaco, Mobil, Phillips, Pan Ocean, etc. are in joint venture partnerships with Nigerian National Petroleum Corporation (NNPC). IOCs are still flaring associated gas in Nigeria and have consistently failed to comply with the zero-gas flaring deadline in Nigeria leading to perpetual shift in zero-gas flaring deadlines from 2003 to 2004 to 2008 to 2009 to 2011 to 2012. The oil multinationals were unable to eliminate gas flaring given that the total gas utilized being 1,781,370,022 scf was below the total gas produced, that is, 2,400,402,880 scf resulting in 619,032,858 scf of total gas flared in 2011 (Ifesinachi and Aniche, 2014).

IOCs place emphasis on maximization of profits over adoption of effective gas flare elimination strategies and efficacious gas utilization technologies. Also, available records indicate that oil multinationals in the oil joint ventures with NNPC prioritized profits and revenues through increase in oil production without pegging oil production to the gas utilization capacity required to meet policy deadline (Aniche, 2015). Perhaps it is noteworthy to state here that gas flaring has global and local environmental, economic and health implications.

The objective of this study, however, is to sufficiently establish if the adoption of ineffective gas utilization technologies and gas flare elimination strategies by IOCs impedes their compliance to the zero-gas flaring deadlines resulting to the failure of zero-gas flaring policy in Nigeria.

## THE ASSOCIATED GAS UTILIZATION TECHNOLOGIES OF IOCS FOR MEETING ZERO-FLARING DEADLINE IN NIGERIA

Apart from providing gas gathering facilities as discussed below, IOCs operating in Nigeria upstream oil subsector in joint ventures with NNPC are also active in providing gas processing facilities. Some of these technologies which are adopted by the IOCs in storing and processing associated gas (AG) include gas flow meters, reinjection, Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), Gas-to-Liquids (GTL), Compressed Natural Gas (CNG), Gas-to-Power (GTP), Gas-to-Solid (GTS), etc.

The available gas flow meters to measure flared and vented gas flow rates associated with oil production include ultrasonic flow meters, optical flow meters, insertion turbines, averaging pilot tubes, and measuring technologies like insertion turbines, pitot tubes, differential pressure flow meters and thermal mass meters are limited by such factors as high flow velocities, large pipe diameters, changing gas composition, low pressure, dirt wet gas, wax, condensate and high concentrations of contaminants like CO<sub>2</sub> and H<sub>2</sub>S. Ultrasonic flow meters have been in use since 1987. They measure flow velocity by determining the time it takes for an ultrasonic pulse to travel between two fixed transducers located in the pipe. Ultrasonic meters are cost effective for measuring gas flare

volumes in that maintenance is minimized by self-diagnostics. They are independent of pipe size, and are not affected by extreme flow velocities and changing gas composition. The measurement accuracies of ultrasonic flow meters range from 2.5 percent to 5 percent of the actual values. Orifice and Venturi meters can be used instead of ultrasonic for stable gas flows and they are applicable to wet and dry gas streams containing contaminants. But they do not perform well for a broad range of flow rates, and need to be calibrated frequently for changing gas composition (Buzcu-Guven, Harriss and Hertzmark, 2010).

Optical flow meters are devices capable of deployment in harsh oil field conditions and use laser or LED light to determine the flow velocity by measuring the time between two perturbations in light beams using the small particles in the gas steam. The perturbations are detected using two optical sensors separated by a known distance. Optical flow meters are independent of gas composition, flow characteristics, pressure and temperature, and have measurement accuracies ranging from 2.5 percent (Buzcu-Guven, Harriss and Hertzmark, 2010).

Re-injection is a commonly used method to preserve gas for future use or to increase the efficiency of the oil production process while utilizing the AG that would otherwise be flared or vented. The technology involves the installation of a gas compressor to re-pressurize areas of low-pressure formation gas thereby enhancing oil production. As an alternative to gas compressors, multiphase pump systems in which oil and gas can flow together, have a smaller equipment size and allow determination of the flow characteristics without the need to separate oil and gas. However, the re-injection option is not applicable in some geological formations (Tengirsek and Mohammed, 2002; Broere, 2008).

The LNG technologies involve liquefaction, shipping and regasification and delivery into the pipeline grid. This is the process by which natural gas, mainly methane, is cooled and liquefied through cryogenic processes at a temperature of approximately  $-260^{\circ}\text{F}$  ( $-163^{\circ}\text{C}$ ) leading to formation of liquefied natural gas. As result of this, natural gas volume is reduced to one six-hundredth ( $1/600$ ) allowing its transportation by specialized LNG tanker ships over long distance. LNG technology uses a refrigeration process in which the gas is pre-treated for impurities like Sulphur,  $\text{CO}_2$ , water, and other contaminants; and transformed into liquid by being cooled to  $-162^{\circ}\text{C}$  and stored until it is shipped on-board LNG tankers (Zhang and Pang, 2005; Lichun, *et al* 2008). A typical LNG receiving terminal includes storage tanks and infrastructure for the regasification processes. The three basic vaporizers or gasifiers are Submerged Combustion Vaporizers (SCV), Open Rack Vaporizers (ORV) and Ambient Air Vaporizers (AAV). This process was adopted by Nigerian Liquefied Natural Gas (NLNG) (Ahmad, *et al*, 2002; Fleisch, *et al*, 2002; Rahman and Al-Masamani, 2004; Apanel, 2005; Rahmin, 2005).

