Nigerian Research Journal of Engineering and Environmental Sciences 5(2) 2020 pp. 873-885

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Review Article

Power Production using Natural Gas in Nigeria: Trends, Challenges and Way Forward

***Ekpu, M. and Obadina, O.B.**

Department of Mechanical Engineering, Delta State University Abraka, Oleh Campus, Delta State, Nigeria.
*ekpum@delsu.edu.ng

ARTICLE INFORMATION

Article history:
Received 26 Oct, 2020
Revised 08 Nov, 2020
Accepted 09 Nov, 2020
Available online 30 Dec, 2020

Keywords:
Gas production
Power
Gas flaring
Challenges
Economy

ABSTRACT

Power is an important aspect of most countries' economic activities especially that of Nigeria. Nigeria is capable of generating about 11,788 MW of electricity from gas power stations in Nigeria. It has become clear that the gas produced in Nigeria is not fully utilised for power production in Nigeria because most of the gas produced is exported. This leaves the Nigerian power sector with reduced amount of gas to produce electricity. Therefore, understanding the trends, challenges, and the way-forward of power production using natural gas in Nigeria is very significant. This research work analysed the gas production and consumption rate data from 1980 to 2018. In addition, the volume of export and demand from 2011 to 2015 was investigated. The variations/fluctuations observed in the production and consumption of gas in Nigeria is attributed to challenges such as insecurity, corruption, pipeline vandalisation, and so many other vices identified in this work. In addition, it was observed that as gas is being exported from Nigeria to other countries, the local demand for the product increased as well. This work showed that the amount of gas flared from 2001 to 2018 reduced from 64.48% to 18.71%. This research proffered solutions on how gas production and utilisation can be effective in order to improve power in Nigerian.

1. INTRODUCTION

Energy is a quantity that reflects the capacity of a physical system to perform mechanical work when it is undergoing a transformation from its original state into another state chosen as the reference state, representing the source of man's daily activities (Sabau, 2015). Energy is an important need in the world as it is regarded as one of the significant contributors to economic and human capital advancement (Santosh, 2008). Energy powers almost everything in a country's economy. Therefore, it is required for electricity production, heating and cooling, transportation, and manufacturing processes (Sadik, 2015). Even as its necessity cannot be underestimated, it has been discovered that the production of energy when compared with the ever-increasing demand for daily utilization are not on the same levels (Sadik, 2015). The reason is

that many technical processes are involved in production stage and the output is not usually commensurate to the input, hence the need to analyse the trends, challenges, and a more efficient method to address the setbacks (Oladipo et al., 2018).

The work of Rapu et al. (2015) talks about energy being a serious influence on economic growth in most countries. They also, reported that energy merchandises support economic growth by growing output and income as well as generating employment. The purpose of a well-organized market is to make available energy supplies to power the manufacturing, transport, home and service sectors of a country's economy. Therefore, energy is described as the backbone of a viable economy. The nature and amount of energy request and consumption in a country's economy are to a huge extent, a measure of its degree of economic expansion (Ahaotu, 2006). Ajayi and Ajanaku (2009) observed that energy has been defined as a force multiplier that increases man's capability to transform raw materials into finished products and providing variations of useful services.

The production of energy is obtained mainly from crude oil, gas, water (hydro), nuclear, solar and wind power plants. Streamlining to the gas power plants which is the focus of this research, comprises of the compressor, combustion chamber, turbine, heat exchanger, intercooler and a re-heater. The various configurations of these components bring about the varying thermal efficiencies and power outputs of gas power plant systems (Uchegbulam et al., 2014).

Hydrocarbon is one of the natural resources Nigeria is privilege to have as a country. Nigeria has the world's 9th biggest proven gas reserves of about 187 Tcf (trillion cubic feet) as of January 2013 (EIA, 2013). The country produced about 1.2 Tcf in 2012, and is rated 25th largest producer of gas according to world ranking (EIA, 2013).

The major constraint in continuing businesses, maintaining standards of living, and increasing economic development in Nigeria is the lack of constant electricity supply which can be linked to underutilization and under-exploration of our natural resources (Biose, 2019). Even though the resources might be there, without proper exploration, conversion and utilisation, the full expected benefits cannot be harnessed. Without energy, most economic activities cannot be carried out and no country in this 21st century has substantially reduced poverty without massively making use of energy (Legros et al., 2009).

2. TRENDS IN POWER PRODUCTION USING NATURAL GAS

For the past forty years, Nigerian on-grid electricity generation has been from oil/gas-fired and hydroelectric power stations while the off-grid electricity generation has been from petroleum products such as petrol and diesel (Roche et al., 2017). However, gas is a major contributor to the Nigerian national electricity grid due to the fact that Nigeria is one of the leading producers of oil and gas.

The world sees Nigeria as one of the prime energy production countries. Nigeria is ranked amongst the top oil producers in Africa, and second in natural gas reserve (Rapu et al., 2015). Despite the huge deposit of gas in Nigeria, only little of the gas deposit has been utilised even though demand has increased (Babajide, 2017). This is because Nigeria's main focus is on the drilling of crude oil. In the local gas market, there is massive underdevelopment because of increased gas flaring and a substantial percentage of available natural gas being shipped as LNG. The country needs to develop clear regulatory and competitive policies to open up her market and focus on being a competitive, low cost and highly reliable supplier to the global market (Rapu et al., 2015).

