REDUCING GREENHOUSE GAS EMISSIONS FROM GAS FLARING IN NIGERIA'S OIL AND GAS INDUSTRY THROUGH ALTERNATIVE PRODUCTIVE USE

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Abstract

Gas flaring in Nigeria's oil and gas industry causes environmental and health hazards and to a large extent, culminates in yearly loss of the Nation's revenue. The aim of the study is to highlight the huge potentials of converting flared gas from the Nigerian oil and gas industry to compressed natural gas (CNG) which could be an alternative fuel for the 220 Lagos Bus Rapid Transit (BRT-lite) while mitigating greenhouse gas (GHG) emissions. The Long-range Energy Alternative Planning System (LEAP) software was employed to model the energy demand and carbon dioxide emissions from the BRT-lite by creating a current scenario and projections to the year 2030. The study revealed that under the mitigation scenario, the complete utilisation of CNG for the 220 units of Lagos BRT-lite in the year 2020 will reduce total carbon dioxide (CO_2) emissions to 34,773.3 trillion metric tonnes from 152,662.7 trillion metric tonnes of diesel fuelled BRT under business as usual scenario. The use of CNG as an alternative fuel for Lagos BRT-Lite will significantly reduce GHG emissions in Nigeria's oil and gas industry. Other utilization options for flared gas from this industry includes: Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), and power generation.

Key words: Nigeria, Greenhouse gas, flaring, alternative, industry

1 INTRODUCTION

Nigeria is Africa's most populous country endowed with large and diverse energy resources which includes but not limited to: crude oil, natural gas, coal and lignite, wind, solar radiation and biomass. The country is often described as a gas province with substantial oil accumulations that can last another 41 years at 2011 production levels [1 & 2]. Globally, Nigeria's gas reserves is ranked as the ninth largest with about 182 trillion cubic feet (tcf) equivalent of 5150.6 billion cubic metres (bcm) [3 & 4]. This immense gas reserve occurs as associated natural gas or non-associated natural gas [5].

A greater volume of Nigeria's gas reserves is found as associated natural gas [6 & 7]. The natural gas reserves in Nigeria has prospects for greater energy efficiency and reduced energy related costs [3] but gas flaring has been a major cause of environmental pollution contributing significantly to GHG emissions, waste of valuable energy resources and a huge loss of her revenue [5,8 & 9].

In the global petroleum and natural gas industry, flaring of unwanted flammable gases via combustion in open atmosphere is regarded as a major environmental concern in addition to wasting the valuable source of energy [10]. Gas flaring has impact on global GHG emissions contributing about 400 million tons of CO_2 annually which accounts for about 1.5 % of the world's CO_2 emissions [11].

Despite Nigeria's large and diverse energy resources, the gap between energy demand and supply is significantly high due to lack of diversification and utilization of energy resources. Diversification of energy sources is economically important for sustainable development with the realities of population growth, urbanization and industrialisation [12]. The substantial imbalance in Nigeria's supply-demand in energy in the phase of enormous and diverse energy resources, cannot be overemphasized. Therefore the aim of the study is to highlight the huge potentials of converting flared gas from the Nigerian oil and gas industry to useful energy. The specific objectives include:

(1) to provide an overview of gas flaring in the oil and gas industry in Nigeria.
(2) to evaluate policies and technical options of converting the flared gas from the oil and gas industry in Nigeria to useful energy (the use of compressed natural gas produced from flared gas for transport fuel: Lag
(3) os BRT-Lite).
(4) to analyse the energy demand and greenhouse gas emissions from Lagos BRT-lite by creating a current scenario and projections to the year 2030.