LPG is an alternative way of utilizing AG because of its easy storage and transport to local markets, and due to the higher percentage or proportion of propane and butane. To extract the LPG, AG must first be

treated for removal of impurities including water vapor, CO<sub>2</sub>, mercury vapor and H<sub>2</sub>S. Conventional LPG processes treat the whole gas steam before extracting the LPG content. However, these processes are not economical and practical for AG which is produced in much lower volumes with a lower pressure than non-associated gas (NAG) from gas wells. The LPG is produced in a three-step process involving the compression of the AG, condensation of the heavy carbon fraction by cooling the compressed gas, and separation of the heavy fraction to produce LPG. LPG production does not require extreme cooling temperatures or extreme pressures, chemicals, and cooling agents (Sonibare and Akeredolu 2006; Buzcu-Guven, Harriss and Hertzmark, 2010).

GTL or syngas involves a chemical reaction of dry natural gas (methane) with either oxygen or steam using reformer producing a mixture of hydrogen and carbon monoxide (H<sub>2</sub> + CO) in a ratio of two is to one (2:1). There are three principal technologies for GTL or syngas production using natural gas as feedstock which include steam methane reforming (SMR), partial oxidation reforming (POXR), and auto-thermal reforming (ATR). The conversion of H<sub>2</sub> and CO mixtures to liquid hydrocarbons is based on F-T Catalytic synthesis with ideally H<sub>2</sub>CO ratio of two is to one (2:1). The reaction is strongly exothermic meaning that significant heat must be removed. In this process, reactors are designed to efficiently remove heat to required practically uniform temperature conditions for the reaction, depending on the reaction conditions, type of catalyst used and the reactor configuration (Aniche, 2015).

Fischer-Tropsch (F-T) Synthesis can be used to produce liquid alkenes (paraffin), liquid alkenes (olefins) and oxygenates such as alcohols. F-T products like paraffin and olefins can be further treated to maximize their sales value or to meet particular market needs. In other words, paraffin and olefins can be upgraded using standard hydro-cracking, hydrogenation, oligomerization, and isomerization processes. The breakdown of the fractions of GTL is naphtha 15-25%, middle distillates 65-85%, and associated LPG condensates about 0-30%. This is the gas utilization proposed strategy by Chevron operated JV Escravos Gas-to-Liquids (EGTL) (Ahmad, *et al*, 2002; Rahmin, 2005).

Therefore, GTL technology is a chemical process that converts methane gas into transportation fuels like naphtha, etc. the GTL technology is therefore often called Fischer-Tropsch-Gas-to-Liquids (FT-GTL) technology because the Fischer-Tropsch (F-T) chemical conversion is the main process in converting the gas into liquid hydrocarbons. The utilization of AG through GTL processes is more challenging and capital intensive for offshore production facilities. The GTL diesel is a low Sulphur, low aromatics, and high cetane number fuel, providing high combustion quality and significant emission reductions and as well compatible with existing diesel engine technology. Also, GTL naphtha with high quantity chemical composition free of metals, aromatics and Sulphur is an ideal feedstock for petrochemical production. GTL kerosene

blends or GTL jet fuel have significantly lower emissions of particulate matter and other pollutants and higher energy density which has recently been approved for use in commercial aircraft (Fleish, *et al*, 2002; Hall, 2005; Oguejiofor, 2006; Buzcu-Guven, Harriss and Hertzmark, 2010).

CNG is obtained when a fluid natural gas is compressed at low or ambient temperature to a density of about 150 to 250 kg/m<sup>3</sup> compared to 600 kg/m<sup>3</sup> for LNG. The CNG is filled into large pressure bottle of about 110cm diameter and 36cm in length and transported by ship to a receiving terminal. This technology is most efficient alternative channel of harnessing stranded gas. CNG is a safe and environmentally friendly fuel that produces non-toxic vapor and provides operations with reduced noise pollution. It provides toxic soot pollution reduction by about 75 to 90 percent and smog forming pollution reduction by about 25 percent compared to conventional automobile fuel (Rahman and Al-Masamani, 2004; Apanel, 2005).

Thus, CNG is natural gas compressed to a much lower volume (1/200 of the original volume) at pressures between 8,300 and 30,000 kilopascals (kpa). CNG is stored and transported in cylinder usually made with fiber reinforced plastic (FRP). The advantages of FRP over metal/steel gas containment systems are that it is light weight, corrosion resistance, durable, safer, and lower capital and operational costs. CNG technology is suitable for land transport over short distance and has the potential to become preferred method of utilizing AG in offshore platforms where building pipelines or LNG plants are not economical or practical. Since CNG is land transportable and easily redeployable, it can be used in fields with relatively short production horizons. Thus, CNG is used primarily as a transport fuel and in small scale transport road projects (Marcano and Cheung, 2007; Buzcu-Guven, Harriss and Hertzmark, 2010).