Due to the surge in population, Nigeria's energy requirement is growing by the day. This issue is not addressed because of the inadequate energy development programme. The present urban-centred energy policy is terrible, as cases of rural and sub-rural energy demand and supply do not reach the centre stage of the country's energy development policy (Occhiali and Falchetta 2018). The rural community largely rely

on timber burning and old-fashioned biomass for their everyday survival, which results in greenhouse effect, excessive deforestation, and pollution of the atmospheres (Uchegbulam et al., 2014; Occhiali and Falchetta 2018). These environmental factors contribute to the heating of the ecosystem and greenhouse worries.

The main focus of gas suppliers has been to supply energy to the cities and various places of industrialisation, thereby creating an energy imbalance within the country's social/economic and political scene. The single dependency on hydro-power stations for energy has not been adequate, as this is controlled by features such as the seasonality in the levels of water in diverse hydro-power electricity plants (Uchegbulam et al., 2014). Nigeria is not able to meet the energy demand of her citizens because of the increase in population as compared with the total capacity of available power stations. Citizens living in the villages are dependent on charcoal and wood for cooking and heating, because of the lack of electric power (Ajayi and Ajanaku 2009).

Most countries policies are influenced by existing natural resources. The existence of natural resources contributes significantly to the developmental strategy of a country. Diugwu et al. (2013) stated that natural resources availability does not necessarily mean development. Fossil fuel are the major natural gas that is likely to rise and have the prospect of shifting the world's focus to a fresher, cheaper and harmless energy. It is the third fuel, reflecting 24% of global primary energy, and it is the second energy source in power generation representing 22% share (World Energy Resources, 2016). Nigeria features on the natural gas production chart but on the natural gas consumption chart, she is nowhere to be found (BP Statistical Review of World Energy, 2017). Odumugbo (2010) stated that the Nigerian gas sector has the capabilities of becoming a major player in the emergent global market.

2.1. Production of Natural Gas

Natural gas is a fuel used by heat engines which produces the energy with which electricity is generated from the turbine. Natural gas is a mixture of hydrocarbon and non-hydrocarbon gases found in formations below the surface of the earth (Akpan, 2009; Wan-Abu-Barka and Ali 2010). Natural gas is comprised of Methane, Ethane, Propane, Butane, Carbon Dioxide, and other minor constituents (Uchegbulam et al., 2014). Natural gas is non-toxic, colourless, flammable, tasteless, odourless, and lighter than air. Carbon and hydrogen are the main composition of the hydrocarbons that produce heat. Methane is the largest component, while ethane, propane and butane are heavier than air (Wan-Abu-Barka and Ali 2010).

Methane is linked with other hydrocarbon fuels in coal beds, as methane clathrates and is a vital fuel source and used as feedstock. Natural gas is mostly linked to non-renewable fossil fuel because the formation of gas is as a result of decayed sea animals and plants over 300 million years ago (The NEED Project, 2017).

When the animals and plants die, they are buried at the bottom of the sea where they are covered by layers of sediment that will later form a rock. After many years, the formed sedimentary rock will become thick, thereby exposing the energy-rich decayed animal and plant to massive pressure. With a combination of the high pressure and heat from the earth, changes are made to the organic mixture which is the source of gas and petroleum. Gases are trapped within the layers of the rock. One of the known clean burning fossil fuels is gas which is readily available in Nigeria.

To produce pipeline quality or dry gas, the process of separating hydrocarbons and fluids from the gas must take place. The use of pipelines to transport gas normally impose limitations on the components of the gas in the pipeline.

Due to the nature of how gas is trapped between rocks it is quite expensive to extract. However, geologists have devised a means to detect gas deep underground. The methods include:

i. Searching surfaces of the rocks to discover evidences about underground formations.

ii. The use of explosions or the dropping of heavy weights on the earth's surface and take note of the sound waves emanating back from the rock layers underground.

iii. Taking measurement of the earth's gravitational pull of the rock masses.

If the test results are discovered to be highly feasible, drilling is recommended to find the natural gas deposits. Natural gas wells average more than 8,600 feet deep and can be quite expensive to drill, hence the need for careful selection of drilling sites.

After the extraction of gas between rock layers, it is transported to a processing plant, where it is cleansed of any contaminations before being separated into components that will be used as fuel. Almost ninety per cent (90%) of natural gas is composed of methane, but other gases are present such as butane, propane, ethane, and pentane and higher molecular weight hydrocarbons, carbon (iv) oxide, helium, elemental sulphur, and nitrogen occasionally (Wan-Abu-Barka and Ali 2010).

Due to the ecological nature of how gas is extracted, it is basically sub-divided into conventional and unconventional gas. Conventional gas could be distinguished from unconventional gas by technicalities (this includes rock and fluid properties, recovery technique etc.) and economies of production (the economic implication of producing gas from unconventional hydrocarbons (crude oil or natural gas) is higher than that of conventional hydrocarbons). Hence, the main focus of the gas industries is on unconventional gas sources. The coal-bed, tight gas, and shale gas are various forms of unconventional gas.