2 GAS FLARING IN NIGERIA'S OIL AND GAS INDUSTRY

The quantity of gas flared in Nigeria is enough to meet its energy demands and leave a healthy balance for export especially for many neighbouring African countries [13 & 14]. Annually, the country flares about 1.3 tcf (36.79 bcm) of natural gas [15] and 1.4 billion cubic feet (0.0392 bcm) per day [16]. About 75 % of the associated gas is flared with just 12 % of produced gas re-injected back into sub-surface reservoirs [17 & 18]. Nigeria flared over 14 % out of 160 bcm gas that was flared globally in 2004 ranking the country as the second to Russia accounting for 16% of global gas flared [19]. Nigeria loses more than 4.9 million USD/day to gas glaring [5]. From 1999 to 2009, Nigeria lost 11 billion USD annually to gas flaring [20]. From earlier study [21] reported that over the period of 1970 to 2006, Nigeria lost about 72 billion USD in revenues and 2.5 billion USD annually to gas flaring.

3 UTILIZATION OPTIONS FOR FLARED GAS FROM OIL AND GAS INDUSTRY

Concerted efforts have been made globally to reduce greenhouse gas emission from gas flaring in oil wells include the development of renewable energy systems [20, 22 & 23]. In United State of America, tremendous success is being recorded in the development and improvement of conventional technologies in the transportation sector to reduce GHG emissions and dependency on foreign oils. The use of CNG, LNG, LPG and hydrogen (H_2) are examples of outstanding success of transportation fuels derived or produced from natural gas in United States [24] Gas that would have been flared was utilised for LPG for household cooking and feedstock to a local fertiliser plant in Rang Dong oilfield in Vietnam operated by Japan Vietnam Petroleum Co. Ltd under the Kyoto Protocol's Clean Development Mechanism [25]. As cited by previous study [25] the project within 10 years will eliminate about 6.8 million tonnes of CO_2 emissions.

By re-injecting gas in Rabi oilfield southern Gabon, flaring of about 0.6 million tonnes (0.54 bcm) of natural gas per year was reduced to 0.02 million tonnes (0.018 bcm) reducing CO_2 emissions by a total of 1.1 million tonnes [25]. In Russia, Irkutsk oil company (IOC) commenced a gas processing plant at the Yarakta field for injecting recovered flare gas into the reservoir with capacity of 0.9 mcm (0.0009 bcm) a day in the first phase commissioning and 6 mcm (0.006 bcm) a day by 2015 [26]. GE's Jenbacher gas engine is an example of a technology that converts flare gas to power with great efficiency. The GE's Jenbacher plant systems was first installed in Italy and generates about 3.6 million MWh of electricity a year supplying about 1.2 million households in Europe [27]. About 900 million litres of diesel fuel per year is saved by generating electrical power with flare gas [27].

In the year 2009, over 4.9 bcm of associated gas was flared in KhMAO Russia but the introduction of gas-powered generating stations and gas turbine plants with the completion of the reconstruction of the Yuzhny Balyk gas refinery increased gas utilisation by 86.5% in the year 2010 increasing the refining capacity by 1.5 bcm [26]. The application of solid oxide fuel cell (SOFC) technology for flare gas recovery in Asalouyeh gas processing plant Iran generated about 1200 MW electrical energy and reduced the equivalent mass of greenhouse gas emission from 1700 kg/s to 68 kg/s [28]. Results from simulation models shows 48,056 barrels per day of valuable gas to liquid (GTL) products is produced from recovered flared gas in Asalooye gas refinery Iran [29]. Methanol which can be processed from flared gas is a unique and promising fuel for transport with a combination of portable liquid petroleum [30].

Some of the technologies considered by Nigeria's government for local utilisation of gas include: gas to power using gas fed by transmission and distribution pipeline networks to supply combined cycle gas turbines (CCGT), gas to fertilizer (GTF), CNG, GTL and LNG [3 & 11]

3.1 Conversion of Flared Gas in Nigeria's Oil and Gas Industry to CNG:

Providing an Alternative Fuel for Lagos Bus Rapid Transit (BRT)-LITE

The conversion of flared gas in Nigeria's oil and gas industry to CNG would be a productive way to reduce pollution, improve the nation's economy and meet the growing energy demand. CNG is an efficient transportation fuel especially for urban transit. CNG vehicles are economic, modern and reliable option to diesel vehicles and they have greater level of reduction of GHG emissions and noise pollutions when used for urban transport [31, 32, 33, 34 & 35]. Studies [36, 37, 38 & 39] reveal that the Fuel economy of CNG buses ranges from 2.51 to 7.37 miles per diesel gallon equivalence (MPDGE) depending on the bus capacity and travel distance. Examples of countries that run CNG buses for BRT in their cities include, Argentina, Australia, Brazil, China, Indonesia, Italy, Jakarta, Lima, Los Angeles, Nantes, Pakistan, Peru, Republic of Korea, Thailand, and United Sates of America [32, 34 & 40].