Gas-to-Power (GTP) or Gas-to-Wire (GTW) or Gas-Fired Power Generation is a strategy of using natural gas to generate electricity in a variety of ways. The most basic natural gas-fired electric generation consists of a steam generation unit, in which fossil fuels are burned in a boiler to heat water and produce steam that turns a turbine to generate electricity. This process of generating electricity through steam boiler has fairly low energy efficiency in that only 33 to 35 percent of the thermal energy used to generate the steam is converted into electrical energy. Gas turbines and combustion engines are also used to generate electricity. In this process, instead of heating steam to turn a turbine, hot gases from burning fossil fuels (particularly natural gas) are used to turn the turbine and generate electricity. Gas turbine and combustion engine plants are traditionally used primarily for peak-load demands, as it is possible to quickly and easily turn them on. However, this process is still traditionally slightly less efficient than large steam-driven power plants (Ahmad, *et al*, 2002; Apanel, 2005; Rahmin, 2005).

The “Combined-Cycle” Units involve many of the new natural gas fired power plant. In this hybrid process of gas-to-power generating

facility, there is both a gas turbine and a steam unit, all in one. The gas turbine operates in much the same way as a normal gas turbine using the hot gases released from burning natural gas to turn a turbine and generate electricity. In combined-cycle plants, the waste heat from the gas-turbine process is channeled or directed towards generating steam, which is used to generate electricity much like a steam unit. As a result of this efficient use of the heat energy released from the natural gas, combined-cycle technologies are much more efficient than steam units or gas turbines alone and can achieve thermal efficiency of 50 to 60 percent. Gas-to-Power technologies are utilized by the NIPP and JVIPP in Nigeria (Fleisch, *et al*, 2002; Rahmin, 2005).

GTS or Gas Hydrates are ice like solid crystalline compounds formed by the chemical combination of natural gas and water. This process is obtained where individual gas molecules exist within cages of water molecules,  $\text{CH}_4 \cdot n\text{H}_2\text{O}$  where  $n$  is greater than or equal to 5.75, under pressure and temperature considerably higher than the freezing point of water. In the presence of free water, hydrate will form when temperature is below a typical temperature called hydrate temperature. Natural Gas Hydrate (NGH) can contain about  $160\text{m}^3$  of methane per  $1\text{m}^3$  of hydrate. Hydrate technology therefore focuses on using gas hydrate to convert gas to a solid to transport natural gas to market as a low cost solution to managing AG in regions lacking in gas infrastructure and/or market. The advantages is that large quantities or volumes could be stored because volumes are reduced by a factor of about 180 which is less than the 200 and 600 volume reductions for CNG and LNG, respectively (Alawode and Omisakin, 2011).

Thus, natural gas hydrate (NGH) is crystallized natural gas which is a solid material or substance in an ice state and chemically stable at  $-20^\circ\text{C}$ . The stabilizing temperature is considerably higher than the LNG temperature  $-162^\circ\text{C}$ , which leads to lower capital transportation and storage costs. However, NGH is far less dense than LNG and the quantity of gas transportable in hydrate form is lower than LNG technology (Buzcu-Guvan, Harriss and Hertzmark, 2010).

Compared to other gas processing technologies such as LNG and GTL, GTS hydrates conversion technology is relatively simple, low cost, less complex, low pressure and temperature. This GTS technology does not require complex processes or extremes of pressure or temperature. It can be small-scale, modular and particularly appropriate for offshore associated gas applications. In much simpler form, the hydrate production concept amounts to adding water to natural gas and “stirring”. Gas hydrate could be produced by contacting natural gas with water at  $10^\circ\text{C}$  and 20 bars, after which the temperature is lowered to  $-10^\circ\text{C}$  for the gas molecules to be trapped in metastable ice structure that forms solids at ambient temperature. Gas hydrate crystals resemble ice in appearance but do not have the solid structure of ice. They are much less dense and exhibit properties that are generally associated with chemical substance. The main framework of their structure is water and the hydrate molecules occupying

the space in the crystal structure are held together by chemically weak bonds with the water (Alawode and Omisakin, 2011).

Methane in AG can also be converted to methanol, which is further used to produce dimethyl ether (DME) and olefins such as ethylene and propylene in simple reactor systems, conventional operating conditions and commercial catalysts. Lurgi's Mega Methanol, MTP, and MegaSyn technologies and Topsoc's DME process provide cost-effective and large economy-of-scale solutions to gas conversion. Methane in AG can also be converted to ammonia through the Haber process to produce nitrogen fertilizers (Buzcu-Guven, Harriss and Hertzmark, 2010).

However, none of the current gas utilization technologies and methods is economical if the AG volumes are below 10 mcm per year and the oil field located more than 2,000 km from the closest market. As for LNG and GTL technologies, LNG has higher plant efficiency and less complex infrastructure needs. Both LNG and GTL have comparable full life cycle capital costs. Although LNG has slightly lower operating costs than GTL, the total production costs for LNG and GTL products for the same amount of natural gas is quite equivalent. Both are environmentally friendly alternatives, but LNG products are generally used as fuel in power generation, heating and industrial processes. GTL serves a different energy market than LNG with most of the GTL plants yield as low Sulphur transportation fuels. The pricing for LNG products requires long-term contracts (more than 20 years) between the supplier and the consumers, and the actual price is adjusted according to the price of crude oil. On the other hand GTL products can be sold in open markets and does not require long term contracts (Buzcu-Guven, Harriss and Hertzmark, 2010).