2.1.1. Gas production by OPEC members (with Nigeria as the focus)

Nigeria has been a member of the Organization of the Petroleum Exporting Countries (OPEC) since 1971. Since that period, records have been kept on the production and export of natural gas amongst members. Figure 1 presents the production and consumption of gas in Nigeria between the period of 1980 to 2013 (Emodi 2016). Comparing the year 2012 with 2013 in Figure 1, it shows a decrease in production of gas with about 9.78%. While the consumption of gas rose with about 9.7% in the same period. In addition, it was observed in Figure 1, that there are lots of fluctuations or variations in the production and consumption of gas in Nigeria which may be attributed to different factors.

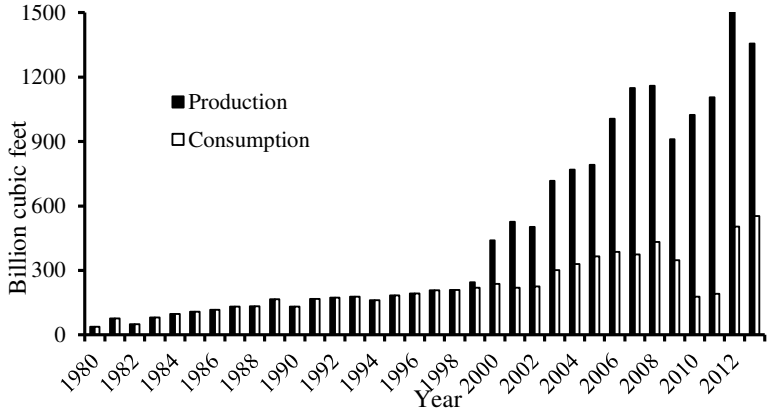

Figure 1: Gas production and consumption in Nigeria (Emodi, 2016)

A focus on Nigeria's gas production from 2014 to 2015, shows variations on the gross production, market production, flaring, reinjection, and shrinkage as seen in Table 1. However, analysis of the data in Table 1 shows that there was about 1.3% reduction in gross production, about 3% increase in market production, about 9.8% reduction in flaring, about 8.1% reduction in reinjection, and about 5.6% increase in shrinkage.

Figure 2 presents the export and demand of gas by Nigeria for the period of 2011 to 2015. From Figure 2, it is observed that there are fluctuations in the export of gas by Nigeria from 2011 to 2015. However, closer look at the 2014 and 2015 data shows that there was about 0.3% reduction in the volume of gas exported by Nigeria. Also, in Figure 2 there was a steady increase in the demand of gas from 2011 to 2015. In addition, there was about 0.4% increase in the demand of gas when the data for 2014 and 2015 were analysed. In the final analyses there were no record of importation of gas of any form during 2011 to 2015.

Table 1: Natural gas production in Nigeria (OPEC 2016)

	2014	2015	%Change
Gross production	86,325.20	85,223.20	-1.3
Market production	43,841.60	45,148.10	3
Flaring	10,736.80	9,687.30	-9.8
Reinjection	22,894.30	21,040.20	-8.1
Shrinkage	8,852.60	9,347.60	5.6

*In standard cubic metres

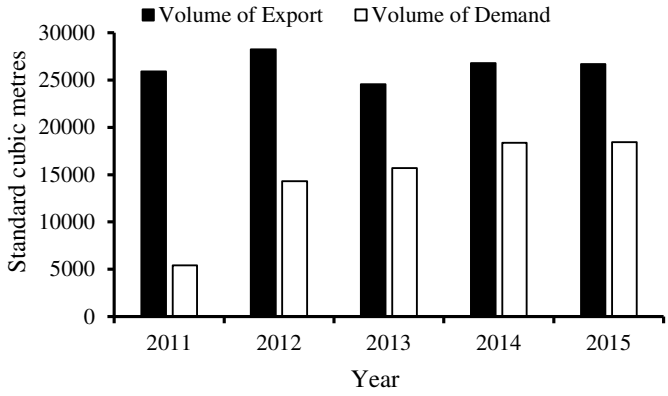

Figure 2: World natural gas exports and demand by Nigeria (OPEC, 2016)

2.2. Transportation and Storage of Natural Gas

2.2.1. Transportation

Natural gas as a volatile substance is usually conveyed from the source point to its final point of utilisation through underground pipelines. The speed of flow decreases overtime with increasing distance due to the collision of gas particles with the wall of the pipe and other molecules of gases, thereby varying the mass flow rates at different sections of the pipes (Key and Ball 2012). Pressure booster compressors increase the pressure of the gas by forcing it to move in pipelines. Compressor stations, which are spread out to about 50 – 100 km apart, move the gas in the pipelines at about 15 – 20 km/h. Figure 3 is an illustration showing how gas is transported by one of Nigeria's leading gas companies (Nigeria Liquefied Natural Gas Company) situated at Bonny Island in Rivers State Nigeria.

Figure 3: Transportation of natural gas (NLNG, 2017)

2.2.2. Storage

Gas that is transferred along subterranean highway are briefly stored in reservoirs underground. Gas is stored in the reservoirs during the hot season to ensure that there is availability in the cold season. Therefore, before gas is transported to the end users the pressure is reduced and an odorant added to enable easy detection of leaking gas. Local gas companies use smaller pipes to carry gas the last few kilometres to homes and businesses. It is common knowledge that a gas consumer usage is measured by a gas meter. A good storage facility is required for gas in order to prevent or limit hazards such as fire. As seen in Figure 4, thick walled and conically shaped tanks are always used to store gas in order to prevent explosion that could be caused by the movement of the gas molecules inside the tank.