Carbon dioxide emissions from fossil fuels in Nigeria has been on a progressive rise (68.5million metric tons to 105.2 million metric tons) from 1980 to 2005 accounting for about 54 % significant emissions [41]. In this study, the energy demand and greenhouse gas emissions from the use of CNG for Lagos BRT-lite was highlighted. Lagos is the sixth largest city in the world having prospects to be the largest urban agglomeration in Africa and third largest agglomeration in the world after Tokyo and Mumbai [42, 43 & 44] but faced with unreliable public transport system [45]. Lagos city representing Nigeria on a global scale ranked 108 out of 178 economies based on the attractiveness of business environments [46]. The city has a total area of 357,700 hectares, a population of 20 million [43] at a growth rate of 6% [47] produces 45 % of Nigeria's skilled manpower making it the hub of the country's industrial and commercial activities [42, 47 & 48]. Despite the availability of air and waterways, road transport is the major mode of transport in Lagos [49] accounting for about 50 % of Nigeria's greenhouse gas emission [48]. Lagos Bureau of Statistics [43] reported that in the year 2010, road transport sector in Lagos state accounted for ₦3.2 trillion (21.3 billion USD) to a GDP of ₦12.091 trillion (80.61 billion USD) representing 26.47 %. In the same year, Lagos GDP contributed 35.6 % to National GDP of ₦33.985 trillion (226.5 billion USD).

The Lagos BRT -Lite is an extensive and integrated approach on public transport launched in March 17, 2008 with the aim of providing Lagos commuters with a clean, affordable, fast, comfortable and reliable intracity mobility and sustainable transport system [43 & 50]. Previous studies [42, 47, 48 51 & 52] reveal the following key characteristics of the Lagos BRT-Lite: the buses runs along Ikorodu Road, Western Avenue and Eko Bridge, a key radial highway that makes the 22 km connection between Mile 12 and Lagos Island. The enabling framework and infrastructure comprising bus depot garage, 3 bus terminals, 65 % segregated bus ways, 28 bus shelters, road markings and other traffic. The corridor covers a distance of about 13.5 km. The width of the existing road is a 7.5 m, with central median of 2 m width. It runs a 16 – hour operations from 6.00 a.m. to 10 p.m weekdays and with reduced hours of operation on the weekends. Cost per km for BRT (1.4 USD), fleet capacity utilization (95 %), average trip per bus per day (5), average waiting time (15 minutes), average journey time (55 minutes), average speed (30 km/hour), kilometres per bus per day (220 km), average passenger kilometre per day (5), average load factor (1000 passengers carried per bus per day). About 220,000 passengers carried daily. It is projected that the system will carry up to 10,000 passengers per direction per hour during peak travel hours. Number of passengers carried by in 2008 and 2009 was 39457962 and 69672333 respectively.

4 METHODOLOGY

Data was sourced from relevant literatures, Long-range Energy Alternatives Planning System (LEAP) starter data for Nigeria and published resources from government institutions like the Nigerian National Petroleum Commission (NNPC), Energy Commission of Nigeria (ECN), Lagos Bureau of Statistics (LBS) and Lagos Metropolitan Area Transport Authority (LAMATA). The study employed LEAP 2014 model for analysis of data collected.