In the case of LNG to pipeline and CNG alternatives for exploitation of stranded gas, the full chain cost of a typical CNG process including compressing, loading, shipping and unloading, is substantially cheaper than that of an LNG process at moderate distances (up to 3,000 km) and for smaller fields (less than 100 mmcf per day). A CNG plant with load facilities, compressors, pipelines, and buoys costs \$30 to \$40 million. CNG ships with chillers and fluid displacement on-board cost about \$230 million, but carry less gas than LNG tankers. For smaller fields or longer distances, CNG becomes uneconomical. CNG facilities require a shorter construction period or timeframe (between 30 and 36 months) than LNG and GTL facilities which are usually completed in 4 to 5 years (Buzcu-Guven, Harriss and Hertzmark, 2010).

### **THE GAS FLARE ELIMINATION STRATEGIES OF IOCS FOR ACHIEVING ZERO-GAS FLARING POLICY IN NIGERIA**

In spite of the shortcomings, the IOCs operating in the Nigerian upstream subsector in joint venture partnerships with NNPC have made some efforts at complying with gas flare out regime. At best, the oil multinationals have been able to reduce the volume of associated gas (AG) flared in Nigeria both in absolute and relative terms, for example, from 59.64 percent

amounting to 792,247,965 in 1999 to 23.84 percent in 2011 totaling 514,799,616 (Aniche, 2014).

The efforts of the oil multinationals in Nigerian upstream oil subsector can be divided into providing gas gathering, gas processing and gas distribution facilities. The gas gathering facilities are provided to gather gas for field injection purposes and to be channeled to the flare stack. Some of these gas gathering facilities are ChevronTexaco facilities, ExxonMobil facilities, Shell facilities, Nigerian Agip Oil Company (NAOC) facilities, etc. The ChevronTexaco gas gathering facilities consist of three phases or stages of Escravos Gas Pipeline (EGP). The first phase of the EGP, EGP-1 was completed in 1997 which facilitates expansion of utilization of natural gas within Nigeria. EGP-1 processes 165 mmcf/d of associated natural gas which is supplied to domestic market by pipeline. The second phase of the EGP, EGP-2 processes an additional 135 mmcf/d of AG, which began operation in 2000 utilized within Nigeria with a provision for export to Benin, Togo, and Ghana through the West African Gas Pipeline (WAGP) when completed. The third phase of the EGP-3 will increase gas processing to 400 mmcf/d of AG from Chevron's fields (Dayo, 2008).

The ExxonMobil gas gathering facilities consist of gas re-injection facility which was completed in 1978. The facilities assisted the ExxonMobil operated JV to reduce flaring of associated gas on its oil fields by about 1.2 bcf from 49.9 bcf in 1977 to 48.7 bcf in 1978. The facilities also consist of ExxonMobil operated Oso Gas Compression facility which commenced operations in 1997 and built to re-inject about 600 mmcf/d of AG to aid the recovery of about 100,000 bbl/d condensate deposits. The facility located at Bonny Island, Rivers State covers 15 wells, 6 gas re-injectors and a 61 kilometer pipeline. The combined gas streams from the wells are compressed to 5500 Psia (Dayo, 2008).

The Shell Gas Gathering facilities which were built as early as the seventies had gas transportation infrastructure to serve specific industrial customers in Port Harcourt and Aba in the south-eastern parts of Nigeria. Other examples of Shell gas gathering facilities at different advanced stage of completion include Cawthorne Channel Gas Injection or Associated Gas Gathering which involve the gathering of about 176 mmcf/d of rich gas, extraction of liquids and supply of the lean gas to the domestic market; Forcados Yokri Integrated project which involves the gathering of about 108 mmcf/d of associated gas (AG) for gas lift and about 53 mmcf/d as fuel. The facilities will also supply about 55 mmcf/d to NLNG Train 3, while some will as well be used for gas lift (Dayo, 2008).

The NAOC Gas Gathering facilities operate two gas re-injection plants. The first was established in 1985 at Obafu/Obrikom. The second was commissioned in 1987 at Kwale/Okpai. Both facilities were built to reduce associate gas flaring in Nigerian oil fields. In 1994, NAOC commissioned another gas plant for the supply of national gas liquids to the Eleme Petrochemical Plant. One other more recent gas gathering



facility that is being implemented by NAOC is the NLNG Gas Supply Phase 3 which will supply additional gas of about 164 mmcf/d to meet the LNG requirements of train 3 and increase total capacity to 650 mmcf/d came on stream in 2005. Another of these facilities, Idu Field Revamping and Gas Recovery built to gather about 100 mmcf/d of associated gas (AG) in Idu and Samabiri fields for gas, supply to NLNG Trains 4 and 5 (Dayo, 2008).