Figure 4: Storage of gas (NLNG, 2017)

2.3. Electricity Generation and Distribution in Nigeria

Power generation is a product of different forms of energy when transformed or processed. Electricity is generated by the movement of a loop of wire, or disc of copper between the poles of a magnet (Oyem, 2013). In the past four decades, Nigeria's electricity generation has centred on gas, oil, and hydroelectric power. However, coal-excited stations with hydroelectric power and gas-fired systems have taken precedence (Ajumogobia and Okeke, 2015).

After natural gas has been processed and transported through pipelines to the plants, the gas mixes with compressed air in the compressor and burns in the combustion chamber. The product of the combustion is the energy required by the turbine for power (electricity) generation. The product from the turbine (i.e., electricity) is directly proportional to the energy produced by the combustion of the fuel (natural gas) in the combustion chamber (Oyem, 2013). This emphasizes the fact that natural gas is of great interest and importance because of the role it plays in the generation of power. For a nation like Nigeria that is one of the world's largest/leading producer of natural gas, it is difficult to comprehend that even with her large natural gas reserves of about 187 Tcf (Ahaotu, 2006), she still suffers from the unavailability of power (electricity) which is a tool for growth and economic development (Oyem, 2013).

Olugbenga et al. (2013) related the inadequate and erratic state of Nigeria's electricity supply as the main reason for the poor economy and slow growth the small and medium scale industries. Also, with regards to gas-powered electricity, combined cycle gas turbines are gradually taking over the inefficient single cycle turbines, and it is expected that this will be a major source of Nigeria's future electricity mix (Roche et al., 2017).

In Nigeria, there is a low supply of electricity despite high demand for the product. In 2013 and 2014, about 23.1% more electricity was generated in Nigeria than in 2012. The power generated in Nigeria between 2007 and 2014 was within 2623.1 – 3485.5 MW/hr which is less than the demand of about 10000 MW per day (CBN Annual Reports 2013; 2014; 2015). In addition, less than 40% of the installed and used electricity capacity in Nigeria is attributed to the unstable nature of the electricity sector (Iwayemi, 2008).

Nigeria's regular energy shortfall has weakened the mechanisation process and greatly affected the required economic growth, competitiveness in the local company, and employment (Iwayemi, 2008). Iwayemi (2008), further affirms the need for radical reform in the sector embodying changes to improve and strengthen the industry governance structure to enhance responsibility and reduce dishonesty. Therefore, enacting policies by the government will further enhance the oil, gas, and power industries in the local, national, and international energy market. These policies will further rejuvenate the market responsiveness in terms of energy pricing and help reduce the security concerns associated with the Niger Delta Region of the country.

2.3.1. Power (electricity) generation from natural gas

In Nigeria, natural gas accounts for about 80 - 86% of the total electricity generated for national grid, while the remaining 14% is generated by hydro-power plants (Roche et al., 2017; Occhiali and Falchetta 2018). There are about 22 gas powered generating plants in Nigeria. Table 2, presents the different gas power stations with their locations and generating capacity (Bureau of Public Enterprises, 2013; Eti et al., 2014; Shell in Nigeria, 2012; Eberhard and Gratwick 2012; Uchegbulam et al., 2014). From Table 2, it is observed that the different gas power stations are capable of generating a total of 11,788 MW of electricity in Nigeria. However, Nigeria is generating under 5,500 MW of electricity regularly from all available generating plants (Oladipo et al., 2018). The low generation of power experienced in Nigeria could be attributed to different factors such as shortages in gas supply, lack of transmission and distribution infrastructures, power plants not fully or partially operated, etc. From the analysis so far, more than 50% of the generating capacity of gas power stations in Nigeria are either wasted or under-utilised.

Table 2: Gas power stations

S/No	Power station	Location	Capacity
1	Afam IV and V	Afam, Rivers state	726 MW
2	Afam V1	Afam, Rivers state	624 MW
3	Egbin	Egbin, near Lagos	1,320 MW
4	AES Barge	Egbin, near Lagos	270 MW
5	Delta power station	Ughelli, Delta state	900 MW
6	Sapele	Sapele, Delta state	450MW
7	Omotosho I	Ondo state	336MW
8	Omotosho II	Ondo state	450 MW
9	Omoku	Rivers state	150 MW
10	Alaoji	Aba, Abia state	1074 MW
11	Egbema	Imo State	338 MW
12	Calabar	Cross River state	561 MW
13	Ibom	Akwa Ibom state	190 MW
14	Ihovbor	Edo State	450 MW
15	Okpai	Delta state	480 MW
16	Olorunsogo I	Ogun state	336 MW
17	Olorunsogo II	Ogun state	675 MW
18	Aba power station	Abia state	140 MW
19	Geregu I power station	Kogi state	414 MW
20	Geregu II power station	Kogi state	434 MW
21	Sapele	Delta state	1020 MW
22	Azura power station	Benin City, Edo state	450 MW

2.4. Challenges in the Production of Gas in Nigeria

Nigeria's energy sector, even as it is seen to be promising, has not fully tapped into energy production using gas as it appears to be overwhelmed by several forms of challenges that professionals consider too significant to be overlooked by the government. Some of the challenges facing the energy sector in Nigeria are thus discussed.