4.1 Leap Model

The Long-range Energy Alternatives Planning system (LEAP) is a modelling software developed by the US Stockholm Environment Institute (SEI) in 1980 for energy policy analysis and climate change mitigation assessment. The main idea of scenario analysis in LEAP is to analyse the current energy situations and to simulate alternative energy futures along with environmental emissions under a range of user-defined assumptions. LEAP employs economic techniques to simulate various future scenarios, given projections about population and social conditions, economic growth, development of prospective technology and its penetration to the future. It has features that could enable the user to estimate energy consumption, production and resource extraction in all sectors of an economy. Furthermore, LEAP can be used to account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks, analyse emissions of local and regional air pollutants.

4.2 Transport Analysis Calculation

Passenger-km (Travel Demand)

Travel demand (t) = ∑Vi (t) * VKTi (t) * Vehicle occupancy rate (1)

where Vi(t) is the number of buses on the street, VKTi(t) is the average annual vehicle-km travelled by a vehicle of type i in year t.

Total kilometres travelled by buses per day = 220 x 220 = 48400

Total kilometres travelled by buses per year = 48400 * 365 = 17666000

Total number of passengers carried by BRT-lite in the year 2009 (vehicle occupancy per year) = 6967233 as reported in previous study [47]

Passenger kilometre in 2009 = 17666000 * 6967233 = 123,083,138,178,000 approximately 123,083 trillion passenger kilometres

Fuel economy

Fuel economy is the average fuel consumption of a vehicle per year in km/litres.

Fuel consumption per bus per day = 208.32 litres using previous study [53]

Fuel consumption for total number of buses per day = 208.32 x 220 = 45830.4 litres

Annual fuel consumption by total number of buses = 45830.4 x 365 = 16728096 litres = 4419095.5 US gallons.

Energy demand

The energy demand of the vehicle by fuel types was computed as a function of the numbers of buses, the average vehicle kilometre travelled and the fuel economy of the vehicle.

Hence, total energy consumption of vehicle is shown in the equation below:

Energy demand = ∑Vi(t) * VKTi(t) * Fi(t) (2)

where Vi(t) is the number of vehicles on the street, VKTi(t) is the average annual vehicle-km travelled by a vehicle of type i in year t and Fi(t) is the fuel economy of vehicle type i in year (t) in km/litres.

Emissions

The emission of buses considered were computed as the product of the energy demand of the vehicles and their emission factors. The emission factor was added from LEAP Technology and Environmental Database (TED) which has extensive information describing the technical characteristics, costs and environmental impacts of a wide range of energy technologies including existing technologies, current best practices and next generation devices. This is shown in the equation below:

Ej(t) = ∑Vi(t) * VKTi(t) * EFij(t) * Fi(t) (3)

where, Ej(t) is the total emission of emission type j in year t by passenger transportation in tonnes, Vi(t) is the number of vehicles on the street, VKTi(t) is the average annual vehicle-km travelled by a vehicle of type i in year t, EFij(t) is the emission factor of pollutant type j of vehicle type i in year (t) in g/km, and Fi(t) is the fuel economy of vehicle type i in year (t) in km/litres.

4.3 Assumptions used for Scenairo Construction

Base year (2009), Lagos state population (20 million at 6% growth rate), GDP (80.61 billion USD at 5 % growth rate), Income (4,030.50 USD at 3.5 % growth rate), CNG bus with fuel economy of 6.01 MPDGE with the same capacity and travel distance of the BRT-lite, Scenario 1 is business as usual (BAU), Scenario 2 involves the use of CNG for 100 units of Lagos BRT-lite in the year 2016 while Scenario 3 entails complete utilization of CNG for 220 units of Lagos BRT-lite.

5 RESULTS AND DISCUSSIONS

5.1 Passenger Kilometres on the Available 220 Lagos BRT-LITE (2030 Projection)

The Lagos BRT-lite will increase from 123,083 trillion passenger kilometres in 2009 to 253,481 trillion passenger kilometres in the year 2030 (Figure 1).