Thus, over the years there has been a growing utilization of natural gas in Nigeria. For instance, in 1970, about 8.1 bcm of natural gas was produced in Nigeria and about 0.1 bcm (slightly less than 1.4%) was utilized for productive activities mostly for gas injection in oil fields for field pressurization and oil lifts and some small amount for power generation mostly in the oil fields. The balance of about 98.6 percent amounting to about 8.0 billion cubic meters (bcm) was wastefully flared. By 2005, there was improvement in gas utilization as out of the 59.3 bcm of natural gas produced about 61.2 percent was utilized domestically as input in production of LNG, injected in oil fields, utilized as fuel in power generation even in power facilities outside the oil and gas fields; as fuel industries while the balance was flared (Dayo, 2008).

The significant increase in domestic utilization in the recent years was propelled by its increased use in generating power, and the use as an industrial energy fuel. Also, the export of natural gas commenced on October 1999 when a consignment of LNG was shipped out of the facilities of NLNG in Bonny. The total production of the NLNG of Trains 1 and 2 of 7.22 bcm per year is exported under a long term sales and purchase agreement with international buyers such as Enel of Italy (3.50 bcm per annum), Gas Natural/Enagas of Spain (1.60 bcm Per annum), Botas of Turkey (1.20 bcm per annum), Gas De France (0.50 bcm per annum), and Tringas of Portugal (0.35 bcm per annum) (Dayo, 2008).

As at February, 2003, NLNG had loaded 318 LNG cargoes to its long term customers since October 1999. A year earlier, in 2002, 107 were actually loaded and four out of the 107 cargoes were sold as spot cargoes. In 2007, 130 cargoes were loaded. The Train 3 which began operation during the fourth quarter of 2002 guarantees the delivery of 317 bcm a year. A 21-year sales and purchase agreements have been executed with the Gas Natural/Enagas (2.7 bcm per annum) and Tringas (1.0 bcm per annum). The above makes NLNG the largest supplier of LNG to Portugal (Dayo, 2008).

The IOCs operated joint venture gas supply systems in Nigeria include one, Shell's gas supplies systems to the defunct National Electric Power Authority (NEPA) in Delta I, II and III, Aba industries and the Rivers State Utility Board (RSUB); two, Nigerian LNG gas transmission; and three, NAOC gas supply system to Eleme Petrochemicals (Dayo, 2008). Shell operated joint venture partnership claims to have pioneered gas utilization in Nigeria, which it pursued since 1960s. For history of the Shell operated JVs gas utilization program, see Table 1 below.

Shell claims that under its flare-out policy or in compliance to Nigeria's zero-gas flaring policy, no new oil field is developed without a comprehensive plan for the immediate utilization of the associated gas produced from it (Omiyi, 2001). Thus, in order to actualize its gas utilization program, some seven major gas gathering projects have been initiated to gather associated gas from over 52 out of the 87 flowstations. For information on Shell operated JV gas gathering projects see Table 2 below. Shell operated JV planned to increase gas gathering capacity in proportion to increase in oil and AG production by gathering and supplying the gas to proposed Trains 4 and 5 of the NLNG plant as well as supply power generation plants. For major future gas gathering projects see Table 3 below.

Shell also claims to have 17 gas gathering projects including the integration of the Forcados oil and gas development which will start in the first quarter of 2015, and will cost \$6 billion when completed. Shell claims that already its investments cost more than \$3 billion to build gas gathering facilities since 2000. Thus, it claims that gas flaring dropped by more than 60 percent from over 0.6 billion cubic feet of gas a day to about 0.2 billion cubic feet. In spite of these efforts made by the oil multinational companies in joint ventures with NNPC, associated gas (AG) is still flared in Nigeria. Thus, the associated gas utilization technologies and gas flare elimination strategies adopted by oil multinationals in joint venture partnerships with NNPC has only reduced associated gas flaring but not able to end associated gas flaring since 1970s.

### **THE IMPACT OF IOCS' INEFFECTIVE GAS UTILIZATION TECHNOLOGIES AND GAS FLARE ELIMINATION STRATEGIES ON ZERO-GAS FLARING REGIME IN NIGERIA**

The IOCs are preoccupied by the desire to maximize profits or revenues. The goal of maximizing profits even at the expense of the NNPC, host communities and governments overrides all other considerations including environmental concerns. In pursuit of these primary concerns, all other considerations are secondary or peripheral including adopting a suitable AG utilization technologies and gas flare elimination strategies (Aniche, 2015).

Thus, in spite of the three options to stop gas flaring like re-injection, utilization for local use or market and utilization for export as well as the numerous economical gas utilization technologies and effective gas flare elimination strategies, gas flaring is still the most common practice to dispose of the gas produced in association with crude oil. The reason being that for oil companies to gain maximum economic profit, flaring is the most efficient way to dispose AG. Since Nigeria has huge non-associated gas deposits, it is more economical for the IOCs operating JVs to use NAG to produce gas for energy source, export and local use and other purposes. This is because AG recovery in terms of gathering, processing

and distribution costs four times more than the straight extraction of NAG (Aniche, 2014).