Gas is the most environmentally friendly fossil fuel readily available in Nigeria. Gas flaring is challenging in Nigeria because it is a source of atmospheric pollution. Due to the nature of gas, it has fewer toxic wastes when burned as compared to other fossil fuels (Occhiali and Falchetta 2018). The impact of natural gas when fully explored in the Nigerian economy cannot be overestimated. It will bring about diversification from oil exploration, thereby easing the pressure on the oil sector and further improving the standard of living of her citizens (Uchegbulam et al., 2014).

Security threats have been one of the major challenges impeding the growth and development of the Nigeria gas industry (especially in the Niger Delta area) as a result of aggrieved individuals and sects of different formations destroying gas pipelines, disrupting production operations and kidnapping crew members working offshore and onshore (Edjenekpo, 2014). Even in some instances, killings of officials have been recorded. Also, the present Nigerian administration should increase her effort targeted towards bringing lasting peace to Niger Delta Region of the country. This would be good in addressing the unrest of the militancy and other social vices (Rapu et al, 2015).

Corruption, today, has eaten deep into the secular systems in Nigeria, like a cankerworm, and has turned well-thriving industries into shambles, leaving them in a state of quagmire, due to lack of accountability and mismanagement of resources (Edjenekpo, 2014). Many folks in top positions of the oil and gas sector in Nigeria seem not to be bothered about how the growth and development of the sector will be fostered and improved upon but rather they go on stealing public funds and trying to satisfy selfish-insatiable wants (Edjenekpo, 2014). The extent to which corruption has eroded integrity values in our systems is alarming because even those thought to be in trustworthy positions are found to be the ones fostering this devilish act (Edjenekpo, 2014).

Lack of basic infrastructures and vandalisation of existing infrastructures could contribute to gas shortages and supply in Nigeria. The gas shortages will directly impact the business of gas-powered generating companies. The gas-powered electricity generating plants in Nigeria are designed to depend directly on the supply of gas to such companies by pipes. This design formation will determine the sustainability and long-term productivity of the gas-powered plants in Nigeria. When the necessary healthy environment for a gas-powered plant to generate more power and the needed infrastructure to aid its continuity is unavailable, there might be no place for the power generating companies in the future (Edjenekpo, 2014).

The nation's gas endowments are yet to be harnessed due to the focus on crude oil production. This has left the local gas market underdeveloped, with a significant percentage of available gas exported as liquefied gas, re-injected to enhance oil retrieval or flared. This has exposed the weaknesses in the structure of the nation's power generation mix, thereby rendering power supply system unstable and unpredictable. This has necessitated the initiation and implementation of an appropriate gas pricing framework, a prerequisite for developing the domestic gas market (Rapu et al., 2015).

Many abandoned projects litter the whole country as a result of awarding contracts to incapable contractors who after being paid to do a project, stop it halfway in an abrupt manner, making mockery of the developmental process. Even while some seem to complete the project, as they often say and portray, inferior materials are used, thereby making the reliability of the project to be questionable and not trustworthy for efficient productive use (Edjenekpo, 2014).

Pipeline vandalization is a social menace that has taken a recurring path due to incessant destruction of pipelines carrying natural gas and petroleum products by group of militants. In the process of expressing their grievances, they take laws into their hands leading to shutting down of flow-stations, environmental degradation, pollutions of land, air and water bodies etc. Most cases of pipeline vandalisation is usually accompanied with series of deaths of different causes ranging from explosion, contaminated water and chemically-induced infections/diseases. The Nigerian economy has been experiencing constant fluctuations in her revenue generation trailing behind the fact that the mainstay of the economy which is the oil and gas sector has been under prolonged threats militating against healthy growth and development of the Nigerian economy (Babajide, 2017).

The forms in which natural gas is being wasted can be classified into two parts (direct and indirect wastage). The direct wastage of natural gas can be noticed in refinery outlets and gas power plants in Nigeria where the excess gas produced are burnt away so as to give way for the production of fresh ones (Abdulkareem and Odigure 2010). Apart from the fact that they pose big threat to the environment, thereby polluting it, they affect natural operations of life to run smoothly, causing diseases such as cancer, lungs infections, skin diseases, sight-power depletion on humans (Udok and Akpan 2017). While some decide to flare the gas, some release the gases into the air directly and the adverse effect is the climate change which is usually accompanied with various unanticipated complications (Orogun, 2015).

Gas flaring is a major challenge affecting the amount of power generated in Nigeria. In 2018, it was recorded that a total of 321.29 BSCF of produced Associated Gas (AG) was flared, which amounts to 11.04% of the volume of gas produced (Department of Petroleum Resources, 2018). Table 3 presents a summary of the gas produced and the percentage flared in Nigeria in 2018. The cost implication of the amount of gas flared in Nigeria in 2018 was estimated to be around N233 Billion, while the environmental effect of flaring gas was estimated to be around N28.76 Billion (PriceWaterhouseCooper Limited, 2019).

Table 3: 2018 Gas produced and flared (Department of Petroleum Resources, 2018).