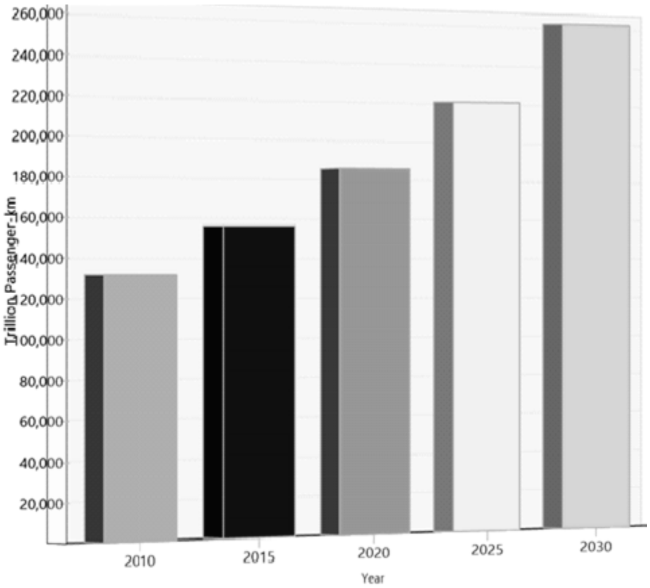

Figure 1. Passenger Kilometres on the Available 220 Lagos BRT-Lite (2030 projection)

5.2 Lagos BRT-lite Energy demand: (2030 projection)

The energy demand for Lagos BRT-lite in the year 2030 will be 2,075,166.8 trillion Gigajoules (Figure 2).

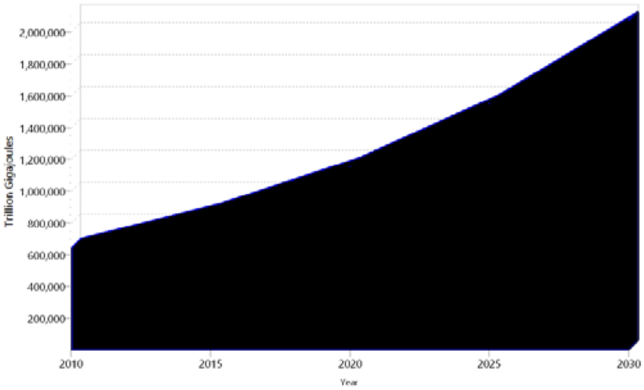

Figure 2. Energy Demand on the 220 Lagos BRT-lite (2030 projection)

5.3 Lagos BRT-lite Carbon Dioxide (Non-Biogenic) emission: Scenario 1 (BAU)

The CO_2 (non-biogenic) emission from the Lagos BRT-lite under business as usual scenario in 2030 will be 152,662.7 trillion metric tonnes (Figure 3).

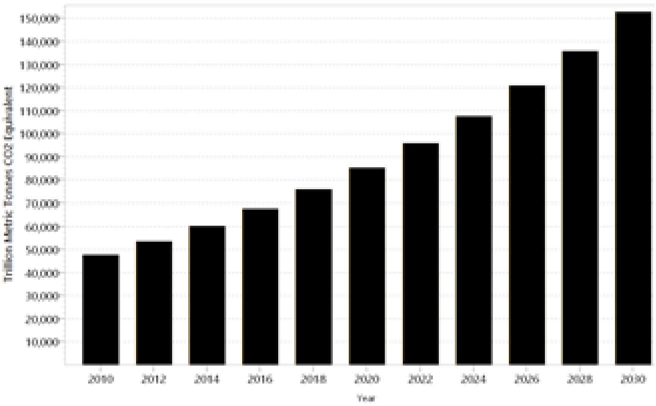

Figure 3. Scenario 1 (BAU)-Lagos BRT-lite Carbon Dioxide (Non Biogenic)

5.4 The Use of CNG for 100 units of Lagos BRT-lite (scenario 2)

The use of CNG for 100 units of Lagos BRT-lite in the year 2016 will reduce the CO_2 emissions to 30,000 trillion metric tonnes from 152,662.7 trillion metric tonnes of diesel fueled BRT under business as usual scenario while the CO_2 emissions from the 100 units converted to CNG will be 7,184.6 trillion metric tonnes (figure 4).