Going by the joint operating agreement developed by the IOCs operated joint venture partnerships for Nigerian government approval in 1992; one, all investment necessary to separate oil and gas from the reservoir or deposit into useable products is considered part of the oil field development; two, capital investment for facilities to deliver AG in useable form at utilization or designated custody transfer points will be treated for fiscal purpose as part of the capital investment for oil development. Therefore, much of the capital costs for the gas gathering projects are embedded in the capital costs (CAPEX) associated with oil production (Economides, Fasina and Oloyede, 2004). For example, the cost estimate of constructing an LNG plant that will process 1.35 bcf/d of natural gas either with a floating LNG or onshore LNG plant is put at \$2.80 billion which approximate with or even slightly less than the cost of recently completed LNG plant in Nigeria. The first phase of the Bonny LNG plant which costed \$2.5 billion is expected to treat 900 million cubic feet (mmcf) per day of feed gas. The cost estimate gives an average activation index (IA) of \$2,074 mscf/d and equilibrium price of \$2.35 mcf for just liquefaction process in Nigeria (Aniche, 2015).

The cost of transportation and regasification of LNG is equally enormous. The cost of transporting LNG from Nigeria to the United States and the cost of regasification has been put between \$0.80/mcf and \$1.05/mcf of natural gas. If the feed gas can be made available at the current tariff price of \$0.30/mcf to the liquefaction plant, then the equilibrium price for supplying LNG from Nigeria to the United States would be \$3.45 mcf. If we consider the cost of gathering gas, the equilibrium price could be at least \$4.25 mcf which is outside the price range that is currently considered attractive and competitive in the international market for export.

In order to be competitive in the international market, the IOCs resort to the drilling of NAG to supply NLNG which it was originally meant for, and thus, avoid the use of AG in order to minimize or reduce cost. The cost of Nigerian natural gas through LNG in terms of developing or constructing gas infrastructure or utilization projects is very capital intensive. To obtain commercial benefits from natural gas exported from Nigeria or for the Nigerian natural gas to be commercially viable or beneficial to IOCs, the price of gas in the export market must be greater than the cost of production, liquefaction, transportation and regasification. The most critical of these costs is liquefaction which in most cases represent between 55 and 75 percent of the total cost.

No wonder, most of the IOCs operated JVs preferred setting up of the Liquefied Natural Gas (LNG) plants which is more cost-efficient for processing NAG than AG thereby de-emphasizing other gas utilization technologies like GTL, CNG and GTS which are more cost-efficient for processing AG in Nigeria. Even in case of gas-to-power technologies, the IOCs have continued to build steam boiler technologies and turbines and

combustion engines technologies instead of the combined cycle technologies with most energy and cost efficiency (Aniche, 2014).

Also, pressure from home states or states of origin of these IOCs for more crude oil supply to meet their oil import targets, meant that they have to be preoccupied with increasing production of crude oil to meet these targets all at the expense of the local or immediate environment. This is because with an inadequate gas utilization or infrastructure facilities increase in oil production will mean increasing volume of gas flaring in Nigeria. IOCs are just willing to gain the short-term profits rather than pursue long-term profits. These driving forces or contradictions have led to keeping the oil flowing at minimal cost without considering the local and immediate environment of the host communities and the people. Thus, gas flaring in Nigeria is a consequence of cost minimization strategy though ineffective for AG utilization or gas flare elimination (Aniche, 2015).

In other words, environment of the oil communities are sacrificed in the altar of cost minimization strategy. The point being that cost minimization strategy is pursued by the IOCs at the expense of effective gas utilization technologies and gas flare elimination strategies. Ishisone (2004) has demonstrated in his study that the LPG production and gas transmission to power plant and industries would be the best solution to eliminate gas flaring for oil communities in Imringi and Obama. But often the IOCs calculate only the economic or monetary cost rather than environmental and health costs, or in terms of economic or material resources than in terms of human resources.

The implication of the above is that the IOCs prioritize cost minimization strategy over efficacious associated gas utilization technologies and gas flare elimination strategies. This leads to five major contradictions; one, contradiction between economic cost and environmental cost; two, tension between monetary cost and health cost; three, conflict between economic benefit and environmental benefit; four, contradiction between monetary benefit and social benefit; and conflict between material resources and human resources. By emphasizing the economic benefit therefore, IOCs de-emphasize the social and environment benefits especially to the oil communities. Thus, gas flaring is not only the cause of economic loss in terms of wasting of energy source, among others, but is also the cause of environmental degradation and health hazard. Gas flaring is rarely successful in the achievement of complete combustion releasing a significant amount of carbon monoxide (CO) and a reasonable amount of methane particularly when vented and both greenhouse gases (GHG) results to carbon emission which contributes to global warming and climate change.

More so, the gas flaring process with incomplete combustion emits a variety of compounds or chemical substances such as methane, propane, and hazardous air pollution like volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and soot as well as benzene, naphthalene, styrene, acetylene, fluoranthene, anthracene,

pyrene, xylene, and ethylene (Stroscher, 1996; Leahey and Preston, 2001). The negative or hazardous effects on human health of these gas flare substances or pollutants include cancer, neurological, reproductive and development effects. Gas flare contains enough amount of substances or compounds like benzene, naphthalene, toluene and xylene to be hazardous to human health or cause numerous illness associated with them (Kindzierski, 2000).