Month	Total gas produced	Total gas utilised	Total gas flared	% Flared
January	258,712.89	223,937.23	34,775.66	13.44
February	243,857.13	213,943.30	29,913.83	12.27
March	257,089.89	229,258.57	27,831.32	10.83
April	242,158.64	217,216.19	24,942.45	10.30
May	240,375.58	217,751.00	22,624.58	9.41
June	210,929.63	188,244.87	22,684.76	10.75
July	238,627.16	214,175.62	24,451.55	10.25
August	260,427.56	233,805.46	26,622.10	10.22
September	242,006.42	217,837.19	24,169.23	9.99
October	248,365.83	222,594.80	25,771.04	10.38
November	215,400.08	187,654.02	27,746.06	12.88
December	251,192.75	221,434.96	29,757.78	11.285
Total	2,909,143.56	2,587,853.21	321,290.35	11.04

The indirect wastage of natural gas is seen in all processes which could have made use of natural gas for their operations but rather, in most cases make use of the 'end-product' energy obtained from processes powered/energized by natural gas. It is an anomaly to generate energy/power using gas and use the same generated power for processes (such as cooking) that could have made use of the natural gas directly.

The lack of concrete policies which are to guide the proper sustenance and execution of projects affects in a great manner the effective operation of the gas industry. Regulatory uncertainty associated with the delay in the wholesome passage of the Petroleum Industry Bill (PIB) resulting in less investment in the development of new natural gas projects (Edjenekpo, 2014). Lack of policy and legislation to address the inefficient use of energy is a very key barrier to the development of energy efficiency (Oyedepo, 2013).

3. WAY-FORWARD AND RECOMMENDATIONS

This research has so far presented the trends and challenges as it affects gas production in Nigeria. This section proffers solutions on gas production in Nigeria and the way-forward. Some of these are discussed thus:

When the people living in a community find ease in satisfying their basic needs as humans, which they get from the readily available amenities around them, such as schools, health care centres, clean water, good transportation facilities, etc., the tendencies of posing threats to the security of their environment might be totally eliminated. Therefore, the need to urgently tackle the challenge of insecurity in gas supply chain in

Nigeria should be the base of policy making in the sector. Also, routine inspection of gas facilities for damage/vandalisation should be carried out frequently (Rapu et al., 2015).

Misrepresentation on salient issues must be stopped if the issue of corruption and its aids must be eliminated. Drastic measures should be taken to entirely discourage anticipating looters and offenders should be severely dealt with, without fear or favour. Also, the law enforcement agencies and their agents should be well monitored so as to ensure equity and fairness without indicting someone indiscriminately. NLNG (2017) talked about how corruption in any shape should be fought against in businesses. By limiting corruption, gas produced and supplied to power plants and local markets can be greatly improved.

Enticing business atmosphere should be created by resuscitating less productive firms and creating new ones to compliment the output of the latter. Strong and binding government policies should be laid down, not only on paper, in order to pull the interest of foreign direct investors with assurance of greater yields on their investment. It is suggested that the governing framework and surroundings should inspire supreme competition. Accordingly, government should repeal any laws that impede healthy competition and pass laws that protect investors (Noruwa and Christopher 2012). Competitiveness is a definite path to industrial revolution.

Gas flaring should stop immediately with strict and firm penalties melted out to defaulters. Rather than the excessive wastage of gas, gas-based industries should be instituted the more and the excess gas channelled for more productivity. Also, more gas power plants with larger capacities should be built so as to accommodate the excess gas and harness them to obtain constant power supply in all sectors of the economy.

In addition, gas flaring activities should be checkmated through increased taxation and greater trade openings should be sought for removal of gas in addition to blending of gas with other fuels in order to achieve less emissions and pollutions with the attendant negative consequences (Madueme, 2010a; 2010b).

The Nigerian government has been working over the years to reduce the amount of gas flared in the oil and gas sector. The progress made by Nigerian government could be seen in Figure 5. From Figure 5, the amount of flared gas has reduced from 64.48% in 2001 to about 18.71% in 2018 (Department of Petroleum Resources, 2018). If this trend continues, Nigeria may be free from gas flaring or be within 0 – 2% in the year 2050.

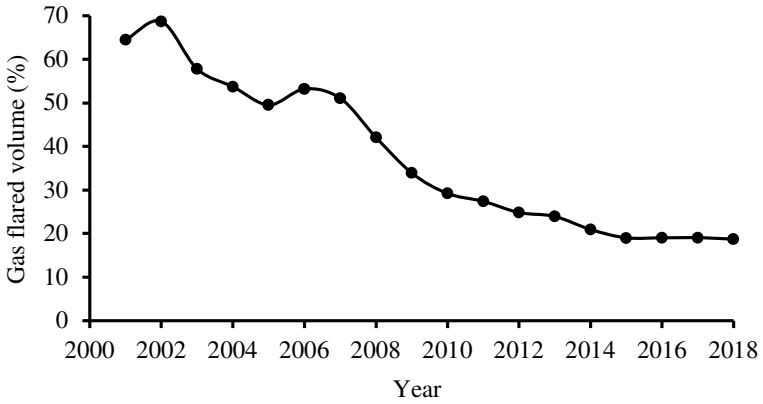

Figure 5: Gas flared as a percentage of AG production

4. CONCLUSION

This paper has reviewed the growth and challenges involved in the gas power plant sector in Nigeria. During the course of the research work, it was found that the production and consumption of gas in Nigeria between 1980 and 1999 showed slight variation. While from the year 2000 to 2015 there was an increase between the percentages of fluctuations. These may be attributed to the challenges identified in this research work. In

addition, the percentage of gas flared from 2001 to 2018 has reduced significantly. Also, it was discovered that Nigeria has the capacity to generate more megawatts of electricity than currently generated. Nigeria has been exporting gas for decades, thereby starving the local market and gas power plants of gas despite the increase in demands. This research work proffered solutions on how gas production and utilisation can be effective in order to improve the Nigerian power sector.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Abdulkareem, A. and Odigure, J. (2010). Economic Benefit of Natural Gas Utilisation in Nigeria: A Case study of the food processing Industry. *Energy Sources*, 5(1), pp. 106 – 114