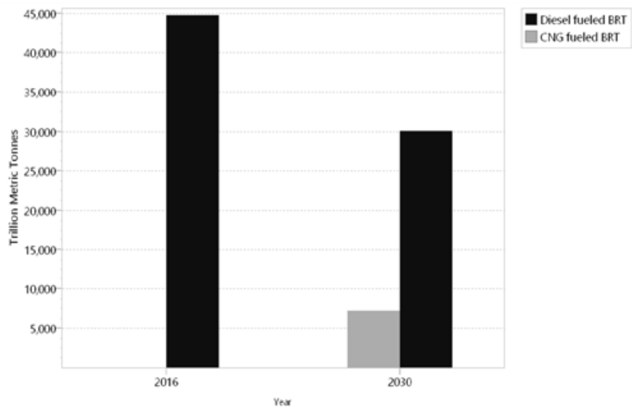

Figure 4. The Use of CNG for 100 Units of Lagos BRT-lite (scenario 2)

5.5 The use of CNG for 220 Units of Lagos BRT-lite (scenario 3)

The complete utilisation of CNG for the 220 units of Lagos BRT-lite in the year 2020 will reduce total CO_2 emissions to 34,773.3 trillion metric tonnes from 152,662.7 trillion metric tonnes of diesel fueled BRT under business as usual scenario (Figure 5).

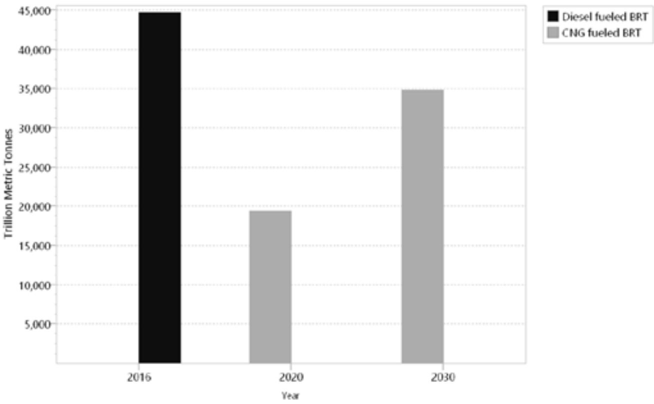

Figure 5. The use of CNG for 220 units of Lagos BRT-lite (scenario 3)

5.6 Constraints to Non-Realization of Flare reduction Policy in Nigeria’s Oil and Gas Industry

Market and institutional barriers are the major hindrances to the realisation of policies to mitigate gas flaring in Nigeria. Such hindrances include: lack of necessary technology capture and convert the gas flared to productive use; high cost of investment needed for gas infrastructure such that it is cheaper to wastefully burn the associated gas than to invest in gas utilization/reinjection schemes; unclear or incomplete disclosures of information on environmental sensitive activities and data needed to tackling climate change impacts; limited and non-competitive market for gas and its related products; government’s failure to meet its financial contribution under the existing joint venture; evidence of general lack of environmental concern by companies operating in the upstream sector for the apparent negative environmental consequences of gas flaring; lack of clearly defined long-term vision for the gas sector; lack of robust fiscal, legal, and regulatory framework to interface with foreign investors; ccorruption and insecurity in the Niger Delta region of Nigeria [5, 54, 2 & 9].

6 CONCLUSIONS

Reducing greenhouse gas emissions from gas flaring in Nigeria’s oil and gas industry through alternative productive use is important to achieving the nation’s commitment to reducing GHG emissions below its 1990 level. It will also contribute to social and industrial growth, meet energy demands and secure a productive economy. The use of CNG produced from flared gas as an alternative fuel for Lagos BRT-Lite in the study revealed reduction of GHG emissions. Other utilization options for flared gas from the Nigerian oil and gas industry include Gas to Liquid (GTL), Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), gas to fertilizer (GTF) and the recapture of flared gas to generate electricity.

Further studies should include the analysis of the volume of CNG that can be produced from recaptured flared gas in the oil and gas industry in Nigeria and estimation of greenhouse gases flared in the sector.

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