Although the elimination of gas flaring is accompanied by increasing economic costs in the short-run, but when the economic, social, health and environmental benefits are calculated there is a net economic benefit for oil companies, oil communities, agriculture, industries and Nigerian government even in the short-run. The improved health will provide human resource for manpower development in Nigeria to harness her abundant mineral resources (Ishisone, 2004).

There is no significant increase in gas re-injected from 332,806,436 scf in 2004 to 348,331,140 scf in 2011 which peaked to 409,848,718 scf in 2009 and dipped to 21,182,682 scf in 2010. The gas for LNG decreased from 463,380,371 scf in 2003 to 313, 087,278 scf in 2011, which dipped to 25,866,822 scf in 2010. Similarly, gas for liquefied petroleum gas, LPG/NGL, as feedstock to Eleme Petrochemical Company Limited (EPCL) reduced from 47,721,060 scf in 2002 to 38,607,385, scf in 2011 dipping in 2010 to 5,204,476 scf (Aniche, 2015).

Also, fuel gas to Eleme Petrochemical Company Limited (EPCL) shows an insignificant or marginal increase from 9,159,870 scf to 9,434,734 scf from 2002 to 2011. The result was that total gas utilized increased insignificantly from 897,789,582 scf in 2002 to 1,781,370,022 scf in 2011 while gas flared reduced insignificantly from 45.64 percent amounting from 753,801,906 scf in 2002 to 25.79 percent amounting to 619,032,858 scf in 2011 as gas produced increased from 1,651,591,488 scf in 2002 to 2,400,402,880 scf in 2011. Generally, the reduction both in absolute and relative terms in gas flaring and increase in gas utilization have not been substantial (Aniche, 2014).

Perhaps, the inference that can be drawn from the above is that various gas flaring elimination strategies and gas utilization technologies like LNG, etc. adopted by IOCs have not been effective in significantly or drastically mitigating gas flaring in Nigeria let alone meeting the zero-gas flaring deadlines leading to incessant shift in zero-gas flaring deadlines. The IOCs operating joint venture with NNPC are preoccupied with the gas utilization strategies which will yield more income or maximize profits by minimizing costs and maximizing revenues, which explains the reason for opting for LNG which is meant to process NAG at much lower costs than AG (Aniche, 2015).

The result is that utilization of associated gas and reduction of gas flaring have not been substantial. The IOCs were unable to eliminate gas flaring given that the total gas utilized being 1,781,370,022 scf was below the total gas produced, that is, 2,400,402,880 scf resulting in 619,032,858 scf of total gas flared in 2011. It resulted in insignificant reduction in gas

flaring in Nigeria from 45.65% in 2002 to 25.79% in 2011 of all the oil companies, instead of total elimination. Thus, we conclude that adoption of ineffective gas utilization technologies and gas flare elimination strategies by IOCs impedes their compliance to the zero-gas flaring deadlines thereby contributing to the failure of zero-gas flaring policy in Nigeria. Hence, the use of inefficacious gas utilization technologies and gas flare elimination strategies by IOCs contributes to the failure of enforcement of zero-gas flaring regime by the Nigerian state.

### **CONCLUSION AND RECOMMENDATIONS**

IOCs in joint ventures with NNPC are still flaring associated gas in Nigeria and have consistently failed to comply with the zero-gas flaring deadline in Nigeria leading to perpetual shift in zero-gas flaring deadlines from 2003 to 2004 to 2008 to 2009 to 2011 to 2012. The IOCs were unable to eliminate gas flaring given that 1,781,370,022 scf of the total gas utilized was below 2,400,402,880 scf of the total gas produced resulting in 619,032,858 scf of total gas flared in 2011. It resulted in insignificant reduction in gas flaring in Nigeria from 45.65% in 2002 to 25.79% in 2011 of all the oil companies, instead of total elimination. Thus, we conclude that adoption of inefficacious gas utilization technologies and gas flare elimination strategies by IOCs hinders them from achieving the zero-gas flaring deadlines thereby resulting to the failure of zero-gas flaring regime in Nigeria. This fact is sufficiently explained by four main contradictions of IOCs in joint venture partnerships with NNPC as captured by rentier state theory, namely, (a) contradiction between rents or revenues and environment (b) conflict between profits and environment (c) tension between national security and environmental security; and (d) contradiction between increase in oil production and efficient utilization of resources. Perhaps, the import of this is that needs of the future generation are sacrificed in the altar of immediate gains. Consequently, the environmental concerns and health of the present generation of oil producing communities as well as global community are endangered. The fact that environment and health of the present generation of oil bearing communities are endangered is secondary to IOCs. In their preoccupation to maximize revenues and profits, oil production is increased and gas flaring continues at the expense of oil communities (Aniche, 2015).