Ahaotu, J.O. (2006). An evaluation of the potentials of Natural gas in the economic development of Nigeria. Master's Thesis, Department of Mechanical Engineering, Faculty of Engineering, University of Nigeria, Nsukka.

Ajayi, O.O. and Ajanaku, K.O. (2009). Nigeria's energy Challenge and Power development: the way forward. *Energy and Environment*, 20(3), pp. 411 – 413

Ajumogobia and Okeke (2015). Nigerian Energy Sector: Legal and Regulatory Overview. Available online at: http://www.ajumogobiaokeke.com/wp-content/uploads/2018/01/2b13946e4257859eb7988150d1c620a2.pdf. Accessed on November, 2020

Akpan, S.E. (2009). The Production and Utilisation of Natural Gas Resources in Nigeria: A Review. The Nigerian Annual International Conference and Exhibition, Abuja, 3, pp. 3 - 5, August 2009.

Babajide, N. (2017). Economic and Environmental Implication of High Gas Dependence for Electricity Generation in Nigeria. *10th NAEE/IAEE International Conference, April 23-26, 2017. PTDF Conference Centre, Abuja Nigeria*, pp. 1-17.

Biose, H. (2019). Gas Production and Utilization in Nigeria: A Long-term Perspective. *International Journal of Engineering Technologies and Management Research*, 6(5), pp. 58-72.

BP Statistical Review of World energy. (2017). Annual Review of World Energy. Available online at: http://www.bp.com/statisticalreview. Accessed on March, 2019

Bureau of Public Enterprises. (2013). Sapele power Plc, Nigeria sale of equity (51%). *Information Brochure*. Available at: https://web.archive.org/web/20131104043527/http://www.nigeriaelectricityprivatisation.com/wp-content/uploads/downloads/2011/01/Sapele-Genco-2011-01-13.pdf. Accessed on November, 2020.

Central Bank of Nigeria. (2013). Annual Economic Report for 2013. Central Bank of Nigeria, Available online at: http://www.cbn.gov.ng

Central Bank of Nigeria. (2014). 2014 Annual Report. Central Bank of Nigeria, Available online at: http://www.cbn.gov.ng

Central Bank of Nigeria. (2015). Annual Report 2015. Central Bank of Nigeria. Available online at: http://www.cbn.gov.ng

Department of Petroleum Resources. (2018). Nigerian Oil and Gas Industry Annual Report. Available online at: https://www.dpr.gov.ng/wp-content/uploads/2020/01/2018-NOGIAR-1.pdf. Accessed on June, 2020

Diugwu, I.A., Ijaiya, M.A., Musa, M. and Egila, A. E. (2013). The Effect of Gas Production, Utilisation, and Flaring on the Economic Growth of Nigeria. *Journal of Natural Resources*, 4, pp. 341 - 348

Eberhard, A. and Gratwick, K.N. (2012). Light inside: the experience of independent power projects in Nigeria. *Management Programme in Infrastructure Reform and Regulation*, pp. 1-38.

Edjenekpo, L.E. (2014). Gas-to-Power and the role of gas compression in the Nigerian Energy Industry: Current challenges, strategies and solutions for sustainable development. *SSRN Electronic Journal*, pp. 1-21.

EIA. (2013). Annual Energy Outlook 2013 with projections to 2040. US Energy Information Administration, Office of Integrated and International Energy Analysis, US Department of Energy, Washington, DC20585. Available online at: http://www.eia.gov/forecasts/aeo. Accessed on March, 2019

Emodi, N.V. (2016). *Energy Policies for Sustainable Development Strategies*. Frontiers in African Business Research, Springer, Singapore, pp. 1-265.

Eti, M.C., Ogaji, S.O.T. and Probert, S.D. (2004). Reliability of the AFAM electric power generation station, Nigeria. *Applied Energy*, 77(3), pp. 309-315.

Iwayemi, A. (2008). Nigeria's Dual Energy Problems: Policy Issues and Challenges. International Association for Energy Economics, Available online at: https://iaee.org/documents/newsletterarticles/408akin.pdf. Accessed on November, 2020, pp. 17 – 21.

Key, J.A. and Ball, D.W. (2012). Kinetic Molecular Theory of Gases. Available online at: https://opentextbc.ca/introductorychemistry/chapter/kinetic-molecular-theory-of-gases-2/. Accessed on November, 2020.

Legros, W., Havet, I., Bruce, N., Bonjour, S. (2009). The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa. *World Health Organization: United Nations Development Programme,* pp. 1-142.

Madueme, S. (2010a). Economic Analysis of Wastages in the Nigerian Gas Industry. *International Journal of Engineering, Science and Technology*, 2(4), pp. 618 - 624

Madueme, S. (2010b). Gas Flaring Activities of major oil companies in Nigeria: An economic investigation, *International Journal of Engineering Science and Technology*, 2(4), pp. 610 - 617

NLNG. (2017). Fact and figures on NLNG 2017. Nigerian Liquefied Natural Gas Limited. Available online at: http://www.nlng.com/Media-Center/Publications/2017%20Facts%20and%20Figures.pdf. Accessed in March, 2019.

Noruwa, A.I. and Christopher, C.O. (2012). Deregulation and privatization of the upstream and downstream oil and gas industry in Economics Curse or blessing? *International Journal of Business Administration*, 3(1), pp. 16 – 20.

Occhiali, G. and Falchetta, G. (2018). The Changing Role of Natural Gas in Nigeria. *Energy Scenarios and Policy*

Odumugbo, C. A. (2010). Natural Gas utilisation in Nigeria: Challenges and Opportunities. *Journal of Natural Gas Science and Engineering*, 2(6), pp. 310 – 316.

Oladipo, K., Agbetuyi, A.F., Owolabi, B., Obiakor, C., Fagbuaro, O. (2018). Power Sector Reform in Nigeria: Challenges and Solutions. *IOP Conf. Series: Materials Science and Engineering*, 413(2018), pp. 1-13.

Olugbenga, T.K., Jumah, A.A. and Phillips, D.A. (2013). The current and future challenges of electricity market in Nigeria in the face of deregulation process. *African Journal of Engineering Research*, 1(2), pp. 33 – 39.

OPEC. (2016). Annual Statistical Bulletin. Organisation of the Petroleum Exporting Countries, Available online at: http://www.asb.opec.org. Accessed in March, 2018.

Orogun, B.O. (2015). Natural Gas to Power in Nigeria, the practices and the way forward for sustainable development. *Sustainable Development and National Resources, University of Manitoba*, pp. 1-13.

Oyedepo, S.O. (2013). Energy in Perspective of Sustainable Development in Nigeria. *Sustainable Energy*, 1(2), pp. 14 – 25.

Oyem, I. L. (2013). Analysis of Nigeria power generation sustainability through natural gas supply. *Journal of Innovative Research in Engineering and Sciences,* 4(1), pp. 434 – 443.

Price Waterhouse Cooper Limited. (2019). Assessing the impact of gas flaring on the Nigerian economy, Available at: www.pwc.com/ng. Accessed on November 2020.

Rapu, C.S., Adenuga, A.O., Kanya, W.J., Abeng, M.O., Golit, P.D., Hilili, M.J., Uba, I.A., Ochu, E.R. (2015). Analysis of Energy market conditions in Nigeria. Central Bank of Nigeria, Occasional Paper No. 55, pp. 1 – 20.

Roche, M.Y., Ude, N. and Ofoegbu, I.D. (2017). True cost of Electricity: Comparison of costs of Electricity Generation in Nigeria. Heinrich Böll Stiftung and the Nigerian Economic Summit Group (RC:303317), Nigeria. Available online at: https://ng.boell.org/sites/default/files/true_cost_of_power_technical_report_final.pdf. Accessed on November, 2020.

Sabau, N.C. (2015). Energy Production in Hydro powers and Electric Thermal Power Plants from the Perspective of European Community Legislation. *Analele Universitatii din Oradea, Fascicular Protectia Mediului*, 24, pp. 235- 248.

Sadik, O. (2015). Energy crisis in Nigeria: Sustainable option using Nanotechnology as the way forward. Redeemer's University Convocation Lecture. Available online at: https://run.edu.ng/media/6182273564112.pdf. Accessed on January, 2018.

Santosh, S. (2008). Trends and Patterns of energy Consumption in India. Munich Personal RePEc Archive, Indian Institute of Technology Bombay, MPRA Paper No. 16774, Available online at: http://mpra.ub.uni-muenchen.de/16774/. Accessed on June, 2018.

Shell in Nigeria. (2012). The AFAM VI power plant and Okoloma Facility. Available at: https://web.archive.org/web/20120303055312/http://www-static.shell.com/static/nga/downloads/pdfs/briefing_notes/afam.pdf. Accessed on November, 2020.

The NEED Project. (2017). Secondary Energy Info book. National Energy Education Development Project, 8408 Kao circle, Manassas, VA20110. 1.800.875.5029. Available online at: http://www.need.org/files/curriculum/guides/Secondary%20Energy%20Infobook.pdf. Accessed on July, 2018.

Uchegbulam, O., Opeh, R.N. and Atenaga, M.O. (2014). Assessment of Power Generation Resources in Nigeria. *IOSR Journal of Applied Physics*, 6(2), pp. 44-50.

Udok, U. and Akpan, E.B. (2017). Gas Flaring in Nigeria: Problems and Prospects. *Global Journal of Politics and Law Research*, 5(1), pp. 16-28.

Wan-Abu-Barka, W.A. and Ali, R. (2010). Natural Gas. Book Chapter in InTech, pp. 1-40.

World Energy Resources. (2016). World Energy Council Report. Available online at: https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf. Accessed on August, 2018.