For instance, the contradiction between profits and environment explain the reason why IOCs are driven by desire to sustain competitive edge over their competitors through increasing oil production in Nigeria in order to make more profits at the expense of the oil communities. The IOCs place high emphasis on profits, through increasing oil production, more than on environmental protection. Thus, their major preoccupation has been on how to develop cutting edge technology to enhance oil recovery from oil wells and to increase deep water drilling than on developing sophisticated technology to increase the capacity of associated gas gathering facilities in Nigeria. The point being made is that the IOCs are more concerned in maximizing profits through improved and efficient

crude oil production in Nigeria than developing or improving the capacity of associated gas gathering facility to meet the zero-gas flaring deadline. In other words, the IOCs would not be able to meet any future gas flare out deadline so long as they are preoccupied with the drive to sustain their competitive edge over their rivals through increase in oil production and profit maximization. IOCs are investing more in oil production to maximize profits through increased oil production than investing to increase the capacity of associated gas utilization facilities (Aniche, 2014). From the foregoing therefore, we recommend that the fundamental thing to do, given the rentier character of the Nigerian state, is to diversify the revenue base of the economy to reduce the excessive dependence on oil revenue by mainstreaming other domestic sources of revenue like direct tax as well as developing other sectors of the economy like manufacturing sector. This is a fundamental and far reaching solution that will enable Nigerian state to de-emphasize oil revenue in limiting oil production to the gas utilization capacity of oil multinationals required to meet policy deadline. This will compel the IOCs to adopt efficacious gas utilization technologies and gas flare elimination strategies.

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**Table 1: History of Shell's Gas Utilization in Nigeria**

| <b>Year</b> | <b>Gas Utilization Program</b>  |
|-------------|---|
| 1962        | Commenced the supply of piped gas to industries at Aba and Port Harcourt.   |
| 1963-1965   | Gas for electricity generation to NEPA plants in Afam and Delta Power Station.  |
| 1976        | The establishment of the Port Harcourt Refinery gave a big boost to the gas utilization program.  |
| 1976        | Supply of gas to NEPA power stations at Sapele.   |
| 1986        | Gas supply to Delta Steel Company, Aladja.  |
| 1987        | Supply to National Fertilizer Company of Nigeria (NAFCON).  |
| 1988        | Gas Supply to Ajaokuta Steel Plant.   |
| 1989        | Gas Supply to another NEPA Station, Egbin Station.  |
| 1998        | Piped gas supply to Aluminum Smelter Company (ALSCON).  |
| 1998        | The Shell Group incorporated Shell Nigeria Gas (SNG) to boost gas utilization by promoting it as fuel of first choice in industry.                    |
| 1999        | The Nigerian LNG project began operation and to export LNG. Shell has been involved in the various attempts to promote the project since early 1960s. |

Source: Omiyi B (2001) Shell Nigeria Corporate Strategy for Ending Gas Flaring. In: *A Seminar on Gas Flaring and Poverty Alleviation* in Oslo, Norway, 18-19 June.

**Table 2: Major Shell's Gas Gathering Projects**

| <b>Gas Gathering Projects</b> | <b>Capacity of Supplies</b>   |
|-------------------------------|---|
| Soku Gas Project              | Completed and already delivering some 60 mscf/d to NLNG as from the first half of 2000. Additional supplies to NLNG later will raise total supply to some 200 mscf/d by the end of 2001.        |
| Obigbo North AGG              | It will take some 100 mscf/d of AG from number of fields to the North and East of Port Harcourt. AG will be supplied to NEPA power plant at Afam, the NAFCON fertilizer plant and ALSCON.       |
| The Odidi Project             | This project will take gas from the flares of Egwa, Batan and Odidi fields, and would supply about 80 mscf of associated gas (AG) initially to the Nigerian Gas Company (NGC) and NLNG Train 3. |
| Cawthorne Channel Project     | This is SPDC's largest gas gathering project which will supply 200 mscf/d of AG from four oil fields to Local markets and the NLNG Plant, Bonny.  |
| The Forcados Yokri Project    | It will collect some 80 mscf/d of AG from four flowstations. The gas will be combined with AG from Odidi and taken by Offshore Gas Gathering System (OGGS) to the NLNG Plant at Bonny.          |
| South Forcados Project        | The Project will gather 150 mscf of AG from Tunu area.  |
| The Belema Project            | This is moving into the construction phase. Already some 50 mscf/d of AG from Belema and Odeama fields is being sent to Soku for supply to NLNG Trains 1 and 2.                                 |

Source: Omiyi B (2001) Shell Nigeria Corporate Strategy for Ending Gas Flaring. In: *A Seminar on Gas Flaring and Poverty Alleviation* in Oslo, Norway, 18-19 June.

**Table 3: Major Future Gas Gathering Projects**

| <b>Gas Gathering Project</b>      | <b>Capacity of Supply</b>   |
|-----------------------------------|---|
| Greater Ughelli Project           | This involves gathering AG from the surrounding oil fields. More than 60 mscf/d will be gathered between 2001 and 2002 for supply to the Delta Power Station and other industries in Delta State. Later additional production will be sent to NGC's Escravos Lagos Pipeline System to supply industries in Lagos and the planned West Africa Gas Pipeline (WAGP). |
| The Otumara Gas Gathering Project | This involves gathering 80 mscf/d from oil fields to the North of the Forcados Estuary.   |
| The Oguta Gas Gathering Project   | AG will be injected into the oil field to maintain pressure in the reservoir, and Gbaran/Ubie will supply gas to the NLNG Train 4.  |

Source: Omiyi B (2001) Shell Nigeria Corporate Strategy for Ending Gas Flaring. In: *A Seminar on Gas Flaring and Poverty Alleviation* in Oslo, Norway, 18-19 June.